THE UNIVERSITY OF WARWICK

From Diversity to Convergence:
British Computer Networks and the Internet, 1970-1995

by

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Declaration

I present this thesis in accordance with the regulations for the degree of Doctor of Philosophy. I composed the dissertation and I have not submitted it for any previous application for a degree. I undertook the work described in the thesis except where otherwise stated.

Abstract

The Internet's success in the 21st century has encouraged analysts to investigate the origin of this network. Much of this literature adopts a teleological approach. Works often begin by discussing the invention of packet switching, describe the design and development of the ARPANET, and then examine how this network evolved into the Internet. Although the ARPANET was a seminal computer network, these accounts usually only briefly consider the many other diverse networks that existed. In addition, apart from momentary asides to alternative internetworking solutions, such as the Open Systems Interconnection (OSI) seven-layer reference model, this literature concentrates exclusively on the ARPANET, the Internet, and the World Wide Web. While focusing on these subjects is important and therefore justified, it can leave the reader with the impression that the world of networking started with the ARPANET and ended with the Internet. This thesis is an attempt to help correct this misconception.

This thesis analyses the evolution of British computer networks and the Internet between the years 1970 and 1995. After an introduction in Chapter 1, the thesis analyses several networks. In Chapters 2 and 3, the focus is on academic networks, especially JANET and SuperJANET. Attention moves to videotex networks in Chapter 4, specifically Prestel, and in Chapter 5, the dissertation examines electronic mail networks such as Telecom Gold and Cable & Wireless Easylink. Chapter 6 considers online services, including CompuServe, American Online, and the Microsoft Network, and the thesis ends with a conclusion in Chapter 7. All of the networks discussed used protocols that were incompatible with each other which limited the utility of the networks for their users. Although it was possible that OSI or another solution could have solved this problem, the Internet's protocols achieved this objective. This thesis shows how the networks converged around TCP/IP.

Abbreviations

A

AAL: ATM Adaptation layer

AARNet: Australia's Academic and Research Network

AbMAN: Aberdeen Metropolitan Area Network

ADMD: Administrative Management Domain

AFNOR: Association Française de Normalisation

AIEE: American Institute of Electrical Engineers

AIM: AOL Instant Messenger

AMEOL: A Most Excellent Offline Reader

ANSI: American National Standards Institute

AOL: American Online

AP: Associated Press

APOD: Astronomy Picture of the Day

APS: Asynchronous Protocol Specification

ARC: Agricultural Research Council

ARP: Address Resolution Protocol

ARPA: Advanced Research Projects Agency

ARPANET: Advanced Research Projects Agency Network

ASCII: American Standard Code for Information Interchange

ATM: Asynchronous Transfer Mode

B

BARD: Bodleian Access to Remote Databases

BBC: British Broadcasting Corporation

BBN: Bolt, Beranek and Newman

BBS: Bulletin Board System

BEN: Backbone Edge Node

BIDS: Bath Information and Data Services

BITNET: Because It's There/Because It's Time Network

BIX: Byte Information eXchange

BL Systems: British Leyland Systems

BORIS: Buyers' On-line Rapid Information Service

BP: British Petroleum

Bps: Bits per second

BSD: Berkeley Software Distribution

BSI: British Standards Institute

BT: British Telecom

BUBL: Bulletin Board for Libraries

C

C&NLMAN: Cumbria and North Lancashire Metropolitan Area Network

CAPTAIN: Character And Pattern Telephone Access Information Network

CATV: Community Antenna Television

CB: Citizens Band

CB Simulator: Citizens Band Simulator

CBBS: Computerized Bulletin Board System

CBL: Computer Based Learning

CCA: Central Computing Agency/Computer Corporation of America

CCIF: International Telephone Consultative Committee

CCIT: International Telegraph Consultative Committee

CCITT: Comité Consultatif International Télégraphique et Téléphonique

CEPT: European Conference of Postal and Telecommunications Administrations

CERN: Conseil Européen pour la Recherche Nucléaire/Centre Européen pour la Recherche Nucléaire

CERNET: Conseil Européen pour la Recherche Nucléaire network

CERT: Computer Emergency Response Team

CIM: CompuServe Information Manager

CIS: CompuServe Information Service

CIX: Compulink Information eXchange/Commercial Internet eXchange

CLI: Command Line Interface

Clydenet: Clyde Area Network

CMC: Cambridge Micro Computers

COSINE: Cooperation for Open Systems Interconnection Networking in Europe

CPoP: Core Points of Presence

CPSE: Campus Packet Switching Exchange

CSA: Cambridge Scientific Abstracts

CSC: Computer Sciences Corporation

CTSS: Compatible Time-Sharing System

CUG: Closed User Group

CURL: Consortium of University Research Libraries

CWIS: Campus-Wide Information System

D

DARPA: Defense Advanced Research Projects Agency

DCN: Data Communications Network

DEC: Digital Equipment Corporation

DECnet: Digital Equipment Corporation network

DES: Department of Education and Science

DESY: Deutsches Elektronen-Synchrotron

DfE: Department for Education

DfEE: Department for Education and Employment

DfES: Department for Education and Skills

DGT: Direction Générale des Télécommunications

DHCP: Dynamic Host Configuration Protocol

DISOSS: Distributed Office Support System

DNS: Domain Name System

DoD: Department of Defense

DoDAG: the Department of Defence Advisory Group

DoI: Department of Industry

DQDB: Distributed Queue Dual Bus

DSA: Directory System Agent

DSL: Digital Subscriber Line

DSx: Digital Signal-X

DTI: Department of Trade and Industry

DUA: Directory User Agent

DW: Digital Wrapper

DWDM: Dense Wave-Division Multiplexing

E

EARN: European Academic Research Network

EaStMAN: Edinburgh and Stirling Metropolitan Area Network

EastNet: East of England Regional Network

EDSAC: Electronic Delay Storage Automatic Calculator

EDVAC: Electronic Discrete Variable Automatic Computer

EIN: European Informatics Network

EIP: External Information Provider

EIS: Executive Information Service

EMAP: East Midland Allied Press

EMMAN: East Midlands Metropolitan Area Network

Epnitex: Electronic Public Network for Information & Videotex

EPSRC: Engineering and Physical Sciences Research Council

EPSS: Experimental Packet Switching Service

EPUB: Electronic Publishing

EUnet: European UNIX network

Eurocomp: European Computing Conference on Communications Networks

e-VLBI: Electronic Very Long Baseline Interferometry

F

FaTMAN: Fife and Tayside Metropolitan Area Network

FCC: Federal Communications Commission

FDDI: Fiber Distributed Data Interface

FTAM: File Transfer Access and Management

FTP: File Transfer Protocol

G

GANNET: General Administrative Network

Gb: Gigabyte

Gbps: Gigabits per second

GE: General Electric

GÉANT: Gigabit European Academic Network

GEISCO: General Electric Information Services Company

GEnie: General Electric Network for Information Exchange

GMING: Greater Manchester Information Network Group

GOSIP: Government Open Systems Interconnection Profile

GPO: General Post Office

GUI: Graphical User Interface

H

HEFCE: Higher Education Funding Council for England

HEFCW: Higher Education Funding Council for Wales

HEP: High-Energy Physics

HP: Hewlett-Packard

HTML: Hypertext Markup Language

HTTP: Hypertext Transfer Protocol

HTTPS: Secure Hypertext Transfer Protocol

I

IAB: Internet Architecture Board

IANA: Internet Assigned Numbers Authority

IBA: Independent Broadcasting Authority

IBM: International Business Machines

ICANN: Internet Corporation for Assigned Names and Numbers

ICCC: International Conference on Computer Communications

ICI: Imperial Chemical Industries

ICL: International Computers Limited

ICMP: Internet Control Message Protocol

ICT: International Computers and Tabulators

IEEE: Institute of Electrical and Electronics Engineers

IESG: Internet Engineering Steering Group

IETF: Internet Engineering Task Force

IGMP: Internet Group Message Protocol

IMAP: Internet Group Message Protocol

IP: Information Provider/Internet Protocol

IP QoS: Internet Protocol Quality of Service

IPP: Internet Printing Protocol

IPSA: I.P. Sharp Associates

IPSAnet: I.P. Sharp Associates network

IPSS: International Packet Switching Service

IPTO: Information Processing Techniques Office

IPv4: IP version 4

IPv6: IP version 6

IRC: Information Retrieval Centre/Internet Relay Chat

IRE: Institute of Radio Engineers

IRTF: Internet Research Task Force

ISC: Information Systems Committee

ISI: Institute for Scientific Information

ISO: International Organization for Standardization

ISOC: Internet Society

ISP: Internet Service Provider

ITU: International Telecommunication Union

ITU-D: International Telecommunication Union-Telecommunication Development

ITU-R: International Telecommunication Union-Radiocommunication

ITU-T: International Telecommunication Union-Telecommunications Standardization

IXI: International X.25 Infrastructure

J

JANET: Joint Academic Network

JIPS: Joint Academic Network Internet Protocol Service

JISC: Joint Information Systems Committee

JIVE: Joint Institute for Very Long Baseline Interferometry in Europe

JNT: Joint Network Team

JNUG: JANET National User Group

JTMP: Job Transfer and Manipulation Protocol

Jughead: Jonzy's Universal Gopher Hierarchy Excavation And Display

JUGL: Joint Academic Network User Group for Libraries

K

Kbps: Kilobits per second

Knowbot: Knowledge robot

L

LAN: Local Area Network

LANE: Local Area Network Emulation

LDAP: Lightweight Directory Access Protocol

LED: Light-Emitting Diode

LeNSE: Learning Network South East

LIDIS: Life Insurance Data Information System

LMN: London Metropolitan Network

M

MAN: Metropolitan Area Network

Mb: Megabyte

Mbps: Megabits per second

MCS: Mail Conversion Service

MDA: Message Delivery Agent

MHS: Message Handling System

MidMAN: Midlands Metropolitan Area Network

MIDnet: Midlands network

MIME: Multipurpose Internet Mail Extensions

MIT: Massachusetts Institute of Technology

Modem: Modulator/demodulator

MPLS: Multiprotocol Label Switching

MRC: Medical Research Council

MSDN: Microbial Strain Data Network

MS-DOS: Microsoft Disk Operating System

MSN: Microsoft Network

MTA: Message Transfer Agent

MTU: Maximum Transmission Unit

MUA: Mail User Agent

N

NAC: Network Advisory Committee

NADH: North American Digital Hierarchy

NAPLPS: North American Presentation Level Protocol Syntax

NASA: National Aeronautics and Space Administration

NCSA: National Center for Supercomputer Applications

NERC: Natural Environment Research Council

NFS: Network File System

NHS: National Health Service

NIC: Network Interface Card

NIF: Network Information Forum

NISP: Networked Information Services Project

NISS: National Information on Software and Services

NMSI: National Museum of Science and Industry

NNTP: Network News Transfer Protocol
NNTT: National New Technology Telescope
NNW: Net North West
NOC: Network Operations Centre
NorMAN: North East Metropolitan Area Network
NORSAR: Norwegian Seismic Array
NPL: National Physical Laboratory
NREN: National Research and Education Network
NRS: Name Registration Scheme
NSF: National Science Foundation
NSFNET: National Science Foundation Network
NTT: Nippon Telephone and Telegraph Public Corporation

O

O/R: Originator/Recipient
OAG: Official Airline Guides
OC: Optical Carrier
Ofcom: Office of Communications
Oftel: Office of Telecommunications
OLR: Offline Reader
OLS: oNline-Line System
OOP: Object Oriented Programming
OPAC: Online Public Access Catalogue
ORACLE: Optional Reception of Announcements by Coded Line Electronics
OSI: Open Systems Interconnection
OSPF: Open Shortest Path First
OSRD: Office of Scientific Research and Development
OUP: Oxford University Press

P

PABX: Private Automatic Branch Exchange
PAC: Prestel Administration Centre
PANDA: Prestel Advanced Network and Database Architecture
Pb: Petabyte
PCFC: Polytechnics and Colleges Funding Council
PDH: Plesiochronous Digital Hierarchy
PG: Prestel Gateway
PIC: Prestel Information Centre
Ping: Packet Internet Gopher
PIPEX: Public Internet Protocol EXchange
PLP: Presentation Level Protocol

PNO: Public Network Operator

POP/PoP: Post Office Protocol/Point of Presence

PPARC: Particle Physics and Astronomy Research Council

PPP: Point-to-Point Protocol

PRMD: Private Management Domain

PRNET: Packet Radio Network

Project Jupiter: JUGL Project for Information Transfer, Education, and Research

PSE: Packet Switching Exchange

PSS: Packet Switching Service/Packet Switched Stream

PSTN: Public Switched Telephone Network

PTT: Post, Telegraph, and Telephone

PUC: Prestel User Centre

R

RAL: Rutherford Appleton Laboratory

RAND: Research and Development Corporation

RCA: Radio Corporation of America

RCOnet: Regional Computing Organization network

RFCs: Request for Comments

RIP: Routing Information Protocol

RJE: Remote Job Entry

RPC: Remote Procedure Call

S

SATNET: Satellite Network

SDC: System Development Corporation

SDH: Synchronous Digital Hierarchy

SERC: Science and Engineering Research Council

SERCnet: Science and Engineering Research Council network

SGML: Standard Generalised Markup Language

SHEFC: Scottish Higher Education Funding Council

SIG: Special Interest Group

SLA: Service Level Agreement

SLD: Second-Level Domain

SLIP: Serial Line Internet Protocol

SMDS: Switched Multimegabit Data Service

SMS: Short Message Service

SMTP: Simple Mail Transfer Protocol

SNA: Systems Network Architecture

SNCF: Société Nationale des Chemins de fer Français

SNMP: Simple Network Management Protocol

SONET: Synchronous Optical Network

SQL: Structured Query Language

SRC: Science Research Council

SRCnet: Science Research Council Network

SRI: Stanford Research Institute

SSEM: Small Scale Experimental Machine

SSL: Secure Sockets Layer

SSRC: Social Science Research Council

SuperJANET: Super Joint Academic Network

SWERN: South West England Regional Network

SWUCN: South West Universities Computer Network

SWURCC: South West Universities Regional Computer Centre

Sysop: System operator

T

TACS: Terminal Access Conversion Service

TBBS: Typical Bulletin Board System

TCA: Telecomputing Corporation of America

TCP: Transmission Control Protocol

TCP/IP: Transmission Control Protocol/Internet Protocol

TDM: Time Division Multiplexing

Telex: Teleprinter exchange

Telnet: Telecommunications network

TEN: Trans-European Network

TEN-155: Trans-European Network-155 Mbps

TEN-34: Trans-European Network-34 Mbps

TFTP: Trivial File Transfer Protocol

TLD: Top-Level Domain

TOP: Thomson Open-line Programme

TRACS: Thomson’s Reservations and Administrative Control System

TTNS: The Times Network Systems

TVN: Thames Valley Network

U

UA: User Agent

UC Berkeley: University of California at Berkeley

UCC: University College Cardiff

UCL: University College London

UDC: Prestel Update Centre

UDP: User Datagram Protocol

UFC: University Funding Council

UGC: University Grants Committee

UHI Network: University of the Highlands and Islands Network

UKERNA: United Kingdom Education and Research Networking Association

ULCC: University of London Computer Centre

UMIST: University of Manchester Institute of Science and Technology

URI: Universal Resource Identifier

URL: Uniform Resource Locator

UUCP: UNIX-to-UNIX CoPy

UWIST: University of Wales Institute of Science and Technology

V

VADS: Value Added and Data Services

VANS: Value Added Network Services

VBI: Vertical Blanking Interval

Veronica: Very Easy Rodent-Oriented Net-wide Index to Computerised Archives

VI: Videotex Internetworking

VLBI: Very Long Baseline Interferometry

VoIP: Voice over IP

W

W3C: World Wide Web Consortium

WAIS: Wide Area Information Server

WAN: Wide Area Network

WDM: Wavelength Division Multiplexing

WELL: Whole Earth ‘Lectronic Link

Wi-Fi: Wireless-Fidelity

WINCIM: CompuServe Information Manager for Windows

WinSock: Windows Sockets

WLAN: Wireless LAN

X

XHTML: eXtensible Hypertext Markup Language

XML: eXtensible Markup Language

XoT: X.25 over Transmission Control Protocol/Internet Protocol

Y

YHMAN: Yorkshire and Humberside Metropolitan Area Network

1. Introduction

1.1 Computer Networks, Convergence, and the Internet

In 2005, approximately 934 million people have access to the Internet.[1] Every week, users send and receive billions of e-mails, conduct e-commerce transactions, retrieve substantial amounts of information from Web sites, access their bank accounts online, download files, and perform other activities such as playing games.[2] The Internet and the World Wide Web have diffused throughout the world and with the emergence of pervasive computing technologies, including notebooks, Personal Digital Assistants, mobile phones, and wireless networks, people are now accessing the largest network on Earth wherever and whenever they want.[3]

The success of the Internet has prompted a lot of analysis about the origin of this network. Since the late 1980s, many people have written papers, articles, books, and theses about the origin and development of computer networks, the Internet, and the World Wide Web. Individuals including Paul Baran, Donald Davies, Lawrence Roberts, and Tim Berners-Lee, have given interviews and/or written first-hand accounts of how they were involved with the design, development, and deployment of

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[1] Determining the precise number of users on the Internet is not an exact science. It is also important to recognise that even though approximately 934 million users is a large number, especially when compared to the number of subscribers that used computer networks during the 1980s and 1990s, it is small when compared to the total amount of people on Earth who do not have access to the Internet. See *Internet User Forecast Methodology*, Computer Industry Almanac, 2003, Available from: http://www.c-i-a.com/methodology.htm#internetuser, Accessed on: 21 June 2005, *Population Explosion!* Jupitermedia Corporation, 2005, Available from: http://www.clickz.com/stats/sectors/geographics/article.php/5911_151151, Accessed on: 21 June 2005. For an overview of the issues raised by the digital divide see P. Norris, *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide* (Cambridge: Cambridge University Press, 2001), S. Marshall, et al. eds., *Closing the Digital Divide: Transforming Regional Economies and Communities with Information Technology* (Westport, CT: Praeger, 2003), *The New Missing Link: The Digital Divide*, ITU, 2002, Available from: http://www.itu.int/ITU-D/conferences/wtdc/2002/brochure/missing_link.html, Accessed on: 14 September 2004, and *Istanbul Action Plan to Bridge the Digital Divide*, ITU, 2002, Available from: http://www.itu.int/ITU-D/conferences/wtdc/2002/doc/winzip/WTDC-02_PDF-EN.zip, Accessed on: 14 September 2004.

[2] According to an IDC study, people sent approximately 31 billion e-mails every day during 2002. The IDC predicts that by 2006, users will send 60 billion e-mails every day. See *Over 60 Billion Daily Email Messages to be Sent*, NUA, 2002, Available from: http://www.nua.ie/surveys/index.cgi?f=VS&art_id=905358417&rel=true, Accessed on: 22 June 2005.

[3] The Internet is a global interconnected network of networks – an internetwork. Computer networks interconnect computers over local and wide areas using communication systems and technologies such as the telephone network, leased lines, coaxial cables, fibre-optic circuits, and satellite links. Computers use hardware and software to communicate and network devices, such as routers, transmit packets of data between computers. Packets can contain several types of data including files, e-mails, and Web pages. On packet switching, local and wide area networks, and fibre-optic circuits see Appendices A, F, and G.

technologies such as packet switching, the Advanced Research Projects Agency's network (ARPANET), and the World Wide Web.[4] Computer historians, including Janet Abbate and Judy O'Neill, have written Ph.D. theses and papers about packet switching and how the ARPANET developed into the Internet.[5] Several people have written books about the history of the Internet and the World Wide Web, some of which are scholarly, others intended for a popular audience.[6] Economists, such as Shane Greenstein, have focused on how governments, companies, and individuals helped to commercialise this network.[7] In addition, during the last 15 years, people have written about the ARPANET, TCP/IP, the Internet, and the World Wide Web in magazines and newspapers.[8]

Much of this literature provides important contributions to our understanding of the development of both the Internet and the World Wide Web. However, many of the sources that explore these subjects usually adopt a teleological approach. Most accounts usually begin by describing how Baran and Davies independently invented

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[4] See P. Baran, Interview by Judy O'Neil, Menlo Park, CA, 5 March 1990, D.W. Davies, "An Historical Study of the Beginnings of Packet Switching," *The Computer Journal*, vol. 44, no. 3, 2001, pp. 152-162, L.G. Roberts, "The ARPANET and Computer Networks," in *A History of Personal Workstations*, A. Goldberg ed. (New York: ACM Press, 1988), pp. 143-167, and T. Berners-Lee, *Weaving the Web: The Past, Present and Future of the World Wide Web by its Inventor* (London: Texere, 2000).

[5] See for example J. Abbate, *From ARPANET to Internet: A History of ARPA-Sponsored Computer Networks, 1966-1988*, Ph.D. thesis (Pennsylvania: University of Pennsylvania, 1994), J.E. O'Neill, *The Evolution of Interactive Computing through Time-sharing and Networking*, Ph.D. thesis (Minnesota: University of Minnesota, 1992), J. Abbate, "The Internet Challenge: Conflict and Compromise in Computer Networking," in *Changing Large Technical Systems*, J. Summerton ed. (Boulder, CO: Westview Press, 1994), pp. 193-210 and J.E. O'Neill, "The Role of ARPA in the Development of the ARPANET, 1961-1972," *IEEE Annals of the History of Computing*, vol. 17, no. 4, 1995, pp. 76-81.

[6] For a thorough analysis of the development of the Internet and the World Wide Web, see J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999). See also C.J.P. Moschovitis, et al., *History of the Internet: A Chronology, 1843 to the Present* (Oxford: ABC-Clio, 1999), J. Naughton, *A Brief History of the Future: The Origins of the Internet* (London: Phoenix, 2000), K. Hafner and M. Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon & Schuster, 1996), M. Hauben and R. Hauben, *Netizens: On the History and Impact of Usenet and the Internet* (Los Alamitos, CA: IEEE Computer Society Press, 1997), P.H. Salus, *Casting the Net: From ARPANET to Internet and Beyond* (Reading, MA: Addison-Wesley, 1995), S. Segaller, *Nerds 2.0.1: A Brief History of the Internet* (New York: TV Books, 1998), Berners-Lee, *Weaving the Web*, and J. Gillies and R. Cailliau, *How the Web was Born: The Story of the World Wide Web* (Oxford: Oxford University Press, 2000).

[7] See S. Greenstein, "The Commercialization of Information Infrastructure as Technological Mediation: The Internet Access Market," *Information Systems Frontiers*, vol. 1, no. 4, 2000, pp. 329-348 and S. Greenstein, "Building and Delivering the Virtual World: Commercializing Services for Internet Access," *Journal of Industrial Economics*, vol. 48, no. 4, 2000, pp. 391-411.

[8] See for example F. Murphy, "Following Protocol," *Personal Computer World*, March 1990, pp. 176-178 and 180, W.M. Grossman, "Into the Internet," *Personal Computer World*, April 1993, pp. 388-390, 392, and 394, S. Schofield, "Getting Started: The Internet," *MacUser*, 14 October 1994, pp. 155-157, and R.W. Wiggins, "Webolution: The Evolution of the Revolutionary World-Wide Web," *Internet World*, April 1995, pp. 32-33 and 36-38, and D. Winder, "World Services," *PC Pro*, January 1995, pp. 198-199, 201, and 204-206.

packet switching. Focus then moves to the development and diffusion of the ARPANET and how this network developed into the Internet during the 1980s. While the ARPANET was undoubtedly a seminal computer network, there were other networks which most of the literature does not discuss in detail. In addition, accounts often only devote small sections to alternative solutions for internetworking such as the Open Systems Interconnection (OSI) seven-layer reference model. While focusing exclusively on the ARPANET, the Internet, and the World Wide Web is important and therefore justified, it can leave the reader with the impression that the networking world started with the ARPANET and ended with the Internet. This thesis is an attempt to help correct this misconception.

1.2 The Thesis

1.2.1 Scope

This thesis analyses the evolution of British computer networks and the Internet between the years 1970 and 1995.[9] Although it does consider other networks, such as Télétel in France, the focus is primarily on networks in the UK. As the dissertation is about computer networks, it only briefly considers the time-sharing systems and computer utilities which preceded them. In addition, as it is difficult to obtain perspective on recent events, the thesis only examines events up to 1995. This thesis analyses several aspects of the evolution of computer networks in the UK, including the technology employed. For this reason, the dissertation includes appendices that help to explain the operation of computer networks as well as a list of abbreviations.

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[9] This thesis uses the concept of evolution to help explain how networks emerged and subsequently developed in the UK. Most of the companies and organisations that created networks in Britain from the 1970s onwards did so in response to the needs of businesses or other types of user. Companies then adapted their networks to suit the requirements of their customers. No single controlling body or committee controlled this evolution, which meant that the networks naturally evolved on their own in response to the needs of users and other factors such as interconnectivity and standards. Continuity existed between each stage of development, with new networks, such as JANET, building on the advances of previous networks such as SERCnet. This process resulted in a diverse range of networks. Companies and organisations then selected from these networks to satisfy their information and communications needs. Basalla proposes a theory of technological evolution which Darwinian evolution influences. The theory incorporates the concepts of diversity, continuity, novelty, and selection. See G. Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988), pp. 1-25.

1.2.2 Sources

The thesis uses both primary and secondary sources. Throughout the course of my Ph.D., I conducted several interviews with people that were involved in the development and diffusion of computer networks in the UK. Most of these occurred face-to-face in London, but others took place in locations such as Oxfordshire and Manchester. I also conducted several telephone and e-mail interviews. For Chapters 2 and 3, I interviewed members of the Joint Network Team (JNT) and the United Kingdom Education and Research Networking Association (UKERNA). These individuals were involved in the convergence of the academic networks to form JANET, the implementation of the TCP/IP Internet protocols on the network, and the diffusion of SuperJANET.[10] Among the interviewees were Professor Roland Rosner, a member of the Network Unit; Professor Mike Wells, the first Director of Networking, and one of his successors Dr Robert Cooper; Professor Peter Linington and Dr Willie Black, two former heads of the JNT; Dr Ian Smith, a Network Operations Manager; Dr James Hutton, a former Business Director of UKERNA; Professor Peter Kirstein CBE, who was instrumental in establishing the first international node on the ARPANET in the UK during 1973; Dr Robert Day, the JANET IP Service Manager; and Professor Christopher Cooper, a member of the SuperJANET project team.

I conducted five interviews for Chapter 4. The interviewees were involved in the operation of Prestel, Ceefax, and the Thomson Open-line Programme private viewdata system. Specifically these were Dr Alexander Reid, the first Director of Prestel, and the second director, Richard Hooper; Colin McIntyre, the first editor of Ceefax; Paul Brannan, the deputy editor of BBC News Interactive; and Nick Tagg, the Service Delivery Manager at Thomson Holidays.

For Chapter 5, I carried out several interviews with individuals who had set up and operated e-mail networks in the UK. These included John Leighfield CBE, British Leyland Systems' IT director; David Brunnen, a Business Development Manager at British Telecom (BT); John Morris, the first managing director of Telecom Gold and his successor Dr Peter Bury; David Sexton, the head of operations and development

[10] On TCP/IP see Appendix E.

of Telecom Gold; Martin Turner, a Telecom Gold product manager; David Flinter, the first managing director of Cable & Wireless Easylink; Barbara Davies, the development manager of Easylink; and Mark Preston, Cable & Wireless' technical design authority.

I conducted several interviews for Chapter 6. At CompuServe, these included Barry Berkov, a former senior vice president of the information services division; Sandy Trevor, a chief information officer; Andrew Gray, European general manager; and David Gilroy, a customer services director. Other interviewees included Peter Dawe OBE, who founded PIPEX, and Bill Thompson, the company's 'Internet Ambassador'; Cliff Stanford, a co-founder and the first managing director of Demon Internet; Grahame Davies, a co-founder of Demon Systems; Steve Kennedy, a founder member of Demon Internet; Shaun Fensom, a co-founder of Poptel; Peter Collinson, the founder of UKnet; and Deri Jones, the first managing director of EUnet GB.

In addition to carrying out interviews, I also visited several libraries, an archive, and an exhibition to conduct research. The libraries and institutions included Warwick University, Birmingham University, the University of Central England in Birmingham, Coventry University, Leeds University, Cambridge University, Imperial College, the British Library, the British Newspaper Library, the London School of Economics, the BT Archives, the Science Museum, and the Rutherford Appleton Laboratory. I obtained copies of many materials from these libraries and institutions including manuals, brochures, and advertisements; academic papers; sections of books; magazine and newspaper articles; and resources from microfilm such as sections of theses and other materials. I also obtained information from authoritative Web sites. In addition, I purchased two Ph.D. theses from the US which were useful for background research. Several people also either lent or gave materials to me.

1.2.3 Overview

During the 1980s, companies developed hundreds of computer networks throughout the world. These provided several of the services that the Internet of the 1990s would provide, including remote login abilities, file transfer facilities, electronic mail, instant messaging utilities, information retrieval applications, graphical services, online shopping and banking, and games. Despite providing many useful facilities, all of the networks suffered from the same problem, which was incompatibility. Even though most of the networks used the open standard X.25 protocol, for the lower layers involved in the transmission of data, they also used higher layer protocols which were incompatible with each other.[11] For example, some, including the academic network JANET, used open standards for the higher layers, but these were incompatible with proprietary protocols used on other networks, including British Telecom's Prestel. There was therefore an interconnectivity problem which meant that it was very difficult to send e-mails from one network to another and hard to retrieve information provided by an incompatible network if you subscribed to a rival service.

To help create a framework for an open systems set of standards, which would enable companies to interconnect their networks, the International Organization for Standardization (ISO) started to develop the Open Systems Interconnection seven-layer reference model during the late 1970s. By 1984, it had ratified its first OSI standard, X.400, which enabled incompatible networks to send and receive e-mails.[12] The ISO followed this by developing a directory services standard, X.500, together with other protocols such as the File Transfer Access and Management facility. In theory, if every company adopted these protocols, they would have converged around the OSI standards to create an OSI internet.[13] Alternatives to this solution existed, specifically the idea of a videotex internet and the Internet itself. However, for most of the 1980s, many assumed that OSI would prevail, believing that it was the natural choice to solve the problem of interconnectivity. Although it was uncertain which solution would succeed, by the early 1990s it was clear that people and companies had

[11] Protocols control how computers communicate. To help impose order on an inherently complex activity, computer scientists divide the processes involved into layers. See Appendices A and D.
[12] See Appendix L.
[13] This convergence would probably have mirrored the convergence of networks around TCP/IP, as users, instead of a single authority, would have probably directed this convergence, as there would have been value in using OSI compatible networks.

failed to adopt OSI and the same applied to the videotex internet. By then, the Internet was becoming very popular with a broad range of users, and people naturally adopted the protocol used on this network, TCP/IP, to solve the problem of interconnectivity and to connect to the Internet.[14] This thesis looks at how a diverse range of incompatible computer networks emerged in Britain during the 1970s, 1980s, and 1990s. It considers why many people assumed OSI was the natural choice to solve the problem of interconnectivity, therefore dismissing TCP/IP which the Internet and other networks used. The thesis looks at the context and background for the protocol wars, which emerged during the late 1980s, by means of detailed reference to significant British networks. The thesis also considers why most people did not adopt OSI in the UK, how and why TCP/IP became the de facto protocol for internetworking and networking in Britain, and how most of the networks that still existed by the mid 1990s converged around the Internet Protocol suite during this decade.

1.2.4 Outline

As my thesis looks at the development of computer networks in the UK, I had to decide which networks to analyse. I decided to focus mainly on public networks which people could pay to access. During the 1980s and early 1990s, the Internet was an academic network, and it was networks, such as Prestel, Telecom Gold, and CompuServe, which were well known and dominant. This focus necessarily precludes privately run networks such as Local Area Networks. A detailed study of the development and diffusion of LANs in the UK would no doubt be important, but it is beyond the scope of my research. I also decided not to focus on Bulletin Board Systems because the sources were not strong enough. Which leaves the academic networks that were not public. However, these were sufficiently important that any

[14] Networks, such as the Internet, developed through distinct stages. Originally, mainly scientists only used them, but by the 1990s, several types of user regularly accessed the resources provided by the networks, including hobbyist and business users as well as consumers. Dempsey's four stages of the development of academic networks are applicable here. Thomas and Wyatt build on this, using the classification scheme to illustrate how the Internet changed. See L. Dempsey, "Research Networks and Academic Information Services: Towards an Academic Information Infrastructure," *Journal of Economic Networking*, vol. 1, no. 1, 1993, pp. 1-27 and G. Thomas and S. Wyatt, "Shaping Cyberspace—Interpreting and Transforming the Internet," *Research Policy*, vol. 28, no. 7, 1999, pp. 681-698.

thesis that looks at the diffusion of networks in the UK would be incomplete if it did not consider these networks in detail.

In a thesis that analyses several computer networks that emerged and co-existed in parallel, it is difficult to create an order for the chapters that mirrors the reality of the situation, as it existed at the time. For example, in a period of about 5 years, several networks emerged including JANET, Prestel, and Telecom Gold. To try to analyse all of these at the same time would be impractical. I therefore decided to introduce my thesis with academic networks, as these were essentially a microcosm of the entire thesis. I then decided to consider each network on its own, starting with the earliest public network, Prestel, followed by the electronic mail networks, and ending with CompuServe and the Internet Service Providers. The remainder of this section provides an outline of each chapter.

The thesis begins in Chapter 2 by analysing the evolution of academic networks in the UK. During the 1970s, several academic networks, such as SWUCN and SRCnet, emerged, but as they were incompatible with each other, this limited their utility. The chapter shows how these and other networks converged around a single standard to form the Joint Academic Network (JANET) and emphasises the speed with which this happened. It describes how JANET evolved during the 1980s, with new services and facilities emerging on the network. It also looks at how the traffic on the network increased and how this prompted the funding bodies to plan a two-phase upgrade of the network, known respectively as JANET Mark II and SuperJANET.

In Chapter 3, the thesis continues to examine the evolution of British academic networks. By the end of the 1980s, it was clear that the demands placed on JANET required the funding bodies to plan a series of upgrades to the network. This chapter discusses these upgrades and focuses particularly on the SuperJANET initiative. In parallel with this discussion, the chapter also highlights how access to the Internet protocols on JANET became very popular, and how the academic community subsequently converged around these protocols.

Having examined the emergence and diffusion of academic networks, the thesis considers the development of a consumer-oriented network. Throughout the late

1960s and into the 1970s, people envisaged that technologies, such as computer networks, would enable consumers to access many different services from their homes. One network particularly embodied this concept: Prestel. Chapter 4 illustrates how Prestel offered services and facilities, such as information retrieval, e-mail, and online banking and shopping, which people now use on the Internet. It shows how rival videotex standards competed and how the standards and technologies could have converged to form a videotex internet. The chapter explores why Prestel did not succeed and places this into context. It also looks at the success of travel information on Prestel and private viewdata networks, and shows how videotex networks, such as Télétel, co-exist in a world dominated by the Internet.

As academic networks and Prestel diffused throughout the UK during the 1980s, a new type of network appeared, aimed at business users. Since the invention of time-sharing systems in the 1960s, computer scientists had experimented with providing forms of electronic communication. With the implementation of electronic mail on the ARPANET during the early 1970s, this concept subsequently diffused throughout several other networks. These included Dialcom, MCI Mail, and Telemail in the US and COMET, Telecom Gold, and Cable & Wireless Easylink in the UK. Chapter 5 focuses on two of the largest British networks, Telecom Gold and Cable & Wireless Easylink. It looks at how these services developed throughout the 1980s and into the 1990s. The chapter also explores the problem of interconnectivity, looking at how companies could have converged around the international standard, X.400, to form a global interconnected e-mail network, and explains why this did not occur. The chapter also discusses why the proprietary networks did not succeed, and what affect the Internet had on the world of electronic mail.

In Chapter 6, the thesis focuses on CompuServe, other online services, and the Internet. It shows how CompuServe developed from being a time-sharing system to an online service accessed by personal computer users. It describes how, by the mid 1980s, the network offered many of the services and facilities that the Internet of the 1990s would provide. It shows how CompuServe became the largest online service in the world by the end of the 1980s and explains why this occurred. The chapter places CompuServe into context by discussing the online service phenomenon, focusing on competitors including America Online, Prodigy, and the Microsoft Network. The chapter explores why CompuServe underestimated the significance of the Internet, and how the commercialisation of this network, and the subsequent emergence of Internet Service Providers, affected the company.

The thesis concludes with Chapter 7 which provides a summary of the dissertation together with an analysis of how computer networks in the UK converged around the Internet. The chapter also places this convergence into context by considering the pervasive computing phenomenon, considers further research questions, and provides concluding remarks to the thesis.

2. From Diversity to Convergence: JANET

2.1 Introduction

The introduction of computers to British universities began during the 1940s. The first computer to become operational was the Small Scale Experimental Machine (SSEM), developed by Tom Kilburn and Frederik C. Williams at Manchester University. Commonly referred to as the Manchester Baby Machine, it demonstrated the feasibility of the stored-program concept proposed in the EDVAC report of 1945 and publicised by the Moore School Lectures of 1946.[1] The second computer to be developed was the Electronic Delay Storage Automatic Calculator (EDSAC) at the University of Cambridge, under the direction of Maurice Wilkes. The first practical example of an electronic digital computer, it became operational in 1949, a year after the Manchester Baby. Additional computers, such as the Manchester Mark I and the Pilot ACE at the National Physical Laboratory (NPL), followed these developments. People subsequently used these custom-built machines for several tasks.

By the mid 1950s, the potential of computers for academic research had attracted the interest of the British government. Several universities had also expressed an interest in these new machines. If a university wanted to obtain a computer, it applied to the University Grants Committee (UGC) for funding. The UGC reported to the Department of Education and Science (DES) and provided general funds for universities (see Figure 2.1). Glasgow University became the first institution to apply, and interest from universities reinforced the government's view that the provision of computers was going to become an issue, with the economic considerations that this implied. The UGC therefore began three rounds of computer provision which would last from 1954 to 1965.[2] During the first round, twelve universities applied for machines and nine declared that they were not interested at that time. Many were vague about why they wanted a computer and not every one who applied for a machine received one. Two further rounds followed, with the UGC supplying more computers to universities.

[1] EDVAC stood for the Electronic Discrete Variable Automatic Computer.
[2] J. Agar, "The Provision of Digital Computers to British Universities up to the Flowers Report (1966)," *The Computer Journal*, vol. 39, no. 7, 1996, pp. 630-642.

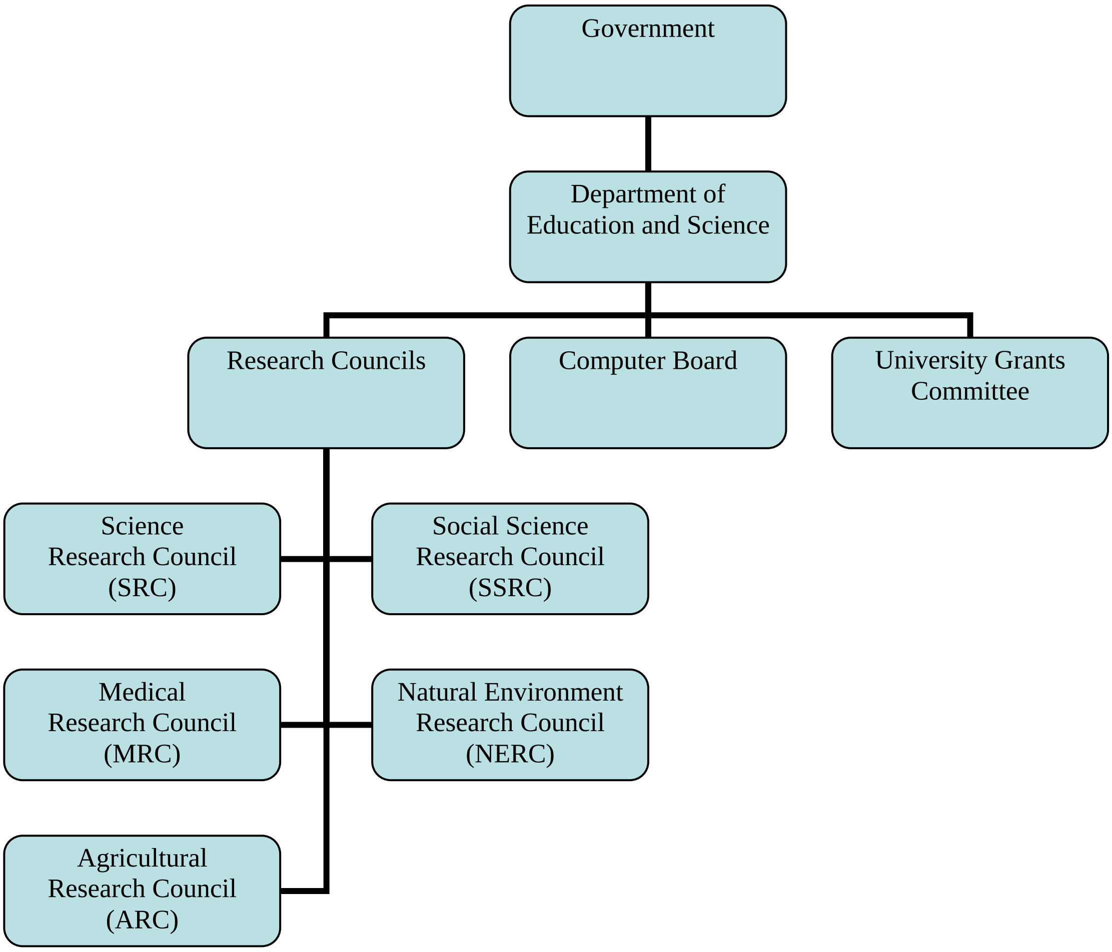

Figure 2.1. Hierarchy of funding bodies circa 1976/1977.[3]

Most institutions requested and received British manufactured machines, including the Ferranti Sirius and English Electric KDF9. By the mid 1960s, this interest in British computers had resulted in UK manufacturers supplying 34 of the 39 machines to universities and colleges. An official 'Buy British' policy had not influenced these events, as such a policy did not exist during this period. For both political and commercial reasons universities implicitly understood that they should support the British computer industry through the purchase of British computers. However, with the rising influence of large US corporations, especially IBM, the government later formalised this stance with its official 'Buy British' policy.

Computer provision to universities during the 1950s and 1960s had been a piecemeal affair, with several organisations, committees, and individuals involved in the process. Many wanted the funding, policy, and organisation of provision to be rationalised and

[3] The Computer Board provided funding for university mainframes, while the University Grants Committee supplied general university funds.

this prompted the Flowers Report of 1966. This report analysed the issue of computer provision within universities. The report recommended that the Department of Education and Science should be responsible for a new funding agency, which would undertake the provision of computers. In response, the government set up the Computer Board in 1966.[4] The Computer Board reported to the DES and continued the earlier work of provision (see Figure 2.1). It also started to address the concerns that existed within academia relating to the provision of computers within institutions. These included dissatisfaction with the number of machines within universities, with many institutions not having access to a machine. Some universities were not content to receive second-hand computers from other institutions. In addition, departments expressed reluctance to share the central computer facilities provided on campus. Both social and political factors influenced these frustrations. Academics within universities, such as scientists, needed access to computers to help with their work. Universities also wanted computers for several reasons, including the status that they conferred on those who had them. Whatever the reasons, the level of computer provision increased from the late 1960s onwards.

However, despite the increase in computers, not every university had a machine. Institutions that did not have a computer on campus had several options. They could wait until the Computer Board provided one, sometimes in association with industry, or they could use the facilities of a machine at another university. Since the mid 1950s, several universities had provided such a service, in response to the increasing demand for computer access. An example was a postal service that Manchester University set up in 1955.[5] Customers from companies, such as Imperial Chemical Industries (ICI), and universities could post their programs to the Computing Machine Laboratory, which would then check the code and execute the programs on the Manchester Mark I. The Laboratory would then post the results back to the customer, usually within a week of receiving the job. The postal service became quite popular, with staff using the Mark I for 12 hours a week for processing customers’ work.

[4] F.P. Verdon and M. Wells, “Computing in British Universities: The Computer Board 1966–1991,” *The Computer Journal*, vol. 38, no. 10, 1995, pp. 822-830.
[5] R.A. Brooker, “The Autocode Programs Developed for the Manchester University Computers,” *The Computer Journal*, vol. 1, no. 1, 1958, pp. 15-21.

Sharing resources intensified with the establishment of regional computer centres. Under the direction of the UGC, the universities of London, Manchester, and Edinburgh obtained large computers, such as the Atlas, to serve the needs of users both within the institutions and throughout academia. The Flowers Report of 1966 recognised the significance of these centres, and recommended the installation of more powerful machines such as the CDC 6800. As more and more universities obtained computers during this period and became aware of the resource sharing services offered by the national centres, they started to use Remote Job Entry (RJE) terminals. RJEs consisted of a card reader and line printer, enabling people at universities to submit batch jobs to the mainframes at the centres, with their terminals printing the results. The combination of powerful computers accessed throughout a region by universities lead to the formation of an innovation: academic computer networks. These were networks used by academic staff at universities and research council funded sites to conduct teaching and research activities such as remote job submission and early forms of communication using computers. Institutions operated these networks for the benefit of local universities and other sites and they did not permit any one to transmit commercial traffic across the networks. Several regions developed a set of heterogeneous computer networks during the late 1960s and 1970s. These began as star networks, with leased lines radiating out from the centres to the terminals in universities. This chapter will focus on two of the earliest and most important networks, SWUCN and SRCnet. It will show how these networks converged around a single standard to form a Joint Academic Network (JANET) and emphasise the speed with which this happened. It will also describe how JANET evolved during the 1980s.

2.2 Early Network Islands

2.2.1 SWUCN

The South West Universities Computer Network (SWUCN) was one of the earliest British academic computer networks to be developed. During the 1960s, the Computer Board had provided five institutions in the South West of England with English Electric System 4 machines. Initially, the universities of Exeter, Bristol, and Bath and the University of Wales Institute of Science and Technology (UWIST) and University College Cardiff (UCC), used their own mainframes in isolation. In 1967, the institutions decided to develop the Integrated Computer Network Service. The rationale for this network was resource sharing. By interconnecting machines, users at different sites could access resources on computers at several universities. In 1969, work began on establishing the South West Universities Computer Network.[6] The project was a collaborative effort between academic, commercial, and governmental institutions and organisations, in association with the General Post Office (GPO).[7] The Department of Trade and Industry (DTI), International Computers Limited (ICL), and the GPO all became involved with the project.[8] The DTI maintained an interest in the developing network as did ICL, which saw the South West universities as a friendly environment in which to test its systems.[9] The Post Office agreed to supply the leased lines for the network for a development period. The SWUCN provided the Post Office with the opportunity to test its new 48 Kbps lines, which were fast when compared to the standard transmission speeds of 2,400 bps and 4,800 bps used at the time.[10]

SWUCN began operation during 1971 (see Figure 2.2). One of the first British academic computer networks, SWUCN was experimental and therefore not used by users. Based on a star network topology, the network used five leased lines to connect the universities to a central CDC 1700 minicomputer. The five ICL host computers within the network communicated with each other using proprietary protocols.[11] The facilities provided included a batch processing service, file transfer, and electronic messaging.

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[6] K. Powell, "Evolution of Networks Using Standard Protocols," *Computer Communications*, vol. 3, no. 3, 1980, pp. 117-122.

[7] The Post Office became a public corporation in 1969 and throughout the 1970s and into the 1980s, it was the state monopoly provider of telecommunications in Britain. See *Events in Telecommunications History*, British Telecom, 2004, Available from: http://www.btplc.com/Thegroup/BTsHistory/Eventsintelecommunicationshistory/Eventsintelecommunicationshistory.htm, Accessed on: 2 July 2004.

[8] The government established the DTI as a department during 1970. The successor to the Board of Trade, the DTI supported the international success of British industry as well overseeing issues such as monopolies and mergers. In 1968, English Electric, International Computers and Tabulators (ICT), Plessey, and the Ministry of Technology agreed a deal in which English Electric and ICT would merge to form a new company, International Computers Limited. English Electric's System 4 computers therefore became ICL machines. See *DTI History*, DTI, 2004, Available from: http://www.dti.gov.uk/about_dti_history.html, Accessed on: 2 July 2004 and M. Campbell-Kelly, *ICL: A Business and Technical History* (Oxford: Clarendon, 1989), pp. 262-263.

[9] J. Brookes, E-mail to D. Rutter, 2 April 2004.

[10] See Appendix B.

[11] See Appendix A.

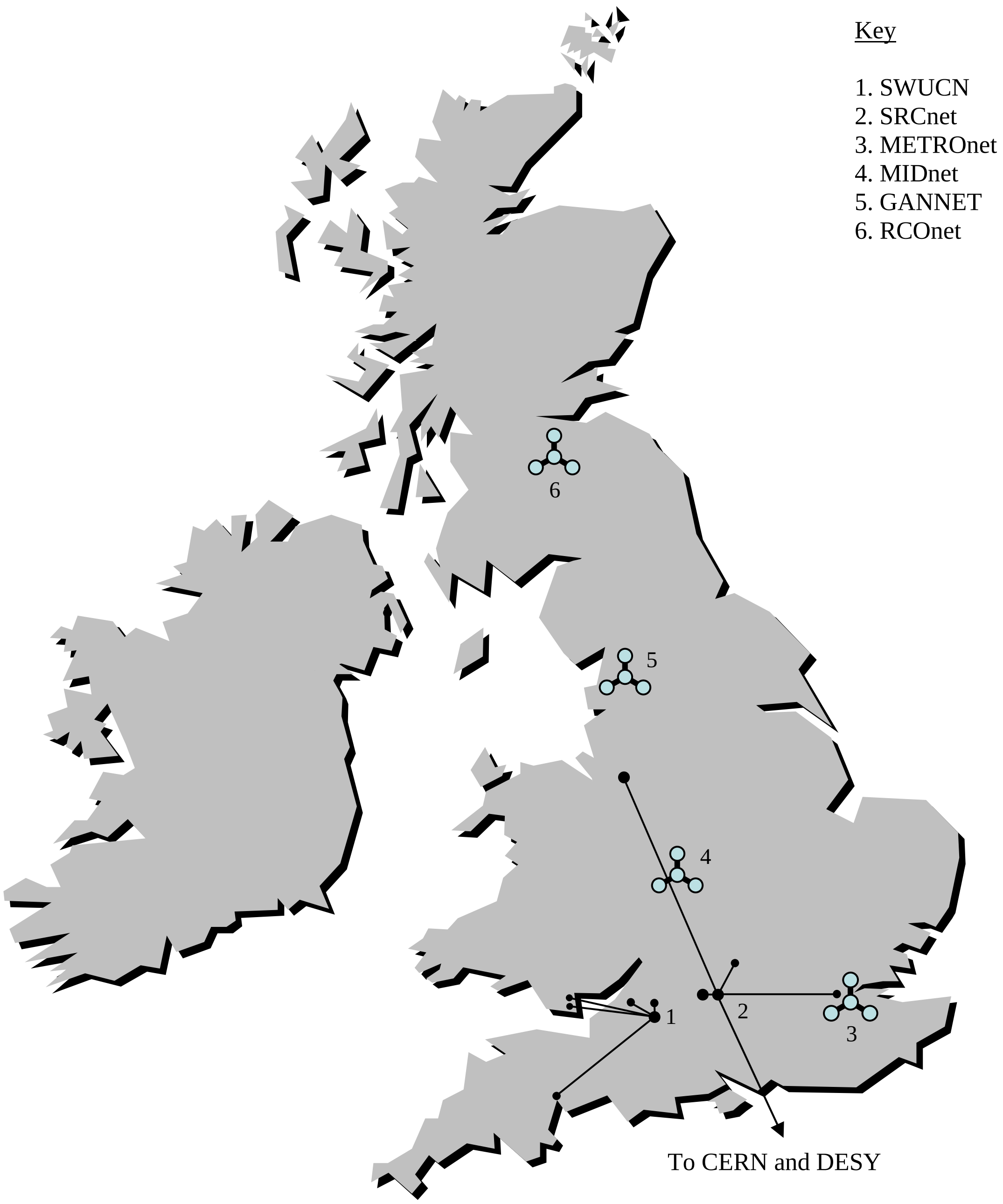

Figure 2.2. UK academic networks developed before JANET.[12]

During the 1971 to 1973 period, this developmental network continued to deliver test services such as these and in 1974, the universities allowed users to access the network for the first time. Four years later, the University of Bath installed an ICL 2980 mainframe and connected it to SWUCN. Compared to the existing System 4s, the 2980 was a large, powerful mainframe which was similar to IBM's System

[12] For clarity, the figure only shows two networks in detail. SWUCN connected institutions at 5 sites: one in Exeter, two in Cardiff, one in Bristol, and one in Bath. SRCnet connected 3 laboratories and many people used RJE terminals in places such as Oxford and Imperial College to access the mainframes at laboratories such as Rutherford.

370/168 in terms of processing power.[13] The addition of a new type of computer to a System 4 only network, redefined the nature of SWUCN. The vice-chancellors of the South West universities established a new organisational entity, the South West Universities Regional Computer Centre (SWURCC), to run the new machine. They chose Bath for political reasons, believing that this new university would not try to dominate the network, unlike Bristol, which was both established, and the largest within the group.[14] As collaboration and not dominance had helped SWUCN to evolve, this decision protected the interests of the network, and therefore the community of users as a whole.[15] In addition, with the installation of another ICL machine, this company consolidated its involvement in one of the first academic computer networks.

The new ICL mainframe also influenced the issue of standards. The ICL 2980 was not compatible with the System 4 machines used throughout the network, and this created a problem. The System 4s used a proprietary ICL protocol which enabled these machines to transmit and receive information. However, it did not permit a different type of computer to join SWUCN and communicate with the existing machines. For this to occur, the institutions would either have to change the protocol used within the network, or adapt the 2980 to emulate a System 4. For technical and economic reasons, the centre chose the latter option, employing an ICL 7905 to handle the protocol conversions. While this solution worked, it was a temporary one, as the centre knew that it would be adding new machines to SWUCN in the future, causing further communication problems. In addition, the development of new academic networks compounded the problem, for if the South West universities were to connect SWUCN to these networks, further protocol problems would probably occur. The SWUCN could use gateways between the networks, but once the centre had replaced every System 4, the gateways would perpetuate a redundant standard, no longer in use

[13] Campbell-Kelly, *ICL*, pp. 308-309.
[14] During the early 1960s, Lord Robbins chaired a committee on higher education, which looked at a several topics including the demand for higher education and the expansion of institutions throughout the UK. The subsequent publication of the Robbins report in 1963 recommended that the government should establish six new universities to provide 30,000 student places. The government considered the report's recommendations and agreed to conduct a review of higher education. These events influenced the establishment of new universities, such as Warwick, Kent, and Bath. See L. Robbins, *Report of the Committee Appointed by the Prime Minister Under the Chairmanship of Lord Robbins 1961-63* (London: HMSO, 1963), pp. 277-285 and *Government Statement on the Report of the Committee under the Chairmanship of Lord Robbins 1961-63* (London: HMSO, 1963), pp. 3-5.
[15] J. Brookes, Interview by D. Rutter, 3 July 2003.

by the hosts.[16] It is for these reasons that the institutions agreed that they should replace the proprietary protocol and adopt international standards. With this decision in mind, they stipulated that any company that wished to offer replacement mainframes would have to ensure that its machines were compatible with the emerging international standards for networks. Specifically this meant that they would have to adopt the new X.25 standard.[17]

The X.25 standard emerged during the mid 1970s. In 1974, representatives from Britain, France, Canada, and the US met to discuss the need for standardisation of packet-switched networks.[18] Attendees came from national Post, Telegraph, and Telephone (PTT) operators and companies including Telenet in the US.[19] These meetings resulted in the Comité Consultatif International Télégraphique et Téléphonique (CCITT) ratifying X.25 during 1976.[20] The X.25 standard was to influence the development of academic networking in the UK for the next 15-20 years, starting with networks such as SWUCN. The South West regional centre chose X.25 for several reasons. First, it was an international standard, which many PTTs and organisations would probably adopt. Compatibility with other networks, including the national network that the Post Office might develop, would therefore be necessary for resource sharing and communication. Second, the standard was flexible and performed well. Third, the centre would only need one protocol converter to connect SWUCN with X.25 networks. However, deciding on the standard for their packet-switched network was only one of the challenges facing the universities. They also needed to decide how to handle the lack of standards for other forms of communication, such as file transfer. International and national standards did not yet exist for these higher layer protocols, so the South West centre chose to adopt interim

[16] A gateway interconnects two networks that use incompatible protocols, providing translation facilities that enable both networks to communicate. Hosts were computers on a network, such as an ICL 2980, which provided services to terminals.
[17] See Appendix D.
[18] See Appendix A.
[19] Bolt, Beranek and Newman set up Telenet as a subsidiary during 1972 with the aim of using the knowledge that it had obtained during the development of the ARPANET to develop a commercial network. Telenet launched its network during 1975 and by 1977 people in 68 cities throughout the US could access the network. See A.L. Norberg and J.E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore: Johns Hopkins University Press, 1996), p. 179.
[20] See Appendix C.

standards developed by the Post Office, with the intention to replace these with their international equivalents, when they became available.

By 1978, the universities had agreed how they should develop their network. One of the most important factors that influenced the planned migration to X.25 was that this development should not disrupt the users of the existing network. The heavy usage of SWUCN influenced this decision. By then, people were establishing 10,000 connections each month within the network, 80 percent of which accessed the ICL 2980 mainframe. The universities also had two other reasons for rationalising network provision. The South West universities wanted to interconnect SWUCN with other networks in the UK, many of which would probably adopt X.25 as their protocol. The universities also wanted to reduce the costs associated with hiring the leased lines provided by the Post Office. With the replacement of a System 4 machine with a Honeywell Level 68 in 1979, the South West universities transition strategy began. For the first time, a computer from a manufacturer other than ICL became part of the network, and the installation of another machine that was incompatible with SWUCN, prompted the beginnings of the phased upgrade of its network. The upgrade continued during the late 1970s and into the 1980s, as the centre replaced its System 4 machines with new computers. These changes gradually converted SWUCN from a proprietary network, to one that used X.25.

2.2.2 SRCnet

Many of the issues encountered by universities in the South West, including standards, would affect other academic networks such as SRCnet. The Science Research Council (SRC) developed this network during the early 1970s.[21] Three sites formed the basis for the research council's work: the Rutherford and Atlas Computing Laboratories in Chilton, Oxfordshire, and the Daresbury Laboratory in Manchester.[22] Each contained a computer centre, equipped with a different mainframe: an IBM System/360 at Rutherford and an ICL 1906A at Daresbury. Scientists initially used these separate machines on-site, but in 1971, the SRC installed the first RJE terminal

[21] P. Bryant, "The SERC Network - Its History and Development," in *Information Technology and the Computer Network,* K.G. Beauchamp ed. (Berlin: Springer-Verlag, 1984), pp. 65-74.
[22] The Rutherford and Atlas Computing Laboratory and the Daresbury Laboratory were institutions that provided researchers with specialised facilities to explore subjects such as astronomy.

in Oxford, which allowed remote access to the IBM mainframe. The research council increased the number of RJEs, by installing terminals for SRC grant holders in university departments (see Figure 2.2). During the next three years, the number of RJEs and leased lines increased and by 1974, there were more than 20 terminals in institutions such as Imperial College. By then, more than 50 percent of the work undertaken by the System/360 originated from remote sites. The SRC had therefore developed a network of terminals which used proprietary protocols based on IBM and ICL standards.

As the number of terminals continued to increase, the Science Research Council became aware that some of its researchers wanted to access resources at more than one site. They had therefore installed multiple terminals within their departments to access both the IBM and ICL mainframes. Before the development of computer networks, it was quite common for people to use more than one type of terminal to access several mainframes. This situation occurred in the US with the Advanced Research Project Agency as well as in the UK with the SRC's network of terminals.[23] As more people adopted RJE terminals to satisfy their need for access to remote resources, the number of leased lines increased between the institutions and laboratories. However, if the number of leased lines continued to increase, it would become uneconomic to support these developments. In 1974 representatives from Rutherford, Appleton, and Daresbury Laboratories met to discuss the problem.[24] They decided that the research council needed to rationalise its provision of RJEs and leased lines, to reduce redundancy and costs, and improve services for its users. To achieve this aim, it would set up a network based on the Post Office's experimental packet-switched network. This protocol would co-exist with the existing proprietary standard, IBM's HASP protocol, used by the RJE terminals. In addition, the new network would support real-time computing as well as batch processing, which people

[23] J. Gillies and R. Cailliau, *How the Web was Born: The Story of the World Wide Web* (Oxford: Oxford University Press, 2000), p. 16.
[24] The Appleton Laboratory was in Slough. During 1979, the Appleton Laboratory merged with the Rutherford Laboratory to form the Rutherford Appleton Laboratory (RAL). See *History*, CCLRC, 2004, Available from: http://www.clrc.ac.uk/Activity/WhoWeAre;Section=5683, Accessed on: 16 September 2004.

had used for years.[25] Engineers would generate this new form of traffic using terminals that would access real-time facilities provided by remote machines.

For about a year, people used the Science Research Council's network. During this period, the research council realised that it had underestimated the significance of standards, having experienced problems interconnecting its network. The Post Office's decision not to develop its experimental network into a commercial service compounded this problem. The research council had to decide how to continue the development of its network. It decided that sustaining the development of an obsolete protocol or waiting for the Post Office to develop a service, were not viable options. This decision meant that the Science Research Council would continue to develop its existing network. The council chose to adopt the emerging X.25 protocol, because it believed that X.25 would become an international standard. Work began immediately on the network and within two years, the SRC had launched the Science Research Council Network (SRCnet). In a parallel development, it also developed a network based on the proprietary Digital Equipment Corporation (DEC) network (DECnet) protocol. This network linked departments to 2 DEC System 10s, installed at the University of Manchester Institute of Science and Technology (UMIST) and the University of Edinburgh.

By 1978, the SRC had a set of RJEs installed throughout the country and two networks: the SRCnet and the DECnet network. To rationalise the situation, the research council connected the terminals to SRCnet, and began to convert the former technology to the X.25 standard. Throughout this period of consolidation, the number of SRCnet users increased. Hundreds of people used the network at several institutions, with 5,000 calls made each week to the IBM System/360 mainframe.[26] International institutions also accessed the network. Scientists at the particle physics laboratories CERN in Geneva, and DESY in Hamburg, used SRCnet to access Rutherford's machine and send electronic messages.[27] They joined a community of

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[25] On batch processing and real-time computing see M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, 2nd ed. (Boulder: Westview Press, 2004), p. 141.

[26] J.W. Burren, "Current state of the SRC X25/EPSS network," *Proceedings of Networkshop 5, University of Kent at Canterbury, 19-21 September 1979* (Canterbury: University of Kent at Canterbury, 1979), pp. 55-58.

[27] CERN originally stood for the Conseil Européen pour la Recherche Nucléaire but the organisation later changed the name to the Centre Européen pour la Recherche Nucléaire (European Centre for

scientists, who used the network for other fields of research, including crystallography, High-Energy Physics (HEP), and astronomy. With the addition of a gateway to the Advanced Research Projects Agency Network (ARPANET), and the installation of new exchanges in five cities to manage the increasing demand, the network continued to develop.[28] However, the research council still needed to address the issue of operating two incompatible networks: one based on a non-proprietary protocol, X.25, and the other on a proprietary standard, DECnet. It planned to merge the two networks to create one X.25 network, and the expertise gained during the development of SRCnet would help this process. The combined network would later form the basis of a new national academic network.

SWUCN and SRCnet were two of the earliest and most important academic networks in the UK. Several others followed these developments (see Figure 2.2). These networks included the Midlands network (MIDnet), the Regional Computing Organization network (RCOnet), and METROnet.[29] The universities of Aston, Birmingham, Leicester, Loughborough, Nottingham, and Warwick developed MIDnet during the mid to late 1970s. At the same time, Edinburgh, Glasgow, and Strathclyde began work on RCOnet, and the University of London, together with other institutions, developed METROnet. All of these networks, together with developments in regions, such as Yorkshire and the South East, followed a similar pattern. Initially universities established star networks of Remote Job Entry terminals throughout campuses and between institutions, to provide access to resources. This situation lead to duplication of leased lines and terminals, a situation that was both costly for the institutions and unacceptable for users, who needed to use different types of terminal to access mainframes. To rationalise this duplication, the star networks developed into computer networks for the purposes of resource sharing. These usually used hardware and software provided by a single manufacturer, such as

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Nuclear Research). DESY stands for Deutsches Elektronen-Synchrotron. Information about SRCnet in relation to CERN and DESY from J. Hutton, Interview by D. Rutter, 2 June 2003.

[28] An exchange interconnects leased lines and transmits traffic throughout a network using a device known as a switch.

[29] See MIDnet see P. Harrison, "Networking in Midlands Universities," *Proceedings of Networkshop 5, University of Kent at Canterbury, 19-21 September 1979* (Canterbury: University of Kent at Canterbury, 1979), pp. 42-54, J. Davies, "RCO," *Proceedings of Networkshop 2, University of Liverpool, 11-12 April 1978* (Liverpool: University of Liverpool, 1978), pp. 53-55, and J.P. Brandon, "METRONET - London Region," *Proceedings of Networkshop 2, University of Liverpool, 11-12 April 1978* (Liverpool: University of Liverpool, 1978), pp. 51-52.

ICL, to form proprietary networks. The main type of users to access these networks at this time were scientists and engineers, who had a need to use them and therefore the desire to obtain the necessary expertise to access the new regional networks. Initially only scientists and engineers used the early UK networks, a situation that also occurred on the ARPANET. However, as the networks developed into the new national academic computer network, this community of users would broaden to include several types of people, including academics and others from outside of academia.[30]

2.2.3 Other Networks

The early developments in computer networking within academia were part of a general interest in packet-switched networks which existed during the late 1960s and early 1970s. Since the independent invention of packet switching by Paul Baran and Donald Davies during the 1960s, this new form of communication had attracted the attention of organisations and people in the US, UK, and other countries. In Britain, organisations such as the NPL sent individuals to the US to inspect time-sharing systems and the embryonic ARPANET.[31] Davies and other people held seminars about networking and individuals presented papers at conferences. In addition, an event organised by the Real Time Club in 1968 entitled “Conversational Computing on the South Bank,” made many people aware of the potential of packet switching.[32] Events such as these prompted a range of networks to be developed. In 1976, the Central Computing Agency (CCA) and ICL established an operational network called the General Administrative Network (GANNET) for administrative work.[33] The project connected mainframes throughout the country, using a proprietary protocol.

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[30] L. Dempsey’s four stages of the evolution of academic networks are applicable here. Each stage corresponds to different types of network activity, beginning with networks as entities used by scientists and ending as part of a universal infrastructure, used by many different types of user. Thomas and Wyatt build on this, using the classification scheme to illustrate how the Internet changed. They focus on the evolving nature of the social groups of users, starting with scientists and ending with commercial users. See L. Dempsey, “Research Networks and Academic Information Services: Towards an Academic Information Infrastructure,” *Journal of Economic Networking*, vol. 1, no. 1, 1993, pp. 1-27 and G. Thomas and S. Wyatt, “Shaping Cyberspace—Interpreting and Transforming the Internet,” *Research Policy*, vol. 28, no. 7, 1999, pp. 681-698.

[31] J.E. O’Neill, *The Evolution of Interactive Computing through Time-sharing and Networking*, Ph.D. thesis (Minnesota: University of Minnesota, 1992), pp. 44-166.

[32] M. Campbell-Kelly, “Data Communications at the National Physical Laboratory (1965–1975),” *Annals of the History of Computing*, vol. 9, no. 3/4, 1988, pp. 221-247.

[33] D. Campbell and S. Connor, *On the Record: Surveillance, Computers and Privacy – The Inside Story* (London: Joseph, 1986), p. 281.

Although the government later cancelled the venture, it developed into an academic network used by universities in the North West of England.

Other organisations and institutions, including the NPL, the Post Office, and University College London (UCL), also investigated networking during the late 1960s and early 1970s. Davies had proposed the NPL Data Communications Network (DCN) during 1966 and the network became operational in 1970. This packet-switched network, which used proprietary protocols, provided services such as RJE terminal access, time-sharing facilities, and an information retrieval system called Scrapbook. Compared to the NPL's interest in packet switching, the Post Office's attitude to the technology was less enthusiastic. At the time, this position was to be expected. For example, AT&T had concerns about the feasibility of packet-switched networks.[34] However, in Britain the efforts of the Real Time Club and several individuals eventually eroded the Post Office's scepticism. In 1973, the Post Office therefore announced its Experimental Packet Switching Service (EPSS), which it intended to develop into a public national packet-switched network. In 1976, a government inquiry confirmed the importance of such a network. This enquiry investigated issues relating to networks and telecommunications, and recommended the development of a national network compatible with international standards.[35] The following year the Post Office launched EPSS, but decided not to develop this into a public network. Instead, it launched the Packet Switching Service (PSS) during 1980 which replaced the EPSS. In parallel with events such as these, UCL undertook a separate network development project. Compared to the other ventures, UCL did not develop a network but linked the university to an existing network: the ARPANET. Larry Roberts, the manager of the US network, originally suggested to Davies that they link the ARPANET with the NPL network, as this was the only other packet-switched network anywhere at this time.[36] A leased line existed from Goonhilly to the Norwegian Seismic Array (NORSAR), and they could therefore use this line for the

[34] AT&T believed that Baran's proposal for a packet switching network was not feasible. It went further saying that the idea could not work and some within the company believed that Baran did not know what he was talking about and that he did not understand how the telephone network operated. See P. Baran, Interview by Judy O'Neil, Menlo Park, CA, 5 March 1990.

[35] J. Howlett, *Report of the National Committee on Computer Networks* (London: Department of Industry, 1978), pp. 25-26.

[36] P.T. Kirstein, "Early Experiences with the Arpanet and Internet in the United Kingdom," *IEEE Annals of the History of Computing*, vol. 21, no. 1, 1999, pp. 38-44. Additional information from P. Kirstein, Interview by D. Rutter, 12 August 2003.

connection. However, as Britain was trying to join the Common Market and because the two previous attempts at entry had not been successful, the Department of Industry would only support a link to Europe, not to the US. As a result, Davies could not take part but suggested that Roberts talk with Peter Kirstein, a Professor at the Institute for Computer Science in London. Enthusiastic about the venture, Kirstein submitted a proposal to the Science Research Council. For the proposal to be a success, it needed the support of universities. As Kirstein remembers, "this was way before we had collaborations between British universities, so the idea of getting a number of universities to back you was quite revolutionary."[37] When the SRC received the proposal, it did not believe that the US agency had agreed to it and "so the chairman of the SRC sent a telegram to the director of ARPA requesting confirmation that this offer had been made. That was the first the director of ARPA had heard about it [and] the director of ARPA doesn't like that sort of surprise!"[38] However, the US research agency did agree to support the proposal, unlike the SRC, which chose not to because they believed it to be "too speculative."[39] Undeterred, Kirstein managed to obtain funding from the Post Office and the NPL. UCL therefore established the first international node on the ARPANET during 1973.[40] This node joined many on several networks throughout the 1970s. By the end of the decade, these ad hoc developments had resulted in the establishment of a new entity: heterogeneous computer networks.

2.3 Towards a National Network: From Diversity to Convergence

2.3.1 Network Rationalisation

In parallel with developments such as SWUCN and SRCnet, the Computer Board also investigated the potential of computer networks during the 1970s. The Board recognised the importance of the regional and national centres, and saw networks as the enabler that would allow people to access the resources provided by these centres. To learn more about computer provision and networking, the Computer Board sent a small group to North America during 1972. The group inspected the types of computers used within universities and looked at the new ARPANET, which by then

[37] Kirstein, Interview.
[38] Ibid.
[39] Ibid.
[40] A node is a computer or a printer connected to a network.

contained 28 nodes at institutions such as UCLA. Having seen this network, the group believed that networking was going to become an integral part of computer provision within universities.[41] On its return to the UK, it therefore recommended that the Board establish a national network, compatible with the ARPANET. The Board set up a Network Working Party to look into this proposal in depth. This group was composed of representatives from several organisations, including the Computer Board, the Science Research Council, the regional centres, and the DTI.

One year after the formation of the Working Party, it published a report that analysed the proposed national network and made a series of recommendations.[42] The report suggested that the Board establish a packet-switched network, compatible with the ARPANET, which would interconnect the emerging regional networks. By 1973, Defense Advanced Research Projects Agency (DARPA) had demonstrated that packet switching worked, which helped to convince others that the technology was viable.[43] The Network Working Party's report acknowledged the success of the US project, and therefore suggested that compatibility with the ARPANET should influence the design of the new national network. The justification for the development of a national network was to rationalise the new regional networks. People used RJE terminals in networks such as SRCnet, and this lead to duplication of leased lines and terminals. Despite the efforts of regional networks to improve the situation, duplicate lines continued to exist, usually to national centres such as London. A national network would standardise this situation, by replacing inflexible and proprietary technologies with open protocols, which would enable terminals to connect to mainframes from different manufacturers as well as enabling inter-mainframe communication. The new network would also reduce costs, by eliminating the redundancy that existed throughout the country. However, if the community did not establish a national network, leased lines would continue to proliferate. As Ian Smith, a former Network Operations Manager, remembers this alternative of "establishing

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[41] M. Wells, Interview by D. Rutter, 7 August 2003.
[42] M. Wells and F.P. Verdon, *Report of the Network Working Party* (London: Computer Board, 1973), pp. 1-29.
[43] ARPA changed its name to DARPA during 1972. See *ARPA-DARPA: The History of the Name,* DARPA, 2003, Available from: http://www.darpa.mil/body/arpa_darpa.html, Accessed on: 24 June 2004. On credible investments see B.H. Clark and S. Chatterjee, "The Evolution of Dominant Market Shares: The Role of Network Effects," *Journal of Marketing Theory and Practice,* vol. 7, no. 2, 1999, pp. 83-96.

more and more point to point connections of limited applicability was just too horrendous (and potentially costly) to contemplate."[44] When the Working Party presented its recommendations to the Computer Board, the Board rejected the findings, believing that the report lacked clarity. It therefore requested another report containing more detail.

The Network Working Party published its second report during 1975.[45] This report recommended that the Computer Board establish a national computer network which universities and research council funded sites would use. However, the report explored this idea in greater depth, making several changes to the original proposal. While the Working Party still believed compatibility with the ARPANET was important, it also felt that the Board should recognise developments such as the Post Office's Experimental Packet Switching Service. It went further, suggesting that the Computer Board, research councils, and the Post Office should design and develop the national network. This network would be compatible with EPSS and the Post Office would operate it on behalf of the interested parties. As the Post Office was the monopoly provider of telecommunications in Britain, the Working Party saw it as the natural organisation to supply the leased lines for the academic community's network. An important shift was therefore occurring. The original report proposed that the national network should be compatible with the ARPANET, the prominent packet-switched network at that time. The second report proposed a network run by the Post Office which would use an EPSS compatible protocol. This shift in emphasis, from compatibility with a US network to a network based on emerging European and later international standards, was to influence the national academic network for the next 15 years. However, in 1975, it was only one of the several recommendations made by the Working Party to the Computer Board. These other recommendations included: the development of a Wide Area Network (WAN), to interconnect many Local Area Networks (LANs) on campuses, forming a hierarchy of networks.[46] Although the Working Party envisaged that people would primarily use RJE terminals to connect to their local mainframe on campus, it also recognised the importance of real-time

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[44] I. Smith, Interview by D. Rutter, 26 June 2003.

[45] M. Wells and F.P. Verdon, *Network Working Party Report* (London: Computer Board, 1975), pp. 1-20.

[46] The terms WAN and LAN did not emerge until the 1980s. The report therefore referred to a WAN as a macronet and a LAN as a micronet. See Appendix G.

processing. The Computer Board would therefore have to consider applications such as file transfer in the design of the new network. The report covered other topics including funding and collaboration. The Working Party recommended that the Computer Board fund network developments, with appropriate contributions from the research councils. As the Board and councils could obtain economies in provision by working together, and because the success of the venture depended on cooperation, the Working Party suggested that the organisations should collaborate. At this point, both the Computer Board and research councils were not closely associated with each other. While the Department of Education and Science funded both of them, they were relatively autonomous organisations that all supported computer provision and academic research in universities. The report recognised the managerial problems that might result from collaboration and stressed the importance of the DES's support for such an association. With this collaboration in mind, the Working Party suggested that the Computer Board and research councils establish a Network Unit. Jointly funded by the Board and councils, this unit would exist for two years and analyse the issues involved in establishing a national academic computer network. Staffed by people from the SWUCN project, the Science Research Council and the Post Office, the organisations set up the Network Unit in 1976 at the Rutherford Laboratory research institution.

The Network Unit published its first report during 1978.[47] This report analysed several areas: new and existing networks, standards, how the funding bodies could create the network, and the formation of a permanent networking organisation. The report reviewed the progress of SRCnet and other networks such as SWUCN, and stressed the importance of network consolidation rather than replacement. It added that the Board and councils could learn from the local experience gained during the development of such networks. The issue of expertise was an important one. At that time computer networking was a relatively new field of computer science, which meant that there was limited experience in this area. Establishing a national network would require many people with a diverse range of skills. To maximise the benefit of the knowledge gained by individuals involved with regional network projects, people needed to share their knowledge. In 1977, the universities involved with RCOnet

[47] *Network Unit Report* (Chilton, Oxon: Network Unit, 1978).

proposed a workshop for people who were interested in academic networks. Roland Rosner, who was one of the main proponents for such an event and a member of the Network Unit, remembers, "we jumped on the bandwagon and said why don't we make it a national thing and invite people who were interested in network development?"[48] As a result, the Network Unit assumed responsibility for the new Networkshop conferences, and began organising workshops every six months. These acted as forums and helped to diffuse knowledge about networks, during this early period in the development of the national network. Attendance at these conferences soon increased. Rosner contemplates their significance for the community as a whole, saying "it was at least important to get the experts together and to create new experts that were part of the community, as it was to do things on the ground and get a physical network going."[49]

Sharing knowledge would also help to establish the new campus LANs, mentioned in the second report of the Network Working Party. The Network Unit believed that campus networks would become an integral part of computing within universities and that the Computer Board should therefore fund these initiatives. These new networks would need to use standards that were compatible with the new academic network, and the existing regional networks would need to do the same. In 1978, the Network Unit therefore proposed that the funding bodies should convert the existing centres and networks to a common protocol: X.25. Like any standard, for X.25 to become a success, it needed a critical mass of adopters.[50] During the late 1970s, an increasing number of regions had begun to convert their proprietary networks to the X.25 standard. These included SWUCN, SRCnet, and other research council networks. Other networks, such as MIDnet, were already compatible with X.25, with the remaining networks continuing to use proprietary protocols during this period. Other organisations outside academia also choose the new CCITT standard for their networks. The Post Office proposed to launch its X.25 Packet Switching Service during 1980. National telecommunications operators in other countries, including France, Germany, and Japan, also expressed an intention to adopt X.25. By choosing this protocol for their services, the operators helped to legitimate the new standard.

[48] R. Rosner, Interview by D. Rutter, 24 July 2003.
[49] Ibid.
[50] On critical mass see D. Allen, "New Telecommunications Services: Network Externalities and Critical Mass," *Telecommunications Policy*, vol. 12, no. 3, 1988, pp. 257-271.

The Network Unit therefore saw the importance of compatibility with this international protocol, and suggested that the Board and councils use the Post Office's PSS for the basis of the national network. It added that any computer centre that wanted to connect to the national academic network must adhere to the chosen standard. To co-ordinate these developments, the Network Unit proposed that the Computer Board and research councils replace the unit with a permanent Joint Network Team (JNT). The funding bodies agreed and set up the JNT during 1979. In addition, they agreed that the community should adopt X.25.

2.3.2 The X.25 Decision

In hindsight, adopting X.25 for the new network was the wrong decision, as the Transmission Control Protocol/Internet Protocol (TCP/IP) suite later became the predominant internetworking standard.[51] However, at the time, the academic community saw X.25 as the rational choice. As Smith remembers, had they known "the way in which networking would develop, we might well have taken a different decision. [However,] in the context of trying to deal with a fairly limited number of systems, and given that X.25 was a wide-area protocol, taking the decision to use X.25 for [the network] was certainly the right one, I believe, even in hindsight."[52] The decision to adopt X.25 occurred during a period when the International Organization for Standardization (ISO) was proposing a new standard for internetworking.[53] The ISO protocols and X.25 both advocated an open systems approach which meant that companies could adopt non-proprietary network standards to form systems composed of hardware and software from different manufacturers. Known as Open Systems Interconnection (OSI), the British Standards Institute had originally begun work on the architecture during 1976.[54] OSI proposed a seven-layer reference model for network communication.[55] When the ISO discussed OSI at a meeting in 1977, there was resistance to the proposed standard. This opposition came from some US industry representatives who felt that the creation of a new standard might threaten proprietary networks, especially IBM's Systems Network Architecture (SNA) and Digital's

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[51] See Appendix E.
[52] I. Smith, *A Farewell to X.25*, UKERNA, 1997, Available from: http://www.ja.net/documents/UKERNA_News/1997/september/UKERNA_News3.html, Accessed on: 19 June 2004.
[53] See Appendix C.
[54] F. Taylor, "The Life and Times of OSI Standards," *Computer Weekly*, 22 May 1986, pp. 38-39.
[55] See Appendix D.

DECnet.[56] However, when the American National Standards Institute (ANSI) later decided to support OSI, concerns such as these failed to influence the outcome of the standardisation process. This process continued into the 1980s, and the ISO ratified the standard in 1983.

The international community's efforts to develop OSI would result in a prospective standard. OSI would define a reference model for the seven layers needed for internetworking. However, as it was a prospective standard, no protocols existed for many of the layers. The proposed standard for the academic network, X.25, defined three of the lower layers of the architecture. However, the international community had not defined the higher layers, especially the application layer that dealt with user-related processes. Therefore, no standards for services such as file transfer existed. The JNT believed that ISO would define these standards, but this process would take several years and potentially delay any network developments. This problem affected everyone that intended to develop OSI networks. The Joint Network Team would need the higher-level protocols for its network, as would the Post Office with its Packet Switching Service. To address this issue, the JNT, together with the Post Office and the DTI, decided to develop a series of interim protocols. These would be compatible with their OSI equivalents and be replaced by these standards when the ISO had ratified them. Work began on defining these protocols during the late 1970s. The Joint Network Team, in association with a Post Office study group and the DTI's Data Communication Protocols Unit, subsequently defined interim standards for processes such as file and job transfer. Called the Coloured Book protocols, after the colour of the covers of each standards document, these would influence the development of the network for the next 15 years.[57] They would also influence the relationship that existed between the Computer Board and industry. The Board

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[56] During the late 1980s, the presumed ascendancy of OSI looked as though it might affect other networking protocols. People therefore explored the implications of OSI for established proprietary networks based on IBM's SNA and Digital's DECnet architectures. Unsurprisingly, because of the established nature of both networks within some corporations, co-existence rather than migration became the approach advocated by some observers. See A.J. Bainbridge, "SNA and OSI: Recent Products and Developments," *Networking Technology and Architectures: Proceedings of the International Conference Held in London, June 1988* (Pinner: Online Publications, 1988), pp. 61-67 and E. Berera, "Digital Network Architecture DNA/OSI Phase V," *Networking Technology and Architectures: Proceedings of the International Conference Held in London, June 1988* (London: Online, 1988), pp. 39-48. On creative destruction see J.A. Schumpeter, *Capitalism, Socialism and Democracy* (London: Allen and Unwin, 1976), pp. 81-86.

[57] See Appendix D.

wanted the Joint Network Team to set up the network, so that it could transfer these public funded standards and technology to the private sector, when they had matured.[58] Companies, such as ICL, would therefore commercialise and support the hardware and software for the proposed national network, and would therefore take over the responsibility for supplying products compatible with OSI.[59] As a result, the Computer Board informed computer manufacturers that it would establish a procurement policy, which would mean that firms would have to adopt international standards for every system supplied to the JNT and to academia in general. By developing interim protocols that ran over X.25, these complementary services increased support for X.25, and, as the academic community began to adopt this standard, this support started to become self-reinforcing.[60]

The decision to develop interim protocols and then transfer to their OSI equivalents reflected the Joint Network Team's commitment to the open standards X.25 and OSI. The original report by the Network Working Party in 1973 had proposed the idea of developing a national network that was compatible with the ARPANET. As the prominence of X.25 grew throughout the late 1970s and as organisations such as the Post Office and the DTI began to support both X.25 and OSI, the Computer Board and research councils changed their opinion of the appropriate standard for the new academic network. However, unlike the government's earlier 'Buy British' policy for academic mainframes, this decision was not one that specifically advocated a British solution to the networking venture compared to an American alternative. The Joint Network Team believed that the academic community should adopt OSI because it assumed that OSI would become the international standard for internetworking. Once the Joint Network Team had decided which protocol to use and how OSI would influence its efforts, it had to decide how to create the new academic network. To achieve this aim, the Computer Board and research councils set up the Network Management Committee in 1981.[61] The purpose of this committee was to ascertain

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[58] On technology transfer see W.S. Piper and S. Naghshpour, "Government Technology Transfer: The Effective Use of Both Push and Pull Marketing Strategies," *International Journal of Technology Management*, vol. 12, no. 1, 1996, pp. 85-94.

[59] Smith, Interview.

[60] On technological interrelatedness see W.B. Arthur, "Competing Technologies: An Overview," in *Technical Change and Economic Theory* G. Dosi, et al. eds. (London: Pinter, 1988), pp. 590-607.

[61] *Report for the Period September 1980 - August 1981* (Chilton, Oxon: Joint Network Team, 1981), pp. 1-20.

what options were available for the establishment of a unified Wide Area Network to serve the needs of academia. The committee undertook two studies which looked at the requirements for the new network. The first determined the type of facilities that the JNT should provide to users. These included a domain name system, to contain the names and addresses of host computers, documentation for the services supplied, an electronic mail service, and gateways to other networks. The second study looked at the operational requirements for the X.25 network, including information relating to current traffic levels and the costs associated with existing facilities. Having undertaken these studies, the Network Management Committee then looked at the options for developing the network. It decided that there were three possibilities. The first would be to use the Packet Switching Service network. Provided by the Post Office's successor, British Telecom (BT), and originally mentioned in the Network Unit's report of 1978, many institutions had requested access to this network. BT based the charges for PSS on how much traffic customers transmitted. During 1979, the Network Unit had analysed the costs associated with the proposed Wide Area Network. It had looked at several options including using leased lines and the Packet Switching Service. The Network Unit's study had found that PSS was too expensive for a network that transmitted a significant amount of traffic. For example, in the South West region the cost of using PSS would be more than twice as expensive as the leased lines and the CDC 1700 minicomputer used by the SWUCN.[62] Later the Joint Network Team looked at the levels of traffic within the academic community and the charges for PSS. The team confirmed that the cost of using BT's service for the Wide Area Network would be too expensive. The second option for the national network would be for BT to provide an alternative solution to a PSS network. The JNT therefore approached British Telecom, but the company could only offer different payment schemes for a network that used the Packet Switching Service. As the JNT believed that usage-based charges would inhibit the development of the network, it dismissed PSS as the underlying service for the national network.[63] The third option was to use leased lines to develop the existing networks. As the Science and Engineering Research Council's (SERC's) X.25 network (SERCnet) had switches

[62] The leased lines and the central CDC 1700 computer, which was used as a switch, cost £73,200 in 1979. The alternative PSS solution would have cost £194,000. See *Network Unit Final Report* (Chilton, Oxon: Network Unit, 1979), pp. 1-31.
[63] *Report for the Period September 1981 - December 1982* (Chilton, Oxon: Joint Network Team, 1982), pp. 1/1-10/2.

throughout the country, this infrastructure could form the basis for the unified national network.[64] The funding bodies could then add additional switches at computer centres where appropriate, and rationalise the use of leased lines provided by British Telecom. In addition, from an operational perspective, the Computer Board and research councils could set up a permanent Network Executive to oversee the management and operation of the new network. The funding bodies could also appoint a Director of Networking, who would be in charge of both the Network Executive and the Joint Network Team. Finally, to ensure simplicity, one organisation could and should fund the venture. The Network Management Committee proposed these suggestions to the Board and research councils, which agreed that this gradual development was the best solution to the need for a unified national network. The Computer Board also agreed that it would cover the costs incurred by the conversion from the proprietary protocols to a unified X.25 national network.

Following publication of the committee's report in 1981, work began on establishing the new network. The 9.6 Kbps leased lines provided by SERCnet would interconnect ten Packet Switching Exchanges at centres such as Rutherford, Manchester, and London.[65] These exchanges would transmit data between the centres and therefore between the campuses connected to the ten exchanges. To increase capacity, the Network Executive planned to upgrade the backbone of the network to 48 Kbps.[66] The new network would solve the problem of how to share the resources provided by many computers throughout the network.[67] The earlier regional networks had also had this aim. However, the difference between the two was that the regional networks used several incompatible standards to achieve this aim, compared to the new network that would use just one: X.25.[68] This evolution would result in the new national network that would serve academia for the following decade.

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[64] When the Science Research Council became the Science and Engineering Research Council in 1980, it changed the name of its network from SRCnet to SERCnet.
[65] I. Smith, "JANET - A Unified Provision," *Proceedings of Networkshop 12, University of Bath, 16-18 April 1984* (Bath: University of Bath, 1984), pp. 1-6.
[66] A backbone is the core infrastructure of a network, which interconnects other networks. The bandwidth of a backbone is greater than the networks that it interconnects, meaning that it can transmit more information per second than the other networks.
[67] On technological trajectories see G. Dosi, "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy*, vol. 11, no. 3, 1982, pp. 147-162.
[68] Some networks, such as SWUCN and SERCnet, used X.25, but they had not chosen to use this protocol as part of a general plan to create a national network, as the funding bodies had not formulated

2.4 The Joint Academic Network

2.4.1 Convergence

The formation of the new national academic computer network occurred during April 1984. Known as the Joint Academic Network, this event did not represent a radical change in network provision within the UK, but rather a continuation of the gradual evolution that had already begun. JANET was a centrally funded and co-ordinated national academic network based on a single standard, which had evolved from several incompatible networks.[69] The justification for the development of JANET was the rationalisation of network provision, the reduction of costs, and the extension of the network to universities not already connected. This period of development involved many individuals, both locally at campuses throughout the UK and nationally with the Network Executive. Regional centres, universities, and the JNT became involved in the process of converting the existing regional networks from proprietary protocols to the X.25 (1980) standard. This process involved the installation of new switches and upgrading leased lines, while ensuring continuity of service for the increasing number of people who used the network. The expertise obtained during the development of networks, such as SWUCN and SERCnet, and the diffusion of this knowledge through the biannual Networkshops, helped this development process. This expertise enabled over 20 different types of mainframes and several types of terminal to connect to the JANET backbone, which interconnected ten switches at Network Operations Centres (NOCs) located throughout the country (see Figure 2.3 and Figure 2.4).[70] Towards the end of 1985, this development had connected 120 institutions to JANET and the Network Executive expected to have removed all of the redundant leased lines by the end of the year.[71]

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a plan and adopted this protocol at the time the two networks chose to use X.25. The networks chose X.25 because it was an international standard, but they made this decision independently of each other. A reader should therefore not draw a teleological line between the development of these networks and the subsequent emergence of JANET, as no single authority directed the development of these networks with JANET in mind.

[69] Initially no one had controlled this evolution, but when the funding bodies decided to develop a new national network, a single authority, in the form of the Network Executive, assumed the responsibility of combining and developing the networks to form a unified academic network.

[70] M. Wells, "JANET - the United Kingdom Joint Academic Network," *Colloquium on the JANET Project (Networking for Universities, Polytechnics and Research Councils), London, 26 November 1985* (London: IEE, 1985), pp. 1/1-1/2.

[71] S. Clark, "Janet Gives Universities an Edge on Commerce," *Computer Weekly*, 8 August 1985, p. 21.

Figure 2.3. The JANET backbone in 1986.[72]

In a period of about 2 years, the academic community had therefore converged around a single standard and converted several types of network to form a national X.25 Joint Academic Network.[73]

[72] The figure shows the 10 Network Operations Centres at the regional computer centres and research council sites. The core of the network was composed of four major nodes at RAL, London, Daresbury, and Manchester, which the backbone connected to the remaining nodes.

[73] The origins of this convergence began when networks such as SWUCN and SERCnet adopted X.25 as the protocol for their networks. As there was not a plan to develop a unified X.25 national network at that stage, the network operators made these decisions to converge around X.25 independently of each other. However, by the time that the funding bodies had decided to create JANET, centralised control over the convergence had emerged.

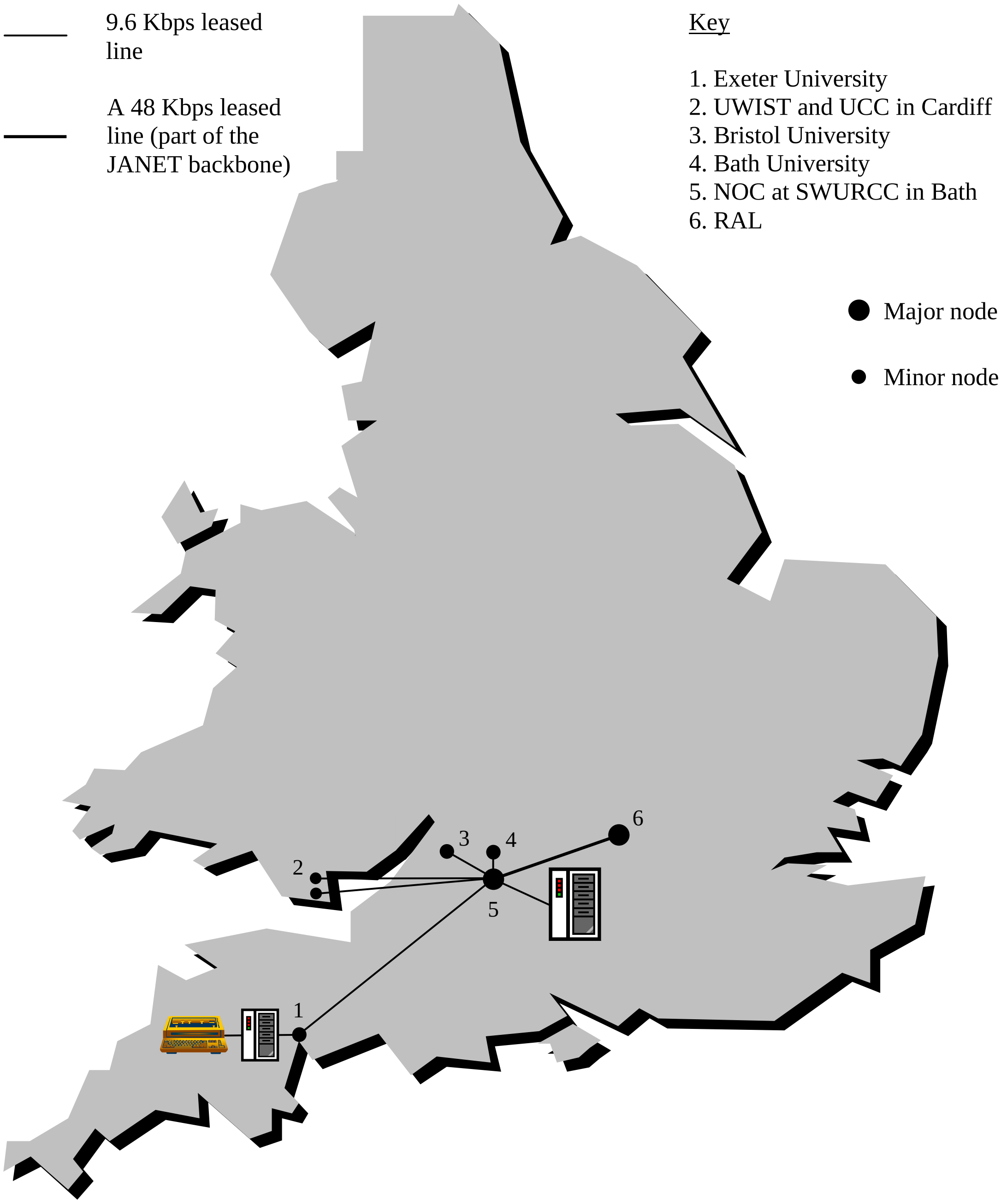

Figure 2.4. A typical Network Operations Centre.[74]

2.4.2 Basic Network Provision and the Development of New Services

One of the main aims of the new national X.25 network was to provide a standardised communications infrastructure that would support the needs of the organisations that

[74] The figure shows the NOC at the SWURCC in Bath. This NOC connected institutions at 5 sites: one in Exeter, two in Cardiff, one in Bristol and one in Bath. The NOC also connected to the JANET backbone, part of which is illustrated. At each site, terminals connected to the local mainframes on campus, which in turn connected to the SWURCC and JANET. The figure shows an example terminal and mainframe at Exeter and an ICL 2980 at SWURCC in Bath.

used the network.[75] Throughout the 1970s, the issue of resource sharing had been one of the principal reasons for the development of the regional networks. With the evolution of electronic messaging into electronic mail during the early 1970s on the ARPANET, new applications joined the traditional services such as remote job submission and file transfer. The development of these new services was often user-driven, which left the funding bodies with the task of providing the network and its associated services. These included a Name Registration Scheme (NRS), for domain name information, and an e-mail service.[76] The Joint Network Team developed the JNT Mail protocol during the early 1980s, in response to a need for an e-mail service that the Network Management Committee had identified in its 1981 report. In line with its general commitment to standards, the JNT designed the new protocol using two existing standards: the ARPANET e-mail header format and the Blue Book file transfer protocol. Since the emergence of e-mail on the ARPANET during the early 1970s, US computer scientists had collaborated on protocols for electronic mail which the ARPANET community had subsequently adopted.[77] By the early 1980s, the e-mail protocols had existed for years and had demonstrated their effectiveness on the network. The Joint Network Team decided to use one of these standards, the ARPANET e-mail header format, to form the basis for its new e-mail service.[78] The JNT would use the Blue Book file transfer protocol to transmit e-mails formatted by the ARPANET e-mail standard. In 1984, the JNT ratified this combination of protocols on JANET, referring to the new standard as the Grey Book protocol.[79]

Apart from services such as the Name Registration Scheme and e-mail, the Network Executive did not provide any additional services, leaving the users to develop the facilities they required. User exploration and development would increase the value of the network for the community as a whole.[80] Two examples of early services that users developed were a Usenet gateway and access to Online Public Access

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[75] I.L. Smith, "Joint Academic Network (JANET)," *Computer Networks and ISDN Systems*, vol. 16, no. 1 and 2, 1988, pp. 101-105.
[76] See Appendix J.
[77] P.H. Salus, *Casting the Net: From ARPANET to Internet and Beyond* (Reading, MA: Addison-Wesley, 1995), pp. 95-98.
[78] See Appendix L.
[79] Ibid.
[80] On co-invention see T. Bresnahan and S. Greenstein, "Technical Progress and Co-invention in Computing and in the Uses of Computers," *Brookings Papers on Economics Activity: Microeconomics*, vol. 1996, 1996, pp. 1-77.

Catalogues (OPACs). To connect to the ARPANET during the 1970s, researchers officially needed to be involved in US Department of Defense (DoD) research and their institutions needed to have the necessary funds to cover the costs of the connections. These constraints excluded others at universities who wanted to access computer networks. In 1979, two graduates at Duke University proposed a network to link UNIX computers together. Called Usenet, it provided people with an alternative to the ARPANET, enabling them to post messages to newsgroups, and send and receive e-mails. Known as the 'poor man's ARPANET', Usenet quickly grew into a worldwide system of thousands of newsgroups covering many subjects.[81] In 1985, the University of Kent at Canterbury joined this growing community by launching a gateway on JANET, to provide access to Usenet for users of the academic network.[82] The university charged sites £30 a month for access to Usenet's newsgroups, and many institutions used the gateway. Another service that people added to the national academic network were online catalogues. In 1984, three libraries in Birmingham launched an OPAC.[83] This catalogue provided basic search facilities at Birmingham Polytechnic and was one of the first networked catalogues in the UK. Other university libraries, such as Cambridge and Surrey, followed this development with their own online catalogues which people could access using JANET. Using simple phrase and keyword search facilities, these systems provided access to library catalogues over the network.[84] The catalogues contained varying amounts of information, from an incomplete set of monographs at the University of East Anglia, to a complete catalogue of over 540,000 titles at Hull University. The library community prompted the development of online catalogues on JANET, and other user-driven initiatives began to mirror these developments. As different communities of users began to develop and then use a range of services, they perceived JANET as a network that satisfied different needs.[85] To some it was a way to access library catalogues, to others it was a way to transfer files. Some used the facilities to access information on networks such as Usenet. Others used it to communicate.

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[81] See Appendix I.
[82] P. Collinson, "The Usenet Gateway at the University of Kent," *Alvey News*, October 1986, pp. 14-17.
[83] W. Foster and R. Wellings, "Development of BLCMP's Online Public Access Catalogue," *Program*, vol. 23, no. 2, 1989, pp. 151-162.
[84] W. Zimin, *A Comparative Study of OPACS on JANET*, M.Sc. thesis (Loughborough: Department of Library and Information Studies, Loughborough University of Technology, 1987), pp. 6-13.
[85] On interpretive flexibility see W.E. Bijker, Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change (Cambridge, MA: MIT Press, 1995), pp. 73-74.

2.4.3 Interim Standards and the Transition to OSI

To provide the necessary standards for applications such as file transfer and e-mail, which helped to support the increasing number of services on JANET, the academic community needed protocols. By 1986, the Joint Network Team, BT, and the DTI had developed a series of Coloured Book protocols.[86] For these interim standards to be a success, the academic community and mainframe manufacturers had to adopt them. Initially, the prospect of the Computer Board stipulating what the community and companies could and could not do was not popular, and in the case of industry, not feasible. However, this policy gradually began to encourage both academia and industry to adopt the Coloured Book protocols.[87] Both therefore started to create a platform.[88] By the mid 1980s, manufacturers had supplied hundreds of systems throughout JANET which were compatible with the Coloured Book standards.[89] These investments and any incremental changes to the standards, helped to increase the value of the Coloured Books for both the academic community and industry. However, the protocols were interim standards, developed while the academic community waited for the ISO to ratify their international equivalents. The development of the OSI protocols was similar to the ratification of any standard. Several rounds of draft proposals and standards involving representatives from many countries meant that it could take years to ratify one of the protocols. In addition, once the ISO had approved a standard, the academic community would then need to convert its interim protocols to their OSI equivalents. In 1984, the JNT and the Network Executive believed that it would take 4 years before the new standards became available, and perhaps 15 years before the community would complete the migration from the Coloured Books to their OSI equivalent protocols.[90]

As the Joint Network Team and the Network Executive intended to migrate from their interim standards to OSI, they would need a plan regarding how this migration should

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[86] See Appendix D.
[87] R. Rosner, "From Copernicus to Computer Networking," *Interfaces in Computing,* vol. 1, no. 2, 1983, pp. 95-104.
[88] On platforms see S. Greenstein, "Industrial Economics and Strategy: Computing Platforms," *IEEE Micro,* vol. 18, no. 3, 1998, pp. 43-53.
[89] P.F. Linington, "Protocol Issues," *Colloquium on the JANET Project (Networking for Universities, Polytechnics and Research Councils), London, 26 November 1985* (London: IEE, 1985), pp. 2/1-2/4.
[90] P.F. Linington, "The Academic Community's Transition to International Standards," *Proceedings of Networkshop 12, University of Bath, 16-18 April 1984* (Bath: University of Bath, 1984), pp. 1-9.

take place. During mid 1984, the team set up the Academic Community's OSI Transition Group to prepare this plan. In 1986, the JNT published a draft transition strategy based on the group's work, which analysed the issues involved in the migration.[91] As the ISO would take several years to ratify each open systems standard, the group proposed a phased migration. This process would gradually replace the old protocols, while ensuring that the JNT and the Network Executive did not disrupt the service provided to users. Interworking between the old and new standards would be important to ensure this continuity, and the transition group identified the Name Registration Scheme as a key component in this process. As part of this replacement programme, the Network Executive would upgrade JANET to the X.25 (1984) standard. This revision of X.25 provided facilities that would support the deployment of OSI. As support from industry had helped to ensure the successful adoption of the Coloured Books, the JNT would prepare detailed requirement specifications for the ISO's standards, to aid the migration process. Having prepared plans for the transition, the JNT and the Network Executive began preliminary work on their transition strategy. In a separate development, the DTI set up a similar project, the Intercept Strategy, in 1983.[92] Part of the government's overall commitment to OSI, which included its Government Open Systems Interconnection Profile (GOSIP) policy, this aimed to identify draft standards based on the ISO's work.[93] The DTI would base these draft protocols on mature versions of the standards, meaning that manufacturers could develop compatible products. As the DTI expected that the final standards would not differ significantly from the chosen draft versions, it would only need to make minor changes to implementations. The government chose the term 'intercept standards' to distinguish it from the academic community's interim Coloured Books. The difference between the two standards was that the academic community's standards contained protocols that covered several layers of the OSI reference model, which presented potential compatibility problems which the DTI hoped to avoid with its proposed strategy. While the JNT and the DTI's efforts differed in several ways, both of their protocols would run over X.25. Efforts such as these helped to consolidate X.25 as the standard of choice for Wide Area Networks in

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[91] L. Clyne and R. Cooper, "JANET Migration Plans," *Computer Networks and ISDN Systems*, vol. 13, no. 3, 1987, pp. 205-206.
[92] S. Price, "DTI Support for OSI," *Computer Communications*, vol. 9, no. 2, 1986, pp. 74-77.
[93] A. Bartholomew, "GOSIP — A Practical Guide to OSI Procurement," *Telecommunications*, November 1989, pp. 33-34 and 36.

the UK. The combination of X.25 and the Coloured Books complemented each other. X.25 and the Coloured Books therefore formed the basis for a network that benefited the community as a whole, something neither could have achieved independently.[94]

2.4.4 Network Organisation, Control, and User Representation

As standardisation initiatives continued, the management and operation of JANET began to mature. By 1987, the funding bodies had set up several organisations to administer the network (see Figure 2.5). The Network Advisory Committee (NAC) established policy, which the JNT and Network Executive implemented. While the JNT was responsible for campus network facilities within universities and the issue of standards, the Network Executive managed the operation of JANET. As part of this responsibility, the Network Executive had set up a series of Network Operations Centres to control the operation of the switches located on the backbone of JANET. In consultation with these centres, the Network Coordination Centre organised fault reporting and resolution.[95] The overall responsibility for JANET lay with the Department of Education and Science, which funded the network through the Computer Board and the research councils. With the Telecommunications Act becoming law in 1984, the legal status of JANET and its relationship with the DES changed. The Act stipulated that any company that wished to operate a telecommunications system must have a licence. As a result, this law would affect JANET. A former head of the JNT, Peter Linington, remembers, "we tried to argue that the Department of Education had Crown exemption, and so, therefore had the UGC, and so the CB and JNT, but it was a very long stretch. The view of the DTI was pretty much that it was for the Courts to decide and they couldn't give advice!"[96] After much discussion, the situation was eventually resolved. To comply with the Act, the Office of Telecommunications (Oftel), in association with the DES and the DTI, agreed to confer Crown Body status on JANET. This status would mean that the Secretary of State for Education and Science would run the network on behalf of the Crown, obviating the need for a licence. This decision formalised the situation about who could access JANET.

[94] On complements see S. Greenstein, "When Technologies Converge," *IEEE Micro*, vol. 19, no. 1, 1999, pp. 8-9.
[95] See Smith, "Joint Academic Network," pp. 101-103 and P. Stone, *JANET: A Report on its Use for Libraries* (London: British Library Board, 1990), p. 13.
[96] P. Linington, E-mails to D. Rutter, 29 July 2003.

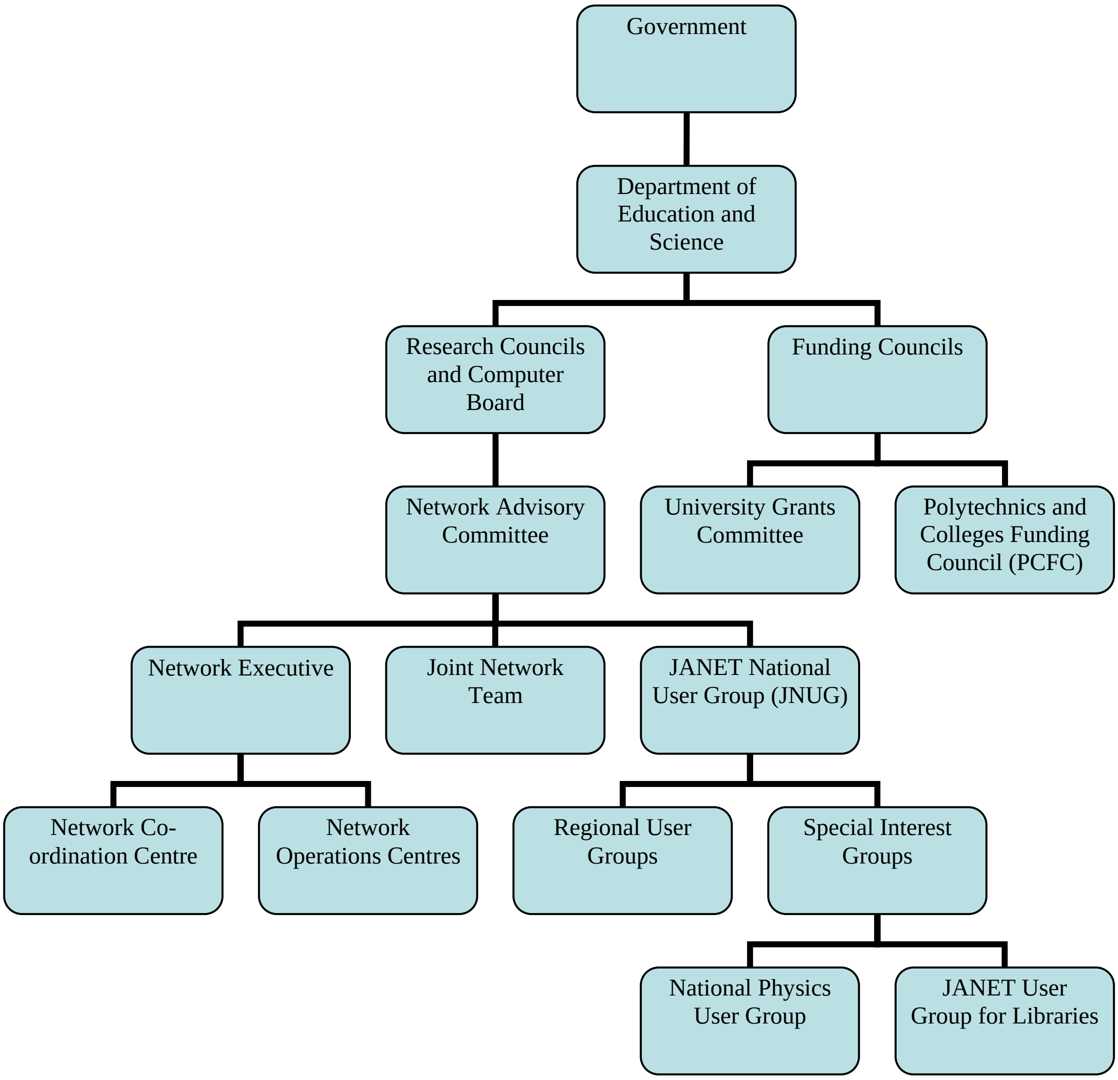

Figure 2.5. Organisational hierarchy in 1987.[97]

Before the Act became law, any university, research council funded institution, or individuals holding a research grant in polytechnics, could connect to the network.[98] Anyone who could legally access JANET could then use the facilities provided for academic-related purposes. With the establishment of the Crown Body status, the Department of Education and Science extended the list of eligible sites to government research laboratories and the British Library. Other sites could apply for connection, but the funding bodies would only grant access if it benefited the DES community,

[97] The Network Advisory Committee reported to the Research Councils and the Computer Board and had overall management responsibility for JANET. The Network Executive managed the Wide Area Network. The Joint Network Team was responsible for several tasks. These included the management of campus networks, the implementation of the interim Coloured Book protocols, product development, and liaison with several communities including universities.

[98] M. Wells, “The JANET project,” *University Computing*, vol. 6, no. 1, 1984, pp. 56-62.

and the Network Executive would not permit access to other networks, including the ARPANET, for these organisations.

The issue of providing access to a network for authorised users, while excluding unauthorised users, can be a significant problem. In the 21st century, the issues of security and hacking are considerable causes for concern. However, they are not new and the security of information systems has posed challenges to those who administer them for years. While the frequency of attacks was lower during the 1980s, there were individuals who tried to access resources without authorisation. In 1987, students hacked into a PSS gateway and accessed services on public networks.[99] Providing access to the Packet Switching Service was expensive, and breaches such as these raised an important issue, as well as being embarrassing for the Network Executive. As Robert Cooper, a former Director of Networking, remembers "we do actually breed hackers in the university community; computer science departments are notorious places and a lot of hacking during the early days was coming from academic sites."[100] People on other networks, such as the ARPANET and the Internet, shared these concerns.[101] To help protect JANET from this type of abuse, the funding bodies needed to introduce new controls. While these would affect how everyone used the network, the benefits would outweigh the potential disadvantages. Consequently, the Network Executive reviewed and improved three areas: authentication, authorisation, and accounting.[102] The team looked at how gateways within the network handled the tasks of authenticating and authorising people and how it could restrict the activities of users. It also looked at how it could simplify the accountancy, by consolidating small bills into single invoices issued to organisations.[103]

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[99] I.L. Smith, *Network Executive Report - February 1987* (Chilton, Oxon: Network Executive, 1987), pp. 1-6.
[100] R. Cooper, Interview by D. Rutter, 19 August 2003.
[101] See J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), p. 138, and S. Hallam, "Misconduct on the Information Highway: Abuse and Misuse of the Internet," *Online Information 94: 18th International Online Information Meeting Proceedings, London, 6-8 December 1994* D.I. Raitt and B. Jeapes eds. (Oxford: Learned Information, 1994), pp. 593-602.
[102] I. Smith, "Gateway Authentication, Authorisation and Accounting," *Proceedings of Networkshop 16, University of Reading, 22-24 March 1988* (Reading: University of Reading, 1988), pp. 77-81.
[103] Later initiatives to improve the security of the network included the formation of the Computer Emergency Response Team (CERT) during 1994, which responded to security issues. Other networks, such as the Internet, also established CERTs. See D. Jackson, *Computer Security and the Academic and Research Community*, UKERNA, 1994, Available from: http://www.ja.net/documents/NetworkNews/Issue42/SECURITY.HTML, Accessed on: 13 May 2004 and K. Fifthen and B. Fraser, "CERT Incident Response and the Internet," *Communications of the ACM*, vol. 37, no. 8, 1994, pp. 108-113.

Ensuring that those who had a legal right to access JANET could do so was important. The Network Executive also ensured that authorised users could represent their views, by establishing user groups during 1984. People could use these groups to let the funding bodies know their views on such issues as the performance of the network, proposed upgrades, and policy matters. The Network Executive proposed two types of user group: regional user groups and Special Interest Groups (see Figure 2.5). Both staff from the computer centres and end users could join either of these groups. Delegates from these groups were members of the National User Group, which liaised with the Network Advisory Committee on matters relating to user representation.[104] During the mid 1980s, communities of users set up interest groups. Nuclear physicists were the first to establish a user group and librarians followed this in 1986 with the establishment of the JANET User Group for Libraries (JUGL). This group represented the views of the community and considered the services provided by the network for librarians.[105] Sponsored by several organisations such as the Standing Conference of National and University Libraries, JUGL actively became involved in services on JANET. With the introduction of a newsletter and conferences, it considered many topics, including the increasing number of online catalogues on the network.[106] Since 1984, these had increased from a small number of early systems to 16 online catalogues at universities.[107] By 1987, libraries and other users had access to a growing number of services on JANET. These included online databases such as Dialog, access to British Telecom's PSS, a JANET news service for network-related information, and the JANET e-mail service.[108] Since the development of the Grey Book mail protocol during the early 1980s, the number of institutions using electronic mail had steadily increased. By 1987, the Name Registration Scheme contained over 600 entries for institutions that used e-mail.[109]

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[104] M. Wells, "A Progress Report on JANET," *University Computing*, vol. 8, no. 3, 1986, pp. 146-153.

[105] A. Buxton, "JANET and the Librarian," *The Electronic Library*, vol. 6, no. 4, 1988, pp. 250-263.

[106] For example, in the first issue of the newsletter, Michele Shoebridge described the University of Birmingham Library's OPAC. See M. Shoebridge, "Birmingham University Library's OPAC," *JUGL Newsletter*, Summer 1990, pp. 9-10.

[107] *Directory of University Library Catalogues on JANET* (Brighton: University of Sussex, 1986), pp. 1-31.

[108] One of the first online databases was Dialog, launched during 1966. Many others followed. On the evolution of online services see C.P. Bourne and T.B. Hahn, *A History of Online Information Services, 1963-1976* (Cambridge, MA: MIT Press, 2003). See also *About Us*, Dialog, 2005, Available from: http://www.dialog.com/about, Accessed on: 16 March 2005.

[109] J. Linn, "Survey of POSTMASTER and Other Recommended Names for Sites Registered in the NRS for JNT-MAIL over JANET," *Proceedings of Networkshop 15, University of Edinburgh, 8-10 April 1987* (Edinburgh: University of Edinburgh, 1987), pp. 315-331.

2.4.5 Network Evolution and the Importance of X.25 and OSI

As traffic on the network increased because of people using new services, this prompted the funding bodies to upgrade the technical infrastructure of the network. The Network Executive rationalised the number of switching centres and upgraded the backbone of JANET and the links to sites (see Figure 2.6). By early 1988, four leased lines between the centres of Rutherford, Daresbury, Manchester, and London operated at 256 Kbps, replacing the old 48 Kbps circuits.[110] As well as upgrading the backbone to 2 Mbps, the Network Executive also started to upgrade the lines between institutions and JANET, from 9.6 Kbps to 48 or 64 Kbps.

As JANET continued to develop, so too did the Local Area Networks on campuses throughout the country. During the early 1980s, institutions began to install campus networks. These linked departmental minicomputers and the campus mainframe to JANET via gateways. Using terminals, people could access both local and remote resources using these facilities. Based on X.25 Campus Packet Switching Exchanges (CPSEs), these networks were slow and competing LAN standards soon emerged.[111] Cambridge University had developed its Cambridge Ring technology during the 1970s, and in 1982, the JNT, in collaboration with the IT Standards Unit of the DTI, announced this as a new Coloured Book, known as the Orange Book standard.[112] By 1985, 43 institutions had installed LANs, 10 of which used 1 Mbps Cambridge Ring technology.[113] Another LAN technology, Ethernet, became the Pink Book standard and together with Cambridge Ring, these 10 Mbps LAN technologies started to replace the X.25 local networks. With the availability of campus networks, institutions began to develop new services such as Campus-Wide Information Systems (CWISs).

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[110] J. Carey, *JANET Upgrade Programme*, UKERNA, 1988, Available from: http://www.ja.net/documents/NetworkNews/Issue25/news25.txt, Accessed on: 31 July 2004.
[111] The CPSEs interconnected campus LANs to the JANET backbone, transmitting traffic between the campus networks and JANET using switches. Universities could also use the exchanges to develop campus LANs. See L. Clyne, "The LAN/WAN Interface," *Colloquium on the JANET Project (Networking for Universities, Polytechnics and Research Councils), London, 26 November 1985* (London: IEE, 1985), pp. 4/1-4/20.
[112] On Cambridge Ring LANs see Appendix G.
[113] *Report of the Computer Board for the Period 1st April 1983 - 31st March 1985* (London: HMSO, 1985).

Figure 2.6. The JANET backbone circa 1988.[114]

These provided a range of academic-related information to people at institutions, including Bristol, Birmingham, and York, and 22 universities had set up campus systems by 1991.[115]

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[114] The figure shows the 8 Network Operations Centres at the regional computer centres and research council sites, interconnected by the upgraded 2 Mbps backbone.

[115] C.K. Work, "An Overview of CWIS Developments in the United Kingdom," in *Campus-Wide Information Systems and Networks: Case Studies in Design and Implementation*, L. Lloyd ed. (Westport, CT: Meckler, 1992), pp. 282-295.

As the funding bodies developed JANET and campus LANs, companies and organisations in other countries continued to expand their networks. During the late 1970s and early 1980s, several countries had developed public packet-switched networks. The first network, Telenet, emerged from work on the ARPANET and several others followed. The Post Office in Britain had set up the PSS and the International Packet Switching Service (IPSS), France had developed Transpac, and Canada had launched Datapac.[116] All of these networks were compatible with the CCITT recommendation X.25. Several academic networks in Europe followed these commercial ventures. Launched in 1976, the experimental European Informatics Network (EIN) linked research centres in five countries.[117] The EIN was a research network that connected the NPL Data Communications Network (DCN), EPSS, and networks within Europe. The Euronet network later succeeded the EIN. Work began on another network in 1984. Called the European Academic Research Network (EARN), this provided a link between European researchers and US institutions. Compatible with the US Because It's There/Because It's Time (BITNET) network and based on proprietary technology provided by IBM, EARN began to develop into an X.25 network during the late 1980s.[118] EARN was similar to other networks, as its operators intended to adopt OSI protocols when the international community had developed these standards. With this process in mind, European network operators launched the Cooperation for Open Systems Interconnection Networking in Europe (COSINE) project in 1986.[119] COSINE encouraged the adoption of OSI protocols for networks, and one of the results of the venture was the International X.25 Infrastructure (IXI) Pilot Service (see Figure 2.7).[120]

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[116] The Post Office established the IPSS during 1978. See "UK-US Packet Switched Service," *Computer Weekly*, 13 April 1978, p. 1.
[117] Wells and Verdon, *Report of the Network Working Party*, p. 7.
[118] Gillies and Cailliau, *How the Web was Born*, pp. 76-77.
[119] H.E. Davies, "European Networking and What it Means to the UK," *University Computing*, vol. 14, no. 4, 1992, pp. 129-140.
[120] See Davies, "European Networking and What it Means to the UK," pp. 133-134 and D. Law, "European Research Networks," *The Common Market for Information: Proceedings of the Annual Conference of the Institute of Information Scientists, June 1992*, M. Blake ed. (London: Taylor Graham, 1992), pp. 44-58.

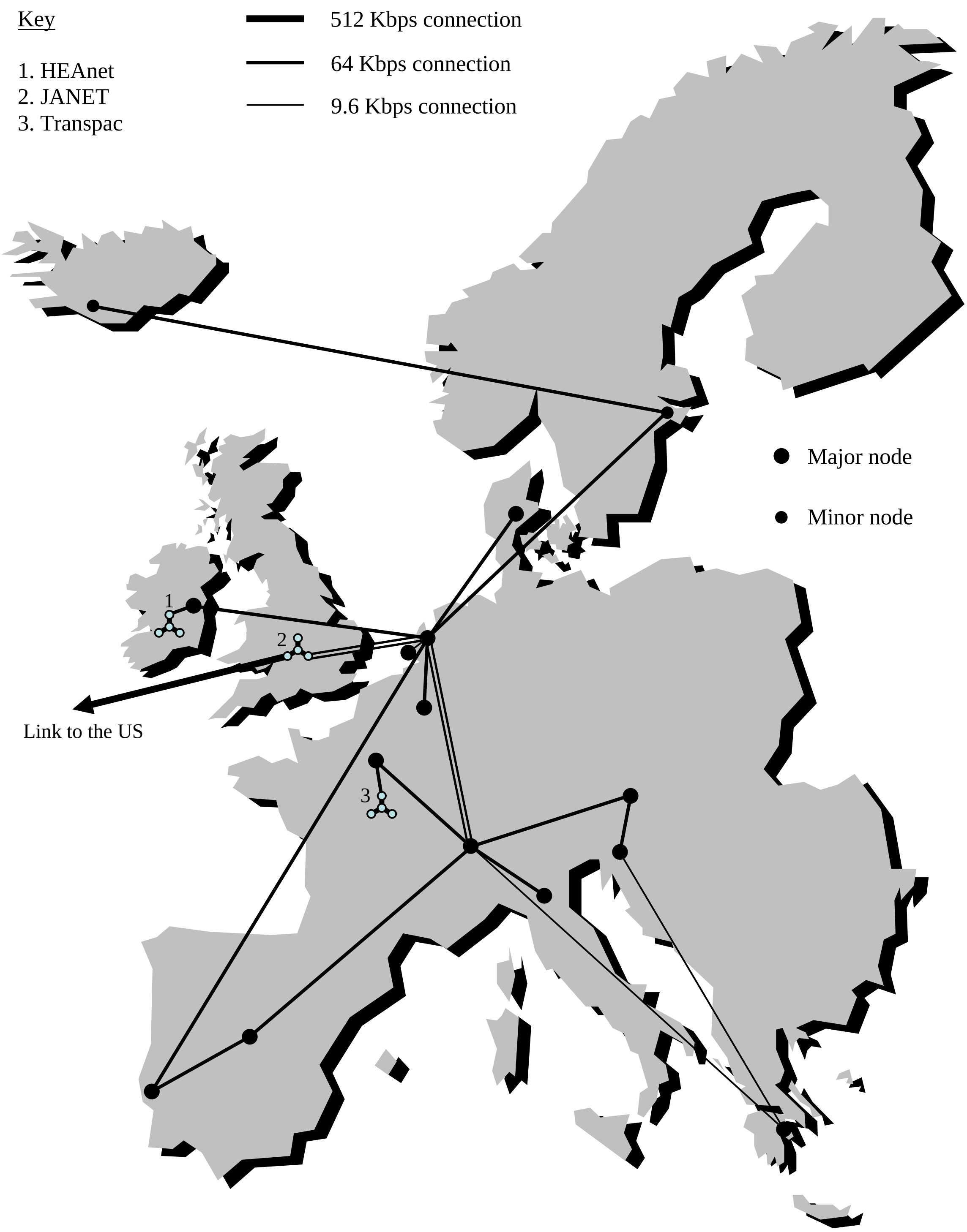

Figure 2.7. IXI in 1992.[121]

Launched in 1990, IXI linked 18 countries, with a further nine connections to public packet-switched networks. These networks had coalesced around standardised hardware and software which were compatible with the X.25 protocol. The decisions to use X.25 had therefore established and reinforced X.25's position as the standard

[121] The figure shows the backbone of the IXI network, which linked 13 major nodes in 8 countries. For clarity, the figure only contains three national packet-switched networks.

chosen by many PTTs and organisations across two continents. Many organisations, including the Joint Network Team, assumed that OSI would also become a prominent standard. It therefore actively worked towards this, continuing with the community's OSI transition strategy. In 1987, the Academic Community's OSI Transition Group published its final report. This report had taken two and a half years to prepare and had involved representatives from academia and other organisations.[122] When the group published its report, the JNT and the Network Executive distributed it to nearly 2,000 people who requested copies, which helped to diffuse the strategy throughout the academic community. Known as the White Book, the report outlined in detail the steps necessary to migrate from the Coloured Book protocols to OSI. The Computer Board approved the proposed transition strategy and therefore allocated £2m to the JNT, which would implement the plan.[123] The group again stressed the importance of continuity of service and ensuring that both standards could co-exist during the period of transition. To achieve this aim, the Joint Network Team would need converters to handle the protocol conversions. The report proposed that the funding bodies should choose functionally appropriate OSI standards to replace their Coloured Book equivalents. The group suggested examples, such as migrating from the Blue Book file transfer protocol to the OSI File Transfer Access and Management (FTAM) protocol. The network team prepared a series of operational requirements to transfer the results of the public-funded transition strategy to the private sector. Companies could then develop and support the products necessary for an OSI network. In connection with the community's transition strategy, the Joint Network Team began two open systems-related projects. The first was the OSI X.400 Message Handling System for e-mail.[124] Introduced by the ISO in 1984, X.400 defined how incompatible e-mail systems could communicate with each other. Dismissing the 1984 standard because it lacked functionality, the JNT chose the revised 1988 version of X.400. As the academic community wanted to migrate to OSI, it chose X.400 as the standard for e-mail on JANET. However, X.400 was not compatible with the Grey Book protocol used on the network, so the Joint Network Team needed a converter to handle the necessary translations. During 1987, University College London launched an

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[122] B. Cooper, *OSI Transition*, UKERNA, 1988, Available from: http://www.ja.net/documents/NetworkNews/Issue25/news25.txt, Accessed on: 31 July 2004.

[123] R. Gillman, "The Academic Community OSI Transition: A Status Report," *Proceedings of Networkshop 18, University of Newcastle upon Tyne, 27-29 March 1990* (Newcastle upon Tyne: University of Newcastle upon Tyne, 1990), pp. 157-194.

[124] See Appendix L.

experimental gateway.[125] This gateway provided conversion facilities between the two standards and enabled JANET users to communicate with people who used European networks such as Ireland's HEAnet.[126] It also allowed interconnection between JANET and commercial networks including BT's Telecom Gold and Microlink.[127] In addition to these X.400-related initiatives, others within academia began to experiment with the standard, including a new X.400 e-mail system developed by the Polytechnic of Central London.[128] Examples such as these highlight the academic community's interest in OSI at this time. Another OSI-related project also illustrates this interest. Known as X.500, this defined a standard for an e-mail directory service.[129] Ratified by the ISO in 1988, the academic community decided to adopt this standard, rather than develop an interim version of its own, believing that both would take the same amount of time to complete.[130] The JNT intended the pilot project to provide information about people who used JANET. The system would also interconnect with the emerging OSI systems that it was deploying across the network.

2.4.6 Traffic and Upgrades

As the Joint Network Team and the Network Executive began to implement their transition strategy, the number of services on the network continued to increase. By the end of the 1980s, over 40 libraries had developed online catalogues, and many of these catalogues contained more than 80 percent coverage of the libraries' holdings.[131] Anyone could access these catalogues using a terminal or personal computer connected to JANET. By using gateways, users on other networks could also search these services. These included X.25 networks, such as the Packet Switching Service and IXI, as well as networks including the Internet and Australia's Academic and

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[125] J. Craigie, *X.400 Update*, UKERNA, 1988, Available from: http://www.ja.net/documents/NetworkNews/Issue26/news26.txt, Accessed on: 31 July 2004.
[126] G. Young, "Academic Networking in Ireland," *Computer Networks and ISDN Systems*, vol. 19, no. 3-5, 1990, pp. 191-194.
[127] A. Buxton, "Implications of JANET for the Academic Community," in *Online Information Retrieval Today and Tomorrow* C.J. Armstrong and R.J. Hartley eds. (Oxford: Learned Information, 1990), pp. 21-33.
[128] E. Sutherland and D. Roberts, "Migration: Plotting Courses and Setting Sail," *Networking Technology and Architectures: Proceedings of the International Conference Held in London, June 1988* (Pinner: Online Publications, 1988), pp. 433-442.
[129] See Appendix L.
[130] J. Craigie, "UK Academic Community Directory Service Pilot Project," *Computer Networks and ISDN Systems*, vol. 17, no. 4 and 5, 1989, pp. 305-310.
[131] *JANET-OPACS: Online Public Access Catalogues in the UK* (Brighton: University of Sussex, 1991).

Research Network (AARNet), which used the Internet protocols.[132] Users on JANET could access more than 40 online catalogues on the Internet, and pilot projects such as the Consortium of University Research Libraries (CURL) initiative provided over two million bibliographic records from UK libraries and the Library of Congress.[133] In addition, other services, such as e-mail, continued to grow, with JANET's Name Registration Scheme containing more than 800 e-mail addresses.[134] Since 1986, the number of scientists using e-mail had increased from 16 to 70 percent.[135] By then, an increasing number of staff in university libraries also used electronic mail, with 75 percent using this facility. Organisations also added new services to the network. Funded by the Computer Board, the National Information on Software and Services (NISS) project became available on the network in 1988.[136] This project established a catalogue of software and services used within the academic community, which people were entitled to access. Another project aimed to supply buyers within academia with information about products, prices, and availability. Called the Buyers' On-line Rapid Information Service (BORIS), this became available in 1987 from the North Eastern Universities Purchasing Group.[137]

By 1987, people understood what JANET was and what it could do for them.[138] As the users accessed an increasing number of services, the funding bodies permitted more institutions to access these facilities. By the end of the 1980s, the network interconnected every UK university and research council funded institution. Several others soon joined the network. These included CERN and the Royal Institution of

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[132] L.A. Tedd, "Accessing Library Catalogues Over the Internet," *Proceedings of the Ninth Annual Computers in Libraries 95 conference, London, 7-9 March 1995* (London: Learned Information, 1995), pp. 123-126.
[133] See Stone, *JANET*, p. 50 and D.J. Foskett and S. Perry, "The Consortium of University Research Libraries: An Experiment in Resource Sharing in the United Kingdom," *Library Acquisitions: Practice & Theory*, vol. 17, no. 3, 1993, pp. 303-310.
[134] J.A. Linn, "Mail Survey-88," *Proceedings of Networkshop 16, University of Reading, 22-24 March 1988* (Reading: University of Reading, 1988), pp. 191-196.
[135] J. Meadows, "Is the Future Beginning to Work? Academics and Networks," *Changing Patterns of Online Information: UKOLUG State-of-the-Art Conference, Edinburgh, June 1994*, C.J. Armstrong and R.J. Hartley eds. (London: Learned Information, 1994), pp. 63-71.
[136] C.K. Work, "The NISS Catalogue: An Approach to the Bibliographic Control of Computer Files on a National Basis," *Bibliographic Access in Europe: Proceedings of a conference held at the University of Bath, 14-17 September 1989*, L. Dempsey ed. (Aldershot: Gower, 1990), pp. 219-224.
[137] H.J. Smith, "Buyers' On-line Rapid Information Service (BORIS)," *University Computing*, vol. 9, no. 2, 1987, pp. 108-109.
[138] Closure had therefore occurred. People now regarded JANET as a network, which offered many services and facilities. On closure see R. Kline and T. Pinch, "The Social Construction of Technology," in *The Social Shaping of Technology*, 2nd ed., D. MacKenzie and J. Wajcman eds. (Buckingham: Open University Press, 1999), pp. 113-115.

Great Britain. With the establishment of the Polytechnics and Colleges Funding Council in 1987, 70 additional higher education establishments joined JANET (see Figure 2.5). By the turn of the decade, the original 50 institutions that had connected to the network in 1984 had increased to 150. By then, there were more than 1,000 host computers connected to the network, supporting hundreds of file and job transfer facilities.[139] With over 20,000 terminals making 50,000 network calls a day, the traffic on the network had increased significantly since the Network Executive had announced the network during 1984.[140] For example, by 1988 the eight Network Operations Centres were transmitting 1,600 Megabytes (Mbs) a day, 1 Gigabytes (Gbs) more than three years previously. The recent upgrade to the network infrastructure, from 48 to 256 Kbps circuits, could not sustain the increase in traffic. Increasing the speed to 512 Kbps helped to ease this problem, but it was not a long-term solution. Faced with an exponential increase in traffic, the funding bodies decided to plan a two-phase upgrade of the network, known respectively as JANET Mark II and SuperJANET.

[139] R. Cooper, "The Janet internet," *Computer Bulletin*, June 1988, pp. 10-11.
[140] I.L. Smith, *Network Executive Report - January 1988* (Chilton, Oxon: Network Executive, 1988).

3. From Convergence to Consolidation: SuperJANET

3.1 From X.25 and OSI to TCP/IP

3.1.1 JANET Mark II

By the end of the 1980s, it was clear to the funding bodies that JANET could not support the exponential increase in traffic. They therefore planned a two-phase upgrade of the network, known respectively as JANET Mark II and SuperJANET. This chapter will look at these upgrades and focus particularly on the SuperJANET initiative. In parallel with this discussion, the chapter will also illustrate how access to the Internet protocols became very popular on the network, and how the academic community subsequently converged around these protocols during the early 1990s.

Planning for JANET Mark II began during the late 1980s. The MK II network was an interim upgrade to JANET which the Joint Network Team believed would support the expected increase in traffic for a maximum of two years.[1] The SuperJANET initiative would then replace the MK II network. The MK II upgrade would support all of the services on the network, and improve response times for applications such as file transfer and interactive applications. In 1989, the Computer Board approved funds for the new venture. It would allocate £5m over five years, starting in 1989. The Joint Network Team therefore began to upgrade JANET to the Mark II version of the network. This process involved upgrading all of the backbone circuits to 2 Mbps. With the majority of links between sites and the backbone operating at either 64 Kbps, or in some cases 9.6 Kbps, the network team also needed to improve the speed of these lines. It therefore started to replace these with 2 Mbps circuits. By December 1990, the JNT had upgraded several of the trunk lines that constituted the backbone and connected five sites at 2 Mbps (see Figure 3.1).[2] By 1991, the number of institutions connected at 2 Mbps speed had increased to 22.

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[1] B. Cooper, *JANET MK II*, UKERNA, 1989, Available from: http://www.ja.net/documents/NetworkNews/Issue29/news29.txt, Accessed on: 31 July 2004.

[2] See I. Smith, "JANET MK II," *Proceedings of Networkshop 18, University of Newcastle upon Tyne, 27-29 March 1990* (Newcastle upon Tyne: University of Newcastle upon Tyne, 1990), pp. 147-155, *JUGL Newsletter: The Journal of the JANET User Group for Libraries, Spring 1991* (Uxbridge: JUGL, 1991), p. 1, and I. Smith, *JANET MARK II - Progress Report*, UKERNA, 1990, Available from: http://www.ja.net/documents/NetworkNews/Issue33/news33.txt, Accessed on: 31 July 2004.

Figure 3.1. JANET Mark II in 1991.[3]

British Telecom supplied most of these new leased lines, with Mercury Communications providing some circuits. As part of the upgrade, the team replaced the switches with new Netcomm models. These replacements were part of an overall strategy to upgrade the network to the 1984 version of the X.25 standard.[4] Since it's inception in 1976, the CCITT's recommendation had developed through three

[3] The figure shows the partially upgraded backbone circuits between the eight Network Operations Centres. Some of the new circuits could transmit 2 Mbps, others anything from 1 Mbps down to 64 Kbps. The Network Executive also started to upgrade the links between sites and the centres, from 9.6 Kbps and 64 Kbps to 2 Mbps. The figure does not show these links.
[4] See Appendix D.

revisions: 1976, 1980, and 1984. Each revision refined elements of the standard, and the funding bodies saw the 1984 variant as particularly important. This version of X.25 contained features that would support the academic community's transition from the Coloured Books to OSI. By 1987, the network team had upgraded the switches used within JANET, so that they were compatible with the X.25 (1984) standard.[5] In addition, the JNT gradually upgraded the hosts and links. As a result, these upgrades provided the community with the basis on which to proceed with its OSI transition strategy. By adopting the revised versions of X.25, the funding bodies continued their long-term commitment to the chosen standard through sustained investment.[6] By adopting X.25, this consolidated the standard's position as the protocol used on the national academic computer network.

3.1.2 New Services on JANET

The JANET Mark II upgrade improved the bandwidth available for the applications accessed by users. As the 1990s began, the range of services on JANET continued to increase, exploiting the speed improvements provided. One social group of users to invest time and money in developing new services was the university libraries. Their efforts would benefit the community of librarians and staff, as well as academics who were familiar with accessing library services, such as online catalogues, directly for teaching and research. Two initiatives would particularly benefit many who used JANET. Established in 1989, the JUGL Project for Information Transfer, Education, and Research (Project Jupiter) aimed to improve library staff training.[7] The JANET User Group for Libraries believed that the successful adoption of JANET within libraries depended on training as well as on other factors such as the provision of IT resources. Funded by the University Funding Council (UFC), which was the successor to the University Grants Committee, this project was part of a broader initiative by the committee to improve the communication of information within libraries, using services on the network.[8] A mainly educational venture, Project

[5] R. Gillman, "The Academic Community OSI Transition: A Status Report," *Proceedings of Networkshop 18, University of Newcastle upon Tyne, 27-29 March 1990* (Newcastle upon Tyne: University of Newcastle upon Tyne, 1990), pp. 167-168.
[6] On platforms see S. Greenstein, "Industrial Economics and Strategy: Computing Platforms," *IEEE Micro*, vol. 18, no. 3, 1998, p. 45.
[7] M. Isaacs, "Project Jupiter: Report and Assessment," *Journal of Librarianship and Information Science*, vol. 24, no. 1, 1992, pp. 15-22.
[8] The University Funding Council (UFC) replaced the University Grants Committee during 1989.

Jupiter also wanted to explore the potential of services for the library community, as well as organising training-related programmes such as seminars. Two services became available during the early 1990s, the first of which was integral to Project Jupiter. Known as the Bulletin Board for Libraries (BUBL), this database provided information such as a guide to JANET for libraries, a list of online catalogues on the network, and a news service. Hosted by Glasgow University, the JUGL launched this experimental project during 1990.[9] Within a year, nearly 300 people were logging on to the bulletin board each month. In 1991, Project Jupiter closed and responsibility for BUBL transferred from the JUGL to the universities of Glasgow and Strathclyde.

The JANET User Group for Libraries launched the second Project Jupiter-related service in 1989. Known as Mailbase, this was part of the Networked Information Services Project (NISP) which aimed to provide communication tools on JANET.[10] Mailbase was a service set up to help those who lacked the necessary expertise in e-mail distribution lists to develop and maintain lists on several subjects. Using commands embedded in e-mail messages, users could interact with Mailbase to subscribe and unsubscribe from the lists. By 1990, more than 2,000 people used the service. The mailing list project had been set up to complement rather than compete with the academic community's X.400 and X.500 projects.[11] The importance of compatibility with these emerging OSI standards for electronic mail therefore influenced the development of the service. This attitude reflected the community's general commitment to OSI, as the standard of choice for JANET and its services. JUGL launched Mailbase as a national service during 1992. By then, 5,000 people had subscribed to more than 140 lists covering many academic disciplines, such as mathematics, computer science, and physics. The University of Bath established an additional library-related service on JANET during 1991. Known as the Bath Information and Data Services (BIDS) project, this licensed access to databases of information provided by the Institute for Scientific Information (ISI). These databases contained 12 million monographs from more than 7,000 journals and 4,000

[9] D. Nicholson, "BUBL and the Development of the UK LIS Networking Community," *Vine*, December 1993, pp. 12-17.
[10] D. Hartland, "The Networked Information Services Project (NISP II): Bringing the Benefits of the Computer Network to a Wider Academic Community," *University Computing*, vol. 14, no. 3, 1992, pp. 85-89.
[11] See Appendix L.

conferences held since 1982.[12] Within two years of Bath University launching the service, the university had provided licenses to 67 institutions which paid £6,000 per annum for access to the databases. People searched the databases for bibliographic information, including abstracts, which might interest them. Users could then ask BIDS ISI to return the results of a search via e-mail. By 1992, 12,000 people accessed BIDS ISI every week.

3.1.3 OSI and the Ascendancy of TCP/IP

As organisations developed new X.25 services to run across the network and as the Mark II upgrade became operational, X.25's position as the standard used on JANET seemed assured. However, for some time the community had been using another networking protocol at the local level. Developed during the 1970s and the 1980s in the US, the Internet Protocol suite diffused throughout the Internet and several other networks during the 1980s. Popular among computer science departments in universities, this protocol came free as part of the UNIX operating system.[13] During the 1980s, many computer science departments within universities adopted UNIX as the de facto standard for operating systems. For example, the University of Edinburgh used UNIX during the late 1980s, and explored the potential of TCP/IP in addition to using X.25 and OSI.[14] Other institutions, such as the Polytechnic of Central London and Aston University, also used TCP/IP, while still supporting the academic community's intention to migrate to OSI.[15] Efforts such as these helped to establish TCP/IP as the protocol used locally with these computer science departments and institutions. Another factor that helped to diffuse TCP/IP throughout the community was the adoption of Ethernet. Since the introduction of Local Area Networks during the early 1980s, universities had adopted X.25, Cambridge Ring, and Ethernet LAN standards. For a while, these standards co-existed, but by the mid to late 1980s many

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[12] See T. Morrow, "Networking Bibliographic Information - Implications Beyond the Campus," *Computer Bulletin*, November/December 1992, pp. 22-23 and T. Morrow, "BIDS ISI: A New National Bibliographic Data Service for the UK Academic Community," *Computer Networks and ISDN Systems*, vol. 25, no. 4-5, 1992, pp. 448-453.

[13] See Appendices E and M.

[14] D. Mercer, "Open Systems UNIX Networking," *Proceedings of Networkshop 15, University of Edinburgh, 8-10 April 1987* (Edinburgh: University of Edinburgh, 1987), pp. 129-154.

[15] See E. Sutherland and D. Roberts, "Migration: Plotting Courses and Setting Sail," *Networking Technology and Architectures: Proceedings of the International Conference Held in London, June 1988* (Pinner: Online Publications, 1988), pp. 433-442 and A. Jordon, "A User's Migration Path to OSI," *Network Management: Proceedings of the Conference Held in Birmingham, June 1989* (London: Blenheim Online Publications, 1989), pp. 401-410.

campuses had adopted Ethernet as the protocol for their LANs. As Ethernet was compatible with TCP/IP, this therefore helped to diffuse the standard throughout campuses as well as within departments.[16] Computer scientists' interest in TCP/IP and their use of the protocol prompted them to approach the Joint Network Team on a regular basis to talk about this standard.[17] They explained that they wanted to communicate with computer scientists at university departments, both in the UK and abroad. They pointed out that TCP/IP came free with UNIX and once departments had installed the operating system, they could start to use the networking facilities. Believing that the Internet protocols could do everything OSI should do, they therefore wondered why JANET did not use TCP/IP and its associated protocols. However, the Joint Network Team did not believe that TCP/IP was the way to proceed.[18] This is not to say that the JNT dismissed TCP/IP-related developments, as the team had used the ARPANET e-mail header standard as the basis for their Grey Book mail protocol. The JNT had always avoided proprietary protocols in favour of open system standards. The open Internet Protocol suite seemed compatible with this ideology, but the team chose to adopt the Open Systems Interconnection standard offered by the ISO. The JNT did this for several reasons. Many users and organisations in numerous countries had spent several years developing the OSI architecture.[19] Seen as a flexible and sophisticated standard for internetworking, the funding bodies continued their support for the international OSI protocols. With many other networks throughout the world doing the same, this seemed to justify the direction adopted by the community. The JNT also did not have the resources to establish a TCP/IP service and then perhaps switch to this protocol from X.25 and OSI.[20] For these reasons, it therefore rejected the idea of providing TCP/IP services over JANET, preferring to use X.25 and the Coloured Books, followed by OSI protocols. Willie Black, a former head of the JNT, considers the reason for this continued dominance of the ISO's standards, saying "there was a lot of very ingrained positions that said no we must go with the OSI protocols – they're open, they're

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[16] See Appendix G.
[17] R. Cooper, Interview by D. Rutter, 19 August 2003.
[18] C. Truman and P. Tinson, *UNIX Networkshop, City University, 12 and 13 December,* UKERNA, 1989, Available from: http://www.ja.net/documents/NetworkNews/Issue26/news26.txt, Accessed on: 31 July 2004.
[19] P.F. Linington, "Why OSI?" *Computer Networks and ISDN Systems*, vol. 17, no. 4 and 5, 1989, pp. 287-290.
[20] On switching costs see P. Klemperer, "Markets with Consumer Switching Costs," *Quarterly Journal of Economics*, vol. 102, no. 2, 1987, pp. 375-394.

technically superior."[21] There were also other reasons for the funding bodies continued commitment to OSI. As Smith remembers, "As spenders of what was in effect public money, we were expected to conform to the GOSIP requirements."[22]

Rejection of TCP/IP in favour of X.25 and OSI would not last. By the turn of the decade, support for the protocol used on the Internet had increased. This support came from several directions. The first came from computer scientists who continued to want the Joint Network Team to provide TCP/IP services over the national network. Others in the scientific community also declared their support for the protocol.[23] For instance, physicists involved in international large-scale collaborative research projects, needed access to the same protocols used by their colleagues in other countries. For instance, the High-Energy Physics Group at Glasgow University needed to access the resources provided by the particle physics accelerators at CERN in Geneva and DESY in Hamburg.[24] These scientists regularly used e-mail to communicate with their colleagues abroad.[25] The use of e-mail to other countries had increased by the end of the 1980s, and as many academics wanted to communicate with people in Europe and the US who used the Internet's SMTP e-mail protocol, they wanted to use this standard as well. While the Joint Network Team had provided a gateway between its Grey Book mail service and the Internet during the 1980s, by the end of the decade this facility presented the team with two problems. The gateway could cope with a certain amount of traffic, but the increased levels created performance problems. Without reconsidering the implementation of the gateway, this meant that the JNT could not upgrade the service to support the increased demand. The SMTP standard also presented problems. The Internet Engineering Task Force (IETF) continued to refine this protocol, and this created difficulties converting between this developing standard and the static Blue Book protocol, which was part

[21] W. Black, Interview by D. Rutter, 17 July 2003.
[22] I. Smith, Interview by D. Rutter, 26 June 2003.
[23] R. Day, Interview by D. Rutter, 23 June 2003.
[24] A.J. Flavell, "User Experience with TCP/IP (V1) for VM," *Managing Communications in a Global Marketplace: Proceedings of the SHARE Europe Spring Meeting, Cannes, March 30 - April 3, 1992* (Geneva: SHARE Europe, 1992), pp. 175-194.
[25] In addition to e-mail, scientists from many different disciplines used other applications such as FTP and telnet to access resources on the Internet. See B.J. Thomas, *The Internet for Scientists and Engineers: Online Tools and Resources*, 2nd ed. (Bellingham, WA: SPIE Optical Engineering Press, 1996).

of the Grey Book standard.[26] For these reasons, the only sensible solution to the problem would be to allow users on JANET to use SMTP to send and receive e-mails.

Support for TCP/IP also came from another direction. During 1984, the Massachusetts Institute of Technology (MIT) had developed the X-Windows system.[27] X-Windows ran on top of the UNIX operating system and presented users with a Graphical User Interface (GUI). As MIT had developed the system using UNIX, X-Windows therefore utilised the networking facilities provided by the operating system. Using the vendor independent X-Windows standard, people could use scientific applications running on a remote server, which would then display the results of a calculation, for example in the form of a graph, within the GUI. By the turn of the decade, many believed that X-Windows had a lot of potential because of these and other reasons.[28] However, they could not use the system on JANET because the network used X.25 instead of TCP/IP. In response, the Joint Network Team decided to develop an X-Windows system that could operate over JANET. People at universities could therefore use their workstations to interact with distant servers, including the supercomputers located at the Rutherford Appleton Laboratory and the University of London Computer Centre (ULCC). While it was possible to remove the TCP/IP protocol stack from beneath X-Windows and replace it with OSI, it became clear that manufacturers would not support such an initiative.[29] They viewed it as a niche activity in the UK, deciding not to invest in any work transferred to the private sector.

Examples such as these illustrate how academics use of JANET continued to evolve.[30] While they still valued facilities provided by the network, such as online catalogues

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[26] On the IETF see Appendix C.

[27] R.W. Scheifler and J. Gettys, “The X Window System,” *ACM Transactions on Graphics*, vol. 5, no. 2, 1986, pp. 79-109.

[28] Day, Interview.

[29] J. Dyer, “X Windows Over OSI,” *Graphics and Communications: Proceedings of an International Workshop, Breuberg, FRG, October 15-17, 1990,* D.B. Arnold, et al. eds. (New York: Springer-Verlag, 1991), pp. 173-179.

[30] No single authority controlled this evolution of JANET. As an increasing number of users started to value a potential new facility on the network, such as SMTP e-mail, this pressure started to influence the direction in which the network would develop. This evolution of the network was typical of most networks in the UK during the 1970s, 1980s, and 1990s. As no one had control over the development, diffusion, and ultimate convergence of the networks, this undermines the teleological approach adopted by some authors who state that packet switching lead to the ARPANET which then lead to its successor the Internet. The situation was much more complicated than this and was only one of potentially several outcomes that could have occurred.

and Mailbase, many also wanted to access TCP/IP-related services such as SMTP e-mail.[31] This user demand prompted many computer centre directors, at institutions such as UCL, Manchester, and Southampton, to declare that they wished to exploit the Internet protocols. While access to the Internet had existed for several years, the computer centre directors wanted the JNT to provide improved access to this network. In addition, they saw the ability to use X-Windows services over TCP/IP as important, and the ability to develop TCP/IP networks using inexpensive products supplied by companies such as Cisco to be of interest. The research councils also supported the idea of access to the Internet protocols. For some time, the SERC had used this standard on its network at the Rutherford Appleton Laboratory, and encouraged greater use of TCP/IP to enable its researchers to work with academics in other countries.

In response to this pressure to provide TCP/IP connectivity, the Joint Network Team set up a group to explore the issues surrounding TCP/IP.[32] Known as the Department of Defence Advisory Group (DoDAG), it proposed that the JNT establish a TCP/IP service on JANET. It suggested that the network team should set up the infrastructure to support this service, and provide access to Internet applications such as telnet, FTP, and X-Windows. This suggestion concerned those who discussed the issue at the Networkshop conference in 1991.[33] Delegates felt that by providing a TCP/IP service on JANET, that this would undermine the community's transition strategy to OSI. Because of this, the group recommended that the Joint Network Team discourage certain activities. These included using the network to transmit SMTP Internet e-mails as well as using TCP/IP to transmit OSI applications. This decision reflected the academic community's continued commitment to OSI migration. The network team accepted the advisory group's recommendations and approached the Computer Board's Network Advisory Committee with the suggestion that it set up a TCP/IP service. Looking back at this period, and how the JNT convinced the Board to establish the project, Robert Day, the JANET IP Service Manager, remembers that the proponents for the service "were the user community in the universities who were

[31] On disruptive technologies see J.L. Bower and C.M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review*, vol. 73, no. 1, 1995, pp. 43-53.
[32] R. Day, "JANET IP Service: Progress Report on Pilot Activities," *University Computing*, vol. 13, no. 4, 1991, pp. 180-182.
[33] B. Day, *Effect on Commitment to OSI over JANET*, Joint Network Team, 1991, Available from: http://www.ja.net/documents/NetworkNews/Issue34/news34.txt, Accessed on: 30 July 2004.

seeing new applications coming in that ran over TCP/IP and also seeing the need to communicate with the outside world."[34] This need was a sufficient reason to establish a TCP/IP service on JANET, especially as "X.25 was losing the battle to IP as the global communications mechanism, certainly in the academic community."[35] However, according to Day the "straw that broke the camels back was the X-Windows application which was widely regarded as the future. That was the vehicle for saying to the powers that be we've got to provide an IP service."[36] The Computer Board agreed and therefore accepted the JNT's proposals.

3.1.4 The Shoestring Project, X.25, and OSI

While the Computer Board accepted the JNT's proposals, the Board did not provide funding for the experimental TCP/IP project.[37] Political factors, such as the intention to migrate to OSI, influenced this decision. As funding was not available, the JNT therefore referred to the initiative as the Shoestring pilot project. To establish Shoestring, the JNT involved individuals at about fifteen institutions. These individuals represented a community of users that were interested in TCP/IP. They also had the necessary expertise to contribute to the project. Shoestring was typical of projects undertaken throughout JANET's existence. These often involved interested experts with the knowledge and skills needed for different ventures. The biannual Networkshops had continued to help to diffuse knowledge about networks and therefore develop a community of experts. This in turn contributed to the development of the network. The Shoestring project was the latest example of this phenomenon. People in several universities donated their time and equipment, in an effort to introduce the pilot TCP/IP initiative. The aim of the project was to develop the infrastructure necessary to support Shoestring's successor, the JANET IP Service (JIPS). JIPS would involve establishing routers between the member institutions as well as adopting a suitable technology to transmit TCP/IP packets over JANET. As TCP/IP would co-exist with the established X.25 protocol on the backbone and site access links, the JNT would transmit TCP/IP packets over the X.25 network. X.25

[34] Day, Interview.
[35] Ibid.
[36] Ibid.
[37] R. Day, E-mail to D. Rutter, 25 June 2003.

packets would therefore encapsulate TCP/IP packets which JANET would then deliver to their destination, reversing the process when they arrived.[38]

The JNT established the Shoestring pilot TCP/IP project during March 1991. The project raised an important issue for the Joint Network Team and for the community as a whole. The Computer Board and research councils still intended to migrate from the Coloured Book protocols to OSI, and they had outlined this objective in the White Book. At the Networkshop conference in 1991, delegates had discussed the White Book and believed that the funding bodies needed to update this strategy. The White Book should reflect the addition of the TCP/IP service to JANET, as well as the US and European efforts to migrate to OSI. By the early 1990s, several academic networks within Europe had developed transition strategies from several protocols to OSI. NORDUnet connected institutions in countries such as Sweden, Denmark, and Finland, using several protocols, including TCP/IP, DECnet, and X.25.[39] Despite using these protocols, the operators of NORDUnet intended to transfer the network to OSI standards when these became available. Two other European networks decided to do the same.[40] The BITNET compatible European Academic Research Network (EARN) adopted a migration strategy in 1987 which would introduce OSI protocols and applications to the X.25 network. Supported by IBM and DEC, work began on this change during the early 1990s. The European UNIX network (EUnet) was another network to explore OSI.[41] EUnet used TCP/IP to provide services, such as e-mail and access to Usenet, to a community of over 1,200 institutions. Countries throughout Europe, such as the UK, Germany, and the Netherlands, had set up the European UNIX User Group to run the network. However, despite the popularity of Internet-related applications, this group still explored the possibilities of migrating from TCP/IP to OSI.

Faced with networks that used TCP/IP, operators needed to decide how they should migrate to the ISO's standard. Using existing leased lines and equipment during the

[38] See Appendix K.
[39] E. Løvdal, "The Challenge of TCP/IP," *Computer Networks and ISDN Systems*, vol. 17, no. 4 and 5, 1989, pp. 376-379.
[40] D. Jennings, "The EARN OSI Programme," *Computer Networks and ISDN Systems*, vol. 19, no. 3-5, 1990, pp. 234-239.
[41] D. Karrenberg, "EUnet and OSI Transition Plans," *Computer Networks and ISDN Systems*, vol. 16, no. 1 and 2, 1988, pp. 94-100.

transition strategies would enable the operators to use both TCP/IP and OSI during the migration.[42] This option would also ensure that they would not disrupt the services provided to end users, an important aspect of any migration strategy.[43] Exploiting the Ethernet Local Area Network standard could also help, as both TCP/IP and OSI were compatible with this LAN standard.[44] Using gateways and routers to convert between the different protocols, would also enable operators to upgrade their networks in different stages. These were some of the options available to the academic networks within Europe. However, academia was not the only sector to express an interest in OSI. For instance, during the early 1980s, governments established Government Open Systems Interconnection Profile (GOSIP) policies and adopted OSI as the standard for all government computer networks.[45] In the UK, any company that wanted to supply systems to the government had to adhere to the government's GOSIP policy. To help encourage support within the private sector for such systems, the DTI set up implementer groups to assist computer companies in developing OSI systems. The National Computer Centre's Networking Centre would then test these products to ensure compliance with the relevant OSI protocols.[46]

Support for OSI also came from several other directions. These included the US government, NATO, and OSI on personal computers. By the mid 1980s, TCP/IP had become the de facto standard for internetworking in the US. Originally funded by the Defense Advanced Research Projects Agency, this connected many universities, institutions, and other organisations. In contrast to Europe, the US government had not expressed significant interest in the ISO's open standards. However, in 1986, the National Bureau of Standards in the US organised workshops that looked at OSI.[47] The National Academy of Sciences followed these workshops with a recommendation

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[42] D. Wallace, "How to Interwork Between TCP/IP and OSI," *Telecommunications*, April 1989, pp. 46 and 51-54.

[43] B. Sales, "TCP/IP–X.25/OSI Interoperation: From the Medium Term to the Long Term," *Computer Networks and ISDN Systems*, vol. 23, no. 1-3, 1991, pp. 171-176.

[44] See Appendix G.

[45] A. Bartholomew, "GOSIP — A Practical Guide to OSI Procurement," *Telecommunications*, November 1989, pp. 33-34 and 36.

[46] See J. Stranger, "UK GOSIP: an overview of the taxonomy and procurement issues," *International Open Systems 88: Proceedings of the conference held in London, April 1988* (London: Online, 1988), pp. 73-80, B. Norris, "UK OSI Implementor Groups - IGOSIS," *International Open Systems 88: Proceedings of the Conference Held in London, April 1988* (London: Online Publications, 1988), pp. 55-63, and J. Turff, "A Testing Time for OSI," *Communications Systems Worldwide*, July/August 1988, pp. 42-43.

[47] M. Witt, "Moving from DoD to OSI Protocols: A First Step," *Computer Communication Review*, vol. 16, no. 2, 1986, pp. 2-7.

that the US DoD replace TCP/IP with OSI. Convinced that the future of internetworking lay with OSI, the US government agreed.[48] It therefore developed a GOSIP policy and encouraged companies to develop OSI systems. Companies, such as Encore Computer Corporation, responded with OSI file transfer and e-mail systems.[49] NATO was another organisation that became interested in OSI during the 1980s.[50] To help connect different communication systems and therefore support interoperability, NATO adopted the ISO's standard. While NATO intended to adopt the reference model primarily for command and control systems, transferring the venture to civilian computer networks could also occur. One of the other OSI initiatives involved the personal computer. Until the late 1980s, support for OSI systems on the PC had been weak. However, as the end of the decade approached, initiatives such as the Carlos project aimed to rectify the situation. The Carlos project proposed to develop prototype systems that companies could use to form the basis of products. The aim was to combine the PC, a "universal computing" platform, with OSI, which many believed would become the "universal communications" platform.[51]

As the 1990s began, support for OSI was perhaps at its strongest. Many universities, governments, and other organisations considered OSI to be the only way to satisfy the demand for open systems from users.[52] Support for the Internet protocols would inevitably decline as OSI became dominant.[53] Despite this, the Joint Network Team still decided not to run OSI applications over TCP/IP. While the IETF had defined a standard to support this, the Joint Network Team rejected it. The JNT did so because it believed that the standard lacked extensive support and the team could not easily expand the service across the network until addressing issues had been resolved. Whether politics also influenced this decision is an open question. The IETF had defined the standard for running OSI applications over TCP/IP, rather than the ISO.

[48] M. Jacobs, "OSI in Perspective – Turning Expectations into Reality," *Network Directions: Proceedings of the International Conference Held in Birmingham, June 1990* (London: Blenheim Online, 1990), pp. 93-103.
[49] "Encore Claims Conformance to UK and US Gosip," *Communications Magazine*, September 1990, p. 10.
[50] N. Neve, "NATO Manoeuvres Towards OSI," *Communications Systems Worldwide*, May 1988, pp. 41, 44, and 46.
[51] L. Mantelman, "OSI on PCs: Bringing the World to the Desktop," *Data Communications International*, April 1989, pp. 64-71.
[52] T. Rixon, "Building Up User Confidence," *Communications Systems Worldwide*, June 1989, pp. 31-32.
[53] L. Pouzin, "Ten Years of OSI—Maturity or Infancy?" *Computer Networks and ISDN Systems*, vol. 23, no. 1-3, 1991, pp. 11-14.

While international committees had defined OSI, this had not happened with TCP/IP, where the Internet community had defined the standards used on the network. The IETF maintained overall control of TCP/IP, but no one had a monopoly over every aspect of the Internet protocols. These ideological factors influenced the community's decision to adopt an OSI solution, compared to an Internet-related option. Others, such as the Dutch SURFnet, chose to run OSI applications such as X.400 over TCP/IP, while it waited for the ISO to ratify the complete set of OSI protocols.[54] Despite rejecting the IETF's option, the Joint Network Team decided to allow certain Internet applications on JANET, such as SMTP for e-mail. The DoDAG had suggested that the network team allow users to access these across JANET and as support for Internet e-mail continued to increase this seemed a logical decision.

3.1.5 The Dominance of TCP/IP

Having established the TCP/IP infrastructure during the Shoestring pilot project, and addressed the main issues involved, the Joint Network Team established the JANET IP Service during November 1991.[55] The Computer Board's successor, the Information Systems Committee (ISC), invited institutions and organisations to apply for connection to the service (see Figure 3.2 for details about the ISC). Anyone that was legally entitled to access the service could do so, and the ISC would charge them as part of the overall costs associated with connection to JANET. Departments on campuses could apply for JIPS through their computer centre which would then formally apply for connection to the service. While the registration of domain names might take a month, the network team would usually connect an institution to the service within a couple of days.[56] Within two weeks of the Joint Network Team establishing the JANET IP Service, 30 institutions had applied for connection. By then, there were 19 .ac.uk domains and over 5,800 hosts.[57] Within 5 months, this had increased to 81 domains and more than 16,800 hosts. Traffic during this period also increased. In August 1991, users sent 26 Gb during the month.

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[54] Day, *Effect on Commitment to OSI over JANET*.
[55] B. Day, *Inauguration of the JANET IP Service*, Joint Network Team, 1991, Available from: http://www.ja.net/documents/NetworkNews/Issue35/news35.txt, Accessed on: 30 July 2004.
[56] See Appendix J.
[57] B. Day, *The JANET IP Service - The First 3 Months*, Joint Network Team, 1992, Available from: http://www.ja.net/documents/NetworkNews/Issue36/news36.txt, Accessed on: 30 July 2004.

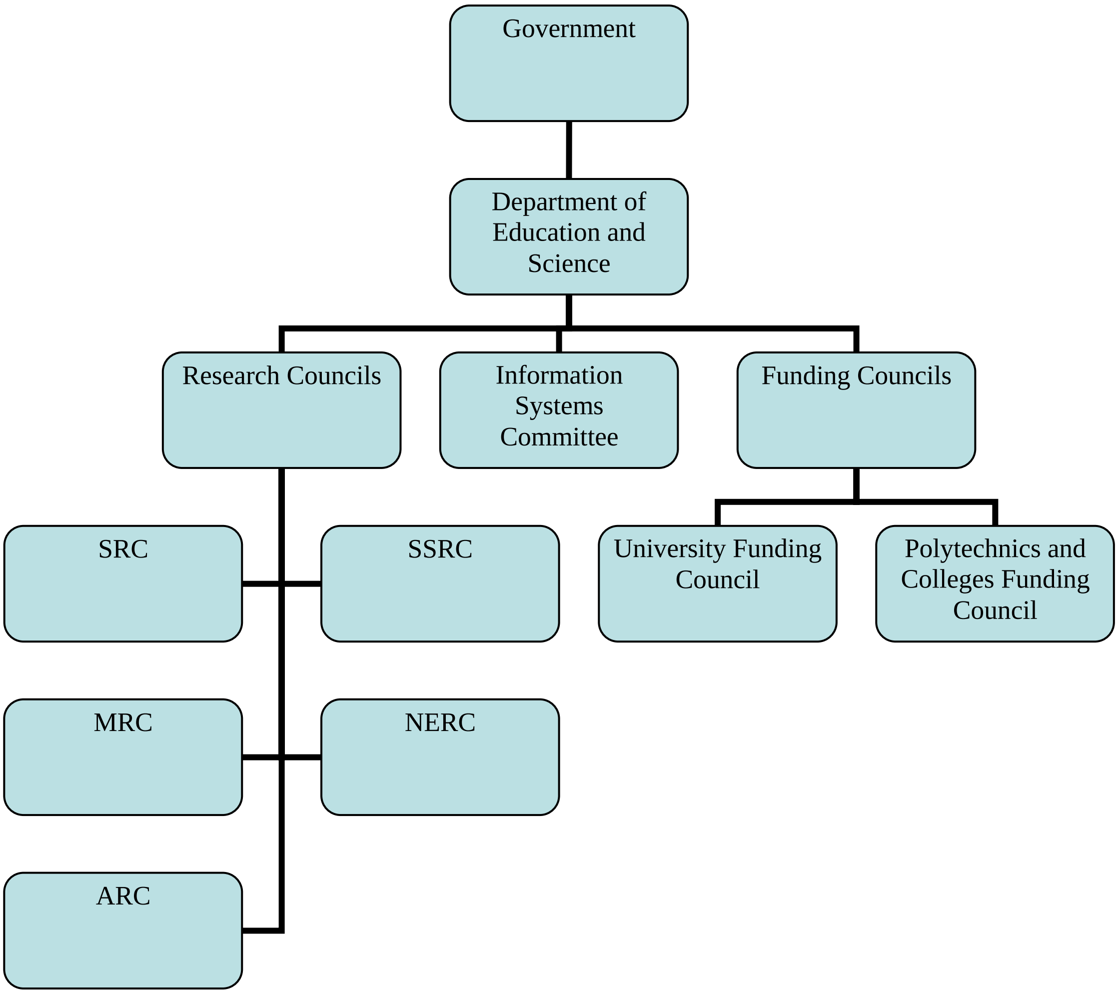

Figure 3.2. Hierarchy of funding bodies circa 1992.[58]

After the launch of JIPS, in January 1992, this had increased to 96 Gb. People mainly used the service to send and receive e-mails and transfer files, confirming the interest that users had shown in these services before the launch of JIPS. This momentum continued to increase, and with the launch of the TCP/IP-only SuperJANET network during 1993, the demise of X.25 would become certain. However, during 1991 support for this protocol continued.

The ISC had launched the JANET IP Service in response to demand from users. The committee had decided to run the service in parallel with X.25 and see how users responded to both services. Within six months of launching JIPS, the ISC had its answer. By then, 80 percent of universities had switched from using X.25 to using TCP/IP. Despite the overwhelming support for TCP/IP compared to OSI from the

[58] The ISC replaced the Computer Board during 1991.

users of the network, support for the ISO standard remained seemingly implacable. Debate continued about the relative merits and likely success of each protocol, both within the UK academic community and throughout the internetworking world.[59] Advocates of the ISO's standard questioned the validity of adopting the Internet protocols over the internationally ratified OSI standards such as X.400.[60] At this time, and with OSI in mind, the JNT set up a successor to the DoDAG, called the IP Technical Advisory Group.[61] This group would look at the issues surrounding migration from TCP/IP to OSI, and complement the community's existing transition from the Coloured Books to OSI. However, the network team would never implement efforts such as these. The continual debate between the protagonists of OSI versus TCP/IP had prompted many to call for a cessation in the protocol wars which had affected computer networks throughout the end of the 1980s and early 1990s.[62] The International Organization for Standardization and the IETF began to work together during the early to mid 1990s, and people therefore hoped that one standard for internetworking would emerge. For a while, co-existence between the protocols became the approach adopted by the internetworking community, especially among OSI advocates.[63] For example, adapting OSI so that it interconnected with the dominant TCP/IP could benefit users that used the OSI protocols, by becoming part of the larger Internet community.[64] People suggested ways in which both could co-exist, and multi-protocol backbone networks, such as EuropaNET, which was IXI's successor, emerged (see Figure 3.3).[65] However, by the early to mid 1990s this outlook changed. By then, support for OSI was beginning to weaken.

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[59] R.d. Jardins, "The Great OSI Debate: OSI Is (Still) a Good Idea," *Interop 92 Spring: The 7th Interoperability Conference & Exhibition, 18-22 May 1992, Washington D.C.* (Washington DC: Interop Company, 1992), pp. 1-4.
[60] Day, Interview.
[61] B. Day, *IP Technical Advisory Group (IPTAG)*, Joint Network Team, 1992, Available from: http://www.ja.net/documents/NetworkNews/Issue36/news36.txt, Accessed on: 30 July 2004.
[62] M. Ward, "Internet Must Win the Numbers Game," *Computer Weekly*, 22 April 1993, p. 12.
[63] See R. Hunt, "The Future of TCP/IP and ISO/GOSIP - Migration or Coexistence?" *Networks '93: Integrating networks with business objectives, Birmingham, June 1993* (London: Blenheim Online, 1993), pp. 423-437 and R.W. Callon, "Integrated Routing for Multi-protocol TCP/IP–OSI Environments," *Computer Networks and ISDN Systems*, vol. 23, no. 1-3, 1991, pp. 185-190.
[64] On adapters see C. Shapiro and H.R. Varian, "The Art of Standards Wars," *California Management Review*, vol. 41, no. 2, 1999, pp. 8-32.
[65] S.M. Nielsen, "EuropaNET - Contemporary High Speed Networking," *Computer Networks and ISDN Systems*, vol. 25, no. S1, 1993, pp. S25-S34.

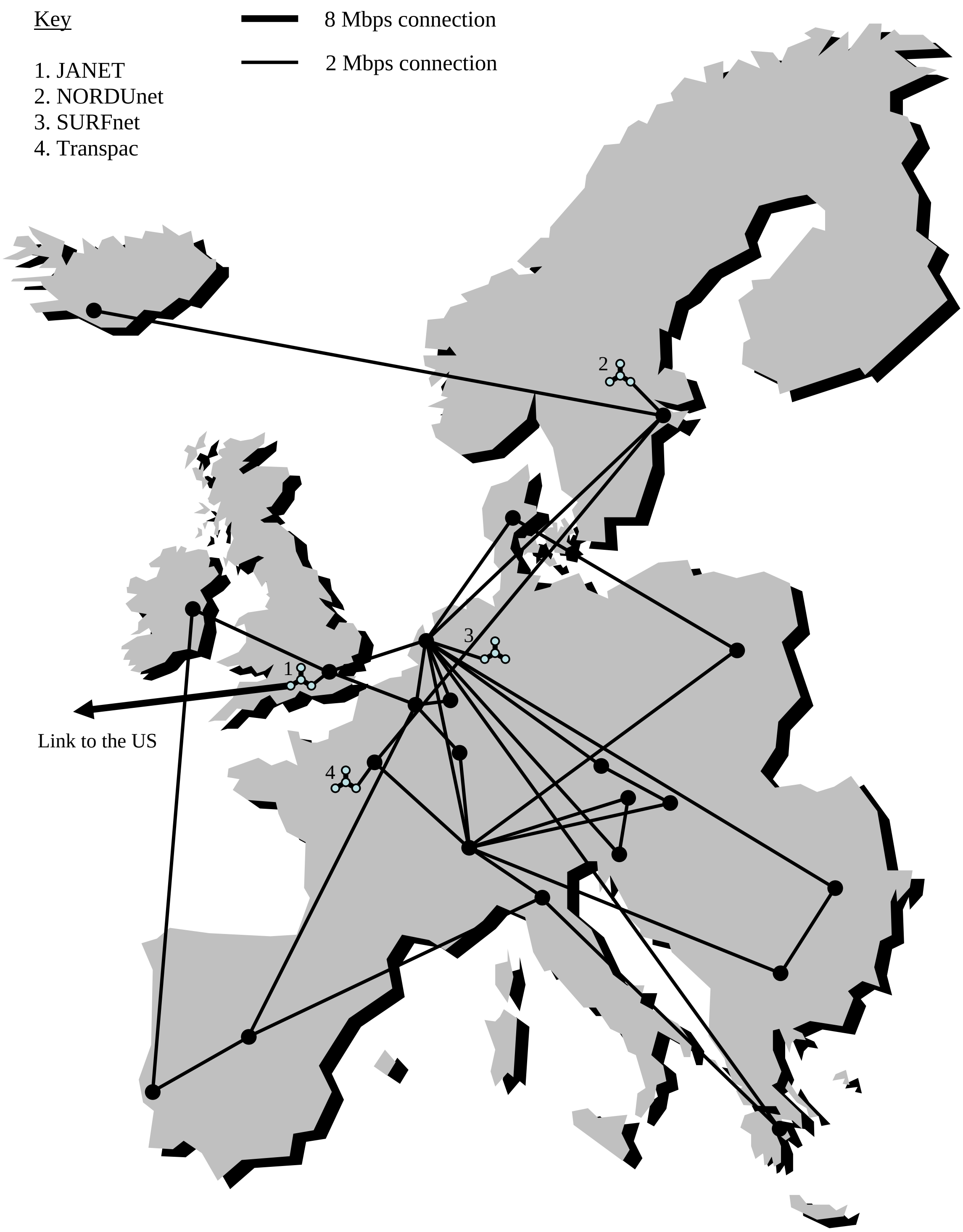

Figure 3.3. EuropaNET in 1995.[66]

The US government decided to abandon its GOSIP policy in favour of TCP/IP, which departments had adopted.[67] Organisations that had been set up to promote OSI, such

[66] The figure shows the backbone of the EuropaNET network, which interconnected 19 countries. The figure also shows the link between JANET and the US. For clarity, the figure only contains four national packet-switched networks.
[67] "End of the Line for Gosip in US?" *Computing*, 27 January 1994, p. 6.

as the Corporation for Open Systems, also chose to change direction.[68] Members of this organisation, which included AT&T and the US Government, convinced the organisation to focus on multi-protocol solutions. The corporation saw OSI as one of many protocols, and it therefore no longer saw it as the only protocol for internetworking. Throughout the world, support for OSI continued to decline as networks, such as PSS, Transpac, and Telenet, replaced X.25 and OSI with TCP/IP. By the mid 1990s, the protocol wars had ended. It had taken too long for the international community to ratify the Open Systems Interconnection standard. In addition, as OSI was too complex and lacked support from manufacturers, communities of users chose not to adopt the ISO's proposed solution to internetworking. The lightweight Internet Protocol suite, which defined only three out of the seven layers of the reference model, had eclipsed the functionally rich but incomplete OSI.[69]

With general support for OSI declining and with 90 percent of traffic Internet-related by 1992, the Joint Network Team capitulated. According to Cooper, the JNT "saw that the battle had been lost and that TCP/IP was going to be the open systems standard for the rest of the world."[70] It therefore approached the Computer Board and, according to Mike Wells, the first Director of Networking, said that "we can't any longer insist that people have to use X.25 because if we did so we are inhibiting their ability to do their jobs; it was as simple as that and the argument was accepted."[71] The funding bodies therefore decided to adopt TCP/IP as the official protocol for JANET.[72] They subsequently announced that they would discontinue support for X.25 by December 1995. The Joint Network Team would therefore no longer run TCP/IP over X.25, running the Internet protocols over their own dedicated circuits. However, the JNT would continue to support X.25 while the remainder of the academic community converted to TCP/IP. To aid this transition, the team began to work on a new transition strategy which would involve the migration from X.25 and the Coloured Books to TCP/IP.[73] The first step in this process would be the establishment

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[68] A. Steffora, "Users and Vendors Steer Clear of OSI," *Computer Weekly*, 29 April 1993, p. 9.
[69] See Appendix E.
[70] Cooper, Interview.
[71] M. Wells, Interview by D. Rutter, 7 August 2003.
[72] B. Day, *The Transition from X.25 to IP - an Update*, UKERNA, 1994, Available from: http://www.ja.net/documents/NetworkNews/Issue43/transition.html, Accessed on: 11 May 2004.
[73] See Appendix K.

of an X.25 over TCP/IP service. Similar to JIPS but in reverse, this would transmit X.25 packets over the TCP/IP network. The aim of this encapsulation service would be to assist X.25 sites to convert to the Internet protocols. Cisco had developed the X.25 over TCP/IP (XoT) technology with support from the IETF in 1994.[74] During the same year, the JNT launched the XoT service on JANET.

The convergence around a single protocol, TCP/IP, was the second time the academic community had converged around a standard.[75] During the early 1980s, JANET had converged around X.25, which replaced a set of heterogeneous computer networks. This process had taken only two years. The Joint Network Team then continued to improve its network, in response to the increased traffic generated by the expanding user community. During the late 1980s and early 1990s, people began to want to access Internet-related services such as SMTP e-mail. With the introduction of a competing standard on the academic network, this began to satisfy this need. However, unlike the first change in protocols, it took just 6 months for the academic community to converge around a single standard, and within a year, the funding bodies had adopted TCP/IP as the new protocol for their network.

3.2 SuperJANET

3.2.1 Expansion

As the academic community converged around the Internet protocols, work began on establishing the second phase of the network upgrade: SuperJANET. When the Joint Network Team proposed the upgrade of JANET during the late 1980s, it expected that the first phase would only support increased traffic for at most two years. It would then gradually replace the JANET Mark II network with a new initiative known as SuperJANET. A multi-service broadband network, this would support the increasing traffic levels on the network, generated by the range of services used by the

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[74] See N. Shield, *X.25 Over TCP/IP Encapsulation - Announcement of Service*, UKERNA, 1994, Available from: http://www.ja.net/documents/NetworkNews/Issue43/xot.html, Accessed on: 11 May 2004 and Appendix K.

[75] However, unlike the first time, when the funding bodies had taken individual decisions to converge around X.25, such as in the case of SERCnet, to form the basis for a nationwide convergence around X.25 to create JANET, this time it was the users who decided to converge around TCP/IP. This convergence was therefore not directed by any single authority and the funding bodies and the JNT did not anticipate that this convergence would occur and with such speed. As no one had control over the convergence of the network around TCP/IP, this undermines the approach adopted by some authors who argue that networks developed teleologically. The situation was much more complicated than this.

community. As both the number of users and increase in traffic also affected campuses, the funding bodies also needed to upgrade campus LANs. The Information Systems Committee therefore approved funds to upgrade all Local Area Networks from 10 to 100 Mbps.[76] Ethernet could not support transmission speeds of 100 Mbps which meant that the ISC chose a fibre-optic-based solution, Fibre Distributed Data Interface (FDDI). Adopting FDDI for LANs became common during the early 1990s, before Fast and Gigabit Ethernet became available during the second half of the decade.[77] Having chosen FDDI, the committee established pilot projects and universities such as Essex employed the technology in their LANs.[78] The new SuperJANET network would interconnect these upgraded LANs to form a high-speed backbone serving the academic community. SuperJANET would support existing services and new applications which people would develop for the network.[79] For years, the academic community had responded well to new services, adopting applications such as e-mail. In addition, they had often played an active role in their development. This trend would continue with SuperJANET, helping to diffuse new applications throughout the community as well as enabling the JNT and others to undertake research in to computer networks. The ISC also intended SuperJANET to generate interest within the private sector which had happened with JANET with companies such as Netcomm developing switches for the Mark II network. The network team hoped the same would happen with SuperJANET, with suppliers developing products for use within the new initiative. Politics also influenced the decision to develop a new broadband network. By the early 1990s, many companies operated X.25 networks throughout the world. The speed of these networks varied, but usually they were not fast. For example, in 1992 the European IXI network had a backbone that ran at 64 Kbps.[80] With a backbone that operated at 8 Mbps, JANET became the highest performance X.25 network in the world by the beginning of the

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[76] S. Weston, *ISC Fund High Speed Multi Vendor LAN Initiative in Universities*, Joint Network Team, 1991, Available from: http://www.ja.net/documents/NetworkNews/Issue34/news34.txt, Accessed on: 30 July 2004.

[77] See Appendix G.

[78] *SMC Networks and the University of Essex*, Computer Weekly, 2000, Available from: http://www.computerweekly.com/Article43154.htm, Accessed on: 19 June 2004.

[79] R. Cooper, et al., “From JANET to SuperJANET,” *Computer Networks and ISDN Systems*, vol. 21, no. 4, 1991, pp. 347-351.

[80] D. Law, “European Research Networks,” *The Common Market for Information: Proceedings of the Annual Conference of the Institute of Information Scientists, June 1992*, M. Blake ed. (London: Taylor Graham, 1992), p. 50.

1990s.[81] However, it would inevitably lose this position if the ISC did not continue to upgrade the network infrastructure to higher speeds. With the US government planning a new multibillion-dollar National Research and Education Network (NREN), this confirmed the ISC's concern.[82]

During 1991, the Information Systems Committee presented the case for a new network to the Department of Education and Science.[83] The DES agreed with the committee that the community needed an upgraded network, and approved funding of £20m over four years.[84] However, the DES attached a condition. The Joint Network Team would have to demonstrate the feasibility of the network, for the project to continue. To do this, the JNT proposed to establish a pilot project which would link a small number of sites to a high-speed backbone. However, unlike JANET the ISC could not develop a private network, as the JNT did not have the legal authority to lay fibre-optic cables between the premises of the funding bodies.[85] The committee therefore proposed to collaborate with a telecommunications company that could provide the fibre-optic infrastructure, at a price that the funding bodies would accept. During 1992, the committee chose British Telecom as the supplier for the new network. The SuperJANET initiative would be a collaborative venture between the academic community and British Telecom, and enable BT to experiment with new broadband applications. The new network would therefore benefit both academia and the interests of a private company.

3.2.2 The SuperJANET Pilot Networks

The ISC awarded BT an £18m four-year contract during 1992. The first stage of the project was to establish the pilot network.[86] This network would need to support a range of applications and services, some of which would involve the transmission of

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[81] P. Fisher, "Linking the LEARNED," *Computer Weekly*, 14 May 1992, p. 36.
[82] See J. Kobielus, "NREN Fiscal and Political Prospects," *Network World*, 26 August 1991, p. 45 and J.T. Johnson, "NREN: Turning the Clock Ahead on Tomorrow's Networks," *Data Communications*, September 1992, pp. 43-44, 46, 48-49, 52, 54-58, and 60-61.
[83] During 1992, the Department of Education and Science became the Department for Education (DfE). Three years later the government renamed the DfE as the Department for Education and Employment (DfEE). In 2001, the Department for Education and Skills (DfES) replaced the DfEE.
[84] R. Cooper, "The SuperJANET Project," *Future Generation Computer Systems*, vol. 10, no. 2 and 3, 1994, pp. 233-240.
[85] R. Cooper, E-mail to D. Rutter, 3 May 2004 and C. Cooper, E-mail to D. Rutter, 29 April 2004.
[86] M. Ward, "Janet Link-Up Outstrips Local Nets for Speed," *Computer Weekly,* 19 November 1992, p. 10.

multimedia data. As quality of service is vital in networks that transmit real-time sensitive information, the choice of the underlying network technology would therefore be crucial. During the early to mid 1990s, a new technology emerged that had the potential to satisfy these demands. Known as Asynchronous Transfer Mode (ATM), it attracted the interest and commitment of many companies.[87] Telecommunication companies, the JNT, and other organisations viewed ATM as the next generation of network technology, as it could transmit several types of information including data, voice, and multimedia data, at speeds such as 155 Mbps. Because of this interest, 370 companies had joined the international ATM Forum, which aimed to diffuse the technology throughout the world.[88] In addition, the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) began to set up ATM networks, and 15 Public Network Operators (PNOs) in Europe planned to trial ATM. Because of the potential of this technology, the project team set up to establish SuperJANET adopted this technology for the new network. It therefore set up an ATM Technical Advisory Group to explore the issues involved in using this new technology.[89]

To support the development and deployment of ATM across the network, the JNT needed to choose an appropriate underlying high-speed technology. To interconnect the new FDDI campus LANs and upgrade the JANET backbone to support the continued increase in traffic, the network team chose a fibre-optic solution. Known as Synchronous Digital Hierarchy (SDH), this emerging standard would be compatible with ATM and support both existing and new bandwidth-intensive applications.[90] However, during the early to mid 1990s, SDH services were not available. The Joint Network Team therefore decided to use a compatible technology, while they waited for SDH to become available. The JNT chose Plesiochronous Digital Hierarchy (PDH) for this purpose. BT proposed to complement this technology with a new service called Switched Multimegabit Data Service (SMDS).[91] British Telecom

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[87] See C. Kalmanek, “A Retrospective View of ATM,” *Computer Communication Review*, vol. 32, no. 5, 2002, pp. 13-19 and Appendix F.
[88] G.P. Parr, “SuperJANET: Architectural Considerations for the UK’s Super-Highway - A Northern Ireland Viewpoint,” *Axis*, vol. 1, no. 2, 1994, pp. 26-33.
[89] S. Weston, *ATM Technical Advisory Group*, Joint Network Team, 1991, Available from: http://www.ja.net/documents/NetworkNews/Issue34/news34.txt, Accessed on: 30 July 2004.
[90] See Appendix F.
[91] See B. Cooper, *An Introduction to SMDS*, Joint Network Team, 1993, Available from: http://www.ja.net/documents/NetworkNews/Issue40/SMDS/SMDS.html, Accessed on: 10 August

wanted to pilot its new SMDS service and it was looking for a network that it could use for this trial. JANET seemed suitable, especially as the funding bodies wanted to upgrade the performance of the network. The ISC's successor, the Joint Information Systems Committee (JISC), agreed with the suggestion, and this meant that the SuperJANET pilot phase would involve three networks which BT and the JNT would develop (see Figure 3.4 and Figure 3.5 for details about the JISC). The first two would be pilot PDH networks linking a small number of sites. One would provide an operational data network and the other an ATM research network. Both would enable people to develop and test new applications. To support these initiatives, the networks would provide 140 Mbps links to the institutions taking part, divided into four 34 Mbps channels on-site.[92] The third network would upgrade the links from universities and other organisations to JANET and use BT's SMDS. The intention was to combine these network developments into a single ATM network, during the mid to late 1990s. With the plans for the SuperJANET pilot phase prepared, work began on establishing the networks. The pilot PDH network would interconnect six sites in the south, centre, and north of England, including Imperial College, the Rutherford Appleton Laboratory, and Edinburgh. The JNT chose these sites because they could develop a range of applications that would demonstrate the feasibility of the network. The research network would link a subset of these sites, and support experimental audio and visual applications.

By March 1993, BT and the JNT had connected eight sites to the PDH network (see Figure 3.6).[93] They had also established the pilot ATM network (see Figure 3.7). In addition to these developments, BT and the network team had set up the SMDS network. This network upgraded access links from the 2 Mbps provided by JANET MK II to 10 Mbps.

2004, R. Dorey and R. Hnyk, "UK Learning on the Information Superhighway," *Telecom Report International*, vol. 17, no. 3, 1994, pp. 12-13., and Appendix F.

[92] See Appendix F.

[93] R. Cooper, "Implementing SuperJANET," *Proceedings of Networkshop 21, University of Birmingham, 23-25 March 1993* (Birmingham: University of Birmingham, 1993), pp. 25 and 27-34.

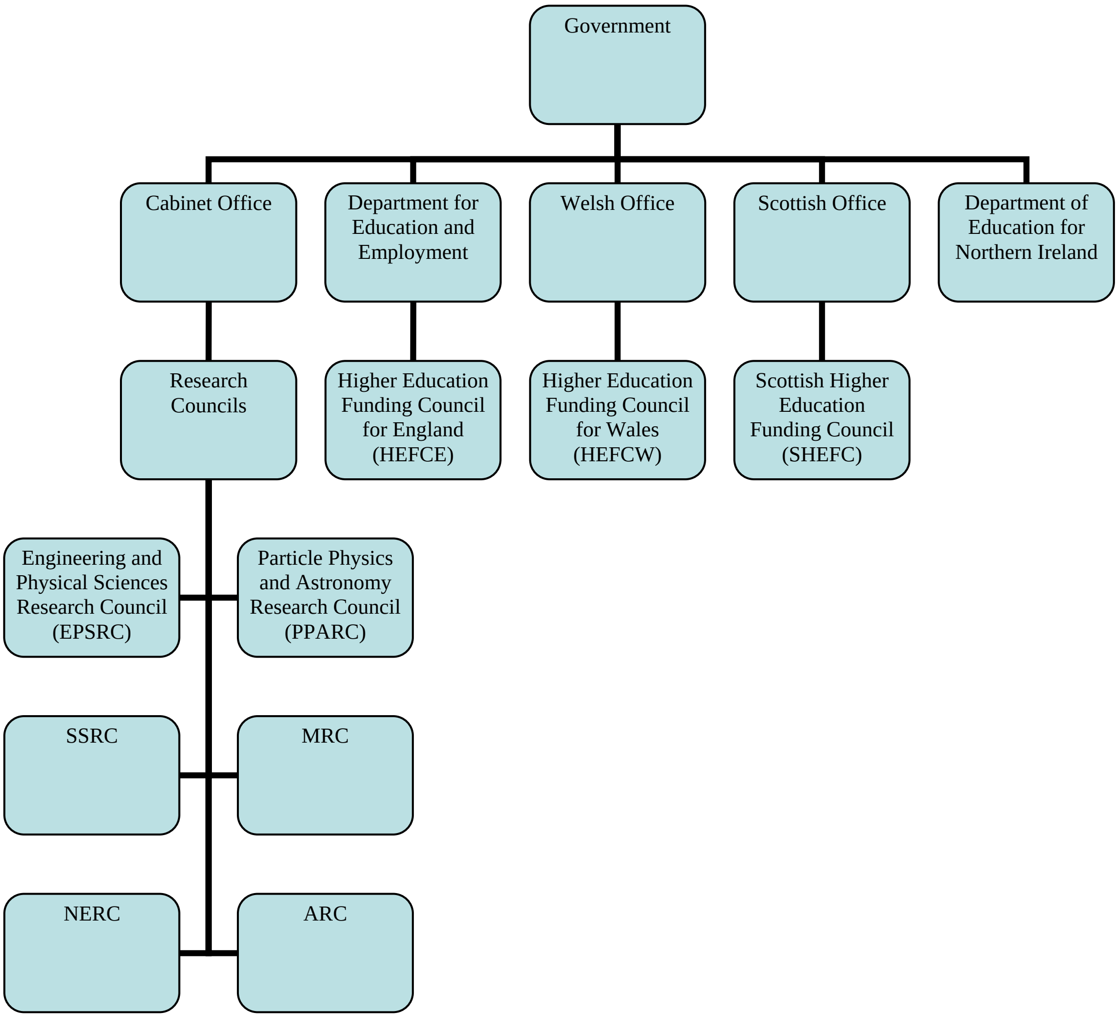

Figure 3.4. Hierarchy of funding bodies in 1995.[94]

The aim was to connect over 30 institutions by the end of 1993, starting with the universities connected to the PDH operational network. SMDS would only use the Internet Protocol suite and institutions would have to use the circuits provided by SMDS.[95] As each site replaced its MK II connections with SMDS, the JNT would cancel the old 64 Kbps and 2 Mbps leased lines. This process therefore continued to reduce the number of X.25 circuits in use, while still providing access to the XoT service for institutions that required this facility.

[94] During 1993, the Higher Education Funding Council for England, the Higher Education Funding Council for Wales, and the Scottish Higher Education Funding Council, replaced the University Funding Council and the Polytechnics and Colleges Funding Council. The JISC reported to these councils. During 1994, the Engineering and Physical Sciences Research Council (EPSRC) and the Particle Physics and Astronomy Research Council (PPARC) replaced the Science and Engineering Research Council.
[95] See Appendix F.

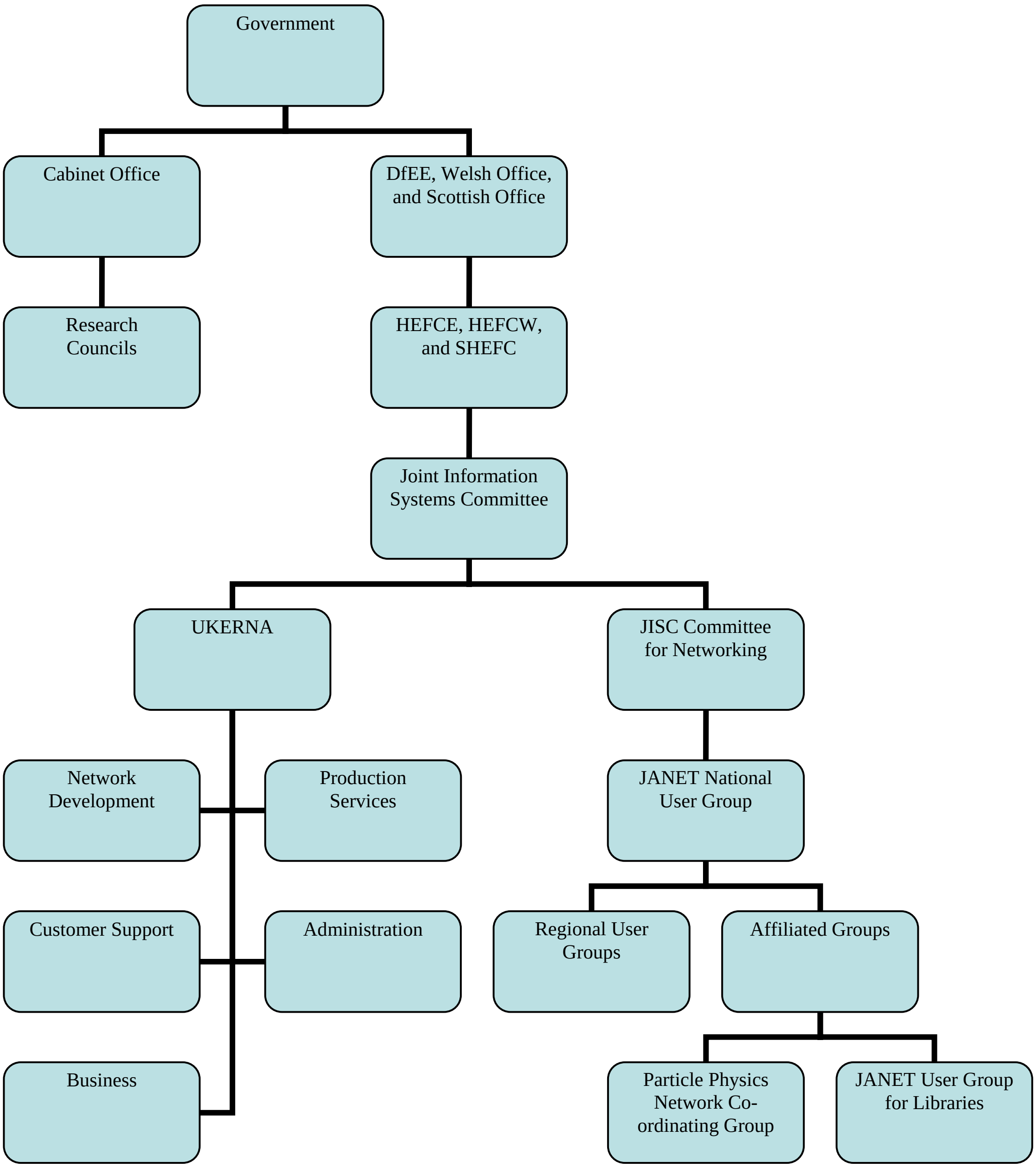

Figure 3.5. Organisational hierarchy in 1999.[96]

To test this new infrastructure and demonstrate that SuperJANET was viable, the funding bodies needed pilot applications. SuperJANET was similar to any network, as it was unclear as to which applications users would adopt. This situation occurred on the ARPANET, where e-mail became a success, and it had occurred on JANET.[97] People originally assumed that remote job submission would become the principal service accessed by users.

[96] UKERNA's five divisions managed tasks such as connection to JANET, security, and e-Science initiatives.
[97] J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), pp. 106-107.

Figure 3.6. The pilot SuperJANET PDH network in 1993.

However, the funding bodies and the Joint Network Team had decided to let the community decide which services they wanted, and by the mid 1990s, the number of people using e-mail and the Web had surpassed all other types of application.

Figure 3.7. The pilot SuperJANET ATM network in 1993.

As Rosner remembers, it is important "to learn from history that 'killer' applications have a habit of appearing only when an adequate infrastructure is well and truly established."[98]

[98] While the 'killer application' hypothesis is interesting, it does not mean that if people had not invented applications such as e-mail and the Web, that computer networks would not have diffused throughout the world. People would have adopted networks whether e-mail, the Web, and other applications existed or not. See R. Rosner, "In the Beginning: An Affectionate Memoir," *Axis*, vol. 3, no. 4, 1996, pp. 25-27 and M. Campbell-Kelly, *From Airline Reservations to Sonic the Hedgehog: A History of the Software Industry* (Cambridge, MA: MIT Press, 2003), pp. 7 and 212-213.

With the development of the SuperJANET pilot applications, these programs would not only demonstrate the feasibility of the network, but also perhaps indicate possible future services which people may later adopt. During the previous year, six institutions had been developing these applications which would exploit the extra bandwidth provided by the new network developments. This initiative had resulted in several trial services, examples of which included chemical, medical, and electronic journal projects.[99] Imperial College investigated ways in which SuperJANET could support applications which would assist chemists. These included 3D representations of chemical structures and group communication using videophone software. Several sites, including the Royal Postgraduate Medical School, explored the possible medical applications that might be able to run over the new network. Possibilities included using SuperJANET to transmit PET scans and 3D ultrasound images and using video to teach students about surgery. Another pilot application provided access to electronic journals. Known as the SuperJournal project, it was the latest initiative to explore the potential of electronic journals.[100] Involving several organisations, such as the British Library and Oxford University Press (OUP), it demonstrated that providing access to journals over the network was practical. The Joint Network Team chose applications such as these to demonstrate the feasibility of SuperJANET. Representatives from the funding bodies and BT witnessed transmission of audiovisual information, at a time when people generally only used networks to send textual information and sometimes still images. Seeing video on the network was something that had therefore never happened before, and the ability to transmit this demanding type of data therefore helped to convince those present about the viability of the network.

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[99] See H. Rzepa, "Chemical Applications of Networks," *Proceedings of Networkshop 21, University of Birmingham, 23-25 March 1993* (Birmingham: University of Birmingham, 1993), pp. 73 and 75-81 and R. Wootton, "Medical Applications of SuperJANET," *Proceedings of Networkshop 21, University of Birmingham, 23-25 March 1993* (Birmingham: University of Birmingham, 1993), pp. 83 and 85-93.

[100] One of the earliest examples of an electronic journal project in the UK was the BLEND system launched by the Universities' of Birmingham and Loughborough in 1981. The SuperJournal project followed this venture in 1994. The JANET User Group for Libraries also investigated this topic in 1997. In addition, during the 1990s, science publishers established electronic journals on the Internet and the idea of Web-only journals followed this development. See B. Shackel, "The BLEND System: Programme for the Study of Some 'Electronic Journals'," *The Computer Journal*, vol. 25, no. 2, 1982, pp. 161-168, D.J. Pullinger, *The SuperJournal project: Electronic Journals on SuperJANET* (Bristol: Institute of Physics Publishing, 1994), pp. 1-47, R. Campbell ed., *Networked Periodicals: Novelty, Nuisance or Necessity?* (Sheffield: Sheffield Hallam University, 1997), pp. 1-33, and J. Porteous, "Plugging Into Electronic Journals," *Nature*, 11 September 1997, pp. 137-138.

3.2.3 SuperJANET Phase I

By the end of 1993, SMDS connected over 30 universities, providing a TCP/IP 10 Mbps service to these institutions (see Figure 3.8).[101] However, problems occurred with SMDS during the initial deployment. These included the network being unable to cope with the traffic load generated by the academic community, which resulted in performance degradation. While British Telecom addressed issues such as these, the number of sites connecting to both networks continued to increase. Having proved the feasibility of the network, work continued with the next stage of the development: SuperJANET Phase I. This phase involved extending access to both the PDH and SMDS networks. BT established PDH links to six new universities, including Birmingham and Cardiff, and set up a connection between this 12-site network and the SMDS network. During early 1994, the PDH operational network connected 14 institutions, while the SMDS provided access to 55 sites.[102] Both networks served different purposes but overlapped in certain areas. The successor to the Network Executive and the JNT, the United Kingdom Education and Research Networking Association (UKERNA), intended to use the operational PDH network to expand the research ATM network.[103] It also decided to use this new high-speed technology to upgrade JANET. By then, the JANET Mark II network could not support the increasing number of institutions connecting to the network and the traffic that resulted from these changes. UKERNA therefore transferred the JIPS traffic from the MK II backbone to the PDH network which improved the speed of JANET.[104] The existing JIPS backbone also helped to provide redundancy, should the PDH backbone fail.[105]

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[101] S. Wood, "The JNT is Dead, Long Live UKERNA!" *Axis*, vol. 1, no. 3, 1994, pp. 45-48.
[102] L. Clyne, "SuperJANET Update," *Computer Networks and ISDN Systems*, vol. 25, no. S3, 1994, pp. S111-S116.
[103] UKERNA replaced the Joint Network Team during 1994.
[104] B. Day, *Data Networking - Progress and Future Plans*, UKERNA, 1993, Available from: http://www.ja.net/documents/NetworkNews/Issue40/NetworkProgress/NetworkProgress.html, Accessed on: 11 May 2004.
[105] An SMDS backbone later replaced its PDH equivalent, once UKERNA and BT judged that SMDS was able to support the community's traffic.

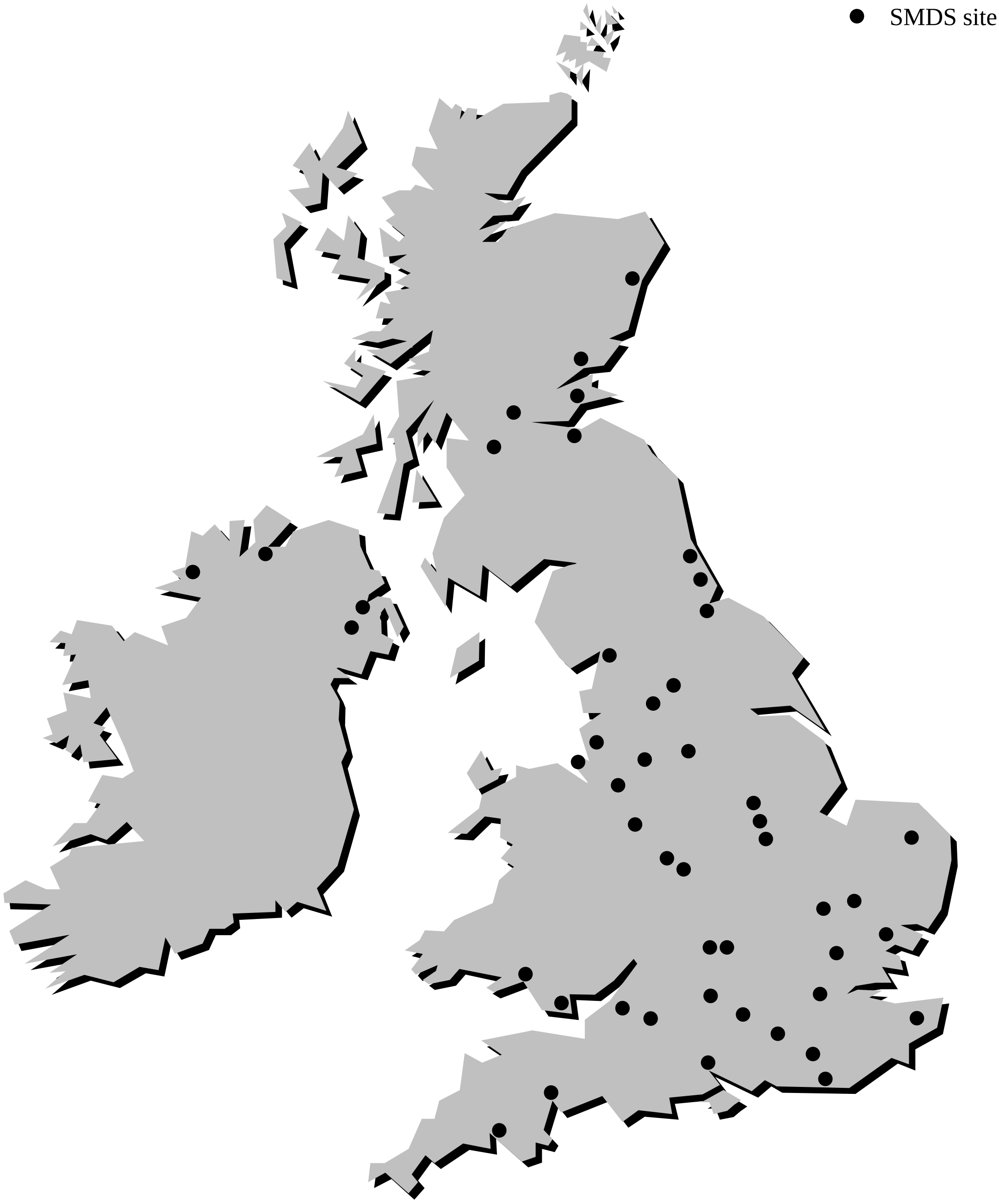

Figure 3.8. Distribution of SMDS sites in 1994.

3.2.4 Network Evolution: Access to JANET

As work continued on establishing SuperJANET, JANET continued to develop. Since the announcement of JANET in 1984, the number and range of institutions that could connect to the network had increased. These included the Open University and government research laboratories.[106] Despite changes such as these, JANET remained a network for academics. Only universities, research councils, polytechnics, and

[106] M. Wells, "Access to JANET," *University Computing*, vol. 10, no. 3, 1988, pp. 149-153.

certain other types of organisation could access the network. This situation changed in 1991. Organisations that were not part of JANET had approached the Information Systems Committee to enquire if they could connect to the network. The ISC decided that companies that were involved with research associated with universities could access the network. As this would expand the number and type of users accessing the network, the ISC believed that this change would benefit the academic community as a whole. As part of this decision, the Joint Network Team developed an acceptable use policy which covered a range of issues relating to the use of the network.[107] The ISC also decided to allow people that were not part of JANET to use mailboxes on the network. Changes such as these affected who could access JANET, and during the next four years, the situation continued to change significantly. Before 1993, any institution or organisation that wanted to connect to JANET had to pay for a full connection. The funding bodies covered these costs for universities, polytechnics, and other institutions. However, other organisations had to pay for their own links and this discouraged eligible organisations from applying for access. To help solve this problem, the JNT therefore established secondary and affiliated connections.[108] Institutions that already had a connection could use their campus networks to provide access to a broad range of organisations and institutions which could then connect to the network, if they were entitled to do so. The Joint Network Team granted licences to these host institutions on the basis that they did not sell connections for a profit, but only to organisations that would benefit the community. The affiliated scheme enabled all colleges of further education to access JANET.[109] In 1994, UKERNA modified this arrangement therefore allowing all schools to connect to the national network.[110] By 1995, over 70 institutions had connected to JANET as part of the secondary and affiliated scheme. This liberalisation benefited the people who used JANET, and meant that the network was no longer the preserve of academics and

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[107] J.S. Hutton and A. Jeffree, "Acceptable Use policy," *Computer Networks and ISDN Systems*, vol. 23, no. 1-3, 1991, pp. 33-36.

[108] B. Day, *Secondary Connections to JANET – A New Initiative*, Joint Network Team, 1992, Available from: http://www.ja.net/documents/NetworkNews/Issue37/news37.txt, Accessed on: 30 July 2004.

[109] S. Wood, *Who Can and Can't Connect to JANET*, UKERNA, 2001, Available from: http://www.ja.net/conferences/JUSW/2001/SWood2.pdf, Accessed on: 2 February 2004.

[110] B. Day, *Revisions to the Secondary Connection and Affiliated Connection Schemes*, UKERNA, 1994, Available from: http://www.ja.net/documents/NetworkNews/Issue42/REVISIONS.HTML, Accessed on: 11 May 2004.

administrators in universities.[111] The funding bodies had extended access to the high-speed network to every educational institution in the UK. Any institution or organisation could access the network, so long as they were eligible to do so and used the network legally. By the early to mid 1990s, this had resulted in over 270 sites linked to the national network, and this number continued to increase as more joined JANET.

3.2.5 Internet Services and the Rise of the World Wide Web

As the community of users expanded so too did the services that people used on the network. Since the early 1970s, people had used telnet, FTP, and e-mail on the ARPANET. However, during the early 1990s a new range of Internet applications emerged. To help organise the information on the Internet and make searching easier and more efficient, people developed several tools. These included Gopher, Veronica, the Wide Area Information Server (WAIS), and the World Wide Web.[112] Developed at the University of Minnesota in 1991, Gopher enabled users to navigate through a hierarchy of menus to find information that interested them. The following year a new service, Veronica, enabled users to search Gopher menus, therefore increasing the speed with which people could potentially find information. Another tool developed during the early 1990s was WAIS. Proposed by the Thinking Machines Corporation, this enabled people to search for information within documents. One of the other services to emerge during this period was the World Wide Web. Developed by Tim Berners-Lee at CERN between 1989 and 1990, this hypertext system used browsers running on client machines to access information stored on servers.

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[111] There were limits to this liberalisation. For example, public libraries remained outside of this enlarged community. This situation occurred for two reasons. The funding bodies were not enthusiastic about many public libraries joining the network, perhaps because of the load that this would place on the network. In addition, the libraries preferred to use the Internet to access resources, instead of becoming part of the national network. See G. Hare, "Networking Public Libraries," *Proceedings of the Ninth Annual Computers in Libraries 95 conference, London, 7-9 March 1995* (London: Learned Information, 1995), pp. 61-67. Despite this restriction, liberalisation continued, and in 2001, the JISC commissioned a study in to the implications surrounding electronic marketing on JANET. Since the launch of JANET during 1984, the acceptable use of the national academic network had therefore changed dramatically in 17 years. See D. McDonald and C. Breslin, *A Study into Advertising on JANET*, University of Strathclyde, 2001, Available from: http://www.strath.ac.uk/IT/projects/reports/jisc-advertising.pdf, Accessed on: 19 January 2004.

[112] See Appendices M and N.

With the availability of tools such as these, people within the academic community, such as librarians, started to become interested in what these services could do for them. Existing JANET services such as BUBL, Mailbase, BIDS, and library online catalogues began to exploit the facilities provided by the new Internet applications. In 1993, the BUBL team planned to establish a Gopher service which would enable people to use Veronica to search for information within the bulletin boards.[113] Having established a Gopher service, the BUBL team started to experiment with the Web. As the Web was a more sophisticated tool than Gopher, the team decided to develop a Web service. Another service to employ Gopher was Mailbase in 1993. Using a client program, about 12,000 subscribers could access over 370 mailing lists. By 1995, this service had also begun to migrate to the Web and provided access to new facilities such as the experimental hypertext e-mail service Hypermail.[114] Mailbase later developed in to the current Web-based JISCmail service used by the academic community. The BIDS service provided by the University of Bath also exploited several Internet applications. In 1993, the university launched a telnet service and followed this with investigations into the use of FTP and Gopher.[115] Bath University also later transferred its service to the Web. It joined an increasing number of online databases, such as the Cambridge Scientific Abstracts (CSA) service, which had launched Web-based access to their information during 1995. Libraries also began to explore the possibilities of providing access to over 100 online catalogues via the Web for both users of JANET and the wider Internet community. One of the first to do so was the British Library which established its online catalogue during 1994.[116] People could access the online catalogue using JIPS, and the British Library later converted it to a Web-based service. This transition was part of a general migration to Web-based catalogues which occurred in other countries, such as the US, during the mid to late 1990s.[117]

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[113] "Report on BUBL," *JUGL Newsletter*, Winter 1993/94, p. 4.
[114] See "Mailbase Developments," *JUGL Newsletter*, Winter 1993/94, p. 13 and "Mailbase News," *JUGL Newsletter*, Autumn 1995, p. 6.
[115] See "Bath Information & Data Services," *JUGL Newsletter*, Winter 1993/94, pp. 8-9 and T. Morrow, "BIDS Upgrade," *Axis*, vol. 1, no. 3, 1994, p. 43.
[116] J. Ashton, "The British Library Network OPAC Opens Worldwide Resources to Researchers," *JUGL Newsletter*, Spring 1994, p. 5.
[117] M. Henry, "Library OPACs with Search Forms on the World Wide Web," *Campus-Wide Information Systems*, vol. 13, no. 1, 1996, pp. 16-20.

Interest in the Web also extended to organisations, universities, and institutions both within the academic community and outside. The Bodleian Library at Oxford University converted its Bodleian Access to Remote Databases (BARD) service to a Web application in 1995.[118] From a user perspective, this simplified the process of accessing information from remote databases. Museums also established Web services. The National Museum of Science and Industry (NMSI) set up its Web site during 1995.[119] This site provided information about the Science Museum, the National Railway Museum, and the National Museum of Photography, Film & Television. The site supplied information for visitors, as well as facilities for academics such as the Science Museum Library's online catalogue. UKERNA and several universities also developed services for the World Wide Web during this period. UKERNA was similar to other organisations, as it had developed FTP and Gopher facilities during the early 1990s which people could use to access information. However, by the mid 1990s it too had started to transfer this data to the Web.[120] By 1995, the association provided several types of information including guides to JANET and SuperJANET, newsletters, the acceptable use policy, and other documents. Universities also began to explore the possibilities presented by the Web. Campus-Wide Information Systems used the Web to present information to staff and students, and this became part of a much broader interest in what this Internet service could do for institutions. Universities installed Web servers to publicise their institutions, while departments started to provide information for both existing and new students. For instance, in 1994 the Department of Information Studies at the University of Sheffield developed a Web site. This site provided a range of information, including details about courses, staff, students, and publications. Many other departments throughout the country followed this initiative. In addition, Heriot-Watt University conducted a study which looked at using the Web to provide courseware, such as Computer Based Learning (CBL) information to students.[121] By

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118 R. Gartner, "BARD: An End-user Internet Gateway at the Bodleian Library," *Proceedings of the Ninth Annual Computers in Libraries 95 conference, London, 7-9 March 1995* (London: Learned Information, 1995), pp. 79-81.
119 S. Gordon, "Museums and the Information Superhighway," *Online Information 95: 19th International Online Information Meeting Proceedings, London, 5-7 December 1995* (Oxford: Learned Information, 1995), pp. 305-310.
120 *The Networking Programme Report 1994-1995* (Chilton, Oxon: UKERNA, 1995).
121 See A. Mumford, "The World Wide Web: A Strategic Tool for UK Higher Education," *Axis*, vol. 2, no. 2, 1995, pp. 36-39, B. Hynds, "A Campus Wide Code of Practice for Mounting Material on a WWW Server," *Axis*, vol. 2, no. 2, 1995, pp. 32-35, J.W. Kirriemuir, et al., "Development of an

the mid 1990s, more institutions used the Web than other Internet applications such as Archie, Gopher, Veronica, or WAIS.[122] People could use Web browsers to access information within Gopherspace, connect to Archie servers to search for files that were stored in FTP archives, and use e-mail through Web-based services. The Web had therefore become the most popular interface of the Internet; a unified user interface through which people accessed information and communicated with people throughout the world.

3.2.6 Consolidation of TCP/IP and the Decline of X.25 and OSI

As the World Wide Web was an Internet service, it used the TCP/IP protocol suite. With the increase in the use of this Internet application, this therefore helped to consolidate TCP/IP as the standard used on JANET. In addition, as SuperJANET had always been a TCP/IP-only network, this also helped to consolidate TCP/IP as the standard used within the academic community. The interest in using the Internet Protocol suite continued during 1995, and by the summer, UKERNA had installed over 70 TCP/IP connections. These new links did not use JIPS supported by the existing X.25 infrastructure.[123] People also used TCP/IP over the 54 SMDS connections that British Telecom had installed.[124] To support these developments and continue with the XoT service, UKERNA and BT deployed increasing numbers of TCP/IP routers throughout JANET. With over 90 percent of all traffic on both JANET and SuperJANET generated by TCP/IP by 1995, these upgrades helped to support this traffic. One of the facilities that people used was the Universities and Colleges Admissions Service. For sites using TCP/IP connections, this generated more than a third of the traffic within JANET. While this organisation supported the OSI File Transfer Access and Management service, the majority of users did not use this ISO application. The information services provided by UKERNA during 1995 were also popular. Within half a year, the amount of data transmitted from its servers to clients had doubled from approximately 450 Mbs a month to 900 Mbs. During 1994 and 1995, traffic between the UK and the US also continued to increase. Throughout the

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Academic Department's World Wide Web Pages," *Axis*, vol. 1, no. 4, 1994, pp. 16-24, and P. McAndrew, "Using the World Wide Web to Support the Dissemination of Courseware," *Axis*, vol. 2, no. 2, 1995, pp. 12-17.

[122] See P. Crocker, et al., "Directions in Academic Networking: What Does the Community Think?" *Axis*, vol. 2, no. 4, 1995, pp. 34-42 and Appendix M

[123] See Appendix K.

[124] *The Networking Programme Report 1994-1995*, pp. 3, 5, and 9.

existence of the US-UK link, the funding bodies had upgraded this link when necessary. In 1994 another 2 Mbps link joined the existing 2 Mbps connection to the US. This was the second time that UKERNA had increased the capacity within half a year. However, the combined 4 Mbps connection was soon unable to cope with the amount of traffic between the UK and the US, and UKERNA therefore upgraded the link to 8 Mbps. Within days of this new capacity becoming available, it too could not cope with the levels of traffic. This process of upgrades therefore continued with, for example, a further upgrade to 17.5 Mbps during 1996 and 2.5 Gbps by 2002.[125]

As TCP/IP traffic increased, X.25 traffic decreased. Throughout the second half of the 1980s, traffic on the X.25 network averaged 5,000 Mb a day.[126] With the JANET IP Service running over X.25 in 1991, traffic levels increased to 10,000 Mbs a day within a year. Two years later, the X.25 backbone was transmitting over 70,000 Mbs a day. However, by spring 1995, X.25 traffic levels had started to decline. There were several reasons for this. Since the launch of the X.25 over TCP/IP service in 1994, the reliance on the X.25 circuits had declined. By mid 1995, 44 sites used the XoT service as a way to connect to the network, and this gradually removed the need for the dedicated X.25 lines.[127] As an increasing number of sites converted from X.25 to TCP/IP over SMDS, this decreased the amount of X.25 traffic on the network. Although many sites were converting to TCP/IP, some would take longer than others to migrate to the Internet protocols. For instance, the High-Energy Physics community used the proprietary DECnet protocol, encapsulating this over X.25.[128] Although early tests indicated that the community could transmit the resulting traffic over the XoT service, they decided to work towards using DECnet over TCP/IP, in line with the rest of the academic community.[129] This process would take time to

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[125] See *UK-US Fat-pipe*, UKERNA, 1994, Available from: http://www.ja.net/documents/reports/winter94.html, Accessed on: 11 May 2004, *UK-US Fat-pipe,* UKERNA, 1995, Available from: http://www.ja.net/documents/reports/summer95.html, Accessed on: 11 May 2004, *UK-US Link*, UKERNA, 1996, Available from: http://www.ja.net/documents/reports/summer96.html, Accessed on: 11 May 2004, and *Access to the North American Internet*, UKERNA, 2002, Available from: http://www.ja.net/documents/reports/spring02.html, Accessed on: 11 May 2004.

[126] *The Networking Programme Report 1994-1995,* p. 3.

[127] *Basic Transmission Service - X.25,* UKERNA, 1995, Available from: http://www.ja.net/documents/reports/summer95.html, Accessed on: 11 May 2004.

[128] Day, *The Transition from X.25 to IP - an Update*.

[129] This decision would mean that the High-Energy Physics community would adopt the same approach, namely to use TCP/IP to transmit another protocol, in this case DECnet. This system would therefore be similar to the X.25 over TCP/IP service.

achieve, as would the conversion of libraries to the Internet protocols. Some libraries used X.25 and as the process of converting their systems to TCP/IP was time-consuming, UKERNA expected that libraries would be the last users of X.25 on JANET. While these examples illustrate that certain connections took time to convert to TCP/IP, for most of the academic community the process was quicker. Many institutions initially used the XoT service and then transferred either to native TCP/IP connections or to TCP/IP over SMDS.[130] As the Internet protocols had become the de facto standard on JANET and as X.25 traffic continued to decline during 1994 and 1995, UKERNA decided not to establish new X.25 connections. Any institution or organisation joining the network would therefore use either native TCP/IP or TCP/IP over SMDS. UKERNA therefore began to rationalise the topology of the X.25 infrastructure. It removed or downgraded the leased lines that formed the X.25 backbone and removed 22 switches. It also decided to set a deadline for the closure of the X.25 switching service.[131] By 1997, everyone that wanted to access JANET would have to use TCP/IP.

When UKERNA launched the X.25 over TCP/IP service during 1994, it had been the first step of a transition strategy. This strategy involved the migration from X.25, the community's interim Coloured Book protocols, and OSI to TCP/IP. To support this transition, UKERNA developed application converters.[132] These converted between the Coloured Book and OSI standards to the Internet protocols. While people used the Internet's telnet protocol to connect to services such as library catalogues, some people and hosts still used the X.25's equivalent standard X.29 for this purpose. In 1994, UKERNA therefore launched a Terminal Access Conversion Service (TACS) to convert between the two standards, enabling users of either X.29 or telnet to connect to hosts running either protocol. The association also established an FT-relay service which converted between the three supported file transfer protocols: Blue Book, the OSI File Transfer Access and Management, and the Internet's FTP.

[130] See Appendix K.
[131] See *The Networking Programme Report 1994-1995* p. 2 and *Closure of the JANET X.25 Service*, UKERNA, 1996, Available from: http://www.ja.net/documents/UKERNA_News/1996/october/UKERNA_News.html, Accessed on: 11 May 2004.
[132] See *The Networking Programme Report 1994-1995*, p. 9 and B. Day, *The JANET X.25 Service and New Application Conversion Services*, UKERNA, 1994, Available from: http://www.ja.net/documents/NetworkNews/Issue42/NEW_APPLICATIONS.HTML, Accessed on: 19 June 2004.

UKERNA also provided a Mail Conversion Service (MCS).[133] Since the launch of JIPS in 1991, UKERNA had supported several e-mail protocols on JANET. These included the Grey Book interim standard, SMTP, X.400 (1984), and X.400 (1988). The JISC originally intended to migrate from the Grey Book and SMTP to X.400 (1988). However, towards the end of 1994, UKERNA recommended that the JISC amend this strategy to reflect the general trend away from the Grey Book towards SMTP. The committee agreed and UKERNA therefore established the e-mail conversion service during the same year. This service allowed users of any of the supported protocols to send and receive e-mails across the network, with the central conversion facility handling the protocol conversions. As part of this process, the association also supported the use of X.400 over TCP/IP. It used the IETF's standard to achieve this, as its earlier concerns about this standard had been resolved. One of the institutions to employ this facility was the University of East Anglia which used an experimental service provided by the British Library's Document Supply Centre.[134] This service provided access to papers from journals, allowing the centre to distribute articles using X.400 (1988) to institutions such as East Anglia using JIPS as well as X.25. Despite some institutions using X.400, by the mid 1990s the majority of the academic community used the SMTP standard. The JISC therefore revised its earlier strategy, adopting SMTP as the e-mail protocol for both JANET and SuperJANET. This decision further consolidated the position of the Internet protocols on the network.

By 1996, X.25 traffic accounted for less than 1 percent of the total traffic on JANET.[135] The academic community had therefore essentially switched from X.25 to TCP/IP, and in the process rejected the former standard.[136] As planned, UKERNA therefore closed X.25 during 1997.[137] This closure involved removing the remaining X.25 leased lines which interconnected the Network Operations Centres such as

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[133] See Appendix K.

[134] R. Moulton and B. Tuck, "Document Delivery Using X.400 Electronic Mail: An Experimental Service at the British Library Document Supply Centre," *Journal of Information Networking*, vol. 1, no. 3, 1994, pp. 191-203.

[135] I. Smith, *A Farewell to X.25*, UKERNA, 1997, Available from: http://www.ja.net/documents/UKERNA_News/1997/september/UKERNA_News3.html, Accessed on: 11 May 2004.

[136] On orphans see N. Gandal, et al., "Adoptions and Orphans in the Early Microcomputer Market," *Journal of Industrial Economics*, vol. 47, no. 1, 1999, p. 87.

[137] *Basic Transmission Service - X.25*, UKERNA, 1997, Available from: http://www.ja.net/documents/reports/autumn97.html, Accessed on: 11 May 2004.

Rutherford and the ULCC. It also involved the closure of several services related to this protocol. By 1997, the majority of institutions used either native TCP/IP or TCP/IP over SMDS. UKERNA therefore closed the redundant XoT service and followed this with the termination of the FT-relay facility. The association continued to support the Terminal Access Conversion Service, but by 2002 it had withdrawn this facility because most people no longer used it. UKERNA also decided to close the MCS. Support continued for X.400 and UKERNA transferred routing information relating to this protocol from the Name Registration Scheme to files that people could access via FTP. However, by then few people used this protocol, and the association withdrew support for it during 2002.[138] By the time the association closed the NRS, the Domain Name System (DNS) used on the Internet had become the de facto standard for domain names on JANET.[139] For a while, there was uncertainty about which standard the community would adopt. As Black remembers, "one of the things we had to say was, are we going to abandon the NRS and just go for DNS completely, and which one should be the master and which one should be the slave. So there was a transition that said that the NRS was the master for a while and then we switched over, so that the DNS was the master."[140] By 1994, it was clear that the DNS had succeeded. The JISC therefore decided to abandon support for the "big endian" order for domain names used on JANET and adopt the "little endian" order used on the Internet.[141]

The X.400 files represented the only OSI information that UKERNA planned to provide to the community. When contrasted with the community's earlier commitment to OSI, these files represented some of the last remaining evidence of a strategy that had dominated the development of JANET. The community had adopted X.25 as the protocol for their network and then developed interim Coloured Book protocols, while they waited for ISO to ratify a complete protocol suite. This process took time, and during this period, the popularity of JIPS changed not only the protocol used on the network but also JISC's attitude towards standards in general. The funding bodies had gone from supporting institutional standards ratified by the

[138] *JANET X.400-SMTP Gateway Closure*, UKERNA, 2002, Available from: http://www.ja.net/documents/UKERNA_News/2002/june/UKERNA_News19.html, Accessed on: 11 May 2004.
[139] See Appendix J.
[140] Black, Interview.
[141] On the "big endian" and "little endian" order for domain names see Appendix J.

CCITT and ISO, to supporting the de facto Internet protocols maintained by organisations such as the IETF. The community's ideology had therefore changed, something that would not have occurred during the 1980s, when people believed OSI would become the dominant standard. By the time the Joint Network Team established JIPS, TCP/IP had existed for several years. While the team and community were aware of this protocol, they still believed that X.25 and OSI offered the best options for internetworking on JANET. They therefore had difficulty assessing the potential of TCP/IP and the possible impact that this protocol might have on X.25, OSI, and therefore on JANET.[142] This problem was one that other organisations shared at this time. For example, companies such as CompuServe also had trouble assessing the opportunities presented by the Internet. The Joint Network Team's attitudes towards the Internet protocols therefore influenced the timing of the JIPS launch. Smith believes that "we were somewhat slow in realising that TCP/IP had become THE strategic protocol by the late 1980s. The Shoestring project ought to have happened perhaps two years sooner than it did."[143] However, the funding bodies were not slow to recognise the significance of the increased TCP/IP traffic levels on the network, once the Internet protocols became available on JANET. Within a year of this traffic surpassing X.25, both the JISC and the Joint Network Team accepted the new protocol. The JNT therefore adapted JANET to reflect this change and soon amended its approach to X.25, the Coloured Books, and OSI as a result. These changes helped to facilitate the significant speed with which the academic community adopted the new protocols.

3.2.7 SuperJANET Phase II

Having converged around a single standard, the continued development of SuperJANET consolidated the position of TCP/IP as the protocol used by the academic community. The intention with the second phase of SuperJANET was to increase access to the network for those institutions not already connected to the backbone. As part of this upgrade, regions would create a series of Metropolitan Area

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[142] On inertia see R.S. Rosenbloom and C.M. Christensen, "Technological Discontinuities, Organizational Capabilities, and Strategic Commitments," *Industrial and Corporate Change*, vol. 3, no. 3, 1994, pp. 655-685.

[143] Smith, *A Farewell to X.25*.

Networks (MANs) throughout the country (see Figure 3.9).[144] These MANs would interconnect campuses, and therefore provide access to the national network for as many institutions as possible.[145] To support these developments and to continue with the planned deployment of ATM throughout the network, UKERNA planned to replace the PDH circuits with SDH technology. In addition, more institutions would connect to SuperJANET II using SMDS.

During 1995, BT installed an experimental SDH 155 Mbps network between five sites, including UCL and the Rutherford Appleton Laboratory.[146] BT continued to add new SDH circuits, and by March 1996, the transition from the 14-site PDH network to SDH was complete (see Figure 3.10).[147] By then, BT had also installed SMDS circuits to 27 new institutions. With the backbone interconnecting 14 sites at a speed of 34 Mbps, the new SDH infrastructure increased the bandwidth available to the community. In addition, UKERNA upgraded the links to European academic networks, as well as SuperJANET's connection to commercial UK Internet Service Providers.[148] These upgrades helped to support the TCP/IP traffic which these networks transmitted.

3.2.8 SuperJANET Phases III, IV, and V

By the mid to late 1990s, the relationship between JANET and SuperJANET was clear. JANET was the UK's national academic network which linked a diverse range of institutions and organisations.

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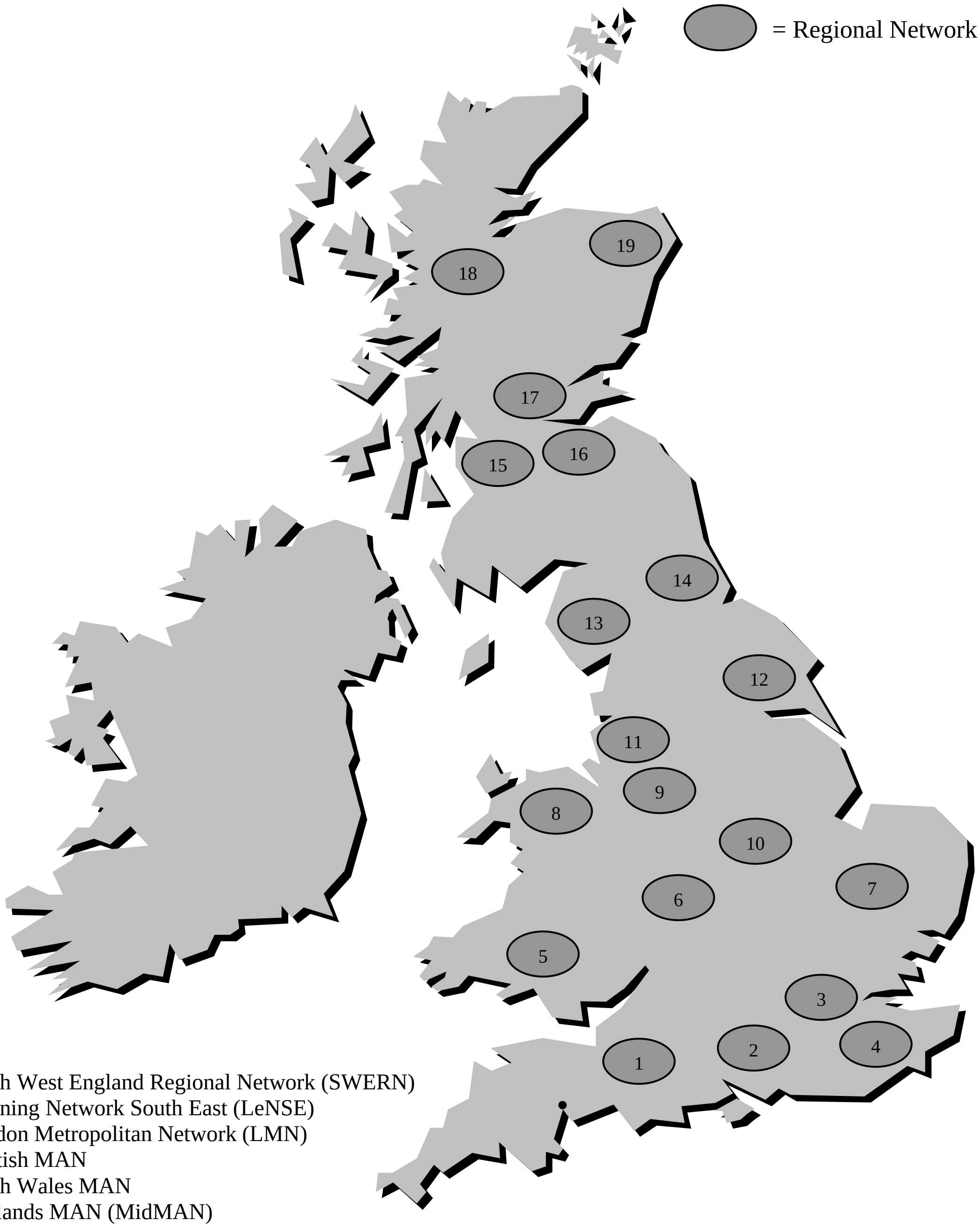
[144] See *JANET: Advancing and Supporting the UK's Education and Research Network*, UKERNA, 2003, Available from: http://www.ja.net/documents/JANET_booklet_4_03.pdf, Accessed on: 2 February 2004, *Regional Networks*, UKERNA, 2001, Available from: http://www.ja.net/janet-sites/MANs, Accessed on: 17 August 2004, and Appendix G.
[145] *The Networking Programme Report 1994-1995*, p. 19.
[146] *Commissioning the SDH Network*, UKERNA, 1995, Available from: http://www.ja.net/documents/reports/summer95.html, Accessed on: 11 May 2004.
[147] *SuperJANET ATM Development*, UKERNA, 1996, Available from: http://www.ja.net/documents/UKERNA_News/1996/october/UKERNA_News.html, Accessed on: 11 May 2004.
[148] See *External Network Access Provision and Transmission*, UKERNA, 1996, Available from: http://www.ja.net/documents/UKERNA_News/1996/october/UKERNA_News.html, Accessed on: 11 May 2004 and *Upgrade to Bandwidth Between JANET and the UK Commercial IP Providers*, UKERNA, 1997, Available from: http://www.ja.net/documents/UKERNA_News/1997/february/UKERNA_News2.html, Accessed on: 11 May 2004.



Key

1. South West England Regional Network (SWERN)
2. Learning Network South East (LeNSE)
3. London Metropolitan Network (LMN)
4. Kentish MAN
5. South Wales MAN
6. Midlands MAN (MidMAN)
7. East of England Regional Network (EastNet)
8. North Wales MAN
9. Greater Manchester Information Network Group (GMING)
10. East Midlands MAN (EMMAN)
11. Net North West (NNW)
12. Yorkshire and Humberside MAN (YHMAN)
13. Cumbria and North Lancashire MAN (C&NLMAN)
14. North East MAN (NorMAN)
15. Clyde Area Network (Clydenet)
16. Edinburgh and Stirling MAN (EaStMAN)
17. Fife and Tayside MAN (FaTMAN)
18. University of the Highlands and Islands Network (UHI Network)
19. Aberdeen MAN (AbMAN)

Figure 3.9. The Regional Networks in 2004.[149]

[149] The actual geographical areas covered by the networks are, of course, larger than the ellipses shown in the figure. UKERNA originally referred to the Regional Networks as MANs.

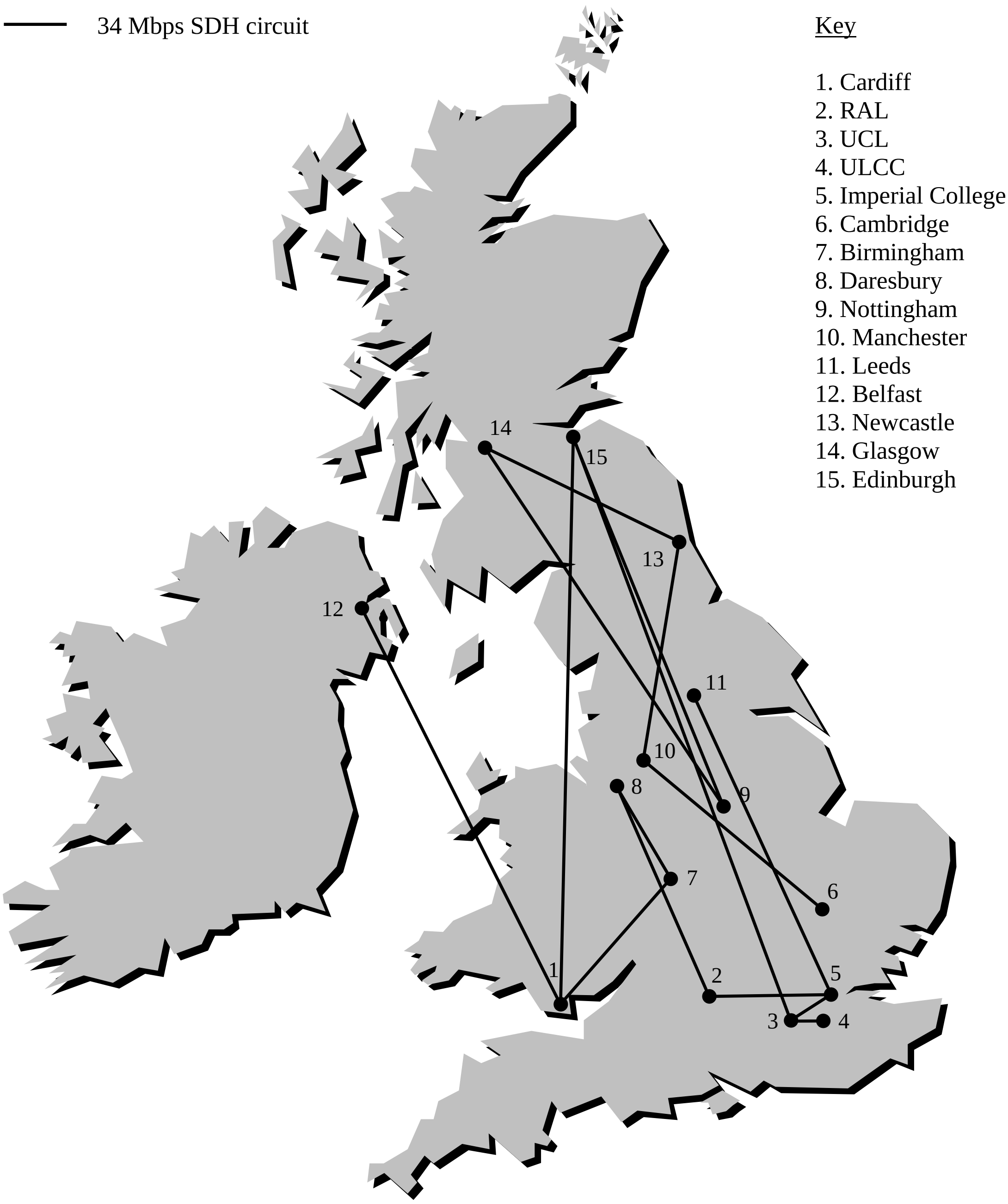


Figure 3.10. SuperJANET II in 1996.[150]

SuperJANET provided the backbone network to support JANET. Having established SuperJANET II, plans began for the next phase which would consolidate the work of the second stage of developments, while upgrading the speed of the network and rationalising the use of the technologies employed throughout the backbone. The JISC awarded a contract for SuperJANET III to Cable & Wireless, which then replaced the

[150] For clarity, the figure only shows 15 SDH sites, which were present in March 1996. The figure therefore does not show the complete SuperJANET topology.

core of the network with new 155 Mbps circuits.[151] These circuits interconnected four sites which the company owned. From these nodes, Cable & Wireless established 34 and 155 Mbps links to institutions via Backbone Edge Nodes (BENs) located at universities such as ULCC, Birmingham, and Newcastle. These nodes interconnected the SuperJANET backbone to the Metropolitan Area Networks (see Figure 3.11).[152] While this company managed the network, under a Service Level Agreement (SLA), UKERNA managed the edge nodes, with the regional universities overseeing the MANs. The SuperJANET backbone interconnected most institutions, but some still used either SMDS or leased lines to connect to the network. The use of the edge nodes and MANs extended SuperJANET to all institutions and did so economically, using the infrastructure to diffuse bandwidth effectively throughout the country. With the establishment of SuperJANET III during 1998, UKERNA planned to remove SMDS from the network, creating an SDH-only network, over which TCP/IP applications would continue to run.[153]

By the end of 1999, UKERNA had started to plan the fourth phase of SuperJANET. As the network would not become operational until, perhaps, 2001, Cable & Wireless installed new 155 Mbps links, for example between London and Manchester, to cope temporarily with the increased demand for bandwidth. SuperJANET IV followed these developments.[154] The Higher Education Funding Council for England (HEFCE) agreed to fund a phased upgrade to the network, from 2.5 Gbps in 2001 to higher speeds by 2005. This upgrade would cost £40m. The JISC awarded the contract to WorldCom during 2000, with the condition that the company hand over the network for service by the end of year. WorldCom began to lay new fibre-optics, and the network became operational by January 2001.

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[151] *SuperJANET III - Leading the Network to the Millennium and Beyond*, UKERNA, 1997, Available from: http://www.ja.net/documents/UKERNA_News/1998/march/UKERNA_News4.html, Accessed on: 11 May 2004.
[152] *SuperJANET Phase III*, UKERNA, 1997, Available from: http://www.ja.net/documents/UKERNA_Bulletin/1997/october/Bullet2.html, Accessed on: 17 August 2004.
[153] *Plan for Phasing out the Use of SMDS*, UKERNA, 1999, Available from: http://www.ja.net/documents/UKERNA_News/1999/january/UKERNA_News6.html, Accessed on: 11 May 2004.
[154] *SuperJANET III Upgrade Plans*, UKERNA, 1999, Available from: http://www.ja.net/documents/UKERNA_News/1999/november/UKERNA_News9.html, Accessed on: 11 May 2004.

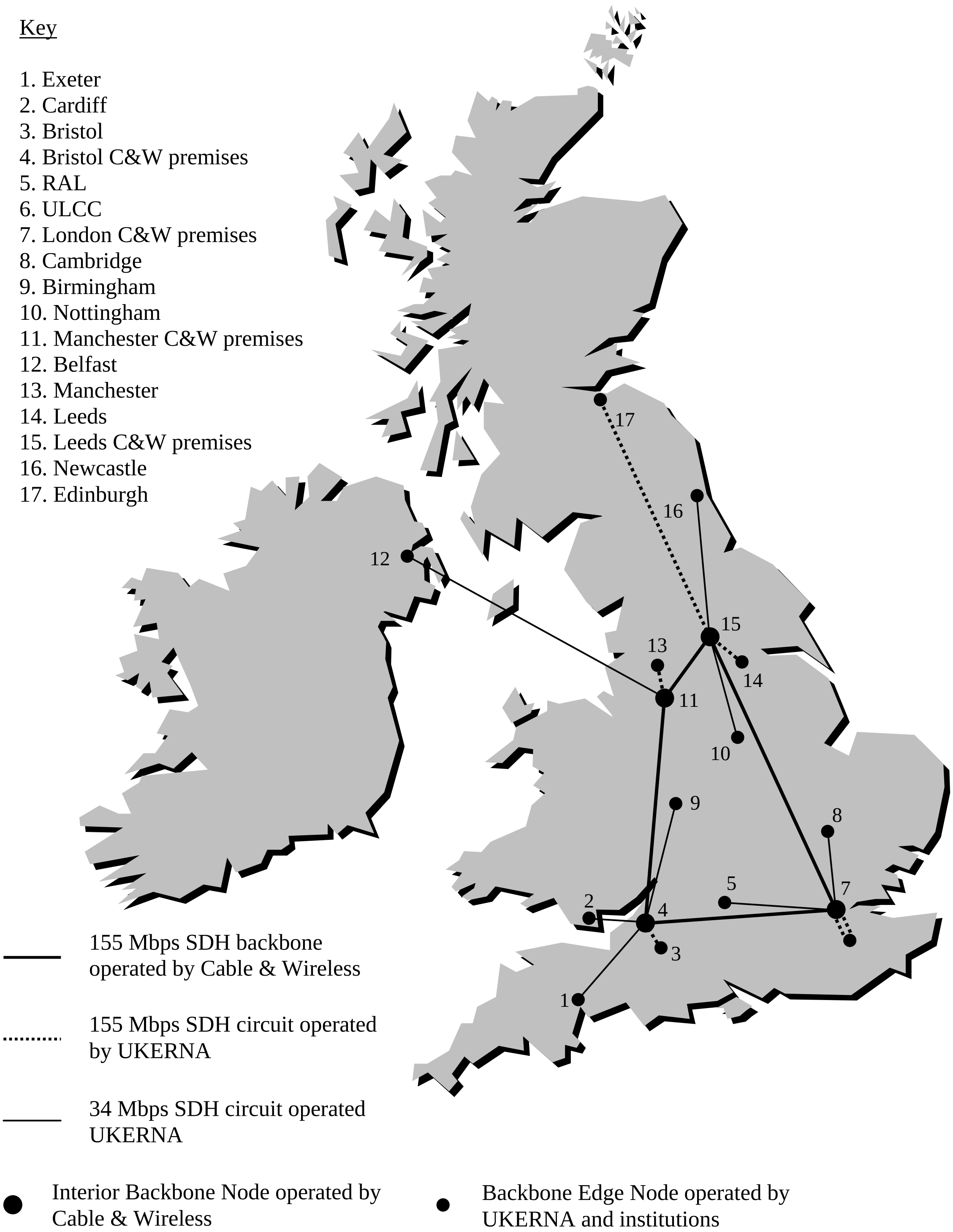

Figure 3.11. SuperJANET III in 1997.[155]

The new 2.5 Gbps circuits interconnected eight Core Points of Presence (CPoPs) which linked the MANs, by then known as regional networks, to SuperJANET (see Figure 3.12).[156]

[155] For clarity, the figure only shows the backbone and access links.
[156] *JANET*.

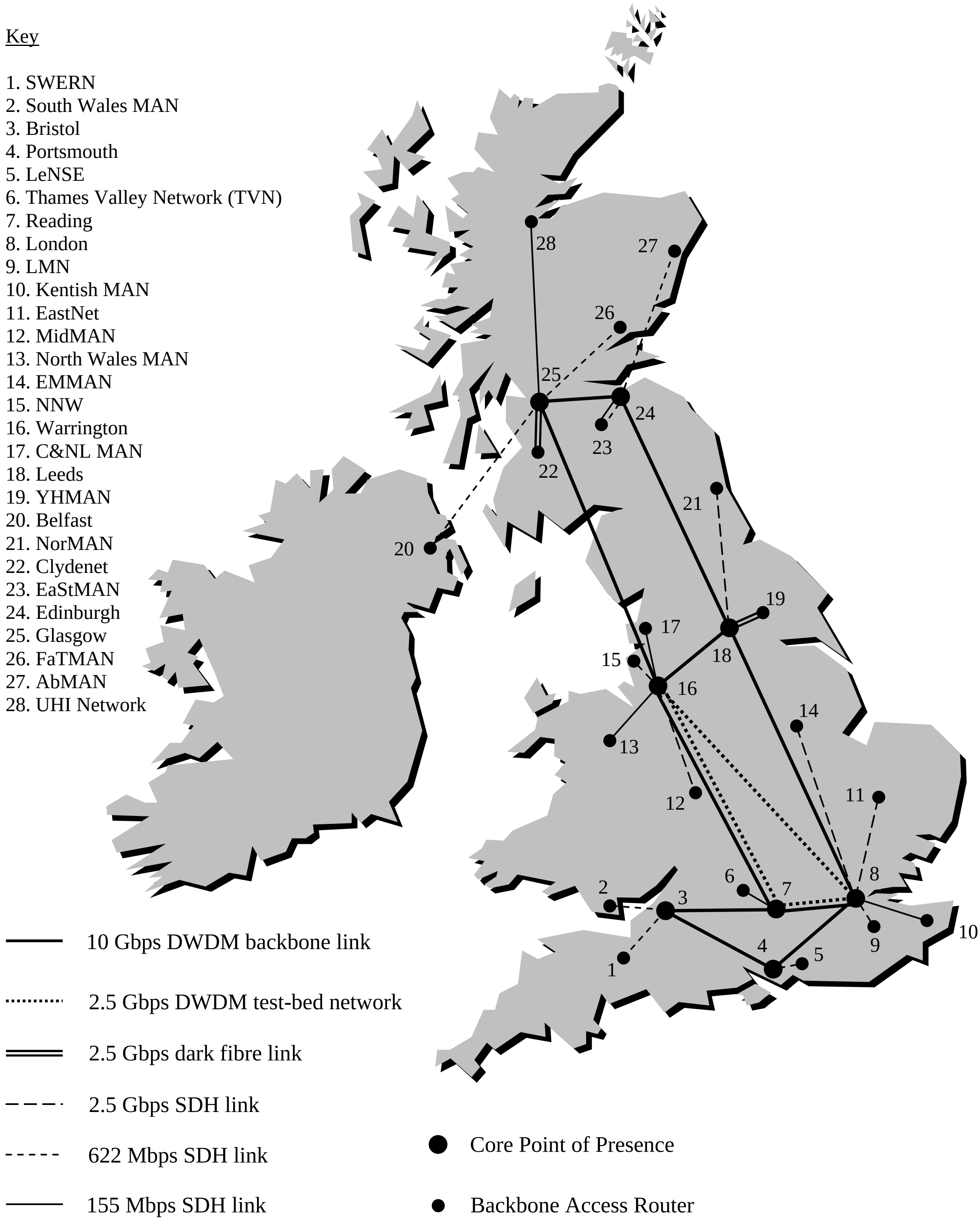

Figure 3.12. SuperJANET IV in 2003.

As usual, traffic continued to increase and in order to ensure that the backbone did not become overloaded, UKERNA began to plan more upgrades to the network. The first stage was to upgrade the backbone of the network from 2.5 to 10 Gbps.[157] By the end of 2002, SuperJANET was running at 10 Gbps.[158]

The need to upgrade network capacity also occurred on other networks during this period. Examples include the Gigabit European Academic Network (GÉANT) and the Internet.[159] GÉANT is a pan-European network which interconnects 28 national research and education networks, such as SuperJANET, and over 3,500 institutions (see Figure 3.13). Academics in many different fields use the network for different purposes. For example, GÉANT assists radio astronomers with the real-time transmission of data from many telescopes which are linked together to form a high-resolution instrument that captures data about phenomena in the universe, such as stars and galaxies.[160] Another research network to upgrade its links is Abilene in the US. Abilene is the first stage of the Internet2 initiative. This initiative is organised by a consortium of universities, companies, and the US government. These organisations are working together to develop the technology and applications which will be necessary for the continued development of the Internet.

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[157] *The SuperJANET Backbone: The Next Stride Forward*, UKERNA, 2002, Available from: http://www.ja.net/documents/UKERNA_News/2002/june/UKERNA_News19.html, Accessed on: 11 May 2004.

[158] *JANET*.

[159] In 2001, GÉANT replaced it predecessor, the Trans-European Network (TEN), which originally operated at 155 Mbps (TEN-155). Three years before, TEN-155 had replaced the TEN-34 network, in response to the need for increased bandwidth to support the traffic generated by the European National Research and Education Networks (NRENs). TEN-34 was the successor to EuropaNET, and replaced this network during 1997. See D. Robertson, *GÉANT - Past, Present and Future*, UKERNA, 2003, Available from: http://www.ja.net/documents/UKERNA_News/2003/December/NEWS25.pdf, Accessed on: 30 July 2004.

[160] Astronomers and astrophysicists refer to this as Very Long Baseline Interferometry (VLBI). Astronomers usually record the data from VLBI onto removable media such as magnetic tapes and then transport the media to a central location where processing takes place. With GÉANT, radio astronomers, who are part of the Joint Institute for VLBI in Europe (JIVE), are experimenting with real-time VLBI, which means that the network transmits the data from the telescopes. On 22 September 2004, astronomers successfully demonstrated the viability of electronic-VLBI (e-VLBI). Telescopes throughout Europe and the Arecibo radio telescope in Puerto Rico observed a supergiant star, IRC+10420, which is approximately 15,000 light years from the Earth. The combined resolution of the telescopes was about 5 times greater than the Hubble Space Telescope. The astronomers transmitted the 9 Terabits of data from the telescopes at 32 Mbps through GÉANT to JIVE. A supercomputer then combined the data and returned the information to the astronomers who produced images of the star. As the press release for the e-VLBI event states, “In a sense, the Internet itself acts like a telescope, performing the same task as the curved surfaces of the individual radio dishes.” See A. Abbott, “Report Praises European Radio Telescope Network,” *Nature*, 28 September 2000, p. 437, *GEANT*, DANTE Ltd, 2003, Available from: http://archive.dante.net/geant/Geant.mov, Accessed on: 18 August 2004, and *Astronomers Demonstrate a Global Internet Telescope*, Arecibo Observatory, 2004, Available from: http://www.naic.edu/~astro/aovlbi/press_release/eVLBI_AR.pdf, Accessed on: 17 December 2004.

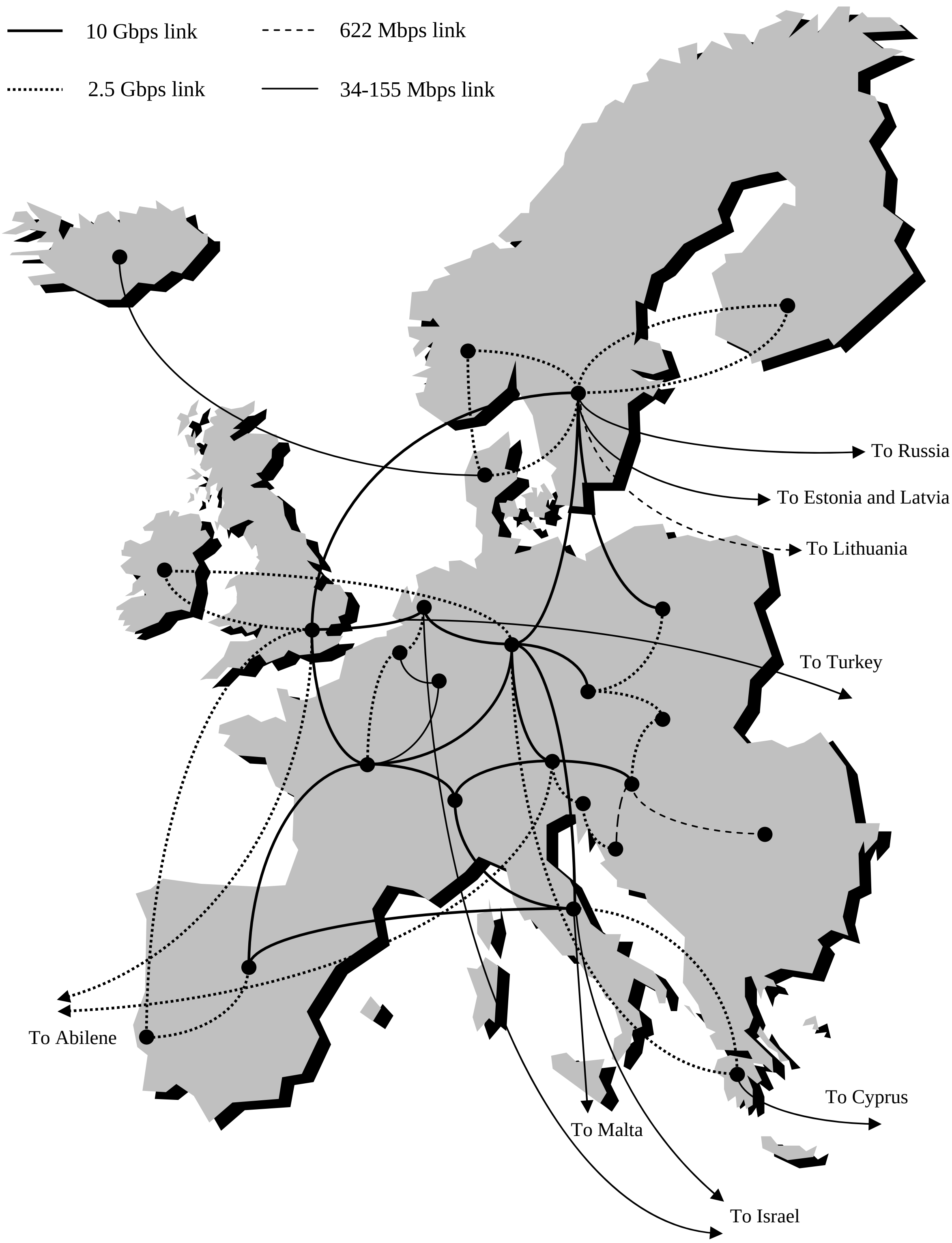

Figure 3.13. GÉANT in 2004.[161]

When Abilene became operational during 1999 it had a backbone with a bandwidth of 2.5 Gbps. During 2003, work began on upgrading the core of the network to 10 Gbps. When complete, this upgrade will help to support the traffic generated by 220

[161] *Lighting the Way to the European Research Area*, DANTE, 2004, Available from: http://www.dante.net/upload/pdf/GEANT_Topology_Apr_2004.pdf, Accessed on: 18 August 2004.

Internet2 organisations.[162] In addition to upgrading the bandwidth of the network, Abilene is also piloting a new version of the Internet Protocol known as IP version 6 (IPv6). IPv6 will address several issues, the most serious of which is the limited number of addresses provided by its predecessor, IP version 4 (IPv4). Other networks, such as GÉANT and SuperJANET, are also exploring this standard. For instance, during September 2003, UKERNA deployed IPv6 on the SuperJANET backbone, enabling institutions to experiment with this new protocol.

The second stage of UKERNA's upgrade plan is SuperJANET phase V. With WorldCom's contract due to expire by the end of 2005, work began on the requirements analysis for this new network during September 2003. SuperJANET V will address several areas.[163] Ensuring the reliable end-to-end delivery of information on a network has become increasingly important. Accessing remote databases, sending and receiving e-mails, browsing the Web, and using new services such as videoconferencing, all require the reliable delivery of information. Aware of this fact, UKERNA believed that it would need technical standards to ensure a satisfactory service for users. To help support applications such as these, UKERNA is looking at technologies such as IP Quality of Service (IP QoS) and IPv6. These will support applications such as videoconferencing, and help to ensure that the performance of the network remains manageable and consistent. SuperJANET V will also need to address the issue of network capacity. Since the funding bodies announced JANET during 1984, the JNT and UKERNA had continually increased the bandwidth available to users (see Table 3.1). Initially this meant incrementally upgrading the network's bandwidth, for example, from 2 to 8 Mbps. The 8 Mbps upgrade was the largest upgrade to JANET, since the funding bodies had established the network.

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[162] See *About Abilene*, Internet2, 2003, Available from: http://abilene.internet2.edu/about/, Accessed on: 18 August 2004, *About Internet2*, Internet2, 2004, Available from: http://www.internet2.edu/about/aboutinternet2.html, Accessed on: 18 August 2004, and D. Fowler, "The Next Internet," *NetWorker*, September 1999, pp. 20-29.

[163] *Requirements Analysis: An Opportunity to Shape the Future of JANET*, UKERNA, 2003, Available from: http://www.ja.net/SJ5/requirements_analysis.pdf, Accessed on: 30 July 2004.

Table 3.1. Evolution of bandwidth on JANET and SuperJANET.[164]

Year	Network	Bandwidth of backbone
1984 to early 1990s	JANET	9.6 Kbps followed by 2 then 8 Mbps
1993	SuperJANET I	34 Mbps
1995	SuperJANET II	34 and 155 Mbps
1998	SuperJANET III	155 Mbps
2001	SuperJANET IV	2.5 and 10 Gbps
2005	SuperJANET V	Greater than 10 Gbps

However, with the introduction of SuperJANET, this upgrade became insignificant. SuperJANET originally operated at 34 Mbps, but eight years later the backbone transmitted information at 10 Gbps. By 2002, the bandwidth on the network was one million times greater than the original capacity of JANET.[165] The increase in TCP/IP traffic on both JANET and SuperJANET provided the catalyst for these changes. Traffic on the network doubles every nine months, and projections suggest that the exponential rise in traffic will continue, with over 60 percent more traffic by 2013 compared to 2002.[166] To support the increasing amount of traffic, the JISC can employ technologies, such as the fibre-optic Dense Wave Division Multiplexing (DWDM) system, which can transmit data at several rates including 40 Gbps (see Figure 3.14).[167] Irrespective of the technology employed within SuperJANET V, it seems likely that traffic will continue to increase, based on the growth seen throughout JANET's existence. Whatever happens, the continual upgrades to SuperJANET have achieved three outcomes. The upgrades expanded the bandwidth to support the increasing traffic generated by the community. For the past 13 years, this traffic has consisted of TCP/IP packets therefore reinforcing the demise of X.25. As Christopher Cooper, a member of the SuperJANET project team remembers, "what happened was as the SuperJANET era came in, so X.25 was swept away."[168] The development of SuperJANET also achieved another more important outcome: it helped to consolidate TCP/IP as the standard used on the UK's national academic computer network.

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[164] Ibid.

[165] M. Yardley, *Next-Generation JANET Backbone Infrastructure: An Assessment of the Options Available*, UKERNA, 2004, Available from: http://www.ja.net/SJ5/final-report.pdf, Accessed on: 10 May 2004.

[166] During 2002, the SuperJANET 4 backbone transmitted 6.5 Petabytes (Pbs), 6.5 million Gbs, during the year. If the amount of traffic continues to increase, the network will be transmitting 10.5 Pbs per year by 2013. See Ibid. Additional information from S. Wood, E-mail to D. Rutter, 13 May 2004.

[167] Yardley, *Next-Generation JANET Backbone Infrastructure* and Appendix F.

[168] C. Cooper, Interview by D. Rutter, 25 June 2003.

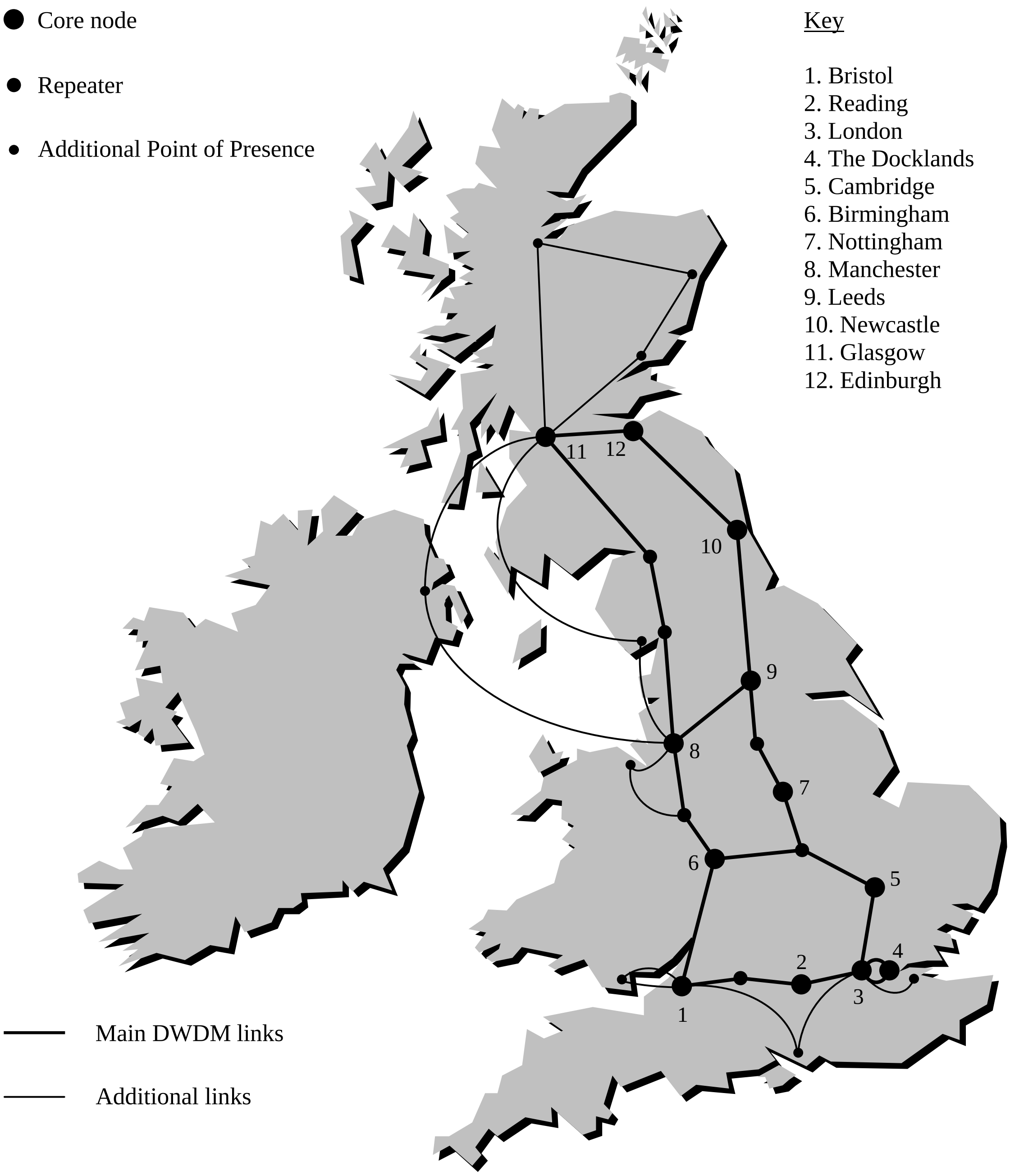

Figure 3.14. A possible topology for SuperJANET V.[169]

[169] SuperJANET V can use several fibre-optic solutions, including DWDM. See Appendix F.

4. Before the Internet: The Rise and Fall of Prestel

4.1 Introduction

During the 1960s, a computer phenomenon occurred. Known as computer utilities, people envisaged that these systems would provide banking, airline reservations, electronic messaging, online shopping, and many other services for people who did not have access to a computer.[1] Although the computer utility idea failed to materialise, the idea of the public accessing centralised computing power from a distance remained. While people would normally use teletypes to communicate with a computer, several companies began to experiment with alternative terminals during the 1960s and 1970s. In particular, attention focused on the telephone and the television. An example of a telephone-based system was Tele-CUPL at Cornell University.[2] During the late 1960s, Cornell investigated a possible replacement to the traditional teletype. Teletypes were slow and expensive and in order for both staff and students to access the resources provided by a central computer, quickly and economically, the university would have to adopt another terminal. Cornell chose the telephone as it was cheaper and more accessible than teletypes. Using an IBM System/360, the university developed Tele-CUPL which enabled people to perform calculations and manipulate programs using a telephone and the computer.

In addition to the telephone as a computer terminal, the television also became quite popular as a replacement for the teletype during the late 1960s. Several companies experimented with the television, the most famous example of which was AT&T's Picturephone.[3] In 1964, AT&T demonstrated the Picturephone at the 1964 World's Fair in New York. In addition to being a videophone, the Picturephone enabled a subscriber to access a remote computer to perform tasks such as calculations. AT&T decided to spend up to $500m to commercialise the technology and opened a limited

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[1] M. Campbell-Kelly and W. Aspray, *Computer: A History of the Information Machine*, 2nd ed. (Boulder: Westview Press, 2004), pp. 193-196.

[2] Another example was the DIALS calculation system. See R.W. Conway and H.L. Morgan, "Tele-CUPL: A Telephone Time Sharing System," *Communications of the ACM*, vol. 10, no. 9, 1967, pp. 538-542 and Y. Mima and T. Shibayama, "Calculation by Telephone –DIALS–," *Japan Telecommunications Review*, vol. 12, no. 3, 1970, pp. 169-175.

[3] Another example was the TICCIT time-sharing educational system. See R.P. Morton, "The Variety of TICCIT Systems — An Overview," *Proceedings of the ACM SIGCSE-SIGCUE Technical Symposium on Computer Science and Education, February, 1976* (New York: ACM Press, 1976), pp. 144-148 and P.S. Warwick and G.W. Phipps, "The Picturephone System: Computer Access," *Bell System Technical Journal*, vol. 50, no. 2, 1971, pp. 683-700.

service between three US cities during 1964. To use the system, AT&T charged people $27 a minute for each call. Despite this high cost, AT&T predicted that 12 million people would subscribe to the service by the year 2000. This situation never happened and the company soon decided to cancel the Picturephone. The system had cost AT&T millions of dollars to develop and the apathy expressed by the potential adopters was concerning for AT&T, and should have been instructive for the General Post Office (GPO) which later developed a similar system called Viewdata.[4] This technology used the telephone network to transmit information from a computer to a television. The Post Office launched the first viewdata network, Prestel, in 1979 and several other countries developed similar systems during the late 1970s and early 1980s. This chapter will focus on Prestel. It will illustrate how the network offered many services and facilities, such as information retrieval, e-mail, and online banking and shopping, which people now use on the Internet. The chapter will show how rival videotex standards competed and how the standards and technologies could have converged to form a videotex internet. It will also explore why Prestel did not succeed and place this into context, look at the success of travel information on Prestel and private viewdata networks, and show how videotex systems such as Télétel co-exist in a world dominated by the Internet.

4.2 Early Network Developments: Teletext and Viewdata

4.2.1 Teletext

In the mid 1960s, the Radio Corporation of America (RCA) developed the Homefax system, which was one of the first technologies to use the spare capacity within a television signal, known as the Vertical Blanking Interval (VBI), to transmit data to modified televisions.[5] By 1966, the BBC Designs Department had begun to design a system which could insert data into the VBI in order to help control the television network.[6] Using this facility, the BBC could also transmit subtitles for the hearing

[4] K. Lipartito, "Picturephone and the Information Age: The Social Meaning of Failure," *Technology and Culture*, vol. 44, no. 1, 2003, pp. 50-81.
[5] W.D. Houghton, "Homefax — A Consumer Information System," *Journal of the SMPTE*, vol. 79, no. 9, 1970, p. 5.
[6] J.R. Chew, "Ceefax: Evolution and Potential," in *Ceefax: Its History and the Record of its Development by BBC Research Department* (London: British Broadcasting Corporation, 1978), pp. 143-158.

impaired and a magazine of information to televisions that contained a decoder.[7] By the end of 1972, the BBC had decided to combine both of these systems to form one service called Ceefax (see facts).[8] The BBC wanted to provide a comprehensive magazine of information which people could access quickly and do so using decoders that were inexpensive. As work continued on Ceefax's development, the Independent Broadcasting Authority (IBA) demonstrated its Optional Reception of Announcements by Coded Line Electronics (ORACLE) teletext service to the BBC and other organisations during 1973. Demonstrations such as this helped to attract interest from the television manufacturers for both systems, and support for teletext was soon strong.[9] To maximise the potential of teletext, the BBC and IBA recognised that it would be prudent to combine the systems to form a unified standard. During mid 1973, the organisations set up a committee to develop the standard. During this period, the BBC and IBA launched their respective services. By 1976, both organisations had published the final specification of the British teletext standard and continued to broadcast teletext in the UK.

4.2.2 Viewdata

In 1970, as the BBC began work on what would become Ceefax, a research engineer, Samuel Fedida, joined the General Post Office. He had previously been Assistant Head of Research at English Electric before working for a US-based consultancy company. One of the projects that Fedida had worked on was an online hotel vacancies system for hotels. As the clerks who used the system on behalf of customers generated 80 percent of the costs, the company that operated the service could have saved money if customers accessed the computer directly.[10] This idea would influence the development of Viewdata when Fedida joined the Post Office during 1970 as the head of the Computer Research Applications Division. The Post

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[7] See C. McIntyre, "Teletext in Britain: The CEEFAX Story," in *Videotext: The Coming Revolution in Home/Office Information Retrieval*, E. Sigel ed. (White Plains, NY: Knowledge Industry, 1980), pp. 23-55 and Appendix H.
[8] Colin McIntyre, the first editor of Ceefax, remembers the development of the service saying, "in a sense Ceefax was engineer-led, and it was the BBC engineers above all who made it work". Information from C. McIntyre, Letter to D. Rutter, 23 October 2004.
[9] G.A. McKenzie, "Teletext—The First Ten Years," in *IBA Technical Review 20: Developments in Teletext* (Winchester: IBA, 1983), pp. 4-10.
[10] M. Wilkinson, "Viewdata: The Prestel System," in *Videotext: The Coming Revolution in Home/Office Information Retrieval*, E. Sigel ed. (White Plains, NY: Knowledge Industry, 1980), pp. 57-85.

Office allowed Fedida to develop his ideas about people and computer access during his first year.[11] Fedida envisaged a system that would use the Public Switched Telephone Network (PSTN) to transmit information stored on a computer in a format that the public could use. To access this system, users would need a suitable terminal which would need to be inexpensive, reliable, and aesthetically pleasing for people to adopt it.[12] The obvious candidate was the telephone. However, it was only able to receive a limited amount of transient voice-based information which would restrict the potential of the system. For this reason, Fedida dismissed the telephone. As Alex Reid, the first director of Prestel, remembers this is when "something novel happened because Fedida said why can't we do this via the television set? After all there are millions of televisions and all we need is a screen and keyboard and the necessary adaptor".[13]

Having decided on the television as the terminal, Fedida had completed the initial Viewdata design. People would use modified televisions to communicate with a centralised computer over the telephone network to access information contained within databases using an inverted tree hierarchy.[14] While Viewdata did not contain a newly designed technology, it was the first time that someone had combined the computer, the telephone network, and the television to form a new information system.[15] Fedida had merged three separate innovations to produce a system that blurred the boundaries between its component parts to form an integrated whole.[16] This convergence and the collocation of heterogeneous technologies within the home would enable the television and the network to exchange data with a centralised

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[11] This research was part of the Post Office's Viewphone, which was equivalent to AT&T's Picturephone. When this invention failed to attract subscribers, the Post Office cancelled their research. See B. Eaves, *An Analysis of the Process of Research, Innovation and Development in the Particular Cases of Teletext and Viewdata in the United Kingdom*, M.Phil thesis (Sunderland: Sunderland Polytechnic, 1983), pp. 134-137.
[12] See S. Fedida, "Viewdata: The Post Office's Textual Information and Communications System: 1 – Background and Introduction," *Wireless World*, February 1977, pp. 32-36 and S. Fedida, *Viewdata: An Interactive Information Service for the General Public* (Ipswich: Post Office, 1976).
[13] A. Reid, Interview by D. Rutter, 10 July 2001.
[14] See Appendix H.
[15] K. Clarke, "The Design of a Viewdata System," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 33-55.
[16] On the boundaries that can exist between technological innovations see E.M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995), pp. 14-15.

computer and therefore create the possibility of new capabilities for potential adopters using two familiar devices.[17]

With the fundamental design of the system complete, Fedida prepared a proposal which he presented to the Post Office Research Directorate. The Directorate believed that the idea had potential and therefore assembled a Viewdata team to develop an experimental system. By January 1973, the Post Office had decided to join one of the early teletext working groups looking at the unified teletext standard.[18] This decision made sense for several reasons. By ensuring that both teletext and Viewdata used the same display format, this would mean that the display electronics, such as the character generator within a decoder, could be standardised. If the BBC, IBA, and the Post Office jointly developed compatible standards for both teletext and Viewdata, they could export these standards to other countries.[19] Collaboration with the broadcasting industry also made sense from a commercial point of view, as television manufacturers had expressed a strong interest in teletext decoders. The common decoder technology manufactured by the television companies, could help lower costs for Viewdata adapted televisions, and therefore encourage potential adopters to use the Post Office system.[20]

Having decided to support the unified viewdata and teletext standard, the Post Office decided to commercialise Viewdata during 1974. It believed that the public wanted access to an inexpensive, efficient, and easy to use online system that could service the needs everyone had for many different types of information.[21] It also believed that its Viewdata service would balance the load placed on the PSTN, with mainly businesses using the telephone network during the working day, and residential users accessing Viewdata during the evenings and at weekends. In addition, according to

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[17] On the convergence in complements concept see S. Greenstein and T. Khanna, "What Does Industry Convergence Mean?" in *Competing in an Age of Digital Convergence*, D.B. Yoffie ed. (Cambridge, MA: Harvard University Press, 1997), pp. 201-226. On innovation junctions see O.d. Wit, et al., "Innovative Junctions: Office Technologies in the Netherlands, 1880-1980," *Technology and Culture*, vol. 43, no. 1, 2002, pp. 50-72.

[18] S.W. Amos, "A History of Ceefax: A Summary of the Steps leading to the Broadcast Teletext Specification of September 1976," in *Ceefax: Its History and the Record of its Development by BBC Research Department* (London: British Broadcasting Corporation, 1978), p. 8.

[19] K.E. Clarke, "The Lessons of the Introduction of Prestel for British Telecom Engineers," *British Telecommunications Engineering*, April 1982, pp. 16-18.

[20] McKenzie, "Teletext—The First Ten Years," p. 4.

[21] S.J. Sandringham, "Prestel and the Consumer," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 129-133.

Reid, the Post Office "didn't want to be criticised later for not having exploited this interesting invention that had come out of their labs".[22] The Post Office established criteria for its new service, stating it should be reliable, easy to use, and inexpensive.[23] The Post Office also began to conduct demonstrations of its invention, the first of which occurred in London during September 1975 at the European Computing Conference on Communications Networks (Eurocomp), where Fedida presented a paper about the technology.[24] As these demonstrations continued, the Post Office authorised a pilot trial of Viewdata. The main purpose of the trial was to encourage television manufacturers and Information Providers (IPs) to become involved with the system, and this strategy worked. Television manufacturers became interested in the technology as they were looking for ways to diversify in order to find a new impetus for people to buy televisions.[25] Several companies, including GEC and ITT, therefore agreed to participate in the pilot trial as a prelude to perhaps manufacturing Viewdata receivers. Several Information Providers were also interested in Viewdata. For example, the Institute for Scientific Information wanted to develop a science magazine, called Scitel, which would provide up-to-date news and articles in the life, physical, and social sciences.[26] The Post Office hoped that its decision to divide the functions of Viewdata between three types of organisation would encourage external companies to invest in the system and become part of the overall infrastructure. If these organisations then began to improve their products and services, this would not only benefit the individual companies, but also the Viewdata service as a whole.[27]

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[22] Reid, Interview.
[23] P. Sommer, "Viewdata in the United Kingdom: Prestel and Beyond," in *The Future of Videotext*, E. Sigel ed. (London: Kogan Page, 1983), pp. 81-91.
[24] Fedida, *Viewdata: An Interactive Information Service*, pp. 1-24.
[25] C. Tipping, "Viewdata and the Television Industry," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 82-88.
[26] Other examples included schools in Hertfordshire, who used Viewdata to create educational content online, and the Birmingham Post and Mail newspaper group which became an IP as it wanted to explore the opportunities offered by the system. This group later launched an online newspaper on Prestel called Viewtel 202. See I. Berkovitch, "Building a Science Magazine within Prestel," *Physics in Technology*, vol. 10, no. 1, 1979, pp. 1-3, M. Aston, "Schools in Contact: Electronic Mail—Myth or Reality?" *Computers & Education*, vol. 15, no. 1-3, 1990, pp. 245-248, and "Viewtel Services—A Publishing Success Story," *The Prestel Directory*, Edition 3, 1985, pp. 62-63.
[27] On technological interrelatedness see M. Frankel, "Obsolescence and Technological Change in a Maturing Economy," *American Economic Review*, vol. 45, no. 3, 1955, pp. 296-319. On endogenous sunk costs see J. Sutton, *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration* (Cambridge, MA: MIT Press, 1991), pp. 11-12 and 45-81.

As the Post Office continued to attract participants for its pilot trial, it made a decision which some praised at the time, but which later adversely affected the service. This decision related to the selection of Information Providers and the editorial control of the information provided by the IPs. Initially, the Post Office wanted to select the companies who would provide information and then retain editorial control over the information within the service. Several Information Providers protested, stating that they did not want to relinquish their editorial freedom. If the Post Office ignored them, they would not co-operate during the pilot trial.[28] To obtain the IPs support and to prevent the Post Office from having to monitor thousands and potentially millions of information pages, the Post Office acquiesced. It therefore decided to act as a common carrier for its service. It would not select IPs or edit information within the system. Any company could therefore become an Information Provider, so long as they could afford to do so and did not publish illegal information.[29]

With support from the third parties in place, the two-year pilot trial began during January 1976. As the Post Office, the television manufacturers, and the Information Providers started to gain experience of the new system, the Post Office took the unusual step of establishing an independent Viewdata department to operate the service. Reid explains saying “there was at that time a tradition of doing things in an extremely ponderous risk averse way which meant that it could take years to introduce a new product. The managing director of Post Office Telecommunications was very nervous that Viewdata would sink into this mire and never happen. And so he decided that they only way to get this thing to happen quickly, was to have an independent department. It was the first time the Post Office had done this”.[30] This new department soon began to prepare plans for the one-year market trial which it would undertake after the successful completion of the pilot trial. The market trial would enable the Post Office to estimate the size of the Viewdata market up to 1985, who would use Viewdata, and how much they would pay to access the service.[31] During

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[28] R. Winsbury, *The Electronic Bookstall: Push-Button Publishing on Videotex* (London: International Institute of Communications, 1979), p. 5.
[29] A. Reid, “Prestel Philosophy and Practice,” in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 16-17.
[30] On intrapreneurism see K.S. Davis, “Decision Criteria in the Evaluation of Potential Intrapreneurs,” *Journal of Engineering and Technology Management*, vol. 16, no. 3-4, 1999, pp. 295-327.
[31] A. Reid ed., *Prestel 1980: The Aims, the Product, the Market, the Marketing Strategy, and the Roles that will be Played in 1980 by Each of the Parties on Whom the Success of Prestel Depends* (London: Post Office, 1980), p. 18.

early 1977, the Viewdata department prepared a plan for the market trial. The trial would begin during June 1978.[32] The Viewdata system would contain a database of 30,000 pages of information which 1,500 people could access using receivers provided by the television manufacturers. Both consumers and businesses would participate in the trial, with the Post Office allocating 800 sets to residential users, and 700 to companies. The market trial would cost the organisation £3.5m to operate. By March 1977, the Post Office had authorised the plans prepared by the project team.

As the Post Office began to work towards the market trial, the pilot trial ended. It had enabled the Post Office and its third parties to obtain experience of the operation of the Viewdata service, experience that they could use during the market trial. However, as the pilot trial concluded, the Post Office became aware that both the television manufacturers and the IPs were concerned about the potential demand for Viewdata from consumers.[33] The reason for this concern was that by 1978 there were less than 500 teletext sets in use. As both teletext and Viewdata were similar services, the third parties were concerned about the demand for the Post Office's service. The television manufacturers were apprehensive about the viability of the consumer market and they would therefore not place large orders with the semiconductor suppliers for the integrated circuits necessary for the Viewdata decoders. However, the semiconductor suppliers would not fabricate the circuits unless the television manufacturers placed large orders. Therefore, the television manufacturers and the IPs wanted the Post Office to assure them that a market existed for Viewdata and that it would establish a public service after the market trial ended. The manufacturers and IPs believed that a market for the technology did exist, but it was not the residential market. During the pilot trial, businesses had expressed an interest in Viewdata and the third parties therefore thought that it was sensible to focus on this market, at least initially. In response to the concerns of its partners, the Post Office declared that it would establish a public service after the cessation of the market trial. By announcing that it would launch a public network, this helped to legitimate the technology and encourage potential adopters, such as the television manufacturers and IPs, to invest

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[32] A.V. Stokes, *Viewdata: A Public Information Utility*, 2nd ed. (Purley: Input Two-Nine, 1980), pp. 21-22.

[33] R. Woolfe, *Videotex: The New Television-Telephone Information Services* (London: Heyden, 1980), pp. 75-76.

in the system.[34] It would also encourage the Post, Telegraph, and Telephone (PTT) operators in other countries to explore the technology, and, as the Post Office would be the first organisation to set up a Viewdata service, this would force other PTTs to either adopt the Post Office's standard or compete with it.[35] The Post Office also encouraged the television manufacturers and IPs to focus on the business market. However, this was a gesture to placate the companies and nothing else. It therefore did not alter the Post Office's belief that the residential market would respond favourably to Viewdata. After making it clear that it would establish a public service after the market trial concluded, the Post Office announced in March 1978 that it would launch the public Viewdata service a year earlier than it had planned.[36] It made this decision to encourage its partners. However, by launching Viewdata during early 1979, this would mean that the market trial, renamed as the test service, would not have finished by the time the public service started. The Post Office and its partners would therefore not receive the results of the test service until after the commercial Viewdata service had started. Despite this concern, the Post Office decided to allocate £23m to establish and operate Viewdata, now called Prestel, with £5m going to set up computer centres in places such as London, Birmingham, and Edinburgh.

While the Post Office continued to plan the details of the commercial service, problems started to occur with the test service. Originally scheduled to begin during June 1978, the Post Office realised that this would not occur and that it would have to delay the start of the test service for about six months. The reason for the delay was that the billing software was not ready.[37] As the new London Prestel centre would not be online for some time, the Post Office continued to use the pilot trial computer. As this computer had only 16 ports, this limited the amount of concurrent connections to the machine and this did not help the 100 Information Providers to store and then edit pages. By September 1978, the Post Office was ready to launch the test service.[38] It

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[34] On credible investments in technology see B.H. Clark and S. Chatterjee, "The Evolution of Dominant Market Shares: The Role of Network Effects," *Journal of Marketing Theory and Practice*, vol. 7, no. 2, 1999, pp. 83-96.

[35] On first movers and adapting or competing with a standard see M.A. Cusumano, et al., "Strategic Manoeuvring and Mass-Market Dynamics: The Triumph of VHS over Beta," *Business History Review*, vol. 66, no. 1, 1992, pp. 51-94.

[36] "Viewdata to Go Public Early in 1979," *Computer Weekly*, 2 March 1978, p. 48.

[37] This software would handle the allocation of charges between the Post Office and the IPs. See "Prestel Trial Problems," *Computer Weekly*, 1 June 1978, p. 1.

[38] "PO Test Service Ready to Go Live," *Computer Weekly*, 21 September 1978, p. 9.

installed two Prestel computers in London and serviced the first six televisions received from the manufacturers. As the test service had started late, this meant that the Post Office had to reschedule the launch of the commercial service for September 1979. In addition, problems with the terminals and the information for the system continued to affect the Post Office's system. The television manufacturers had originally agreed to supply 1,500 terminals for the test service. By September 1978, there were only 902 terminals in use: 524 used by businesses and 378 used by residential participants. The shortage of terminals concerned the Post Office, the IPs, and the television manufacturers. The Post Office and other organisations started to blame the manufacturers for the delays and shortages, who then passed the problem onto the semiconductor suppliers who were obviously still not willing to fabricate chipsets without substantial orders from the television companies.[39] This supply problem not only affected the number of terminals available for the users of the system, it also affected the IPs, which lacked editing terminals. In an attempt to remedy the shortage of terminals, the Post Office considered selling viewdata adaptors which people could connect to their televisions.[40] However, when the television companies learnt of this idea, they immediately objected. This suggestion threatened the manufacturers which believed that they, and not the Post Office, should supply the receivers that the public would use to access Prestel. However, due to the continued acute shortage of terminals, the Post Office needed to do something to address this issue. It asked companies to design an adaptor that would cost £50, if the manufacturers made 200,000 devices. The interest from most companies was less than enthusiastic, as they did not believe that such a proposition was viable. One company, Ayr Viewdata, did try to develop an adaptor, but they were not successful.

Despite the problems with the test service, the Post Office and other organisations remained optimistic about the future of Prestel. For example, the Post Office planned to enable 60 percent of the country to access Prestel at local call rates by mid 1980. By that point, the network would be able to support 70,000 business users and many consumers. In addition to these expansion plans, the Post Office began to make predictions about how many people would adopt the service. The Post Office

[39] Tipping, "Viewdata and the Television Industry," pp. 84-86.
[40] R. Green, "Post Office Gives Viewdata a Wrong Number," *New Scientist*, 30 October 1980, pp. 300-303.

estimated that by the end of 1980, there would be 90,000 subscribers, and by mid 1981, the computers within the network would be able to support one million users.[41] The Post Office went further, saying that it believed three million people would use Prestel by 1983 and that by then, the service would generate £150m per annum. ITT was also confident, estimating that by 1983, the service would have 2.5m subscribers.[42] Early support from the government also emerged at this point, with an MP speaking in the House of Commons referring to Prestel as "a brilliant British invention, ranking with the jet engine and radar".[43] While this statement is, of course, excessive, it does capture the general mood of the late 1970s in relation to the Post Office's invention. As Frank Burgess, a former General Manager of Prestel, remembers, "we were all fired with enthusiasm that information retrieval was what everyone wanted. We all assumed people would rush out and buy a Prestel set".[44] Many believed this rhetoric and assumed that Prestel had great potential and would undoubtedly succeed. With the launch of Prestel in 1979, people would learn if these expectations were correct.

4.3 Prestel: Expectations and Reality

4.3.1 Early Problems

The Post Office had hoped to launch the full Prestel service during early 1979. However, this was not possible because of the problems that had affected the test service. To ensure that it did establish some form of service during early 1979, the Post Office launched a limited London Residential Service in March for customers in the capital.[45] It restricted this to consumers within London, because of continued problems relating to the supply of terminals and software issues. By May 1979, the test service computer in London served 1,000 terminals. The Post Office followed the Residential Service with the launch of the full commercial service during September 1979. With the launch of Prestel, the Post Office opened three new computer

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[41] See C. Wright and D. Donovan, *Prestel - A Market Investigation* (Lancaster: University of Lancaster, 1978), p. 38 and Stokes, *Viewdata*, p. 23.
[42] See A. Stokes, "The Viewdata Age: Power to the People," *Computer Weekly,* 18 January 1979, p. 4, A. Jones, "The Role of Advertising," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 164-171, and "ITT to Enter Viewdata Market," *Computer Weekly*, 18 May 1978, p. 10.
[43] "Govt Backs Viewdata in Europe," *Computer Weekly,* 13 April 1978, p. 1.
[44] F. Burgess, "Prestel from Day One," *The Prestel Directory,* Edition 2, 1985, p. 97.
[45] Stokes, *Viewdata,* pp. 22-23.

centres.[46] Two, called Byron and Juniper, contained copies of the Prestel database, and a third, Duke, was an update centre. Information Providers would use this Prestel Update Centre (UDC) to update their information which Prestel would then distribute to the Information Retrieval Centres (IRCs) using the X.25 Packet Switching Service (PSS).[47] Another IRC, Dickens, joined the network during December, this time in Birmingham (see Figure 4.1). This network of IRCs and the UDC supplied over 160,000 pages of information from 130 Information Providers to about 2,000 terminals.

Having launched Prestel, the Post Office decided to close its Prestel marketing department.[48] It made this decision in an attempt to rationalise marketing within the organisation. It also believed that its partners, especially the Information Providers, were ideally suited to market Prestel. The closure of the Post Office's Prestel marketing department concerned its partners, as they believed the decision might undermine the confidence of the television manufacturers. In an attempt to increase the public's awareness of Prestel and perhaps increase confidence in the service, the Post Office announced that its marketing department would continue to promote Prestel and in particular launch an extensive marketing campaign to promote the service.[49] The Post Office launched this campaign during March 1980, spending £1.7m on advertisements on television and in newspapers. The Post Office hoped that its efforts would increase the number of subscribers from the 2,400, who were using Prestel by mid 1980, to the thousands of users it had expected would use the service by then.[50] As its predictions had been inaccurate, the Post Office revised its estimates during March, predicting that by the end of the year 50,000 people would be using Prestel. By the end of 1980, the actual figure was 6,000. When compared to the Post Office's 1979 estimate of 90,000 users by then, some analysts stated that this was a "pathetic performance".[51]

[46] Woolfe, *Videotex*, p. 80.
[47] See Appendix H.
[48] "Prestel Changes Alarm Industry," *Computer Weekly*, 27 September 1979, p. 1.
[49] K. Levis, "Pop the Corks! Prestel Launches into the '80s," *The Prestel User*, January 1980, pp. 13-14.
[50] "Prestel Ploughs On," *Displays*, vol. 2, no. 2, 1980, p. 63.
[51] "Videotex: Writ Large or Small?" *The Economist*, 31 October 1981, pp. 80-81.

Figure 4.1. The Prestel network in September 1979.

There were several reasons why the Post Office and its partners had failed to encourage people to adopt Prestel. The continuing shortage of terminals was a significant problem. As the television manufacturers had not placed large orders with the semiconductor suppliers, this meant that the suppliers were only willing to provide sample chip sets.[52] Without the integrated circuits, the television manufacturers could not build the Prestel decoders for inclusion within televisions. Throughout 1980, the television manufacturers kept revising their estimates for the number of sets that they

[52] D. Kennett, "Volume Production of Sets Next Year," *Computer Weekly*, 30 August 1979, p. 5.

would sell, from 900 a week in February to 600 a week by March.[53] However, because of the shortage of chips, they were not able to reach even this reduced target. One possible solution to the shortage of terminals was the external viewdata adaptor suggested by the Post Office. By 1980, Ayr Viewdata had managed to develop an adaptor, but the Post Office changed its mind about distributing 200,000 terminals, because of the objections raised by the television manufacturers.

The shortage of terminals was a serious issue not least because it maintained the high prices of the receivers. This problem contributed to the high costs associated with using Prestel which was one of the main deterrents to adopting the service. As an example of these costs, if a person wanted to buy a colour Prestel television in 1980, a retailer would charge them £1,100.[54] If they preferred to rent the set, it would cost them £30 a month. Having paid for a receiver, the Post Office and Information Providers would then of course charge customers for accessing the service. If the user accessed ten pages on Prestel for one hour every weekend during a one-month period, the Post Office, IPs, and television rental company would charge them over £34. When compared to the average gross monthly income of a male or female worker in 1980, this represented nearly 7 or 11 percent of his or her monthly income.[55] Prestel was therefore very expensive. When the Post Office's successor, British Telecom, obtained the results of the test service during 1980, the report confirmed this fact. For example, of the 1,389 people interviewed, 55 percent of residential users and 19 percent of business said that Prestel was an expensive service.[56]

In addition to the problems of terminal shortages and costs, three other issues affected Prestel at this time. The first two related to the information on the service and the IPs. The test service results revealed that many people were disappointed with the information on Prestel in terms of how up-to-date it was. In addition, the service contained pages that offered people useless information, incomplete instructions on

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[53] R. Nicholson and G. Consterdine, *The Prestel Business* (London: Northwood Books, 1980), p. 40.
[54] "Who'll Buy?" *The Economist*, 15 March 1980, pp. 63-64.
[55] In 1980, a male worker earned, on average, £498 a month compared to a female worker who earned £315.20. See Department of Employment, *New Earnings Survey 1980 Part A - Report: General and Selected Key Results* (London: HMSO, 1980), p. A5.
[56] See *The Prestel Market Research Executive Summary No.1: Introduction and Plan* (London: Post Office, 1979), p. 1.2 and A. Harris, *Initial Reactions: An Analysis of Interim Results of Wave 2 Interviews* (London: Post Office Prestel, 1980), p. 6.3.

how to navigate through pages, and poorly designed frames.[57] Clearly, the IPs needed to improve the quality of information on Prestel substantially. As a lot of the credibility of Prestel depended on the quality of the information provided by the IPs, BT could have set up a small organisation to monitor the quality of the information on the service. However, this did not happen. To help improve standards, BT decided to ask certain IPs to leave the service, which undermined the IPs confidence in the common carrier policy.[58] The IPs were also a cause for concern. Since the start of the public service in September 1979, several prominent IPs had left Prestel. For instance, during 1981 three Information Providers withdrew or reduced their presence on the service.[59] Extel, which had provided sports news, left because Prestel had not become a mass-market service and it considered this would never happen. Scitel, one of the earliest providers of information on Prestel, also left. Another IP, Eastern Counties Newspapers, substantially reduced its presence on the service, while it waited to see if the number of subscribers improved. Information Providers would continue to leave, with the Financial Times and the Economist withdrawing during 1983.[60] While the total number of IPs had always remained at about 150, more than two thirds of the Information Providers had left Prestel since 1979. By 1983, this would increase to over 70 percent. The factors affecting the high attrition rate included inadequate reasons for becoming an IP and focusing too much on the technology and not on the quality and value of the information provided.[61]

The third issue that affected Prestel was the usability of the viewdata technology. In particular, BT needed to improve the usability of Prestel’s index. In 1982, the National Consumer Council published a report which looked at the inverted tree hierarchy provided by BT.[62] The report concluded that this index was unsatisfactory

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[57] See E.S. Maynes, *Prestel in Use: A Consumer View* (London: National Consumer Council, 1982), pp. 17 and 37-38 and S. Sutherland, *Prestel and the User: A Survey of Psychological and Ergonomic Research* (Brighton: Centre for Research on Perception and Cognition, University of Sussex, 1980), p. 97.

[58] R. Brooks, “Prestel Homes in on Viewers,” *Sunday Times*, 10 January 1982, p. 60.

[59] D. Kennett, “Gloom as Three Axe Prestel,” *Computer Weekly*, 5 November 1981, p. 1.

[60] See D. Kennett, “Viewdata Pioneer to Cut Back,” *Computer Weekly*, 25 June 1981, p. 1 and J. Young ed., *Videotex and Teletext in the US and UK* (London: Financial Times Business Information, 1984), p. 21.

[61] See P. Sommer, “Does Prestel Know Where it’s Going?” *Computer Weekly*, 9 June 1983, p. 22 and P. Sommer, “Electronic Attrition – The Battle for Survival,” *Viewdata 82: The European Conference on Viewdata, Videotex and Teletext, London, October 1982* (Middlesex: Online Publications Limited, 1982), pp. 281-286.

[62] Maynes, *Prestel in Use*, pp. 29 and 34.

because navigating through it could be very expensive for users, especially if they did not know where to find the information. The test service results supported this conclusion.[63] As the Prestel index was inadequate, the Council recommended that British Telecom either redesign or replace it with a more satisfactory method of finding information. BT could improve the index in several ways. For example, it could incorporate a device on-screen which indicated the user's position within the hierarchy.[64] If British Telecom chose to replace the index, they could provide a keyword search facility which would enable people to select or enter keywords to find information and therefore increase the speed with which they found information.[65]

With problems such as costs, information, and usability resulting in only 6,000 terminals on the network by the end of 1980, it was clear that BT and its partners had overestimated the actual demand for Prestel, especially from residential users. A mass-market had failed to materialise and this meant that it would take time for the viewdata companies to receive a return on their investments. In particular, by the end of 1980 BT had invested £30m in Prestel, a lot of it going towards expanding the number of Information Retrieval Centres in an attempt to extend access to the service to as many people as possible at local call rates (see Figure 4.2).[66] While British Telecom had demonstrated the feasibility of operating a national viewdata network, it had failed to prove that potential adopters, especially consumers, wanted to use the service.[67] The test service results had contained evidence that this might happen. For example, of the 475 residential users interviewed by BT, only 9 percent of consumers expressed an interest in keeping their terminals after the test service ended. The main reason for this was the cost of using the service which 59 percent of people thought was excessive.

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[63] Harris, *Initial Reactions*, p. 3.1.
[64] Beacons indicate where a user is located within an information space such as the Prestel viewdata service. See G.E. Field, *Navigation of Menu-Accessed Information Space: Psychological Experimentation in Human Computer Interaction*, Ph.D. thesis (London: Department of Electrical Engineering, Imperial College, 1988), pp. 38-39.
[65] A. Powell, *Prestel: An Assessment of Methods of Retrieval of Information*, M.Sc. thesis (London: Centre for Information Science, City University, 1982), pp. 39-41.
[66] "'Long Haul' to Profit for Prestel Information Providers," *Computer Weekly*, 6 March 1980, p. 5.
[67] A. Stephens, "Prestel – The First Year of Public Service," *New Systems and Services in Telecommunications: Proceedings of the International Conference on New Systems and Services in Telecommunications Liege, Belgium, November 24-26, 1980*, G. Cantraine and J. Destine eds. (Amsterdam: North-Holland, 1981), pp. 3-5.

Figure 4.2. The Prestel network in 1980.

As BT had not obtained these results until after it had launched the network, it could do little more than hope that these results were not indicative of the how the public regarded Prestel. However, BT was more than just hopeful – it remained adamant that Prestel would become a mass-market service, although this might take longer than initially expected.

British Telecom therefore encouraged its partners to remain resolute and to continue their investment in the network.[68] BT believed that the slow growth of Prestel would soon end and when it did the number of subscribers would increase exponentially. In this sense, the organisation believed that it was similar to other innovations, such as commercial radio, which took time to establish itself before the dramatic increases in listeners occurred. However, BT's prediction of several hundred million pounds per annum in revenues by this time had not materialised and British Telecom, together with its partners, was losing money. BT therefore needed to be realistic about the apathy expressed towards Prestel by consumers. However, the business market was not apathetic. For example, over half of the 914 companies that participated in the test service, had indicated that they would probably keep their terminals after the test service ended. And 80 percent of Prestel's subscribers were businesses. BT therefore decided to change its marketing strategy to focus on business users, in an effort to stimulate demand for the service. It would do this by targeting certain markets, in particular travel.[69]

4.3.2 Travel Information and Private Viewdata Networks

The origin of travel-related information on Prestel began in 1979.[70] British Rail's Sealink company decided to subsidise the cost of terminals in order to stimulate demand for its information on Prestel within the travel industry. It ordered 2,400 terminals and offered them to travel agents throughout the country. The offer of subsidised Prestel receivers attracted the interest of travel agents which wanted to access Sealink's information on Prestel. Sealink maintained a database of 4,000 pages on the Post Office's service which provided information on the schedules of Channel ferries and hovercraft, news, and tour packages. With the installation of the terminals in travel agents, Sealink had solved the 'chicken and egg' problem for the travel

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[68] See Harris, *Initial Reactions*, p. 6.2 and "'Prestel Growth is Leading to Boom'," *Computer Weekly*, 11 September 1980, p. 19.

[69] Other users, such as educational institutions, libraries, and people with disabilities, also became interested in Prestel and videotex at this time. See M.J. Baker and B. Witcher, "The Marketing of Prestel," *Physics in Technology*, vol. 13, no. 3, 1982, pp. 114-122, V. Thompson, et al., *Videotex in Education: A New Technology Briefing* (London: Council for Educational Technology, 1982), V.L. Hayden, *Information Scientists and Librarians as a Market for Viewdata in the U.K.*, Ph.D. thesis (Bradford: Postgraduate School of Studies in Management and Administration, University of Bradford, 1988), and N. Cope, *The Design and Evaluation of a Braille Videotex Terminal*, Ph.D. thesis (Southampton: Department of Electronics, University of Southampton, 1985).

[70] D. Kennett, "First Bulk Order," *Computer Weekly*, 30 August 1979, p. 5.

industry, a problem which continued to afflict Prestel.[71] Any Information Provider that produced travel-related information, by then had a user base of at least 2,400 terminals. This fact encouraged an increasing number of IPs to create travel information on Prestel, and this in turn encouraged more travel agents to purchase terminals and learn about the system in order to access travel information.[72] As the number of travel users expanded, this encouraged an increasing number of potential adopters to become users, therefore increasing the value for the community of travel users as a whole.[73] This expansion in subscribers began during the early 1980s. Travel companies developed many services. For example, British Rail joined Prestel in the late 1970s with a few pages. By the mid 1980s, it had increased its database to 14,500 frames which made it one of the largest IPs on Prestel. People could access the schedules of every train using their own terminal or a terminal provided by British Rail in places such as Waterloo Station. By 1986, people were accessing 7 million frames each year.[74]

Despite the success of services such as British Rail's facilities, Prestel contained a limitation which would restrict the continued adoption of the service by the travel industry. In order for travel agents to use Prestel to book holidays, BT needed to interconnect its network with the computers of the tour operators. In 1981, BT therefore announced that it would establish a service called Prestel Gateway which would use the Prestel computers and the Packet Switching Service to connect terminals to external computers operated by Information Providers or other companies.[75] However, when it became clear that BT would not launch this service until 1982, companies such as Thomson Holidays, decided to establish their own private services. Known as private viewdata networks, these emerged during the early

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[71] British Telecom was aware that it could have adopted a similar approach to Sealink, which may have stimulated demand for its service. However, it chose not to do so. See R. Hooper, "Experiences and Lessons from the First 2 Years of Prestel," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), pp. 449-453. Additional information from R. Hooper, Interview by D. Rutter, 22 October 2001.
[72] On learning by using and informational increasing returns see W.B. Arthur, "Competing Technologies: An Overview," in *Technical Change and Economic Theory*, G. Dosi, et al. eds. (London: Pinter, 1988), p. 591.
[73] On network externalities see M.L. Katz and C. Shapiro, "Systems Competition and Network Effects," *Journal of Economic Perspectives*, vol. 8, no. 2, 1994, pp. 93-115.
[74] See "The Age of the Train—on Prestel," *The Prestel Directory*, Edition 4, 1984, p. 75 and S. Green, "Getting There: British Rail's Plans for 1986," *The Prestel Directory*, Edition 1, 1986, p. 63.
[75] See Appendix H.

1980s.[76] Using viewdata technology, these systems enabled companies to establish private networks which they could customise to suit their particular requirements. After the capital expenditure involved in establishing such networks, these systems could cost less to operate than using BT's equivalent Private Prestel Closed User Group (CUG) service.[77] In addition, firms could connect their computers to private viewdata networks and as a company could use leased lines between its viewdata computers, this could improve the speed with which people could access information. As these networks were separate from the public Prestel service, these private systems were isolated from the public which improved security. These factors encouraged companies to develop private viewdata networks.[78]

Thomson Holidays started to experiment with private viewdata during 1980. The company had established a real-time reservations system called Thomson's Reservations and Administrative Control System (TRACS) in 1976. With TRACS, travel agents phoned Thomson in order to book a holiday for a customer.[79] As congestion offered occurred with Thomson's telephone exchanges during the summer and winter promotional periods, the company wanted to provide direct access to TRACS for the travel agents. By 1981, travel information on Prestel was becoming quite successful, so Thomson decided to conduct a pilot trial of viewdata in London.[80] Thomson connected a front-end minicomputer to the TRACS mainframe and installed software that would translate between the data formats used by the mainframe and viewdata. The company selected 66 travel agents which could access limited search and online booking facilities. As 60 percent of the travels agents claimed the system had increased their sales, Thomson decided to invest £2m in an operational system called the Thomson Open-line Programme (TOP). Thomson launched TOP to a

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[76] L. Wedlake, *Private Viewdata in the UK: A Review of Systems, Users and Applications*, M.Sc. thesis (London: Centre for Information Science, City University, 1982), pp. 33-43.
[77] Closed User Groups enabled a company to restrict who accessed their information. The existence of private viewdata systems prompted BT to lower the costs of Private Prestel by 90 percent, from £2,500 to £250, during 1982. See D. Kennett, "BT Cuts Prices 90% on Private Prestel," *Computer Weekly*, 8 April 1982, p. 1.
[78] *Videotex: Public and Private Systems* (Farnham Common: Urwick Nexos, 1982), pp. 13-14.
[79] See C. Palmer, "The 'TOP' Story — A Case History of Videotex in Travel," *Videotex User '86: Proceedings of the Conference held at the Barbican Centre, London, 29-31 January 1986* (Richmond, Surrey: Marathon Videotex, 1986), pp. 129-138 and C. Palmer, "Booking Package Holidays," *Data Processing*, vol. 24, no. 10, 1982, pp. 24-26.
[80] N. Detjejaruwat, *Information Technology and Organisation Structure: Case Studies of Viewdata in the Travel Industry*, Ph.D. thesis (London: London School of Economics and Political Science, 1988), p. 275.

network of 1,250 travel agents during 1982.[81] By then, 50 percent of Britain's travel agents owned or rented Prestel terminals, an indication of the success Prestel and viewdata in general were having in the travel industry.

4.3.3 Revisiting the Residential Market

Despite the success in the travel industry, the number of subscribers on Prestel remained low. By 1982, the number of users had only reached 13,933, with 400 to 500 new users joining every month.[82] The predictions made by the Post Office and ITT during the late 1970s of hundreds of thousands of users by the early 1980s, made a total of less than 14,000 users look pathetic, especially when compared with the increasing success of private viewdata networks in the travel industry and teletext. After teletext's initial slow start, because of delays in the supplies of teletext-adapted receivers, the number of users had increased significantly. By 1979, people were using 40,000 sets and by 1982 that number had risen to 350,000.[83] With 60,000 to 70,000 customers buying new televisions every month, this number would continue to increase. During 1978, a report that looked at teletext and viewdata argued that teletext would create the opportunity viewdata needed to become a mass-market online service.[84] If this was going to happen, it had not done so by 1982. The Social Information Providers' Group, which was composed of non-profit, public, and voluntary organisations that provided information to people, was eager to help obtain information about the information needs of consumers, data that would be vital if people were going to adopt Prestel. The Group proposed a project, called Prestel for People, which help to obtain this information. BT supported the venture and the Department of Industry (DoI) provided £65,000 for its operation. Prestel for People placed 40 Prestel terminals in public areas in Greater London.[85] By the time the project ended in early 1983, it was clear that the terminals had only attracted a small

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[81] See "Thomson's Big Viewdata Net Goes Live," *Computing*, 14 October 1982, p. 5 and V. Haszeldine, *Use of Viewdata by the Travel and Tourism Industries – A Survey*, M.Sc. thesis (London: Department of Information Science, City University, 1984), p. 100.
[82] B.J. Witcher, "Videotex in the UK: Problems of Public Service Viewdata and Implications for Publishers," in *Trends in Information Transfer*, P.J. Hills ed. (London: Pinter, 1982), pp. 65-85.
[83] See B.S. Greenberg and C.A. Lin, *Patterns of Teletext Use in the UK* (London: Libbey, 1988), pp. 3-4 and C. McIntyre, "Time to Hand on the Baton," *The Prestel User*, April 1982, p. 67.
[84] On the Mackintosh teletext and viewdata report and Reid's reaction to it see A. Reid, "Future for Viewdata: Teletext and Viewdata," *Telecommunications Policy*, vol. 2, no. 3, 1978, pp. 255-256.
[85] See R. Parry, "Prestel for People Launched," *Computer Weekly*, 25 March 1982, p. 4 and H. Kania, *Prestel for People* (London: Council for Educational Technology, 1983), p. 1-65.

percentage of people who had access to the service. This result was not encouraging and supported the earlier findings of the test service as well as the apathy expressed by the public for Prestel.

Despite the findings of the Prestel for People initiative, BT remained adamant that a mass-market existed for the service. During February 1982, it therefore decided to return its focus to the residential market. BT planned to launch a new facility, called Home Service, which would enable people to access Prestel during off-peak periods at inexpensive rates.[86] BT also decided to meet with the DoI and television manufacturers to see if they could decide on how to emulate the success of teletext in the residential market.[87] To do this, they searched for a ‘killer’ application which could encourage people to adopt the service. Two main possibilities presented themselves: a service for microcomputer users and a home banking service.[88] In addition, electronic mail had potential. In 1983, BT and East Midland Allied Press launched the Micronet 800 Closed User Group service on Prestel for users of Apple, Commodore, and Sinclair microcomputers.[89] Micronet initially contained 30,000 pages and offered users several facilities including news, online games, and software that people could download, known as telesoftware. Micronet did not charge users for viewing most pages, although certain telesoftware pages cost 50 pence to access.[90] Within three months, the service had encouraged 1,000 people to become users and in July 1983, people had accessed the database one million times, the first time an Information Provider on Prestel had done so.[91] The aim with Micronet 800 was to encourage 100,000 people to become Prestel subscribers within three years of

[86] “Prestel Goes Off-peak for Bigger Sales,” *New Scientist*, 11 February 1982, p. 376.
[87] O. Ashcroft, “Fight is on for the Domestic Market,” *Computer Weekly*, 9 June 1983, p. 23.
[88] BT and other organisations also investigated the potential of online shopping applications during the 1990s. Users of Club 403 rejected the service as it was too expensive and Keyline failed to attract investment for the 500,000 terminals it planned to distribute for its separate viewdata network. See *Home Videotex A Blueprint: The Club 403 Research Report* (London: DTI, 1985), pp. 220-221, T.J. Westlake, *The Planning Implications of Interactive Viewdata Systems: A Study of Electronic Home Shopping*, Ph.D. thesis (Cardiff: University of Wales, 1992), pp. 103-123 and M. Jones, “Dial M for Margarine,” *The Guardian*, 7 July 1988, p. 27.
[89] BT, East Midland Allied Press (EMAP), and several other organisations had experimented with services for microcomputer users prior to the launch of Micronet 800. See B. Hickford, *The Micronet Handbook: Micronet, Prestel and Teletext A User’s Guide* (London: Century Communications, 1984), pp. 9-11.
[90] “Prestel’s Telesoftware Gets Micro Database,” *Computer Weekly*, 9 September 1982, p. 1.
[91] See “Micronet Grows,” *The Prestel Directory*, July 1983, p. 67 and “Micronet Million,” *The Prestel Directory*, October 1983, p. 79.

Micronet's launch.[92] The service's initial success was encouraging and helped to confirm BT's confidence in the value of Prestel.

In addition to Micronet, there were two other services which many hoped would help Prestel to attract a critical mass of users.[93] In 1983, the Nottingham Building Society, in association with BT and the Bank of Scotland, launched its telebanking service on Prestel called Homelink. To help encourage customers of the building society to become subscribers, BT and the Nottingham Building Society decided to distribute 100,000 free terminals to any one that wanted to become a user.[94] Both companies would cover the costs of the terminals, expected to be about £50 each. Homelink enabled people to access statements, transfer funds between accounts, and pay bills. The building society predicted that by 1986, 100,000 people would be using Homelink. The other service that people hoped would help Prestel to attract a critical mass of users was electronic mail. During 1980, businesses had expressed an interest in an e-mail service and BT therefore launched Mailbox during 1981. BT charged users 5 pence to send a message. Mailbox attracted interest from many users, and within a couple of years, people had sent approximately 125,000 e-mails.[95] However, this number was not large considering that it took two years to reach this number. Mailbox also had other problems. Users had to compose messages while online which even for short messages could be expensive. For example, depending on the time of day that the user sent the message, it could cost 12 pence to compose and then send an e-mail. In addition, each frame could only contain a limited amount of text and as a user could not scroll down through a message, the system forced them to view the whole e-mail as a series of "electronic postcards".[96]

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[92] B. Sedacca, "The Man Who Wants to Get 100,000 New Users on to Prestel," *Computer Weekly*, 9 June 1983, p. 28.

[93] On critical mass see D. Allen, "New Telecommunications Services: Network Externalities and Critical Mass," *Telecommunications Policy*, vol. 12, no. 3, 1988, pp. 257-271.

[94] See "The Bank In Your Front Room?" *The Prestel Directory*, July 1983, p. 70, *Viewdata in the Financial Sector* (London: DTI, 1984), pp. 6-7, and D. Kennett, "Prestel to Give Free Adaptors for 100,000 More Homes," *Computer Weekly*, 2 September 1982, p. 2.

[95] See "Viewdata Business Users Want Message Service," *Computer Weekly*, 3 July 1980, p. 17, A. Burkitt, "Prestel Users to Get Electronic Mail," *Computing*, 6 August 1981, p. 5, "Prestel Cuts the Cost of Posting," *Computing*, 24 September 1981, p. 1, and S. Heesom and S. Rogers, "Say it with Mailbox," *The Prestel Directory*, July 1983, pp. 74-75.

[96] A. Cawson, et al., *The Shape of Things to Consume: Delivering Information Technology into the Home* (Aldershot: Avebury, 1995), p. 142.

By June 1984, services such as the provision of travel information, Micronet 800, and Mailbox had encouraged 45,000 people to become subscribers of Prestel.[97] Of these, 61 percent were business users and 39 percent consumers. Prestel contained 320,000 frames of information which the network's users accessed on average 14.6 million times a month. If BT had launched Prestel during early 1984, then these statistics might have been impressive. But it had not. By then, BT had been operating its viewdata network for nearly five years without any substantial success in the consumer market. In 1979, the Post Office had predicted that by 1983, three million people would use Prestel and the service would generate £150m in revenues. However, BT was operating at a loss of about £13m a year and the rate of adoption had been very slow.[98] BT continued to hope that this period of slow growth was natural and a necessary prelude to the development of a critical mass for Prestel. Once this occurred, the number of people adopting the service would no doubt substantially increase and this growth would become self-sustaining. However, BT had so far failed to find an application that appealed to millions of people, despite several attempts to generate market demand.[99] Because of this, articles appeared in newspapers with titles such as "Prestel is a failure" and "Does Prestel know where it's going?"[100] These highlighted some of the serious issues that faced British Telecom and its partners and captured the general mood of the period.

In addition to the problems of the cost and quality of information, other reasons existed for Prestel's failure to become a mass-market service. In particular, Prestel competed with several established and new media, such as newspapers, videocassette recorders, and teletext. In 1979, if a potential adopter compared Prestel to a newspaper, then the Post Office's viewdata service appeared to be very expensive.[101] For example, if a user looked at, say, three pages on Prestel during a single session, this would cost them 9 pence. When compared to a newspaper, which in 1978 cost 10

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[97] *Viewdata in Retail and Distribution* (London: DTI, 1984), p. 8.
[98] Brooks, "Prestel Homes in on Viewers," p. 60.
[99] On technology push see W.S. Piper and S. Naghshpour, "Government Technology Transfer: The Effective Use of Both Push and Pull Marketing Strategies," *International Journal of Technology Management*, vol. 12, no. 1, 1996, p. 88.
[100] See B. Sedacca, "'Prestel is a Failure'," *Computer Weekly*, 29 July 1982, p. 1 and Sommer, "Does Prestel Know Where it's Going?" p. 22.
[101] E. Williams, "Strengths and Weaknesses of Prestel," *Computer Communications*, vol. 2, no. 2, 1979, pp. 56-59.

pence, Prestel was clearly more expensive.[102] Prestel also competed with the videocassette recorder for the disposable income of consumers. In 1979, the total sales of VCRs in Europe were 340,000.[103] By late 1981, there were over 800,000 recorders in the UK and the rate of growth continued into 1982.[104] By 1983, 29 percent of households owned or rented a videocassette recorder. Clearly, most people preferred to buy or rent VCRs and videocassettes, than spend money on a commercial online service that they could access using their television. However, demand did exist for an online service via a television: teletext. Two reasons for the success of teletext were price and content. If a person wanted to buy a teletext television in 1979 it cost them £1,000, which was about £200, more than a standard colour television. If a consumer wanted to rent a teletext receiver, this would cost them £5 a month more than a colour set. By 1982, both of these costs had reduced to under £100 and about £1 respectively.[105] This fact encouraged people to buy teletext televisions, either because they wanted to or more likely because they wanted to replace an older receiver. Once a person had acquired a teletext set, accessing the services was free. The second factor that helped to increase the number of teletext users was the content provided by Ceefax and ORACLE. By the mid 1980s, both the BBC and the IBA broadcast about 200 pages per channel, some of the most of popular of which were news, weather, and television guides which many people often accessed on a daily basis. These factors resulted in 2.6 million teletext users by 1984.[106]

4.4 Prestel in Context

4.4.1 The Evolution of International Videotex Networks

Since the early to mid 1970s, one of the objectives of the Post Office's service was to extend Britain's interests in information and communications technologies to other

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[102] Newspapers originally became interested in viewdata because of the threats and opportunities it posed. When neither emerged, newspapers such as the Financial Times withdrew from Prestel.
[103] J. Tydeman and E.J. Kelm, *New Media in Europe: Satellites, Cable, VCRs and Videotex* (London: McGraw-Hill, 1986), p. 159.
[104] E. Sigel, "Conclusions," in *The Future of Videotext*, E. Sigel ed. (London: Kogan Page, 1983), pp. 161-172.
[105] See McIntyre, "Teletext in Britain," p. 43, C. McIntyre, "Broadcast Teletext - Who Says It Isn't Interactive?" *Videotex–Key to the Information Revolution: Videotex 82 International Conference and Exhibition on Videotex, Viewdata and Teletex, New York, June 28-30, 1982* (Middlesex: Online Conferences Ltd, 1982), pp. 1-12, and C. McIntyre, "Teletext in the United Kingdom," in *The Future of Videotext*, E. Sigel ed. (London: Kogan Page, 1983), pp. 113-126.
[106] See Greenberg and Lin, *Patterns of Teletext Use in the UK*, pp. 21-22 and 24 and Tydeman and Kelm, *New Media in Europe*, p. 212.

countries. The Post Office was adamant that it would establish Prestel as the standard for viewdata, both at home and abroad, and do so before its international competitors. To achieve this, the Post Office began to licence or sell its viewdata software and expertise during the mid 1970s, exporting both to several countries, including the Netherlands, Switzerland, and Finland. The British government gave the Post Office its full support for developing Prestel within Europe and in other countries.[107] However, despite these efforts, the Post Office was aware that Prestel was not an inherently complicated system, and this fact could give its international competitors an opportunity to replicate viewdata in other countries. This situation would leave the Post Office with little to export, in terms of hardware, software, and expertise. The Post Office was right to be concerned. During the late 1970s and early 1980s, several countries began to develop similar systems, both in Europe and in other continents.[108] This section will briefly consider two networks: Télétel and Telidon.

One of the earliest countries in Europe to develop a viewdata network was France. During 1975, the French government decided to modernise its telephone network. This project would last for eight years and cost billions of francs a year.[109] To help recover the costs of the investment, the French PTT, the Direction Générale des Télécommunications (DGT), realised it needed to generate more telephone traffic. After considering several possibilities, the government decided to develop a viewdata and electronic directory project. The DGT started to create its viewdata network, Télétel, during the mid 1970s, and by 1977, it was able to demonstrate the system.[110] As the modernisation of the telephone network created new telephone numbers, the hardcopy of the telephone book continually needed updating and was expensive to produce.[111] By distributing free terminals to subscribers which they could use to access an electronic directory, the French government could recover its investment in the terminals and ultimately save money when compared with the printed phone book.

[107] "Govt Backs Viewdata in Europe," p. 1.
[108] See "Standards Delay May Limit Prestel Revenue," *Computer Weekly*, 16 November 1978, p. 5 and H. Bouwman and M. Christoffersen eds., *Relaunching Videotex* (Dordrecht: Kluwer Academic Publishers, 1992).
[109] A.L. Fletcher, "France Enters the Information Age: A Political History of Minitel," *History and Technology*, vol. 18, no. 2, 2002, pp. 103-119.
[110] T.J. Housel and W.H. Davidson, "The Development of Information Services in France: The Case of Public Videotex," *International Journal of Information Management*, vol. 11, no. 1, 1991, pp. 35-54.
[111] W.L. Cats-Baril and T. Jelassi, "The French Videotex System Minitel: A Successful Implementation of a National Information Technology Infrastructure," *MIS Quarterly*, vol. 18, no. 1, 1994, pp. 1-20.

The DGT therefore planned to conduct a trial of the electronic telephone directory starting in July 1980 in the Ile-et-Vilaine département, followed by a trial of Télétel, starting in 1981 in Paris. For the Télétel trial, the DGT selected 2,500 residential users to take part in the experiment and during the next two years, these users accessed 100 services on the network. In general, the participants responded favourably to the new technology and services and the DGT therefore decided to commence distribution of the free Minitel terminals used during the trials. By the end of 1983, 120,000 terminals were in use throughout France. Four years later, 3 million people could access 2,000 services on Télétel. Before this point, no other viewdata network had approached this level of diffusion. The success of Télétel was therefore unprecedented.

Outside Europe, many countries developed viewdata networks, including Canada. During the early 1970s, the Department of Communications began to conduct research into the transmission of images over the PSTN. When the Canadians became aware of Prestel and Télétel during the mid 1970s, the Department of Communications decided to apply what it had learnt about the transmission of images over the telephone network, and develop a Canadian viewdata system. The resulting network would be more sophisticated than its European counterparts, as it would be able to transmit higher quality graphics. By 1977, the Department of Communications had developed a prototype of its viewdata system, Telidon, and it followed this with a demonstration during 1978. In 1979, the Department of Communications decided to invest $Can 10 million dollars to develop Telidon during the next four years. By May 1979, the Department of Communications had encouraged five companies to become Information Providers and it had distributed 150 terminals for use in the field trial. The Department of Communications predicted that the technology would have a significant impact on Canadian society, with job losses within the postal industry and the creation of thousands of new jobs in viewdata companies.[112] The Department of Communications estimated that by the early 1980s, five million people would have subscribed to the Telidon service which would generate $Can 1.25 billion dollars.

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[112] See J.C. Madden, "Videotex in Canada," *Computer Communications*, vol. 3, no. 2, 1980, pp. 58-64, U.A. Tenne-Sens, "Telidon Graphics and Applications," *Displays*, vol. 3, no. 4, 1982, pp. 197-206, J. Feeley, "The Canadian Telidon Field Trials," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), pp. 17-26, and D.R. Raymond, "Why Videotex Is (Still) a Failure," *Canadian Journal of Information Science*, vol. 14, no. 1, 1989, pp. 27-38.

4.4.2 From Diversity to Convergence: A Videotex internet

With the development of viewdata networks throughout the world, the issue of standards emerged. By the end of the 1970s, two main display standards for viewdata existed: alphamosaic and alphageometric.[113] Alphamosaic systems, such as Prestel and Télétel, used cells on-screen to display characters and basic graphics, compared to alphageometric systems, such as Telidon, which used instructions to generate frames of information. The emergence of different display standards interested the Comité Consultatif International Télégraphique et Téléphonique (CCITT). The organisation became involved in viewdata during 1978 when it became clear that it should undertake the standardisation of both teletext and viewdata as an integrated process.[114] The CCITT was interested in establishing standards that would enable countries to set up effective international telecommunications. To achieve this aim, the CCITT established working groups to analyse videotex, the new name it adopted for teletext and viewdata (see Figure 4.3). Some organisations used this word to refer only to viewdata. One of these organisations was the European Conference of Postal and Telecommunications Administrations (CEPT), an organisation composed of European PTT operators. Both the CEPT and CCITT were interested in establishing European and global videotex standards. This impetus came from the PTTs. In particular, as soon as the Post Office had developed a viable system during the late 1970s, it approached the CCITT to propose Prestel as the standard for viewdata. It did this because it believed that its standard was technically competent and extensible. The German PTT, the Deutsche Bundespost, which was developing a Prestel compatible system, agreed that the CCITT should ratify a videotex standard at the earliest opportunity. However, the French were against this idea, as the DGT wanted to establish Télétel as the videotex standard. The French also wanted to reduce the two to three year lead that the General Post Office had with Prestel.[115] The DGT therefore approached the CCITT, proposing its alternative display standard, Antiope, as the standard the CCITT should adopt.

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[113] See Appendix H.

[114] R. Clark, "International Technical Standards," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 71-81.

[115] See F. Lamond, "The Challenge of Viewdata," *Computer Weekly*, 12 January 1978, p. 36, Reid, "Prestel Philosophy and Practice," p. 25, and "Standards Delay May Limit Prestel Revenue," p. 5.

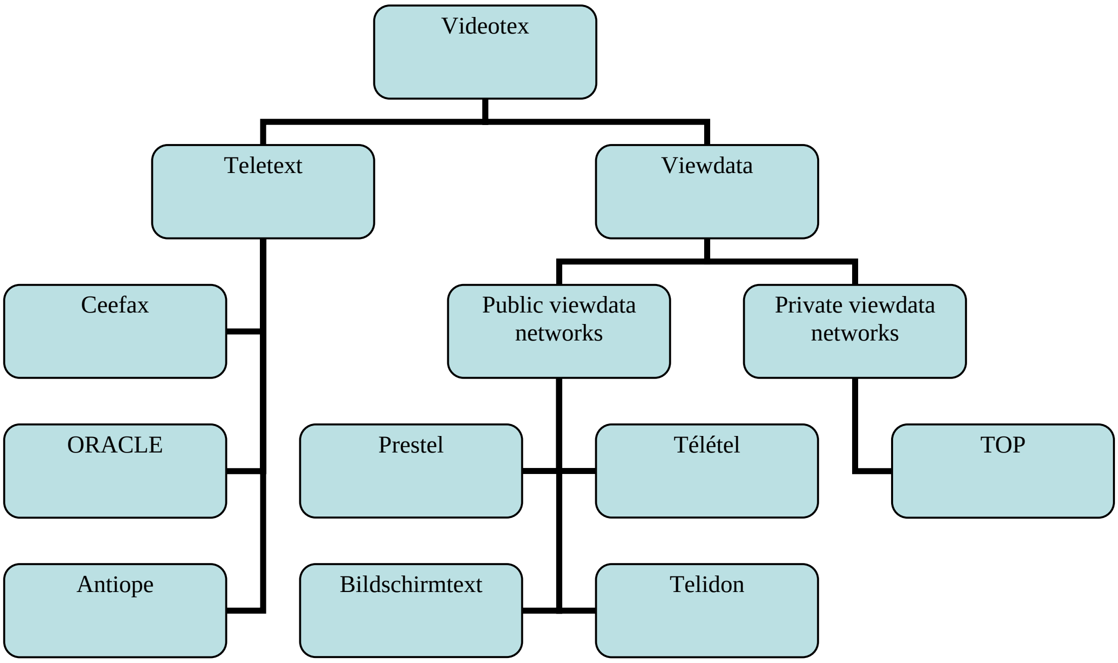

Figure 4.3. A hierarchy of videotex networks.

While the DGT was willing to interconnect its videotex system to other systems, such as telex and facsimile, it was unwilling to compromise when it came to videotex standards. Towards the end of the 1970s, the rivalry between the British and the French continued with both countries either ignoring each other or sometimes maligning the competition.[116] While this rivalry never abated, an event that occurred during 1978 did help to bring both countries closer together to support a common standard. In January 1978, the General Post Office, the Deutsche Bundespost, and the DGT agreed to meet in order to define a possible European videotex standard.[117] The Deutsche Bundespost suggested that a compromise between the British and French standards was achievable. The three organisations agreed on a compromise solution which was compatible with both Prestel and Antiope. Later that year, the CEPT modified the solution and several PTTs supported the resulting proposal.

By 1980, three videotex standards existed: the Prestel compatible alphamosaic, the Antiope alphamosaic, and the alphageometric standard based on Telidon. Since 1978, the CCITT's working groups had being looking at these protocols in an attempt to

[116] See D. Kennett, "French Seek End to Incompatibility," *Computer Weekly*, 12 April 1979, p. 14 and D. Butler, "'France and UK Becoming the Laughing Stock of Videotex World'," *Computer Weekly*, 12 July 1979, p. 9.
[117] B. Marti, "Videotex Developments in France," *Computer Communications*, vol. 2, no. 2, 1979, pp. 60-64.

create a videotex standard. However, they faced a dilemma. Should they recommend one of the protocols or combine one or more of them into a single standard. As the CCITT considered the alternatives, it became clear that the three proponents of the videotex standards were adamant that the CCITT should preserve the presentation protocols of each standard.[118] By encouraging the CCITT to incorporate each of the three standards into a CCITT recommendation, this undermined the aim of producing a unified videotex standard. While the British, French, and Canadians supported the idea of a single videotex standard, this support clearly had its limitations. The interests of the countries involved therefore exercised significant influence over the development of the videotex standard. The actual support for the resulting standard, in terms of CCITT videotex networks, would be crucial for the diffusion of the standard. In response to the protestations of the three member countries, the CCITT proposed a single standard containing the three separate presentation protocols: the two alphamosaic standards, used by Prestel and Télétel, and the alphageometric standard, used by Telidon. While this was, of course, a compromise, the single standard could have prevented continued diversification of the videotex protocols and did provide a basis for organisations to continue videotex standardisation work. In November 1980, the CCITT therefore ratified two standards for interactive videotex, S.100 and F.300, which defined the technical details of videotex and the facilities that networks should provide to users.[119] S.100 approved the use of the videotex protocols proposed by the British, the French, and the Canadians. One of the main purposes of the standard was to enable national videotex operators to interconnect their networks. However, this would not occur so long as the two protocols for alphamosaic networks remained incompatible. CEPT therefore decided to develop a unified alphamosaic protocol for adoption in Europe which was compatible with both S.100 and F.300. It ratified this standard, known as the CEPT European Standard, during 1981.[120] CEPT terminals would be compatible with both Prestel and Antiope and any terminal that adhered to the standard could therefore communicate with remote databases available on

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[118] J.D. Wetherington, "The Story of PLP," *IEEE Journal on Selected Areas in Communications*, vol. 1, no. 2, 1983, pp. 267-277.

[119] See G. Childs, "United Kingdom Videotex Service and the European Unified Videotex Standard," *IEEE Journal on Selected Areas in Communications*, vol. 1, no. 2, 1983, pp. 245-249, W. Staudinger, "Standards for New Telematic Services," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), pp. 389-399, and *ITU-T Recommendation F.300: Videotex Service* (Geneva: ITU-T, 1993).

[120] G. Childs, "The European Videotex Standard," *Computer Communications*, vol. 5, no. 5, 1982, pp. 226-233.

networks in other countries within Europe. It was clear that the CEPT recommendations had the potential to become the unified European standard for videotex terminals.[121] However, for the standard to succeed it would need the support of the national PTTs. If each country replaced its existing terminals with the CEPT equivalents, the European videotex standard would emerge. By 1982, several European countries, including Britain and Germany, had pledged their support, stating that their networks would use the standard. During the same year, the British, German, and Dutch PTTs intended to interconnect their networks in an experiment that would explore the CEPT's new protocol. For this experiment to work and for every European PTT to then interconnect their videotex networks, they would need public packet-switched networks for this purpose. One network in particular seemed particularly suitable for this task: Euronet.[122] This packet-switched network interconnected nine European countries using 9.6 kbps circuits. As Euronet used X.25 for communication purposes and as videotex networks, such as Prestel, also used X.25, the possibilities of interworking between Euronet and the European videotex networks was a possibility.[123] Several options for this interworking emerged. A national videotex network, such as Prestel, could use Euronet to connect its users to a network in mainland Europe, such as Télétel. The CEPT terminals would need to be able to interface and communicate with Euronet and trials confirmed the feasibility of this option. Other possibilities included using videotex terminals to access scientific and technical information stored on Euronet host databases and using Euronet hosts to access information stored within videotex networks. Both of these were possible and in 1981, the Commission of the European Community launched a study to investigate these issues.

As the Europeans began to explore the CEPT's recommendations and the possibility of interconnecting their videotex networks using Euronet, two new videotex standards emerged, one in the US and another in Japan. During 1980, AT&T decided the US needed a videotex standard to satisfy the presumed requirements of both consumers

[121] F.A. Heys, "International Videotex Standards – How Will they Affect the User?" *Viewdata '81: The Second World Conference on Viewdata, Videotex and Teletext, Held in London, October 1981* (Northwood: Online Conferences Ltd, 1981), pp. 417-423.
[122] R. Haber, "Euronet and Videotex: Competitive or Complementary?" *Computer Communications,* vol. 4, no. 3, 1981, pp. 99-105.
[123] See Appendix H.

and Information Providers.[124] AT&T therefore analysed the existing videotex standards, Prestel, Antiope, and Telidon, in order to decide which of the three protocols the corporation should adopt. AT&T chose Telidon as it was more sophisticated and flexible than its British and French counterparts. The alphageometric Presentation Level Protocol (PLP) contained extensions to the Telidon standard which the Department of Communications and ANSI approved.[125] These organisations therefore prepared a draft North American standard for videotex based on PLP which became the North American Presentation Level Protocol Syntax (NAPLPS) standard. Aware of the development of NAPLPS, CEPT decided to investigate if the compatibility between this standard and S.100 and F.300 could be improved.[126] CEPT believed that it could, and it therefore approached AT&T during 1981 to see if this compatibility issue could be resolved. If compatibility between NAPLPS and the CCITT standard could have occurred, this would mean that NAPLPS would have been compatible with the CEPT European Standard, as CEPT had designed this with S.100 and F.300 in mind. While AT&T wanted to achieve compatibility with the CCITT, as this had been one of the objectives of PLP, the Federal Communications Commission (FCC) could not achieve this, as industry set standards in the US, not the government. As AT&T had designed PLP based on the needs of consumers, the US videotex operators, and the Information Providers, this early attempt at compatibility between the North American videotex protocol and the CCITT standard therefore failed. However, another attempt looked as though it might succeed. In 1981, a proposal for a new Presentation Level Protocol emerged.[127] This protocol was similar to NAPLPS but also incorporated fundamental elements of S.100 and the CEPT standard, such as alphamosaic character encoding. The proponents of the new PLP demonstrated the system at the Viewdata 81 conference in London. Using custom-built terminals, they accessed alphamosaic data stored on BT's Prestel computer and data stored on a computer in Zurich containing both alphamosaic and alphageometric frames. Companies could therefore adopt, test, and extend this proposal to form a worldwide videotex standard. However, it did not incorporate another videotex protocol which had emerged in Japan by then. During 1979, the

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[124] Wetherington, "The Story of PLP," pp. 268-269.
[125] C.D. O'Brien and H.G. Bown, "A Perspective on the Development of Videotex in North America," *IEEE Journal on Selected Areas in Communications*, vol. 1, no. 2, 1983, pp. 260-265.
[126] Childs, "The European Videotex Standard," p. 232.
[127] P. Schmid and C. Maurer, "Presentation-Level Protocol for National Videotex Services," *Computer Communications*, vol. 4, no. 6, 1981, pp. 267-272.

Nippon Telephone and Telegraph (NTT) Public Corporation had launched an experimental videotex system called the Character And Pattern Telephone Access Information Network (CAPTAIN).[128] As NTT needed CAPTAIN to transmit and display many different forms of Kanji, the Chinese ideograph, and as the shapes of these symbols were complicated, the technology would be inherently more complicated than other videotex systems such as Prestel. CAPTAIN was an alphaphotographic system which used codes and patterns to transmit and display characters, graphics, and photographs on an end user's terminal. With the launch of CAPTAIN during 1984, NTT decided to approach the CCITT in order for the standards body to ratify its protocol as a videotex standard.

By the mid 1980s, there were three main international videotex standards: CEPT, NAPLPS, and CAPTAIN. Faced with three incompatible protocols, the CCITT decided to combine them into one standard: T1.01.[129] In essence, this combination was nothing more than the original S.100 had been: a single standard which contained three incompatible videotex protocols. However, it did represent a convergence of three protocols to create a standard that could form the basis of a global videotex standard that would enable companies to interconnect national networks.[130] While the standard recognised that every country was entitled to continue using its existing videotex networks, it stated that internetworking between the networks was desirable and should be undertaken using the PSTNs and packet-switched networks available within and between many countries. This internetworking could occur if gateways between the networks existed and so long as the terminals and host computers adopted the F.300 specifications for services. In such a system, the gateways would handle the conversions between the incompatible videotex protocols.[131] As T.101 offered the possibility of interconnecting the national networks, it therefore became, at least on paper, a worldwide videotex standard.

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[128] S. Harashima and T. Kitamura, "Current Status of the CAPTAIN System," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), pp. 113-121.
[129] *ITU-T Recommendation T1.01: International Interworking for Videotex Services* (Geneva: ITU-T, 1994).
[130] Y. Yamazaki, "Standardization Activities in Image Communication for Telematic Services," *Signal Processing: Image Communication*, vol. 1, no. 1, 1989, pp. 55-73.
[131] *ITU-T Recommendation T.564: Gateway Characteristics for Videotex Interworking* (Geneva: ITU-T, 1993).

By the late 1980s, two new efforts at internetworking had emerged. In 1989, Kamifukuoka R&D Laboratories in Japan had demonstrated the feasibility of establishing a connection between CAPTAIN and Prestel and translating Prestel frames into CAPTAIN frames.[132] The quality and performance of the conversions were good, although converting CAPTAIN frames into Prestel frames was not possible at the time. The second effort to internetwork videotex networks was the Videotex Internetworking (VI) set of standards.[133] Originally developed by the CCITT, the CEPT assumed responsibility for the standards during the mid 1980s. By connecting two countries to an X.25 packet-switched network and providing gateways at the interface between the videotex networks within these countries and the X.25 network, it would be possible to use the Videotex Internetworking protocol for communications between incompatible networks. VI would translate between the local protocols used within countries and the VI protocol (see Figure 4.4). By adopting the VI protocol at the gateway between a country's videotex network and the X.25 network, this meant that countries would not need to change the videotex protocols they had adopted. By 1987, trials of VI in Europe were ready to begin. For VI to become a success, the videotex companies would need to co-operate and not seek to control the emerging standard or promote their rival protocols.[134]

By the end of the 1980s, the global videotex community contained several of the elements of the current Internet, albeit with different technology. By the end of the decade, developments such as T.101 provided national PTTs and other organisations with the ability to interconnect their videotex networks. In addition, the emergence of the Videotex Internetwork standards during the late 1980s, offered the global videotex community an opportunity to converge around a single standard to create a global videotex internetwork – a videotex internet.[135]

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[132] T. Miyasato and Y. Hatori, "Inter-Videotex Conversion from Prestel to CAPTAIN," *IEEE Transactions on Communications*, vol. 37, no. 6, 1989, pp. 659-663.

[133] P.F. Shimell, "A Key to Open the Videotex Marketplace," *Telephone Engineer and Management*, 15 April 1987, p. 122.

[134] On architectures see C.R. Morris and C.H. Ferguson, "How Architecture Wins Technology Wars," *Harvard Business Review*, vol. 71, no. 2, 1993, pp. 86-96.

[135] This chapter introduces the term 'videotex internet' to describe a global interconnected network of networks – an internetwork – based on videotex technology. Videotex practitioners and analysts did not use the term 'videotex internet', although the term 'videotex internetworking' was in use towards the end of the 1980s. However, the videotex internet accurately describes the type of network that could have emerged, if users had adopted the technology. On videotex internetworking see Shimell, "A Key to Open the Videotex Marketplace," pp. 118, 122-123, and 127.

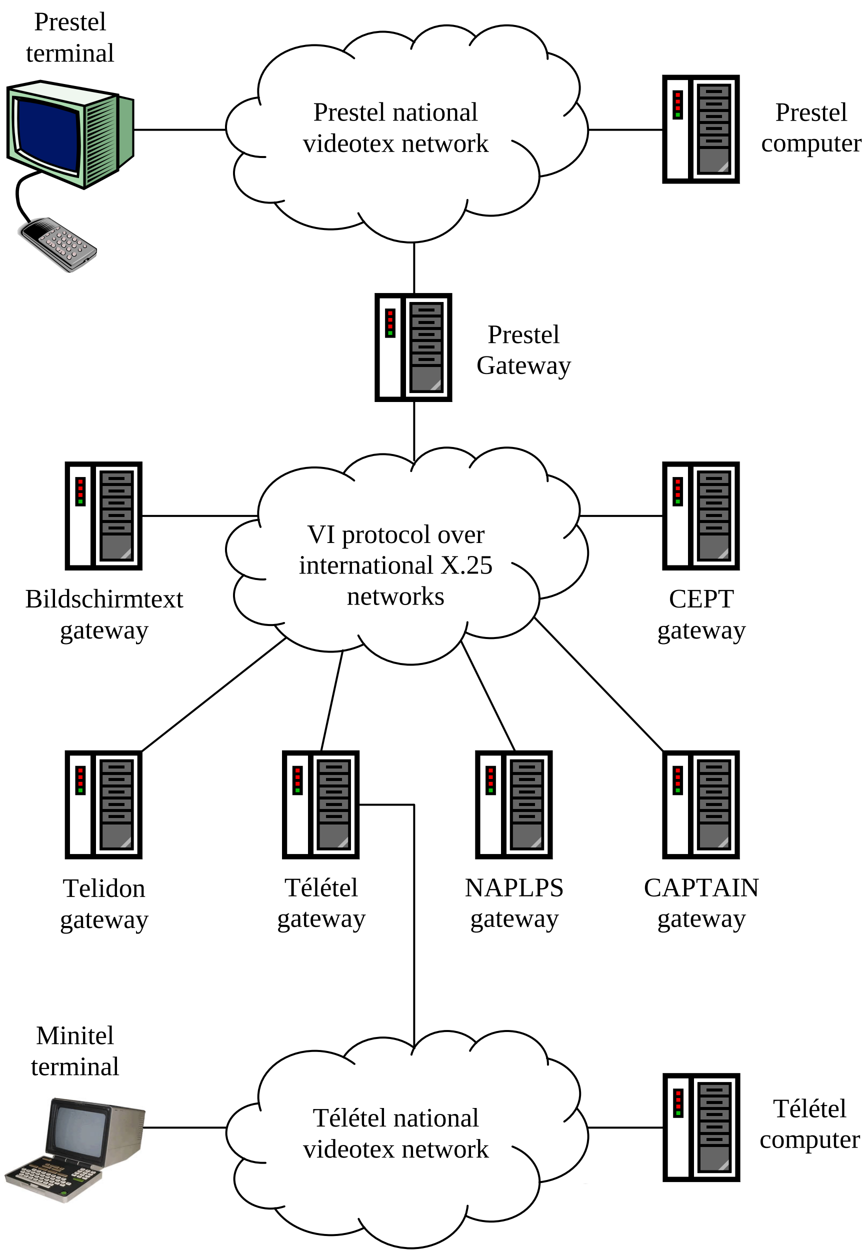

Figure 4.4. An example of the Videotex Internetwork.[136]

If the international videotex community adopted the VI protocol then this would handle the inter-protocol conversions and enable incompatible networks to interconnect with each other.[137]

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[136] The image of the Minitel terminal came from *History of Computing Industrial Era 1980 - 1981*, History of Computing Project, 2005, Available from: http://www.thocp.net/timeline/1980.htm, Accessed on: 13 February 2005.

[137] Users would have to see the value of the videotex internet for it to materialise and become a success. If this happened, the users would converge around the VI protocol and adopt the videotex internet as a solution to their information and communication needs. The users would therefore control the convergence around the videotex internet.

As well as interconnecting public videotex networks, a videotex internet could also interconnect private viewdata networks used by businesses, educational institutions, and governments. In this sense, these private networks would be similar to Local Area Networks. Companies could extend their local videotex networks over larger areas to form Metropolitan Area Networks and Wide Area Networks. Companies could also employ Closed User Groups to provide information and services to a select number of people who could access the CUGs either from within the company or from outside. Closed User Groups were therefore similar to intranets and extranets.

In addition to the infrastructure, there was other ways in which videotex had the potential to become an internet. During the mid to late 1980s, British Telecom operated Prestel as a centralised network of Information Retrieval Centres, each of which contained a replicated copy of the Prestel database. If each IRC within the Prestel network contained its own distinct database containing millions of frames of information, then this would greatly expand the amount of information available on Prestel and, because of the videotex internet, the world as a whole. If every country that developed local and national videotex networks adopted a similar approach using IRCs, then the amount of information available to users would perhaps have started to approach the vast amount of information currently available on the World Wide Web. Of course, one of the reasons why so much information exists on the Web today is because anyone who can use a simple Web editor can create information and then upload this data to a Web server, often for free. Although similar services usually did not exist with videotex networks, the concept of the umbrella IP and sub-IPs helped to increase the amount of information on Prestel. Most who chose to become a sub-IP were usually companies who could afford it. However, by 1985, anyone who had access to Micronet 800 could rent frames of information for 25 pence per frame for a period of six months.[138] To navigate this information space created by companies and individuals, users would need some mechanism. As users of videotex networks used an inverted tree hierarchy to find information, companies could extend this to a global system of menus. In this sense, it would be similar to how Gopher worked. Users

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[138] An umbrella IP would rent hundreds or thousands of pages from BT and then resell these pages at reduced prices to sub IPs. Micronet 800 would charge users 4 pence to edit a frame and people could only have 26 frames. See T. Chapman, "Using An 'Umbrella'," in *Viewdata in Action: A Comparative Study of Prestel*, R. Winsbury ed. (London: McGraw-Hill, 1981), pp. 155-163 and "Micronet 800," *The Prestel Directory*, Edition 3, 1985, p. 89.

would start at their desired homepage and then navigate from there to find information. As the user navigated through the series of menus, the videotex networks would find and display the contents of the menus without the user being necessarily aware that they were navigating around the world through a series of videotex hosts. When the user found the information they wanted they could access this and do so for the price of a local telephone call, as a connection would exist between their terminal and a local Information Retrieval Centre. However, for this scenario to work then the videotex internet would need a competent addressing mechanism which uniquely identified each page on the global network of networks. Videotex had such a scheme, although it does not appear that people explored its ability to cope with many frames on multiple networks. However, during the early 1980s, there were examples of people using the numbers of pages on Prestel in a similar way in which people now use Uniform Resource Locators. For example, in 1981 an article appeared in a Prestel magazine quoting the numbers for several pages on Prestel, such as the National Consumer Council's mainframe, or home page, 33561.[139] Users could also easily access Mailbox by entering page 486.[140] When a user had found a page, he or she could use Prestel to add it to a list of favourite pages, in a similar way in which Web browsers work.[141]

The ability to use the videotex internet to find information would have been one of several applications available to users. The development of electronic mail on Prestel during the early 1980s provided a messaging service that companies could have extended to a global system. Although the nature of a videotex frame was restrictive, the system did have potential particularly when it came to interconnecting it to other communication systems such as national and international telex and e-mail networks. In addition to e-mail, people could have accessed libraries of programs stored on videotex hosts. They could download this telesoftware to their terminals from any

[139] Of course, humans find it hard to remember long numbers, hence the need for a system that translates between numbers and names, which are easier to remember. See Appendix J.

[140] An alternative addressing scheme emerged in the 1990s, which, if implemented, would provide access to videotex networks on the Internet using a videotex URL. BT added the 'Pagemarking' facility to Prestel during 1987. See Appendix H, S.J. Sandringham, "Home Is Where Prestel's Heart Should Be," *The Prestel User*, January 1981, p. 96, S. Rogers, "Have You Got The Message?" *The Prestel Directory*, Edition 4, 1984, p. 89, and P. Tootill, "Hey, Presto!" *Personal Computer World*, January 1987, pp. 204-205.

[141] However, this list of favourite pages was not permanent, as Prestel's Pagemarker facility did not permanently store the information once a user had disconnected from the network. See *Prestel User Guide* (Hemel Hempstead: British Telecom, 1990), p. 16.

host computer connected to the videotex internet. Conducting online shopping and online banking were also possible, as example systems existed. International online stores, such as Amazon.co.uk, could have enhanced these systems to sell products to customers throughout the world. With the use of encryption, online stores could have accepted credit card details from customers. Online banks could also have extended their services to many people and the banks could have adopted the encryption used for online shopping for communications between customers and their computers. All of these applications were possible by the late 1980s and by then, many PTTs and other companies throughout the world were actively working towards what could have become a videotex internet.

4.5 Prestel, Videotex, and the Internet

4.5.1 The Decline of Prestel and Videotex and the Rise of the Internet

While the international videotex community continued its efforts to interconnect networks, British Telecom assessed two of its services, one planned and one in use. During the early 1980s, BT had planned to replace its existing network with a new network (see Figure 4.5). Known as the Prestel Advanced Network and Database Architecture (PANDA), BT decided to create this network for several reasons including the need to install separate computers for registration and billing functions. To prepare for the implementation of PANDA, BT closed 12 Information Retrieval Centres in 1981, leaving 6 centres in London and Birmingham. However, demand for the new network never arose and BT therefore did not develop the network.[142] However, demand for another service, e-mail, was more encouraging. By 1984, users were sending about 71,000 e-mails a month. BT therefore extended Mailbox to become a national service.[143] It also interconnected Prestel to the national and international telex networks, enabling Prestel users to send and receive telexes at a cost of 50 pence a message.[144] In 1987, BT also decided to interconnect its Prestel and Telecom Gold networks, using an X.400 service.

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[142] BT also terminated its plans for Picture Prestel, an alphaphotographic version of its service. See J. Bird, “BT Axes 12 Sites in Prestel Shuffle,” *Computing*, 17 September 1981, p. 1, K. Clarke, “Putting Prestel Right in the Picture,” *The Prestel User*, April 1981, p. 84, and Appendix H.

[143] See “The Art of Communication with Prestel,” *The Prestel Directory*, Edition 3, 1984, pp. 76-77 and “National Mailbox on the Way,” *The Prestel Directory*, April 1984, p. 79.

[144] See “Prestel Launch Telex Link,” *The Prestel Directory*, October 1983, p. 75, “New Telex Service,” *The Prestel Directory*, Edition 4, 1985, p. 71, and “Telex Link Goes International,” *The Prestel Directory*, Edition 2, 1985, p. 73.

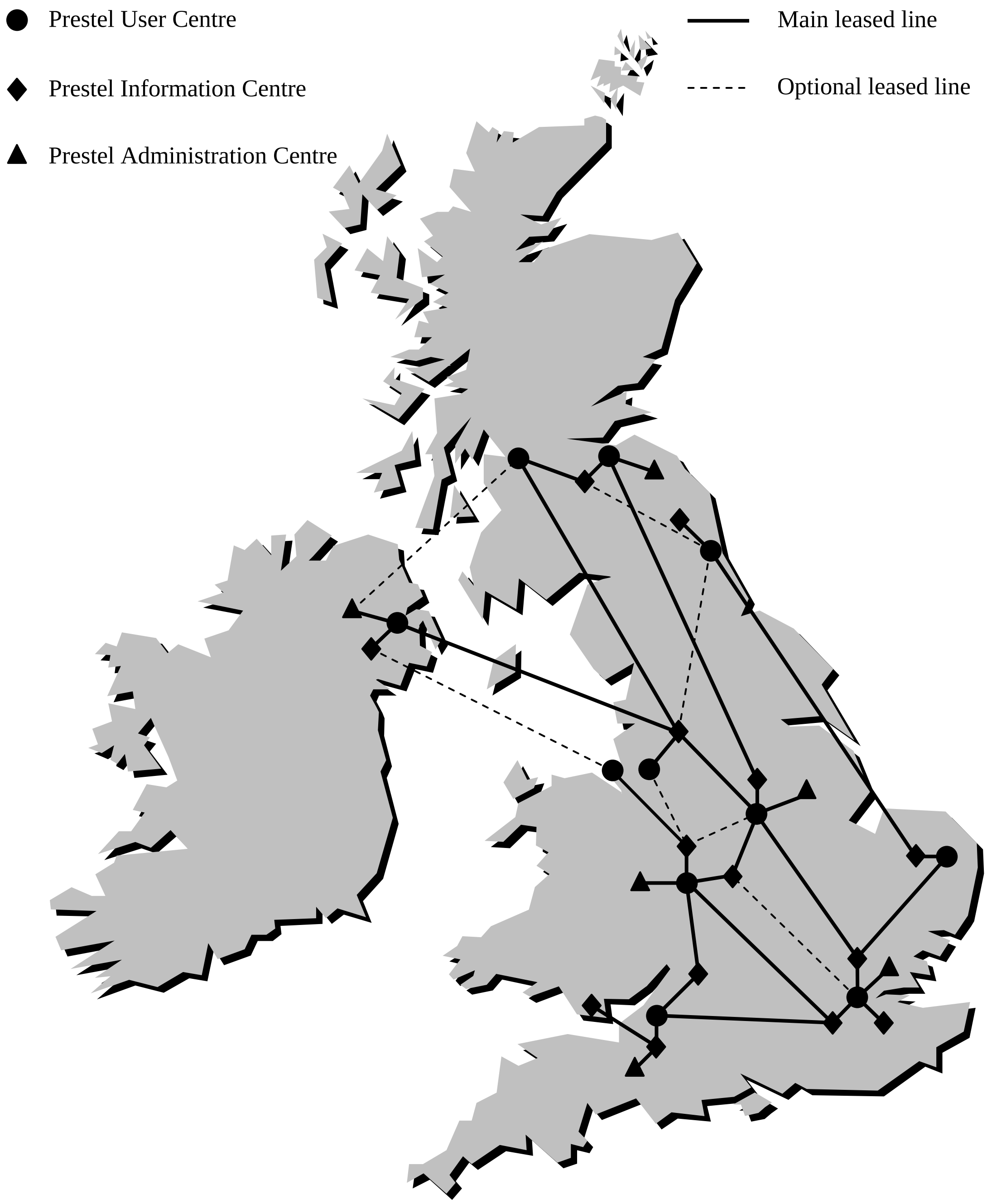

Figure 4.5. An example configuration of PANDA.[145]

Known as Gold 400, this enabled Prestel and Telecom Gold users to send and receive e-mails between the two networks. At this time, BT publicised the security of Prestel, claiming that any e-mail sent by a Prestel subscriber to another user of the videotex

[145] Plans for PANDA included three types of Prestel centre: the Prestel User Centre (PUCs), the Prestel Information Centres (PICs), and the Prestel Administration Centres (PACs). PUCs were analogous to the Information Retrieval Centres, while PACs would contain master copies of the database. The PACs would handle customer registration and billing. See K.E. Clarke and B. Fenn, "The UK Prestel Service: Technical Developments Between March 1980 and March 1981," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), pp. 147-162.

network was confidential.[146] However, an embarrassing event in 1986 proved that Prestel was not as secure as BT claimed it to be.[147] While reviewing a communications program at Micronet 800's office in London, Robert Schifreen, a journalist, had managed to obtain the user account details of a Prestel user. Schifreen later managed to find the ID number and password of a Prestel system editor. These details enabled him to find the user account details for every subscriber, including HRH the Duke of Edinburgh. Schifreen logged on to HRH's account and sent an e-mail. This successful attempt at hacking into the network highlighted how insecure Prestel was under the wrong circumstances. Security on many videotex systems was often disorganized and in an attempt to address this aspect people developed encryption systems.[148]

Stories in the press about hacking did little to help Prestel's image as an attractive online service with mass-market appeal. With only 62,000 subscribers by 1985 and 33,000 additional users three years later, the performance of BT's service was disappointing, especially when compared to BT's original estimates and the 2 million people who had joined Télétel during the same period.[149] Despite becoming a profitable service during 1985, Prestel had cost BT about £30m to develop with

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[146] See "Goodbye Postman Pat!" *Connexions*, September/October 1987, pp. 15-16 and 18 and Heesom and Rogers, "Say it with Mailbox," pp. 74-75.
[147] D. Machin, "Hackers Guilty of Forgery," *Direct Line*, No. 5, 1986, p. 57.
[148] Southwark Crown Court found Schifreen and another hacker guilty of forgery, but the House of Lords later quashed their convictions. In 1983, BT experimented with encryption on Prestel although it never became widespread. See "House of Lords Clears Prestel Hackers," *Computer Fraud & Security Bulletin*, vol. 10, no. 7, 1988, pp. 1-2, P.W. Sanders and V. Varadharajan, "Secure Communications Between Microcomputer Systems," *Computer Communications*, vol. 6, no. 5, 1983, pp. 245-252, and M. Conibear, "Security — The Basis of User Confidence in Financial Services," *Videotex User '86: Proceedings of the Conference held at the Barbican Centre, London, 29-31 January 1986* (Richmond, Surrey: Marathon Videotex, 1986), pp. 53-61.
[149] Despite the problems encountered by Prestel, some companies still believed that a market existed for a public videotex network in the UK. In 1983, Online Viewdata Marketing launched a consumer-oriented public service that offered information about topics such as travel and entertainment. The service never became a success. Four years later, a former Prestel IP, Timefame International, launched the Electronic Public Network for Information & Videotex (Epnitex). Epnitex offered several services and facilities including information retrieval, a more sophisticated electronic mail system, radio paging, Closed User Groups, and private videotex facilities. To access the service, Epnitex charged business customers £300 per annum and £2.40 a week for consumers, with a 5 pence per minute access charge. Although organisations such as the Home Office and British Aerospace became interested in Epnitex, the service never attracted a critical mass of users, and Timefame closed it during 1996. See Young ed., *Videotex and Teletext in the US and UK*, p. 18, P. Tootill, "A Different View," *Personal Computer World*, March 1987, pp. 166-167, "CBN's Guide to Epnitex," *Business News*, July/August 1987, p. 13, S. Mansfield, "Prestel Rival Offers Extras," *The Times*, 20 October 1987, p. 17, and P. Tootill, "Modems and More," *Personal Computer World*, March 1988, pp. 174-175. Additional information from R. Norman, E-mail to D. Rutter, 21 November 2004 and R. Norman, E-mail to D. Rutter, 23 November 2004.

annual operating costs of about £12m. BT needed to do something to increase the number of subscribers and the answer might have come from France.[150] During 1988, BT decided to investigate whether it should distribute subsidised terminals en masse in Britain, as the French had done during the mid 1980s. BT would charge subscribers a rental fee for the terminals and the company believed that if it distributed two million terminals and adjusted its tariff, in time it might be able to establish a profitable service. BT predicted that it could attract between 400,000 and 500,000 users within five years of launching such a service. However, in 1989 BT rejected the idea of setting up the new service, as it considered the seven-year period to recover the investment too long.

Within two years of BT's decision not to re-launch Prestel, it was clear that the service had stagnated. During the late 1980s, the increased number of personal computers that people were buying had prompted BT and other companies to develop software which would enable users to access Prestel using their PC.[151] While this had expanded the number of people who could access Prestel, it did not increase the amount of people who wanted to use a PC to access the service. However, support from computer enthusiasts for using PCs to access Prestel remained quite strong. For example, BT's Micronet 800 Chatlines public conferencing service, which it had launched during 1987, processed 150,000 messages a month.[152] However, by 1991, BT had decided to close Micronet, because of concerns about some of the illicit content on the conferencing service. With the closure of Micronet 800, Prestel lost about 20,000 subscribers. Another closure during 1991 also decreased the number of Prestel users. When the Nottingham Building Society launched Homelink during 1983, it had predicted that within 3 years 100,000 people would become

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[150] See G. Thomas, et al., "The United Kingdom, France and Germany: Setting the Stage," in *Relaunching Videotex,* H. Bouwman and M. Christoffersen eds. (Dordrecht: Kluwer Academic Publishers, 1992), pp. 15-30, M. Berne, "French Lessons: The Minitel Case," in *The Social Shaping of Information Superhighways: European and American Roads to the Information Society,* H. Kubicek, et al. eds. (Frankfurt: Campus Verlag, 1998), pp. 97-116, M. May, "Prestel Puts Itself Into Profit," *The Times*, 5 November 1985, p. 26, and C. Hobbs, *A Comparison of Videotex Strategy in France and the United Kingdom*, M.Phil thesis University College, University of Oxford, 1993), pp. 42-46.
[151] An example is the Dialcom Communicator which people could use to access Prestel and Telecom Gold. See *Dialcom Communicator: Easy Access to Prestel and Telecom Gold* (London: Dialcom, 1989), pp. 1-6.
[152] "Prestel Mailbox: The Message Gets Through," *Connexions*, September/October 1987, pp. 19-21.

subscribers.[153] By 1991, only 5,000 people used Homelink, and the building society therefore closed the service. Several reasons existed for the failure of Homelink including the decision not to distribute free terminals and the apathy from potential adopters.[154] With the closure of Micronet 800 and Homelink, this reduced the number of Prestel subscribers to about 70,000. As approximately 60 percent of these were business customers, BT decided to close Prestel to residential users during 1991.[155] It would also close more Information Retrieval Centres to help reduce the operational costs of the network. For the next three years, business customers could continue to access several services including Prestel Travel, e-mail, and third party databases such as Infocheck.[156] However, by 1994 it was clear that BT could not maintain a profitable service with only 42,000 users. The company therefore decided to sell Prestel to a consortium of companies which planned to re-launch the service.[157] Called NewPrestel, the consortium hoped to market it to companies that needed access to information on an infrequent basis and ultimately become a successful provider of online information. This situation never occurred and by the late 1990s, a Glasgow-based Internet Service Provider had bought the Prestel trademark for use in its Internet service, Prestel On-line.[158]

The failure of British Telecom to develop a mass-market consumer-oriented online service was not an isolated event. By the 1990s, every videotex network except Télétel had been unable to encourage enough potential adopters to become subscribers to make their services successful. Examples include Bildschirmtext, Telidon, Viewtron, and CAPTAIN. When the Deutsche Bundespost launched Bildschirmtext in 1983, it predicted that within three years there would be one million subscribers. However, it took until 1988 for the service to attract 100,000 users. DBP Telekom, the

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[153] P.A. Dover, "Why Home Banking Bombed in Britain," *Journal of Retail Banking*, vol. 15, no. 4, 1993, pp. 30-38.

[154] The decision not to distribute free terminals probably encountered a similar obstacle as BT's plans to supply 200,000 terminals did during 1980, specifically opposition from the television manufacturers.

[155] J. Green-Armytage, "BT Plans to Switch Off Prestel Centres," *Computer Weekly*, 25 July 1991, p. 1.

[156] See *Prestel User Guide* (London: British Telecom, 1991), pp. 1-19 and *Business Information Services* (London: British Telecom, 1993), pp. 1-2.

[157] M. Ward, "Joint Venture Buys Up BT's Prestel Service," *Computing*, 10 March 1994, p. 4.

[158] Demon Internet bought Prestel On-line during 2002 and then closed the service. See *Important News About the Prestel Internet Service,* Demon, 2002, Available from: http://www.dialup-migration.prestel.net, Accessed on: 1 October 2004.

Deutsche Bundespost's successor, re-launched Bildschirmtext during 1992.[159] By the mid 1990s, there were approximately 500,000 business subscribers. Although Bildschirmtext was, by then, the second largest videotex network in the world, it had taken several years to achieve this number of subscribers. Problems also occurred in Canada. In 1978, the Department of Communications had estimated that during the early 1980s five million people would become users of Telidon and this technology would generate $Can 1.25 billion dollars for the companies involved. However, by 1985 the Canadian government had invested $65m and been unable to encourage a substantial number of people to become users.[160] The Department of Communications therefore closed the network in 1985. In the US, a similar situation occurred. After the Viewdata Corporation of America had invested $40m in Viewtron and launched its market trial during 1983, it predicted that within a year 4,500 subscribers would use the service. Despite reducing the cost of accessing Viewtron by 40 percent, the network had only attracted 1,700 users by 1984.[161] In Japan, NTT launched CAPTAIN during 1984 with expectations that three million people would be using terminals to access the videotex network within three years. However, with only 120,000 subscribers by 1992, the Japanese considered the system to be a failure.

With the decline of videotex services throughout the world, the opportunity and motivation to interconnect national networks to create a videotex internet also declined. In reality, the motivation had never really been there. This is not to say that PTTs did not want to interconnect their networks and in the process therefore develop a videotex internet.[162] The opportunities to increase the number of adopters that could, for example, access Prestel were attractive to the national telecommunications operators. Many countries had therefore spent years contributing to the ratification of standards such as S.100, T.101, and VI. However, their support for the standards was

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[159] See P. Purton, "Videotex Struggles to Leave its Stamp on Europe," *Telephony*, vol. 214, no. 26, 1988, pp. 44 and 46 and M.-W. Stoetzer, "New Telecommunication Services: Current Situation and Prospects in Germany," *Telecommunications Policy*, vol. 18, no. 7, 1994, pp. 522-537.

[160] S. Proulx, "The Videotex Industry in Québec: The Difficulties of Mass Marketing Telematics," *Canadian Journal of Communication*, vol. 16, no. 3/4, 1991, pp. 1-5.

[161] Viewtron was typical of the videotex systems developed in the US during the 1980s.

[162] As most users had rejected videotex networks by the early 1990s, the motivations of the PTTs were irrelevant. For the videotex internet to have become a success users would have had to seen the value of this network. If this had happened, they would have probably converged around a standard, such as the VI protocol, and therefore converged around the videotex internet. However, this did not happen. Users did not see the value of using the individual videotex networks and no one could therefore expect them to want to use a videotex internet if one existed.

selfish, unconvincing, and ultimately helped to undermine any chance of success the standards may have had. When the General Post Office approached the CCITT to propose Prestel as the standard for viewdata during the late 1970s, the French were quick to propose Antiope as an alternative. Canada later did the same with Telidon as too did the US with NAPLPS and Japan with CAPTAIN. For each country it became a matter of national pride to establish their system as the videotex standard and therefore prevent them from having to adopt a standard from another country.[163] When this became impossible, protecting and expanding their interests in the international standardisation arena became of paramount importance. The reason for this was mainly that most countries believed that mass-markets would emerge and it was therefore vital that a country represented its interests within internationally agreed standards. The rivalries that existed between the proponents of each videotex standard lasted until videotex declined. Each country, in particular Britain and France, were vociferous when it came to promoting their standards, often at the expense of the other standards.[164] The competition between countries also emerged when the PTTs decided to increase the number of subscribers, not by implementing internationally agreed standards, but by trying to establish their own standards for videotex in the potentially large markets that they believed existed in countries throughout the world. From the early 1980s onwards, several countries including Britain, France, and Germany adopted this approach. Most notable among these were Britain and France. During the late 1970s and 1980, British Telecom, the BBC, and the IBA had tried to establish Prestel and the British teletext standard as the global standards for videotex networks. It was the closest any country came to doing this. BT was the main company to promote British interests abroad and it usually, of course, focused mainly on Prestel. It exported expertise in viewdata to countries such as Hong Kong and sold or licensed its viewdata hardware and software to PTTs such as the Deutsche Bundespost. Initially only a few countries imported the British videotex hardware and software. However, by 1981, 10 countries in Europe used the Prestel videotex standard. By 1982, 15 countries used the British videotex protocol.[165] Of the total

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[163] D.O. Case, "The Social Shaping of Videotex: How Information Services for the Public Have Evolved," *Journal of the American Society for Information Science*, vol. 45, no. 7, 1994, pp. 483-497.
[164] R. Jones, "Where Now for Videotex?" *Data Processing*, vol. 26, no. 6, 1984, pp. 4-6.
[165] See "Viewdata Expertise Exported," *Displays*, vol. 2, no. 3, 1980, p. 107, G.H.L. Childs, "The Situation on Videotex Standards in Europe," *Videotex '81: International Conference & Exhibition, May 20-22, 1981, Toronto, Canada* (Middlesex: Online Conferences Ltd, 1981), p. 385, and R. Hooper, "The British Viewdata and Teletext Standard," *Videotex–key to the information revolution:*

number of videotex terminals in use by then, 98 percent used British standards. France also worked hard to extend its Antiope standard into as many countries as possible. During the 1980s and 1990s, countries such as the US became interested in Télétel. For example, US West wanted to determine if it could replicate the success of Télétel in the US.[166] The US company sold Minitels for a cost of $299 or rented them at rates of between $8 to $12 a month and people could use these terminals to access services, such as Yellow Pages and an electronic telephone directory, which US West charged users 15 to 20 cents a minute to use. However, the service never became popular.

In addition to establishing Prestel and Télétel services in other countries, Britain, France, and other countries also set up international links between several networks. For example, in 1981 BT launched Prestel International. Any country in the world could use this service via PSTNs and packet-switched networks to access over 185,000 pages of information stored on the Prestel computers in Britain.[167] BT planned to establish a Prestel computer in the US during 1981 and follow this with computers in other countries as the demand for Prestel increased. While several countries, such as the US, Australia, and Switzerland expressed an interest in the service, demand never met the expectations set by BT. Another example of international links occurred during 1985. During this year, the DGT, the Deutsche Bundespost, and BT explored the possibility of connecting Télétel to Bildschirmtext and Télétel to Prestel.[168] Such links would have enabled the PTTs to expand the number of potential adopters who could access their networks and allow the users of the videotex systems to access an increased number of services. However, efforts such as these did not materialise and by 1987 although users in Britain and France could access their respective networks, they had to use the PSTN for this task which was expensive.[169] Although these attempts at international communications did create

Videotex 82 International Conference and Exhibition on Videotex, Viewdata and Teletex, New York, June 28-30, 1982 (Middlesex: Online Conferences Ltd, 1982), pp. 413-421.
[166] R. Lever, "French Videotex Crosses the Atlantic," *Europe*, December 1993/January 1994, pp. 14-15.
[167] See "Prestel Goes International," *Displays*, vol. 2, no. 5, 1981, p. 222 and P. Fisher and M. Hayman, "International Prestel to Merge with UK," *Computer Weekly*, 2 July 1981, p. 1.
[168] F.V. Bornstaedt, "Global Developments for Videotex: A Breakdown of Public and Private Videotex Services in Europe, USA and Japan," *Data Processing*, vol. 27, no. 8, 1985, pp. 20-24.
[169] D. Morris, *Prestel and Teletel: Entente Visuelle?* M.A. thesis (Loughborough: Department of Library and Information Studies, Loughborough University of Technology, 1987), p. 45.

traffic on the PSTNs, the total amount of videotex traffic generated between countries during the 1980s never became significant.

As the traffic declined on videotex networks throughout the world, traffic on the Internet started to increase. During the 1980s, the number of computers that could access the Internet increased from 2,000 in 1985 to 159,000 by 1989.[170] During this decade only academic users could access the network. Anyone who therefore wanted to use information and communication systems therefore had to consider alternatives including videotex networks such as Prestel. BT's network had used a combination of open and proprietary standards: X.25, for the three lower layers of the Open Systems Interconnection seven-layer reference model; a proprietary protocol, the Prestel standard, for the presentation layer of the model; and applications such as e-mail running on top of this within the application layer.[171] These two standards therefore co-existed to form an online network in a similar way in which the Joint Network Team had used X.25 with the Coloured Books to create the Joint Academic Network. As people started to converge around the open Internet Protocol suite during the early to mid 1990s, the popularity of X.25 and the use of proprietary higher-layer protocols, such as the Coloured Books, started to decline. By the late 1990s, most videotex networks had disappeared and while the convergence around TCP/IP had not directly affected the decline of networks such as Prestel, the Internet had assumed many of the applications provided by videotex networks, such as FTP, e-mail, information retrieval, online shopping, and online banking. As BT had sold Prestel during 1994 and as the Internet soon became very popular, it is likely that the Internet probably attracted a large number of Prestel's 42,000 business customers. In addition, of the 28,000 residential subscribers who used Prestel in 1991, it is probable that many of these also became Internet users during the 1990s, contributing to the more than 26 million people who used the Internet by the end of 1995.[172] The former users of Prestel and other videotex networks therefore helped to contribute to the speed and scale of convergence around the Internet Protocol suite.

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[170] J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), p. 186.
[171] See Appendix H.
[172] *Nua Internet How Many Online*, Nua, 2003, Available from: http://www.nua.ie/surveys/how_many_online/world.html, Accessed on: 13 May 2004.

4.5.2 Survival in an Internet world: Teletext, TOP, and Télétel

By the early 1990s, it was clear that most videotex networks had not attracted many subscribers. Throughout the 1980s and into the 1990s, critics wrote about networks such as Prestel and derided their low number of users, the losses their operators had sustained, and problems with the technology. Videotex was clearly a failure, one that was comparable to AT&T's Picturephone. However, the success or failure of videotex was not black and white. To use the word 'failure' as a general term when describing videotex networks is therefore inappropriate. In reality, several videotex networks both failed and succeeded. An analyst therefore has some flexibility in interpreting the success and failure of the videotex technology.[173] To address the issue of failure first, this is a grey area. For example, it is clear that if people continued to adopt Prestel and did so in large numbers, there would come a point when this rate of adoption would become self-sustaining, creating a critical mass of users. However, the number of users required to create this critical mass was nebulous and therefore open to interpretation. Clearly, if Prestel had become a mass-market service, then people would probably have regarded it as a successful network. However, it was unclear as to how many users it would take to develop such a service. As Prestel had only 95,000 users by 1988, BT's efforts to create a mass-market network had clearly not succeeded. When the losses sustained by BT are also considered, it is reasonable to conclude that Prestel was a failure, but only a failure in these contexts. Other aspects of Prestel and competing videotex networks were successful. For example, although Prestel and most videotex services did not survive, they did anticipate the emergence of the Internet. They introduced thousands of people to the concept of online information and communications services. In particular, people experienced e-mail, online shopping, and online banking for the first time on videotex networks in Britain and in other countries such as Germany. Videotex therefore helped to influence many peoples' perception of what a computer network was and what it could do for them.[174] In a way, it therefore prepared them for the emergence of the Internet as a consumer

[173] On interpretive flexibility in relation to technological success and failure see G. Gooday, "Re-writing the 'Book of Blots': Critical Reflections on Histories of Technological 'Failure'," *History and Technology*, vol. 14, 1998, pp. 265-291.

[174] A similar situation occurred with the National New Technology Telescope (NNTT) in Arizona during the 1980s. Although considered a failure, its influence over the design and construction of telescopes was important. See W.P. McCray, "What Makes a Failure? Designing a New National Telescope, 1975–1984," *Technology and Culture*, vol. 42, no. 2, 2001, pp. 265-291.

and business resource during the 1990s. In addition, the utility of several videotex networks for their subscribers was significant. For example, in 1987, the Swiss PTT established a videotex network in Switzerland.[175] Within seven years, it had attracted only 95,000 subscribers which was too small a number to operate a successful service. As the network had a limited number of users with an operator that was losing money, it was similar to Prestel and an analyst might fairly conclude that the network had failed by the mid 1990s. However, this ignores the fact that the Swiss service provided banks with an opportunity to modernise their systems. In particular, by providing customers with access to their accounts using videotex, this transferred some of the work involved in payment processing from the banks to their customers, with obvious financial implications. Videotex also enabled the Swiss banks to obtain valuable experience with network technology and online banking, experience that they transferred to Internet banking when they launched these services during the 1990s.

The success of an application on the Swiss videotex system also occurred on three other videotex services and networks: teletext, TOP, and Télétel. However, by the late 1990s, all of these networks had to confront the same challenge: the Internet and the implications raised for their systems by the dominance of this network. By 1991, there were 50 million teletext televisions in over 40 countries.[176] The most successful services were Ceefax and ORACLE's replacement Teletext.[177] By 1996, over 33 million people in Britain could access teletext, of which 18 million did so every week.[178] However, with the closure of services such as Channel Five's teletext service and the increasing popularity of the Web, with its millions of hypermedia-based pages, the future of teletext looked uncertain. While it was no doubt true that the Web would replace teletext, corporations such as the BBC decided to adapt their teletext

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[175] B. Bonhage and K. Girschik, *From Technology to Services: Videotex in Banking and Retailing*, European Business History Association, 2004, Available from: http://www.econ.upf.edu/ebha2004/papers/6C2.pdf, Accessed on: 19 August 2004.

[176] See R. Dratva, "WWW-based Home Banking Services in Switzerland: A Case Study," *Computer Networks and ISDN Systems*, vol. 28, no. 1-2, 1995, pp. 199-208, B. Fox, *Juggling Memories Bring Teletext to Chinese Screens*, New Scientist, 1991, Available from: http://archive.newscientist.com/archive.jsp?id=17943600, Accessed on: 15 January 2001, and L.R. Graziplene, *Teletext: Its Promise and Demise* (Bethlehem, PA: Lehigh University Press, 2000).

[177] The Teletext service replaced ORACLE during 1993.

[178] T. Standage, *Networks that Run the World*, Electronic Telegraph, 1996, Available from: http://www.telegraph.co.uk/et?ac=000977395300781&rtmo=gjgGZgru&atmo=9999999, Accessed on: 16 December 2000.

systems to co-exist with the Internet, until this happened. The BBC therefore created a single department, BBC News Interactive, to create content for several platforms including Ceefax, the Web, and mobile phones.[179] By integrating teletext into its new Web-based department, the BBC helped to extend the life of Ceefax, until analogue television transmissions cease at the end of 2012.[180]

The Internet also affected Thomson Holidays' TOP service. By 1986, travel information on Prestel had become the most successful service on the network. People could use Prestel to search for flight arrival and departure information, look at holidays including prices, and communicate with travel companies. In addition, travel agents could use Prestel to establish connections to the computers of tour operators through gateways in order to make reservations for holidays. Travel agents could also use this facility to book flights directly with airlines. These facilities had encouraged 5,400 travel agents to become users of Prestel by 1986 which meant that 90% of British travel agents used BT's national videotex network. By the late 1980s, most tour operators had established their own private viewdata networks, the most successful of which was Thomson Holidays' system. When the company established the Thomson Open-line Programme service during October 1983, it had connected 3,000 travel agents to TRACS by the end of the month. By 1984, over 4,000 travel agents used TOP which accounted for nearly 80 percent of the agents with whom Thomson traded.[181] TOP enabled the company to book 95 percent of the holidays it offered to its customers and by 1986, the demand for these holidays from the travel agents' 12,000 terminals generated 450,000 calls every week, with 25 transactions per second. The system provided 5,000 frames of information and could support over

[179] P. Brannan, Interview by D. Rutter, 5 November 2004.

[180] The Office of Communications (Ofcom) requires that all broadcasters that hold Digital Replacement Licences cease analogue television broadcasts by 31 December 2012. See *Planning Options for Digital Switchover*, Ofcom, 2005, Available from: http://www.ofcom.org.uk/consult/condocs/pods1/main/pods.pdf, Accessed on: 8 October 2005.

[181] By the late 1980s, private viewdata systems, including travel services, had become quite popular. For example, over 400 companies had established systems, including 50 private viewdata services within local authorities. See *Viewdata in Travel and Hotels* (London: DTI, 1987), "Travel with Prestel," *The Prestel Directory*, Edition 1, 1986, pp. 54-56, N. Jagger, *Prestel's Alter Egos: The Diffusion of Private Videotex Systems in the UK* (Brighton: Science Policy Research Unit, University of Sussex, 1989), pp. 1-28, *Directory of Local Government Private Viewdata Systems* (London: LASER, 1990), and Detjejaruwat, *Information Technology and Organisation Structure*, pp. 288 and 294.

2,500 concurrent users.[182] By 1986, TOP provided 83 percent of Thomson's business, saving them £28m in administrative costs each year. TOP was therefore a very successful private viewdata network and this success continued throughout the 1990s. However, by the end of the decade, the ageing viewdata technology together with the success of the Internet presented Thomson with a problem. Throughout the 1980s and into the 1990s, videotex had enabled Thomson to solve a specific set of problems, particularly how to interconnect thousands of travel agents to TRACS in order for the agents to make direct bookings and therefore create an efficient and cost-effective reservation system. With the popularity of the Internet during the late 1990s, this could have encouraged travel agents to demand access to TRACS via a Web-based version of TOP or a similar system.[183] If other tour operators adopted the Internet for reservations, the creation of this new business may have undermined Thomson's market leading position in the travel industry. In 1998, Thomson therefore decided to develop a new IP-based solution for its travel business which would replace TOP and enable travel agents to use the Internet to book holidays.[184]

The increasing popularity of the Internet also affected Télétel. In 1987, there were 3 million Minitels connected to the network and by 1992, this number had increased to over 6 million.[185] With a 50 percent increase in the number of people using Télétel, the value of belonging to the network had significantly increased in a period of five years. This value continued to attract potential adopters to the service. As well as the large user community, the number and range of service available encouraged people to acquire Minitels. By 1992, people could access over 14,000 services such as the

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182 P. Shimell, "Development in Public and Private Videotex Networking," *Videotex User '86: Proceedings of the Conference held at the Barbican Centre, London, 29-31 January 1986* (Richmond, Surrey: Marathon Videotex, 1986), pp. 19-37. See also Jagger, *Prestel's Alter Egos*, p. 13. Additional information from N. Tagg, E-mail to D. Rutter, 19 June 2001.

183 On technological paradigms and trajectories see G. Dosi, "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change," *Research Policy*, vol. 11, no. 3, 1982, pp. 147-162. On disruptive technologies see J.L. Bower and C.M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review*, vol. 73, no. 1, 1995, p. 45.

184 Other travel companies, such as Thomas Cook, chose to do the same. In 2001, Thomas Cook decided to migrate away from its videotex network towards a Web-based solution for holiday bookings. See G. Black, *Thomson Claims Net First*, Computer Weekly, 1998, Available from: http://www.findarticles.com/p/articles/mi_m0COW/is_1998_August_13/ai_21049504, Accessed on: 30 July 2001 and A. Adshead, *Top Travel Firms Adopt IP-based Booking System*, Computer Weekly, 2000, Available from: http://www.findarticles.com/p/articles/mi_m0COW/is_2000_July_27/ai_63857013, Accessed on: 30 July 2001.

185 Cats-Baril and Jelassi, "The French Videotex System Minitel," p. 5.

electronic directory, e-mail, online shopping and banking, hotel reservations, online newspapers, and bulletin boards. French citizens spent 23 million hours a year accessing the electronic directory and they could do so at home or using Minitels installed in public places.[186] With millions of users and thousands of services, by the early 1990s, Télétel had become the most successful videotex network.[187] Many analysts postulated the reasons for this success, including millions of free or subsidised Minitels, a 'killer' application in the form of the electronic directory, substantial and consistent investment from the DGT's successor, France Télécom, user-friendly technology, and thousands of services that people wanted to use.[188]

Despite the success of Télétel, France Télécom faced two problems. By 1991, the government had invested 60 billion Francs in the network.[189] Although a study predicted that Télétel would become profitable by the year 2000, several assumptions in the study had not occurred by 1994, and therefore undermined confidence in this prediction. The second problem was the Internet. In 1996, Internet access in France was low, especially when compared with the 14 million users using 6 million Minitels to connect to Télétel.[190] However, the Internet could undermine the success of the network if the French government did not understand the potential threat the Internet posed to its videotex network.[191] It did and by 1998, it had announced that it considered that the Internet, and not Télétel, would become the dominant network of the future in France. It therefore committed $163m to establish new circuits for

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[186] See W. Conhaim, "French Videotex: Reaching Out for New Markets," *Information Today*, January 1991, pp. 28 and 30, Housel and Davidson, "The Development of Information Services in France," pp. 35-54 and *France's Experience with the Minitel: Lessons for Electronic Commerce Over the Internet*, OECD, 1998, Available from: http://appli1.oecd.org/olis/1997doc.nsf/43bb6130e5e86e5fc12569fa005d004c/a8093b855bd4ea32802566ad0056749d/$FILE/10E87215.ENG, Accessed on: 14 December 2000.

[187] For an analysis of Télétel's success see Hobbs, *A Comparison of Videotex Strategy*, pp. 67-80 and Berne, "French Lessons," pp. 105-106.

[188] The Direction Générale des Télécommunications became France Télécom in 1988.

[189] G. Poirot, "Minitel: Oui! Multimedia: Non!" *Communications International*, vol. 22, no. 7, 1995, pp. 23-24.

[190] D. Lavin, *France Telecom Set to Sign on Internet in Controversial Plan - Phone Company is Beefing up Data Network but Move Could Threaten Minitel*, Wall Street Journal, 1995, Available from: http://proquest.umi.com/pqdweb?did=23871952, Accessed on: 17 December 2004.

[191] Since 1983, the DGT had incrementally improved Télétel in response to its users. With the emergence of the Internet, Télétel's users might begin to value attributes of the Internet, in particular the Web, which the videotex network could not satisfy. To survive, the DGT therefore needed to interconnect its network with the Internet. On incremental innovations, competitive shifts, and radical technological innovations see R.S. Rosenbloom and C.M. Christensen, "Technological Discontinuities, Organizational Capabilities, and Strategic Commitments," *Industrial and Corporate Change*, vol. 3, no. 3, 1994, pp. 655-685.

Internet access. However, this caused a problem for France Télécom. With only about 3 percent of the population using the Internet, substantial support from Télétel users for the videotex network, and vociferous opposition from companies that supplied information on the service, the popularity of the videotex system might impede the diffusion of the Internet throughout France.[192] France Télécom needed to decide how Télétel should co-exist with the Internet. One of the reasons for Télétel's success had been the Minitels. However, by the mid 1990s, this success inhibited France Télécom's planned adaptation strategy which involved interconnecting Télétel with the Internet.[193] Télétel was an obsolete technology which transmitted and displayed non-ASCII formatted frames of information with limited graphics. This technology was therefore incompatible with the ASCII text and high-resolution graphics available on the Web. These limitations meant that the 6 million Minitels could not access the Web and read full-screen Internet e-mails. Ideally, the French PTT would have been able to reuse components of its videotex architecture as part of its adaptation strategy.[194] However, this was not possible and so France Télécom developed a new Minitel that could access both Télétel and the Internet.[195] However, as this terminal cost $500, this no doubt deterred many Télétel users from upgrading their Minitels. The old terminals would therefore remain and France Télécom would have to adjust its adaptation strategy. Ideally, millions of French citizens would use their personal computers to access Télétel using software provided by the French PTT. During the early 1990s, this had happened in Germany, where the PC became the preferred terminal for accessing Bildschirmtext. At the time, German citizens and companies bought PCs for applications such as word processing and to access the German network. Their decisions to buy these computers therefore had nothing to do with the Internet. However, this advance in the capabilities of most terminals enabled DBP Telekom to adapt Bildschirmtext incrementally to the Internet during the late

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[192] For example, most of the Société Nationale des Chemins de fer Français' (SNCFs') telebooking custom for train tickets came from Minitels, and the Internet therefore represented a threat to this organisation's business. See K.A. Strassel, *Gallic Passion for Minitel Thwarts L'Internet in France*, Wall Street Journal, 1998, Available from: http://0-proquest.umi.com.pugwash.lib.warwick.ac.uk/pqdweb?index=7&did=000000027812705&SrchMode=1&sid=3&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1103211761&clientId=9678, Accessed on: 16 December 2004.

[193] On adapters see C. Shapiro and H.R. Varian, "The Art of Standards Wars," *California Management Review*, vol. 41, no. 2, 1999, pp. 8-32.

[194] S. Greenstein, "Industrial Economics and Strategy: Computing Platforms," *IEEE Micro*, vol. 18, no. 3, 1998, p. 47.

[195] Strassel, *Gallic Passion for Minitel*.

1990s.[196] As this advance was not available to France Télécom, it therefore established two internetwork connections. In 2000, the company set up I-Minitel which enabled Internet users to access the Télétel network using a Minitel emulator (see Figure 4.6).[197] During the following year, France Télécom set up Et Hop Minitel! which allowed Télétel users to access Web sites, with their Minitels displaying the information as text. Efforts such as these enable Télétel to co-exist with the Internet and will extend the life of the videotex network until such a time as France Télécom decides to close it. When this happens, Télétel will join teletext and TOP as one of the last videotex services to end. With the disappearance of technologies such as videotex, this will help to consolidate TCP/IP as the standard used on consumer and business-oriented computer networks.

[196] This trait was a pre-adaptive advance, as the original diffusion of PCs was unconnected with the Internet, but later gained adaptive value when DBP Telekom needed to adapt Bildschirmtext to the Internet. The concept of pre-adaptation comes from evolution. See V. Schneider, "Evolution in Cyberspace: The Adaptation of National Videotext Systems to the Internet," *Information Society*, vol. 16, no. 4, 2000, pp. 319-328 and R. Dawkins, *The Ancestor's Tale: A Pilgrimage to the Dawn of Life* (London: Weidenfeld & Nicolson, 2004), pp. 82-83.
[197] M. Selignan, *France's Precursor to the Internet Lives On: '80s-Vintage Minitel Network Upgraded to 'Complement' the Web*, Washington Post, 2003, Available from: http://www.washingtonpost.com/ac2/wp-dyn?pagename=article&contentId=A61058-2003Sep24&notFound=true, Accessed on: 6 November 2004.

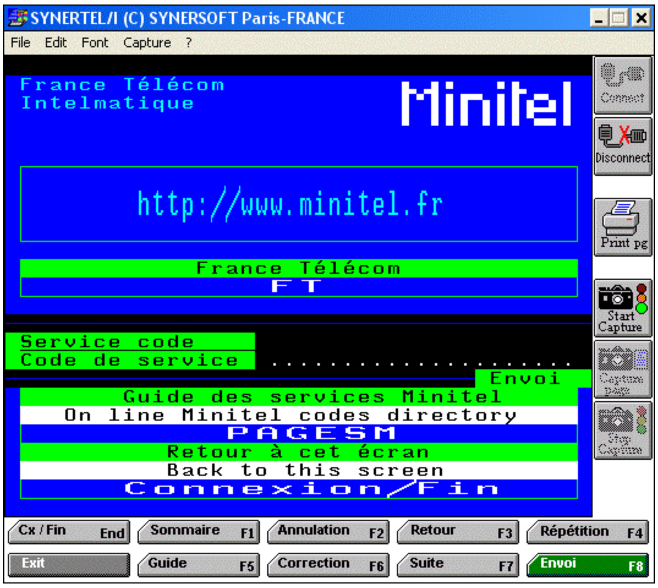

Figure 4.6. Accessing Télétel over the Internet using a Minitel emulator.[198]

[198] The emulator is available from http://www.minitelfr.com. See Appendix H.

5. Getting the Message: Public Electronic Mail Networks

5.1 Introduction

The symbiosis between computers and communications began during the 1960s.[1] During the previous decade, large computers such as the IBM 1401 had processed work in batches, with the machine executing one job at a time for users. This situation changed in the 1960s, with the invention of time-sharing systems. These new computers enabled more than one person to use a machine at the same time and because the computers were quite fast this enabled them to switch between users. From each user's point of view, it therefore seemed that he or she had exclusive access to the computer.[2] With multiple usage, the issue of communication between people became of interest. By enabling users to leave messages for each other on a central time-sharing system, this would allow people to communicate with each other. The first computer to develop this concept into a real electronic messaging facility was the Compatible Time-Sharing System (CTSS) at MIT during the early 1960s.[3] Computer scientists developed a program called Mailbox which enabled people to deposit short messages for other users into files stored on the computer. By the end of the 1960s, most time-sharing systems had similar messaging facilities.[4] However, because communications only existed between users of single machines, this limited the utility of these systems. What people needed was a system that could exchange messages between computers. The Advanced Research Projects Agency's network (ARPANET) did not provide such a facility because the agency saw the purpose of the network as providing remote login and file transfer abilities, not communications.[5]

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[1] Before the invention of the electronic digital computer, people had developed several communication systems that could transmit information over distances. These included the telegraph, the telephone, the facsimile machine, and the telex. Computer communications would later assume many of the responsibilities of these devices, as the fields of computing and communications began to converge from the 1960s onwards. See L. Solymar, *Getting the Message: A History of Communications* (Oxford: Oxford University Press, 1999) and T. Standage, *The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's Online Pioneers* (London: Phoenix, 1999).

[2] A.L. Norberg and J.E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore: Johns Hopkins University Press, 1996), pp. 68-118.

[3] K. Hafner and M. Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon & Schuster, 1996), p. 190.

[4] For example, the System Development Corporation's (SDC's) Time-Sharing System had a Dial command that was similar to the CTSS's Mailbox program. See H. Sackman, *Computers, System Science, and Evolving Society: The Challenge of Man-machine Digital Systems* (New York: Wiley, 1967), p. 77.

[5] J. Abbate, *From ARPANET to Internet: A History of ARPA-Sponsored Computer Networks, 1966-1988*, Ph.D. thesis (Pennsylvania: University of Pennsylvania, 1994), p. 82.

However, in 1971 Ray Tomlinson, an engineer at Bolt, Beranek and Newman (BBN), decided to implement such a system. Tomlinson had written two electronic messaging programs, SNDMSG and READMAIL, which ran on time-sharing systems throughout the ARPANET.[6] By combining these programs with a file transfer facility, CPYNET, he was able to send messages between two machines in his office. After deciding on an addressing format, Tomlinson sent an electronic mail to his group, announcing the new facility.

With the implementation of electronic mail on the ARPANET, the concept began to diffuse throughout other networks, such as SRCnet, Prestel, and CompuServe.[7] During the early 1980s, new networks emerged, whose main purpose was communication. These included Dialcom, MCI Mail, and Telemail in the US and COMET, Telecom Gold, and Cable & Wireless Easylink in the UK.[8] This chapter will focus on two of the largest British networks, Telecom Gold and Cable & Wireless Easylink. It will explore the problem of interconnectivity, look at how companies could have converged around the international standard, X.400, to form a global interconnected e-mail network, and explain why this did not occur. It will also discuss why the proprietary networks did not succeed, and what affect the Internet had on the world of electronic mail.

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[6] See J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), pp. 106-110, *The First Email*, BBN, 2005, Available from: http://www.bbn.com/Historical_Highlights/?name=Email.html&search=email, Accessed on: 16 March 2005, and *The @ Sign*, BBN, 2005, Available from: http://www.bbn.com/Historical_Highlights/?name=Email.html&search=email, Accessed on: 16 March 2005.

[7] Electronic mail was an innovation because the potential adopters on the ARPANET and other computer networks perceived the idea as being something new, as distinct from electronic messaging. During the 1970s, this innovation diffused throughout the world using different channels, such as word of mouth and articles in publications. On the concepts of innovation and diffusion see *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995), pp. 5-7 and 11.

[8] Founded in 1968, MCI became one of the largest providers of telecommunications services in the US during the 1980s. The company launched MCI Mail during 1983. Two years later, people in 43 countries could access the service. By 1988, there were 90,000 subscribers of MCI Mail. On the origin of MCI Mail see V. Cerf, *Interview by David Hochfelder, Reston, Virginia, 17 May 1999*, IEEE History Center, 1999, Available from: http://www.ieee.org/organizations/history_center/oral_histories/transcripts/cerf.html, Accessed on: 3 May 2005. See also W. Rash, Jr., “E-Mail for the Masses,” *Byte*, February 1985, pp. 317-321 and A. Brodsky, “Online Services: A Buyer’s Guide,” *Link-Up*, May/June 1988, pp. 14-15.

5.2 Early Electronic Mail Networks

During the 1970s and early 1980s, several companies established e-mail networks in the UK which companies could either deploy internally or access publicly.[9] One of the first companies to launch a public electronic e-mail network was British Leyland Systems (BL Systems) during 1981. Using software supplied from the Computer Corporation of America (CCA), subscribers could use teletypes, word processors, and PCs to connect to the COMET service provided by the central PDP-11 in Redditch. Having logged on to the e-mail system, users could then send and receive e-mails to other users of COMET who were located in the UK, the US, and in other countries that had licences such as Switzerland, Italy, and Australia. As well as establishing a public service, BL Systems also sold COMET to corporations such as BP, Shell, and Citibank which used the e-mail software on their internal networks. BL Systems also used the service and as John Leighfield, the company's IT director remembers, it "certainly made the company more effective and repaid its cost".[10] COMET helped to define what public and private electronic mail networks should provide. It therefore influenced the networks that emerged from the early 1980s onwards, especially Telecom Gold and Cable & Wireless Easylink (see Figure 5.1).

5.3 Public Electronic Mail Networks

5.3.1 Telecom Gold

During 1979, the incoming Conservative government decided that it wanted to encourage competition in the provision of telecommunications, because the General Post Office's monopoly was hindering innovation in the supply of network services.

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[9] One of the earliest organisations to launch an e-mail service for businesses in the UK was I.P. Sharp Associates (IPSA), which set up Mailbox in 1972. Subscribers could connect to the international I.P. Sharp Associates network (IPSAnet) packet-switched network to send and receive e-mails to people in 28 countries using teletypes. Another example was the Computer Sciences Corporation (CSC), which set up an e-mail network, Notice, in 1977, which people could access from 125 cities. Customers ranged from small organisations to NASA. See *The I.P.Sharp Connection*, 2004, Available from: http://www.t0.or.at/~radrian/ARTEX, Accessed on: 16 March 2005 and *Our History*, CSC, 2005, Available from: http://www.csc.com/aboutus/history.shtml, Accessed on: 16 March 2005.
[10] However, Leighfield adds that by the end of the 1980s the company had "failed to make it a commercial success as an external success. The way we had to look at COMET was that it's a damn good service for Istel and for BL, but that's it". In 1989, AT&T bought BL Systems' successor, Istel, and adopted the new name AT&T Istel. Information from J. Leighfield, Interview by D. Rutter, 22 March 2002. On AT&T's acquisition of Istel see *AT&T Offers Managed Network Services in Europe via AT&T ISTEL*, AT&T, 1992, Available from: http://www.att.com/news/0392/920310.isb.html, Accessed on: 19 October 2005.

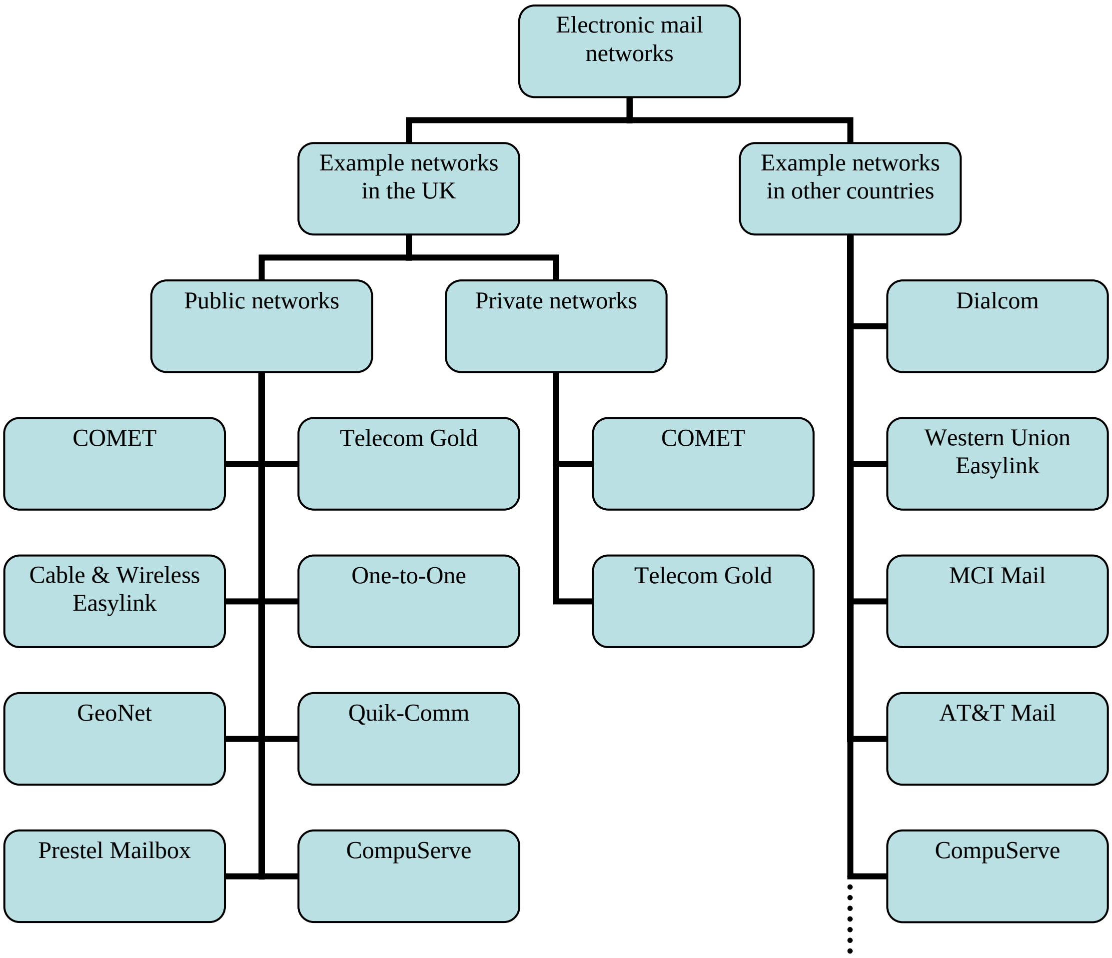

Figure 5.1. A hierarchy of e-mail networks circa early 1980s.

The GPO also needed to modernise the public telephone network and the government had to secure the funds for such an initiative.[11] To achieve its aim, the government decided to separate the postal and telecommunications functions of the General Post Office, which it did in 1981 with the passing of the British Telecommunications Act. The government formed a new nationalised Corporation, called British Telecom, and announced that while this Corporation would still provide telecommunications hardware for customers, other companies could compete to provide terminal equipment which the government would assess and approve. The government also declared that competitors would be able to provide Value Added and Data Services

[11] At the time, only the GPO could supply telecommunications circuits for use by corporations and the public. The GPO was also the only organisation that could supply customer premises equipment such as telephones and Private Automatic Branch Exchanges (PABXs). See S. Macpherson, *What are VADS? A Guide to Value Added and Data Services* (Manchester: NCC, 1987), p. 9, M.E. Beesley, *Liberalisation of the Use of British Telecommunications Network* (London: HMSO, 1981), and K.-S. Bae, *Work Organisation and the Restructuring of the Telecommunications in British Telecom and Korea Telecom*, Ph.D. thesis (Coventry: Warwick Business School, University of Warwick, 2000), p. 67.

(VADS) to consumers and businesses, and it would institute a licensing scheme for such services.[12]

As the government and British Telecom became involved in the liberalisation of the telecommunications industry, David Brunnen, a Business Development Manager at BT, became interested in electronic mail. Brunnen had discovered e-mail in 1979 while reading a report that analysed world telecommunications.[13] Published in 1972, it looked at topics such as the telegraph, the telephone, and satellite communications. It also examined the ARPANET and messaging. Brunnen was interested in electronic mail and decided to learn how the technology had evolved since its invention. Convinced of its potential as a messaging service for BT, Brunnen "touted the idea around the senior management and eventually found a friend in Alex Reid".[14] Reid had been the first director of Prestel and since then he had been promoting the idea of a Spectrum of VADS which BT could sell to customers. Reid assigned an employee in his department, John Morris, to the project and Morris and Brunnen then wrote a report about e-mail.[15] This report looked at several aspects of an electronic mail service including British Telecom's objectives, integration with other BT networks and services, the products available, and which e-mail software BT should choose. The ongoing liberalisation process posed several challenges for British Telecom. For example, to maintain its customer base and expand into new markets, BT needed to develop new services. These services would generate traffic on the telephone network and help to create revenues for the Corporation. In addition to these recommendations, the report considered how the new system should integrate with existing networks and services. In particular, a computer message service could help to increase telex traffic significantly, by enabling more businesses to access the national and international telex networks via the e-mail service. By connecting BT's new electronic mail system to Prestel, this would also benefit viewdata users by providing access to a sophisticated e-mail service. Having analysed these issues in

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[12] Examples of telecommunications equipment included telephones and PABXs. VADS were services, such as e-mail, that were independent of the network and added value to the underlying telecommunications infrastructure provided by BT. See D. Weatherall, "Value Added Network Services," *Management Services*, January 1988, pp. 22-25.
[13] *World Telecommunications Report Volume 2: Technology* (Cambridge, Massachusetts: Arthur D. Little, Inc., 1972).
[14] D. Brunnen, Interview by D. Rutter, 15 February 2002.
[15] J. Morris, et al., *Automated Office Services Bureau Mailboxing and Related Products* (London: British Telecom, 1981).

depth, the report considered the services available in the US, specifically the Computer Corporation of America's COMET, Telenet's Telemail, and Dialcom's service.[16] After assessing each system in detail, the report recommended that BT purchase a licence for the Dialcom service as this offered a good range of facilities, had flexibility in how BT could market the service, and had good technical credibility. BT agreed and therefore approached Dialcom during 1981 to obtain a licence to market the service in the UK. At that time, Dialcom was considering how it could expand its e-mail network outside the US. The aim was to develop the service into an international network, with computer centres in Europe, the Middle East, the Far East, Africa, South America, and Australasia. For this reason, BT's proposal complemented the expansion policy of Dialcom.[17]

With the Dialcom licence obtained, BT offered the job of running the new e-mail service to Brunnen. However, he refused believing that Morris' "energy and enthusiasm for running something would make it happen".[18] Morris believed that BT's bureaucratic structure could impede the development of the new network and perhaps undermine the service's chance of success. Peter Benton, BT's managing director, agreed and stated that he wanted to "really kick-start this new breed of services into the marketplace, unencumbered with traditional BT bureaucracy".[19] Both he and Reid decided that the best way to achieve this was to set up a new company,

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[16] The founders of Dialcom and the Computer Corporation of America had set up their companies during the 1970s to provide time-sharing services. Bolt, Beranek and Newman had established Telenet in 1972 in order to exploit the packet-switched network technology developed as part of the ARPANET. Of the three organisations, Dialcom was the smallest with a handful of offices in cities such as New York and Chicago serving a few hundred users in the early 1980s. CCA had more subscribers, between 800 and 900, who accessed the COMET service using networks such as Tymnet. Telenet's Telemail was one of the larger e-mail networks in the US. In 1977, it served 68 cities and this expanded to over 250 by the mid 1980s, by which time it had more than 40,000 mailboxes. During the 1980s, Telenet expanded its network worldwide, and it became one of Dialcom's main competitors during this decade. On CCA and COMET see D. Flint, *Electronic Mail* (London: Butler Cox & Partners Limited, 1980), pp. 13-16. On the origins of Telenet see J.E. O'Neill, *The Evolution of Interactive Computing through Time-sharing and Networking*, Ph.D. thesis (Minnesota: University of Minnesota, 1992), pp. 210-211. On Telemail see *Integrated Message Systems: Development and Opportunities* (Tunbridge Wells: Applied Telematics, 1984), p. 88.

[17] See *International mail* (London: Telecom Gold Limited, 1981) and J. Quillinan, "Stamp of Approval for Electronic Mail," *British Telecom World*, March 1989, pp. 62-63 and 66.

[18] Morris possessed several of the attributes of a corporate entrepreneur or intrapreneur, including enthusiasm, a positive attitude, and good organisational skills. On intrapreneurial attributes see K.S. Davis, "Decision Criteria in the Evaluation of Potential Intrapreneurs," *Journal of Engineering and Technology Management*, vol. 16, no. 3-4, 1999, pp. 295-327. Additional information from Brunnen, Interview.

[19] The services, which Benton referred to, were the Spectrum of VADS managed by Reid. The proposed e-mail system was part of this range of services. Information from J. Morris, Interview by D. Rutter, 11 February 2002.

called Telecom Gold, which would be independent of BT, but responsible to its parent company.[20] While this was not the first time that BT had undertaken such an initiative, it was the first time that the Corporation had established an independent company.[21] As Morris remembers, "Telecom Gold was created as a company by BT which gave it the licence to operate and sell the service on its behalf, in return for which BT received a management fee".[22] During late 1981, Morris secured offices in London and obtained two Prime 750 minicomputers, recruited staff, and agreed on the costs for the new service.[23] Morris undertook this task "over dinner at a restaurant in Tottenham Court Road on the tablecloth, working out how much everything cost and what we needed to generate, and we ended up with 10.5 pence a minute".[24] With everything set up, British Telecom launched Telecom Gold in March 1982, with Morris as its first managing director. It had taken six months to prepare the service for launch. Morris remembers this period, saying that they had been "through this whirlwind process to prove that if you were unencumbered by bureaucracy how fast you can do things".[25]

Telecom Gold used a proprietary electronic mail protocol. Custom-built software ran on Prime 750 minicomputers which subscribers accessed using several types of terminal, including teletypes, word processors, viewdata equipment, and personal computers. Brunnen and Morris's report had stated that specifying, and therefore restricting, the type of terminal that could access the e-mail network, would be detrimental to the service. This decision would encourage many potential adopters to become customers of the new e-mail system and as a result contribute to the success of the network. Whether companies chose to use teletypes, PCs, or another type of terminal did not matter. Either way, the chicken and egg problem that had afflicted

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[20] BT was one of several organisations to support corporate entrepreneurs or intrapreneurs during the 1980s. Others included IBM with the development of the PC and 3M with the Post-it note. 3M particularly fosters intrapreneurs, encouraging employees to work on their own projects for 15 percent of their time. See V. Sathe, *Corporate Entrepreneurship: Top Managers and New Business Creation* (Cambridge: Cambridge University Press, 2003) and G.C. Nicholson, "How 3M Manages Its Global Laboratory Network," *Research Technology Management*, vol. 37, no. 4, 1994, pp. 21-24.
[21] Benton had suggested that the GPO create a viewdata department in 1976. This decision had helped the organisation to establish a national viewdata network within a short period.
[22] Morris, Interview.
[23] D. Kennett, "BT Goes for Gold with Independent Company," *Computer Weekly*, 28 January 1982, p. 3.
[24] Information from Morris, Interview. Additional information from J. Morris, "Electronic Mail: The Communications Medium for the 1980s," *British Telecommunications Engineering*, April 1984, pp. 14-15.
[25] Morris, Interview.

Prestel would not affect Telecom Gold. Irrespective of the hardware used to access the service, everyone did so using the telephone network. Terminals would establish a dial-up connection to the central Prime 750s' in London. Because long-distance telephone calls could be expensive, Telecom Gold enabled people to access the e-mail service using the X.25 Packet Switching Service (PSS) network (see Figure 5.2).[26] By connecting to a local Packet Switching Exchange (PSE), users could access the services provided by Telecom Gold but do so at local call rates. PSS therefore provided a way to access the central minicomputers in London from distant locations. Once a user had logged onto the Telecom Gold network, it provided a range of services. The subscriber could send, receive, reply, forward, and store electronic mail, set up directories of contacts using address books, request delivery receipts, and send express or priority e-mails. Telecom Gold also provided a Bulletin Board System and enabled people to send telemessages.[27] To access these facilities, BT charged users a £40 registration fee and 10.5 pence per minute during weekdays and 3.5 pence per minute during off-peak periods.[28] Subscribers also had to pay the cost of telephone calls, typically 2 pence per minute, or the PSS charges of 2.5 pence per minute at 300 bps or 3 pence per minute at 1,200 bps.[29] By 1983, 2,800 users were paying these prices to access the service and as Morris remembers, "from that point onwards, the thing really snowballed".[30]

One of the reasons why companies became interested in Telecom Gold was that it provided access to business databases. For years, third party companies had provided online services to companies that needed current information in many areas including business, law, and science.[31]

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[26] See Appendix L.
[27] *Telecom Gold Quick Guide to Mail* (London: Telecom Gold Ltd, 1983). BT's telemessage service replaced telegrams during 1982. See *Events in Telecommunications History - 1982*, BT, 2005, Available from: http://www.btplc.com/Thegroup/BTsHistory/1981-1983.htm#1982, Accessed on: 24 March 2005.
[28] J. Schofield, "Prospecting for Gold," *The Guardian*, 13 June 1985, p. 15.
[29] P. Tootill, "Microlink Live!" *Personal Computer World*, September 1987, pp. 178-179.
[30] Morris, Interview.
[31] One of the first online databases was Dialog, launched during 1966. Many others followed. On the evolution of online services see C.P. Bourne and T.B. Hahn, *A History of Online Information Services, 1963-1976* (Cambridge, MA: MIT Press, 2003). See also *About Us*, Dialog, 2005, Available from: http://www.dialog.com/about, Accessed on: 16 March 2005.

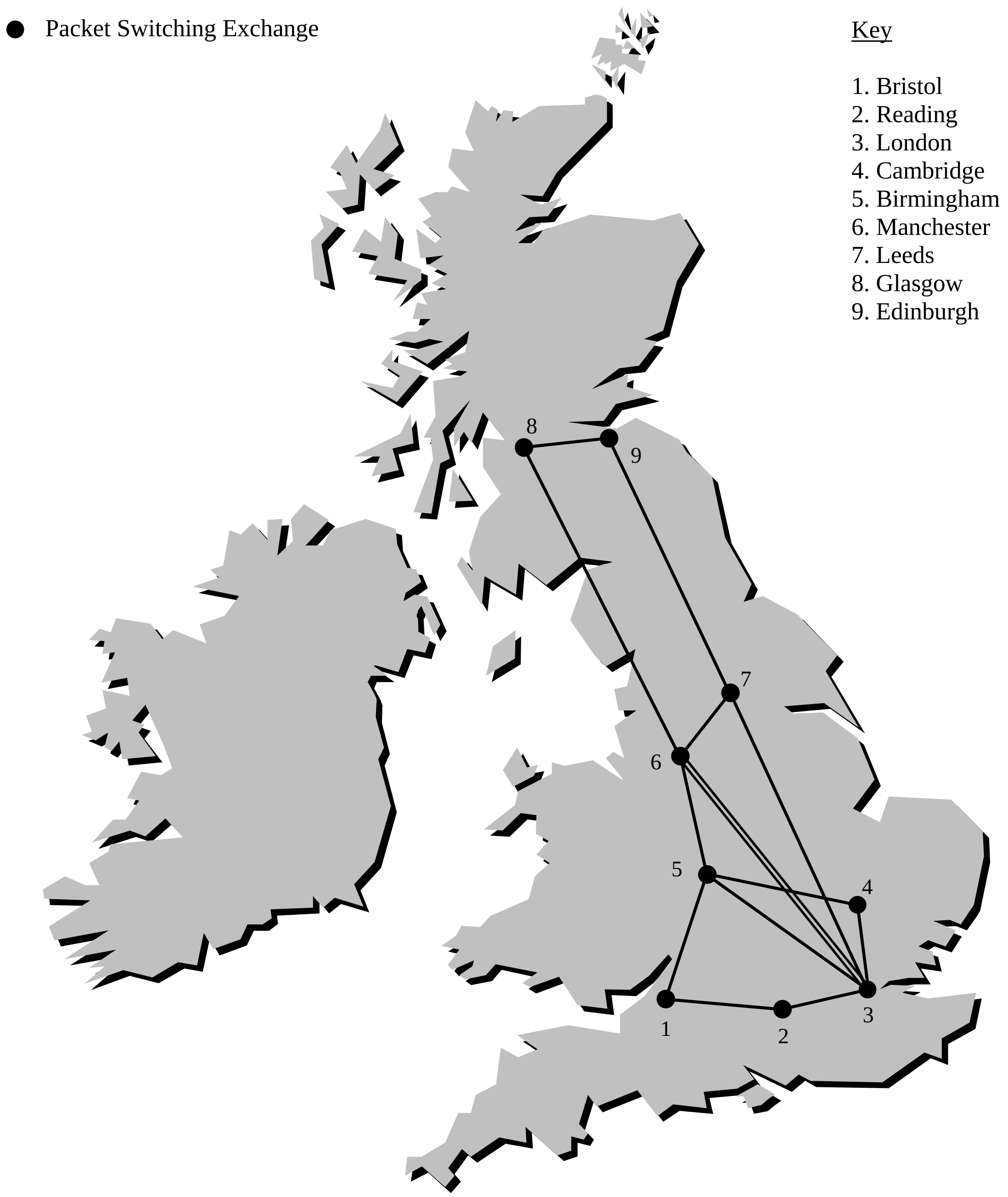

Figure 5.2. The Packet Switching Service network in 1980.[32]

Usually people would connect to these facilities directly, but with the arrival of e-mail networks, users could access online databases via an intermediate network such as

[32] By 1982, BT had added two additional Packet Switching Exchanges to the PSS network in Liverpool and Newcastle upon Tyne. Throughout the 1980s, BT continued to increase the number of PSEs and by 1988, there were 27, of which 6 were in London. See D.W.F. Medcraft, "Data Transmission Services and Network Developments in the United Kingdom," *Applications, Technologies, Architectures, and Protocols for Computer Communication: Proceedings of the Sixth Symposium on Data Communications, Pacific Grove, California* (New York: ACM Press, 1979), pp. 212-220, *UK Access to British Telecom's Dialcom Service* (London: Telecom Gold Limited, 1981), and *Telecom Gold: Opening Your Mailbox* (London: Dialcom, 1988).

Telecom Gold.[33] Using a terminal, subscribers would log onto the network and then enter commands to access the required database. BT, together with third party companies, handled any conversion between the data and screen formats of the e-mail network and an external information source.[34] BT's e-mail service therefore presented information from databases to users in a format that they were already familiar with which made the facility easier to learn and use. By the mid 1980s, Telecom Gold subscribers could access several online databases, including the Official Airline Guides (OAG) Electronic Edition.[35] The OAG provided details about two million flights from 750 airlines, as well as information about 30,000 hotels in the US and Europe. This convergence, between Telecom Gold and third party databases, to create an integrated online service for subscribers, benefited both types of system. Businesses would often become Telecom Gold users to access information sources such as the OAG and then use the e-mail system, and those who became Telecom Gold subscribers would often access online databases.[36] Both attracted new users to British Telecom's network. And as the third party companies improved their databases this not only benefited the external companies, but also the e-mail service as a whole, creating new capabilities for both type of company.[37]

Another factor that encouraged companies to become subscribers was BT's licences for its e-mail service.[38] During the mid 1980s, two types of licensed electronic mail system materialised. The first enabled companies to purchase a licence from British

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[33] Other examples include Prestel, Mercury Link 7500, and CompuServe.

[34] See Appendix L.

[35] *Official Airline Guides Facts Sheet* (London: Telecom Gold Limited, 1987).

[36] Technological interrelatedness therefore affected both Telecom Gold and the database providers. On technological interrelatedness see M. Frankel, "Obsolescence and Technological Change in a Maturing Economy," *American Economic Review*, vol. 45, no. 3, 1955, pp. 296-319.

[37] Telecom Gold and services provided by third party organisations, such as databases, therefore represented a platform. By improving their services through investment, these endogenous sunk costs helped to increase the attractiveness of the platform for both existing customers and potential adopters. See S. Greenstein and T. Khanna, "What Does Industry Convergence Mean?" in *Competing in an Age of Digital Convergence*, D.B. Yoffie ed. (Cambridge, MA: Harvard University Press, 1997), pp. 201-226, T.F. Bresnahan and S. Greenstein, "Technological Competition and the Structure of the Computer Industry," *Journal of Industrial Economics*, vol. 47, no. 1, 1999, pp. 1-40, and J. Sutton, *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration* (Cambridge, MA: MIT Press, 1991), pp. 11-12 and 45-81.

[38] There were alternatives for organisations that wanted to use the facilities offered by Telecom Gold for private communications. These included an online diary, an Electronic Publishing service (EPUB) which companies could use to store, categorise, and retrieve information, and Closed User Groups. An example of a CUG was the Network for Law group on Telecom Gold, which enabled 150 solicitors to communicate using Telecom Gold as well as accessing facilities such as Law Society bulletins. EPUB and CUGs were therefore similar to intranets. See M. Howell, "Law in the Fast Lane," *British Telecom Journal*, vol. 7, no. 3, 1986, pp. 68-69.

Telecom to run the Telecom Gold software on their Local Area Networks. BT allocated a range of e-mail addresses to a company which the firm's system manager would then assign to employees.[39] Telecom Gold provided training for a firm's workforce to teach its customers how to use the e-mail system. By investing in training, this increased the chances of a firm continuing to use Telecom Gold which helped to consolidate Telecom Gold's control over companies.[40] As well as training employees, Telecom Gold also encouraged companies to interconnect their private networks with the national public network which increased the value of belonging to Telecom Gold for every company that purchased a licence. The second type of system created through licensing were networks that employed Telecom Gold for communications purposes as part of a broader range of services. By the mid 1980s, several such networks existed including Microlink, The Times Network Systems (TTNS), and the Microbial Strain Data Network (MSDN).[41] Although the TTNS and MSDN did not compete with Telecom Gold, Microlink did.[42] Database Communications originally launched Microlink in 1985 as a way of reselling Telecom Gold mailboxes to microcomputer enthusiasts.[43] It offered subscribers facilities such as e-mail, bulletin boards, access to the telex network, and downloadable software, and so competed with Telecom Gold indirectly. By 1987, Microlink had increased the number of Telecom Gold subscribers by 7,500.[44] However, in 1989 Database

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[39] *Telecom Gold System Manager Guide* (London: British Telecom, 1990).

[40] Switching costs, especially the costs associated with learning, therefore affected Telecom Gold. These would help to lock-in customers to BT's e-mail network. On switching costs see P. Klemperer, "Markets with Consumer Switching Costs," *Quarterly Journal of Economics*, vol. 102, no. 2, 1987, pp. 375-394. On technological lock-in see W.B. Arthur, "Competing Technologies, Increasing Returns, and Lock-in by Historical Events," *Economic Journal*, vol. 99, no. 394, 1989, pp. 116-131. On customer groove-in see W.B. Arthur, "Increasing Returns and the New World of Business," *Harvard Business Review*, vol. 74, no. 4, 1996, pp. 100-109. The role of training in the diffusion of a technology has played an important role with other devices, such as the QWERTY keyboard. See P.A. David, "Understanding the Economics of QWERTY: the Necessity of History," in *Economic History and the Modern Economist*, W.N. Parker ed. (Oxford: Blackwell, 1986), pp. 30-49.

[41] News International launched TTNS in 1984 to provide e-mail and other services for schools. The Microbial Strain Data Network contained information about microorganisms from laboratories throughout the UK. See *The Times Network Systems Handbook 1988/89* (London: Times Network Systems, 1988) and S. Buff, *Evaluation of Users' Opinions of Telecom Gold Services for the Microbial Strain Data Network*, M.Sc. thesis (Sheffield: Department of Information Studies, University of Sheffield, 1989).

[42] The TTNS and MSDN were educational and medical science services that used the e-mail facilities provided by Telecom Gold and offered additional services not provided by BT's e-mail network. They therefore did not compete with Telecom Gold.

[43] Tootill, "Microlink Live!" pp. 178-179.

[44] As it used the same e-mail system, it did not compete with Telecom Gold, adding users to BT's network. However, because it also offered facilities such as access to the telex network, it did compete with British Telecom's service. See Ibid., p. 178.

Communications decided to move Microlink onto a rival network, and therefore competed with Telecom Gold directly.[45]

5.3.2 Cable & Wireless Easylink

In 1928, the Imperial and International Communications Ltd decided to merge its radio and cable services which it operated throughout the world. By 1934, it had changed the name of the company to Cable & Wireless. In 1947, the government nationalised the firm. Thirty-four years later, the government decided to privatise the company, as part of the liberalisation of the telecommunications industry.[46] As a result, the company could compete with British Telecom and it did so by exploring the opportunities presented by Value Added and Data Services. By 1983, the idea of VADS, which had existed for two years, crystallised when the government issued the Value Added Network Services (VANS) General Licence.[47] VANS were services that transmitted information using computers and telecommunications links. Examples included store-and-forward messaging systems, viewdata networks, and voice retrieval services. If a company wanted to provide a Value Added Network Service, it applied to the government for a VANS licence.[48] Cable & Wireless did this in order to run an electronic mail service. As David Flinter, the first managing director of Cable & Wireless Easylink, remembers the reason for this decision was that “others seemed to be doing it and Cable & Wireless therefore thought that it ought to have an equivalent”.[49]

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[45] Istel, which operated the COMET e-mail service in the UK, also provided the Infotrac packet-switched public data network, which Database Communications used for its Microlink service. See J.P. Leighfield, “Implementing and Operating a Value Added Network,” *Computer Communications*, vol. 8, no. 4, 1985, pp. 199-202.
[46] See *Imperial and International Communications Ltd*, Cable & Wireless, 1997, Available from: http://www.cwhistory.com/history/html/ImpIntComs.html, Accessed on: 17 March 2005, *Nationalisation*, Cable & Wireless, 1997, Available from: http://www.cwhistory.com/history/html/Natisation.html, Accessed on: 17 March 2005, and *Privatisation of Cable & Wireless*, Cable & Wireless, 1997, Available from: http://www.cwhistory.com/history/html/Privatise.html, Accessed on: 17 March 2005.
[47] Macpherson, *What are VADS?*, pp. 10-12.
[48] Oftel later changed this, stipulating the VANS General Licence was a class licence granted to everyone, unless specifically rescinded by Oftel. See Ibid., pp. 11-15 and 53-61. Database Communications switched networks because of disenchantment with the Telecom Gold licence fee. On the development of Microlink see A. Cawson, et al., *The Shape of Things to Consume: Delivering Information Technology into the Home* (Aldershot: Avebury, 1995), pp. 158-160.
[49] D. Flinter, Interview by D. Rutter, 13 March 2002.

Having decided to establish an electronic mail network, Cable & Wireless need to acquire suitable software. The company turned to Western Union which was also looking to diversify. At that time, there were two separate Western Union companies: the Western Union Telegraph Company and Western Union International. There was a clear demarcation between the two: the former was a national record carrier, as it transmitted telexes, while the latter was an international voice carrier. Because the Western Union Telegraph Company could not operate internationally, it had been looking for a way to expand its domestic business. For this reason, it developed the Easylink e-mail service. Western Union designed Easylink for telex operators.[50] It was essentially a way of accessing the national telex network using terminals other than teleprinters. Because telex operators were adept at entering commands, this meant that the interface of Easylink was not easy to use for other less skilled users. However, Western Union did not see this as a problem as it had targeted Easylink at proficient telex operators and not at the general business user. This rationale influenced Cable & Wireless which obtained a licence for the software from Western Union and launched its Easylink service during 1983. Like its US counterpart, Cable & Wireless marketed the system as a way of accessing a national telex network. By the early 1980s, there were over 85,000 telex subscribers in the UK and one million worldwide.[51] As Flinter comments, telex had become "the business communications method of choice" and one of the reasons for this was the answerback facility which "was established in law as proof of receipt and accepted as guaranteed delivery".[52] However, telex services were expensive. For instance, sending, say, a 1,200-character telex to the US would cost £1.74 by the mid 1980s.[53] Like Western Union, Cable & Wireless believed that offering Easylink to existing and new telex customers would enable them to access the telex networks using different types of terminal and do so

[50] Telex was a synchronous communications technology, which meant that both telex operators conducted the communication in real-time. In this respect, it was similar to the telephone. In contrast, e-mail is an asynchronous technology, which means that the sender and recipient of a message do not need to correspond in real-time, so that a recipient can reply to an e-mail when it suits them. E-mail is therefore similar to the fax. See T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications,* 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 436-437.

[51] Telex had emerged during the 1930s as a new technology that overcame the problems inherent with telegraphic transmissions. The telegraph required two skilled operators, did not provide printed output, and relied on messengers to deliver communications to their destinations. By connecting a teleprinter to the telephone network, people could type messages that a receiving teleprinter could print out. By the early 1930s, demand existed for a teleprinter network in the UK and so the GPO opened a teleprinter exchange (telex) service in 1932. Other countries soon established telex networks. See Solymar, *Getting the Message,* pp. 167-168 and *Integrated Message Systems,* p. 12.

[52] Flinter, Interview.

[53] M. McLening, "The Message is that Telex's Reign May Soon End," *The Times*, 14 May 1986, p. 16.

inexpensively. For example, Cable & Wireless would send the same 1,200-character message for 82 pence, less than half the price of a telex sent using a teleprinter and the international telex network.[54] As well as lowering costs and enabling Easylink customers to send telexes, Cable & Wireless allowed telex users to send messages to subscribers of the e-mail service.[55] Its competitors, such as Telecom Gold, also began to offer telex facilities at this time and by 1983, these companies had interconnected their e-mail networks with the national and international telex networks. By linking the small electronic mail networks with the global telex network of one million users, this enhanced the value of being part of the e-mail services for new and existing subscribers.[56] These links encouraged companies to use the e-mail services to access the telex networks and in so doing introduced them to electronic mail for the first time.

5.4 From Diversity to Convergence: X.400

5.4.1 The Need for Interconnection

By the mid 1980s, many computer networks offered e-mail facilities. In the UK, these included COMET, Telecom Gold, Cable & Wireless Easylink, Kensington Datacom's One-to-One service, Prestel, JANET, Quik-Comm, and GeoNet.[57] In other countries,

[54] S. Watts, "Easylink Cuts US Telex Costs," *Computer Weekly*, 19 September 1985, p. 8.
[55] *Easylink User Manual* (London: Cable & Wireless, 1983), pp. 2/3 and A-1.
[56] By employing adapters, organisations such as BT ensured compatibility between the e-mail networks and telex. On adapters see J. Farrell and G. Saloner, "Converters, Compatibility, and the Control of Interfaces," *Journal of Industrial Economics*, vol. 40, no. 1, 1992, pp. 9-35. Network externalities therefore affected both e-mail and telex users. See M.L. Katz and C. Shapiro, "Network Externalities, Competition, and Compatibility," *American Economic Review*, vol. 75, no. 3, 1985, pp. 424-440.
[57] Kensington Datacom was a new e-mail company that launched its One-to-One service in 1984. By 1987, it had 17,000 users, but it never challenged Telecom Gold in terms of the number of subscribers. General Electric set up the General Electric Information Services Company (GEISCO) in 1965 to market a time-sharing service. During the early 1970s, GEISCO established a worldwide network, which enabled customers to access the centralised facilities provided by the time-sharing system in the US. In 1981, GEISCO launched the Quik-Comm e-mail service in the UK and in other countries. By 1987, there were 40,000 customers, which used GEISCO's replacement network, the General Electric Network for Information Exchange (GEnie), to communicate. By the end of the 1980s, 100,000 subscribers used GEnie and Quik-Comm to send and receive e-mails. GeoNet Mailbox Systems set up its e-mail service, Geomail, during 1981 in West Germany. By the late 1980s, GeoNet had over 10,000 users in 10 countries, such as the Germany, the UK, the US, and Switzerland. See C. Gooding, "Why the Receptionist Misses Out on Electronic Mailboxes," *Computer Weekly*, 12 September 1985, pp. 30-31, T. Reed, "Operating and Managing a Commercial Worldwide Network," *Computer Communications*, vol. 8, no. 3, 1985, pp. 141-147, C. Chang and D. Hitchcock eds., *The VANS Handbook: Value Added Network Services* (Middlesex: Online Publications, 1987), p. 79, Brodsky, "Online Services," p. 15, J. Agar, et al., *From Cotton to Computers: The Social Contexts of Virtual Manchester*, University of Manchester, 1999, Available from: http://les.man.ac.uk/sa/virtsoc/cotton.htm, Accessed on: 4 May 2005, R. Lockwood, "A Smaller,

a similar number of systems had also materialised. For example, in the US, networks such as Dialcom, MCI Mail, CompuServe, and FidoNet all provided e-mail services, as too did Télétel in France. To communicate with people on different networks, users needed to subscribe to the relevant systems. However, having invested time and money in software and training for one service, users would not be inclined to pay to access another network just because colleagues and customers used a rival system, especially as this would mean additional training to learn multiple address formats (see Table 5.1). As a result, most companies and individuals decided not to subscribe to multiple networks.[58] Incompatibility was therefore a serious problem. For example, according to a survey commissioned in 1986 by Kensington Datacom, 85 percent of medium-sized companies in the UK were reticent about adopting e-mail because of the issue of incompatibility.[59] For electronic mail to become a truly useful service for many people, the e-mail industry had to find a solution to the impossible situation that existed by the mid 1980s.

Aware of the complex problem facing e-mail companies, Kensington Datacom introduced a Charter of Compatibility which it suggested the industry could use as the basis for a European Electronic Mail Association. Competitors such as BT agreed, believing that finding a solution to the incompatibility problem was the main issue that electronic mail companies needed to address. However, these firms were unsure of how to solve this problem, although they were certain that the telex network was insufficient for this task. By 1986, the e-mail networks' ability to send and receive telexes meant that a subscriber of, say, Telecom Gold could communicate with an Easylink customer via the national telex network (see Figure 5.3). Although communication was possible, it was slow and telexes could only contain uppercase characters. For these reasons, most e-mail users did not use telexes to communicate with subscribers of other e-mail networks.

Integrated World," *Practical Computing*, March 1988, p. 36, and T. Dennis, "Where It Isn't Easy to be an in Person," *The Guardian*, 24 September 1987, p. 15.

[58] There were exceptions. For example, Tony Dennis, a journalist, subscribed to COMET, Telecom Gold, Prestel, and GeoNet. He therefore had four e-mail addresses (see Table 5.1).

[59] S. Watts, "Mail Firm Links With Its Rivals," *Computer Weekly*, 6 March 1986, p. 17.

Table 5.1. Electronic mail networks and local addressing formats.[60]

Network	Local address format
AT&T Mail	username (e.g. johnsmith)
BITNET	user@node (e.g. jsmith@bitnic)
BIX	username (e.g. jsmith)
CIX	username@cix (e.g. jsmith@cix)
COMET	username (e.g. Tony Dennis)
CompuServe	xxxxx,yyy (e.g. 72300,247)
Dialcom	host:XYZ000 (e.g. 10098:ZYG264)
Easylink	19000000 (e.g. 19876159)
EASYnet	area.node::user (e.g. 15.27::jsmith)
EcoNet	igc:username (e.g. igc:jsmith)
EUnet GB	host1!target-host!user (e.g. uunet!uknet!jsmith)
FidoNet	ZZ:NN/FF.PP@DO (e.g. 4:610/34.0@fidonet)
GeoNet	host:username (e.g. Tony Dennis)
Internet	username@host.domain (e.g. j.smith@jnt.ac.uk)
JANET	username@domain.host (e.g. j.smith@uk.ac.jnt)
MCI Mail	000-0000 (e.g. 2964814)
Prestel	Mailbox number (e.g. 919993843)
Telecom Gold	host:AAA000 (e.g. 10076:MTR007)

5.4.2 The Promise of X.400: A Global Interconnected E-mail Network

To address the problem of incompatibility, the Comité Consultatif International Télégraphique et Téléphonique (CCITT) recommended that the Open Systems Interconnection seven-layer reference model should influence the development of a Message Handling System (MHS) which could interconnect the e-mail networks.[61] Companies such as BT agreed and the CCITT began to work on a standard for an MHS during 1982. Two years later, it ratified the first OSI standard: X.400. Known as X.400 (1984) or simply as the Red Book, this defined a Message Handling System that enabled computers to exchange electronic mails. The rationale behind X.400 was to create a global messaging system.[62]

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[60] By the mid 1980s, there were hundreds of computer networks throughout the world. Table 5.1 therefore only shows a selection of these networks. See M. Holderness, *GEO2: Wakefield Host User Manual* (Wakefield: City of Wakefield Metropolitan District Council, 1994), p. 170, D. Frey and R. Adams, *A Directory of Electronic Mail Addressing & Networks*, 4th ed. (Sebastopol, CA: O'Reilly & Associates, 1994), and T. Dennis, "Electronic Mail," *Which Computer?* September 1987, pp. 76-77.

[61] "New Gateway Opens Up the World's Databases," *New Scientist*, 16 January 1986, p. 29.

[62] This "universal electronic mail system" or "global electronic messaging architecture" would include all public and private e-mail networks and enable people to send and receive e-mails between different systems and provide the basis on which global electronic trading would occur. See S. Kerr, "X.400 E-Mail Standard Picks Up Steam in the U.S.," *Datamation*, 15 December 1987, pp. 24 and 26 and G. Wild, "A Global Electronic Messaging Architecture," *Telecommunications*, May 1992, pp. 55-56.

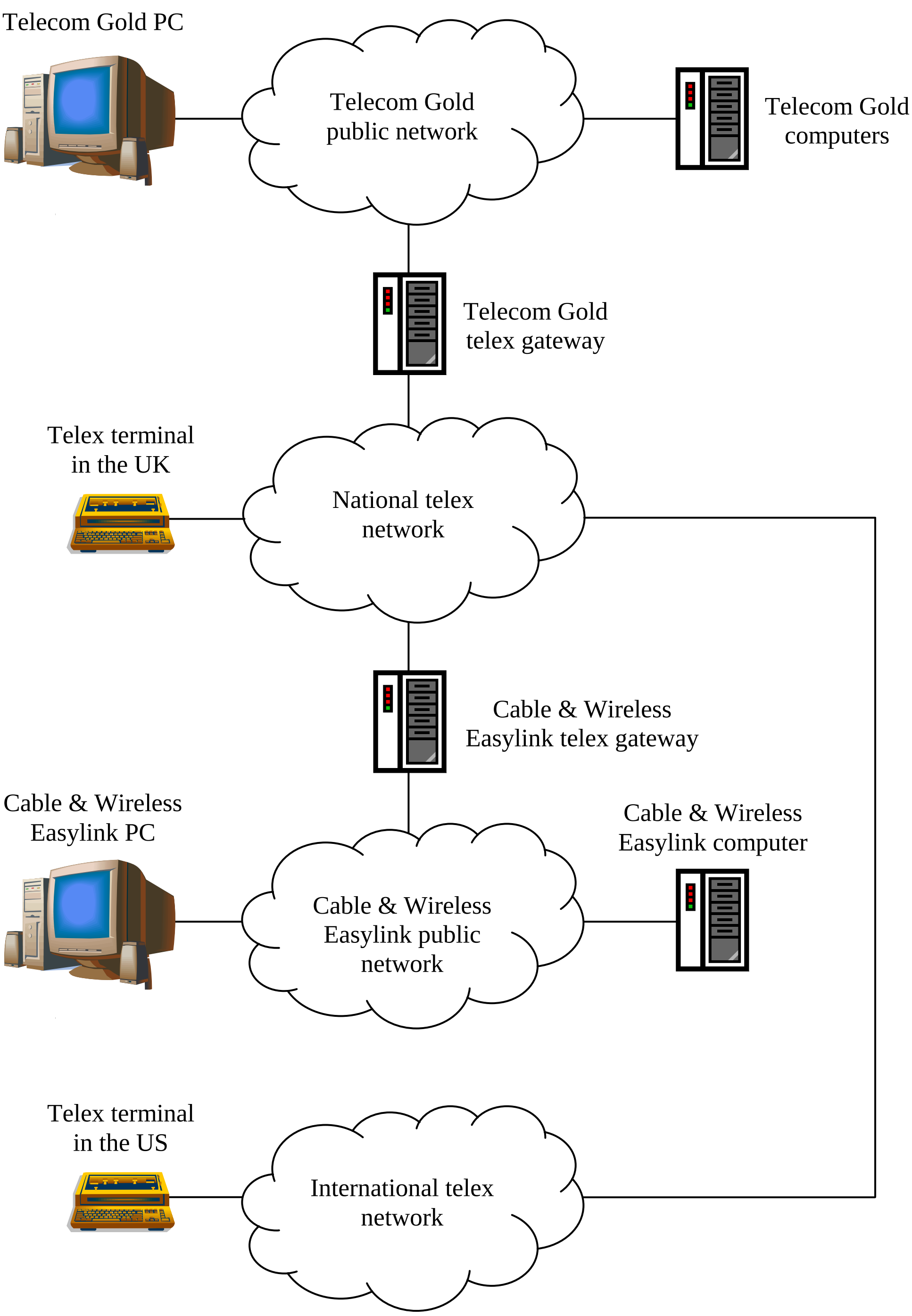

Figure 5.3. Using the national telex network to interconnect two e-mail networks.[63]

The Red Book specifications allowed companies to develop X.400 hardware and software which customers could use to interconnect their e-mail systems, enabling people to communicate. If governments, companies, organisations, and individuals

[63] The figure shows two telex terminals, one in the UK and another in the US. These are included to illustrate how the e-mail networks connected to the national and international telex networks. The figure shows two PCs which are running software that enables them to connect to the two e-mail networks, Telecom Gold and Cable & Wireless Easylink.

adopted these solutions, they would converge around X.400 to form a global interconnected e-mail network (see Figure 5.4).[64] The idea was for this network to develop incrementally, as an increasing number of companies converted their services to the X.400 standard, and in the process expand the geographic coverage and user community of this network.

For the X.400 global e-mail network to become a reality, companies needed to develop compatible hardware and software. One of the first companies to announce its support for the OSI standard was British Telecom. In 1986, BT announced that it would invest £5m to establish an X.400 Message Handling System, called Gold 400, which would interconnect electronic mail networks.[65] BT hoped that Gold 400 would become the "universal clearing house" for every e-mail transmitted in the UK.[66] It therefore wanted to persuade its competitors to install the X.400 software, provided by Dialcom, so that these companies could gradually interconnect the networks.[67] If its rivals installed the Gold 400 software onto their machines and then connected these to compatible Gold 400 Message Transfer Agent (MTA) operated by, for instance, BT, then this would create an interconnected network of X.400 MTAs in the UK.[68] If every e-mail network also adopted the X.400 addressing format, this would provide a uniform addressing scheme for e-mail addresses. Users could then send an e-mail from one network, such as Telecom Gold, to say Cable & Wireless Easylink. If this scenario occurred, the e-mail networks could gradually replace their proprietary protocols with the X.400 (1984) standard. An alternative would be to interconnect the e-mail networks using X.400 gateways which would provide the conversion facilities between the different protocols used by the proprietary services.[69]

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[64] If this convergence occurred, the users would direct it, as they would see the value of using X.400 to interconnect incompatible networks in order for communication to occur between users, and therefore demand access to products and services that were compatible with X.400. No single authority would therefore control this convergence around this network. The word 'network' in this sense refers to multiple X.400 e-mail networks in a similar way in which the Internet refers to a network of networks.

[65] See "BT Plans Electronic Mail Link," *Computer Weekly*, 16 January 1986, p. 5 and J. Green-Armytage, "X.400 Could Link Islands at Last," *Computer Weekly*, 29 May 1986, p. 26.

[66] P. Hunter, "Standard Delivery," *Communications Management*, February 1987, pp. 25-26.

[67] "Smoothing the Path of Communication," *New Scientist*, 17 July 1986, p. 27.

[68] Message Transfer Agents (MTAs) forwarded e-mails to their destinations. In the figure above, the X.400 MTAs indicate that the networks attached to these computers were running the X.400 standard. See Appendix L. On Gold 400 see B. Brown, "Link Boosts Electronic Mail 'Explosion'," *British Telecom Journal*, vol. 7, no. 4, 1986, pp. 38-40.

[69] C. Betanov, *Introduction to X.400* (Boston: Artech House, 1993), pp. 195-243.

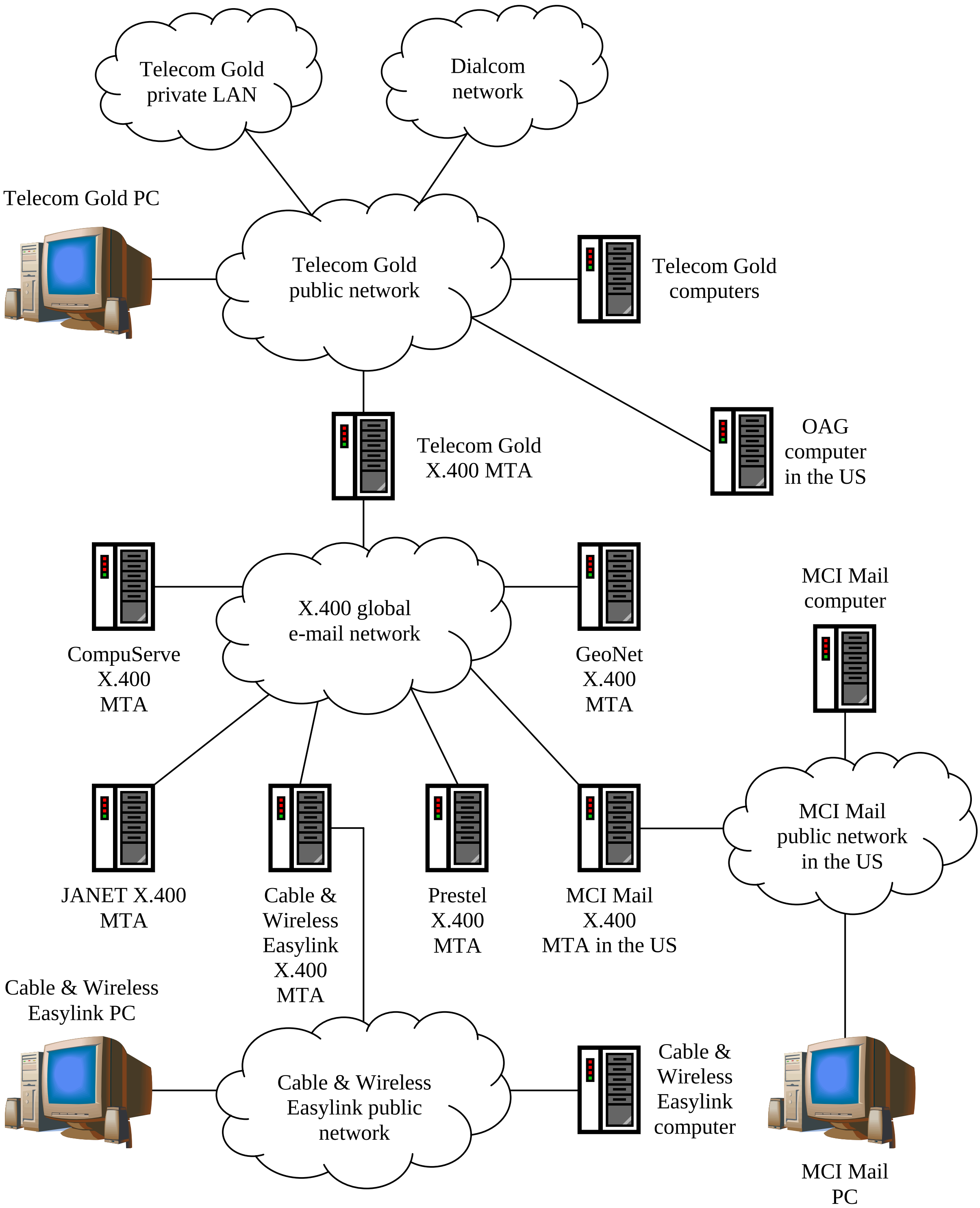

Figure 5.4. An example of the X.400 global interconnected e-mail network.

These gateways would also be able to handle X.400 addresses and convert between these and the formats used by the networks they connected. Companies could implement X.400 gateways to help protect their investment in their proprietary protocols and more importantly retain their existing customer base. As X.400 became more widely adopted, these companies could use their gateways as part of a transition plan to migrate away from proprietary protocols towards X.400. The chapter will return to X.400 in section 5.6.

5.5 Network Evolution

5.5.1 Telecom Gold

As electronic mail companies started to become interested in X.400, the Conservative government continued with the liberalisation of the telecommunications industry. When the government had announced its intention to liberalise this industry during the early 1980s, it had initiated a program of reforms, the ultimate aim of which was the privatisation of British Telecom. By 1983, liberalisation had opened up the telecommunications market to companies that wanted to compete within this industry. The following year British Telecom became a Public Limited Company, and the House of Commons passed the Telecommunications Act, privatising BT.[70] Initially the government owned all of BT's shares but during late 1984, it floated over half of them on the world's stock markets.[71] As part of the liberalisation process, the government established a new telecommunications regulating body, the Office of Telecommunications (Oftel), which assumed the task of issuing licences for services such as VADS.[72] As a result, the government had replaced political control of the telecommunications industry with regulatory control.[73]

As British Telecom became a PLC, Telecom Gold continued to develop. By the mid to late 1980s, BT had increased the number of online databases that subscribers could access. Users could choose from 15 databases covering several types of information, such as financial data provided by FT Profile and directory details from the Electronic Yellow Pages.[74] Telecom Gold also added three new services to the e-mail network during this period. Goldtelex enabled subscribers to receive as well as send telexes,

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[70] J. Harper, *Monopoly and Competition in British Telecommunications: The Past, the Present and the Future* (London: Pinter, 1997), p. 155.
[71] The actual figure was 50.2 percent. By 1993, the government had sold most of its shares in BT. See S. Hallett, *Privatisation and Industrial Relations: The Re-structuring of British Telecom*, M.A. thesis (Coventry: University of Warwick, 1987), p. 24 and *Events in Telecommunications History - 1993*, BT, 2005, Available from: http://www.btplc.com/Thegroup/BTsHistory/1991-1993.htm#1993, Accessed on: 3 May 2005.
[72] Macpherson, *What are VADS?*, p. 10.
[73] Bae, *Work Organisation and the Restructuring of the Telecommunications*, p. 68.
[74] See *Telecom Gold FT Profile Reference Guide* (London: British Telecom, 1991) and *Telecom Gold Electronic Yellow Pages Reference Guide* (London: British Telecom, 1991).

while Goldfax provided the ability to send faxes to up to 500 fax numbers simultaneously.[75] According to David Sexton, the first head of operations and development, while Goldtelex was quite successful, enabling customers to communicate with telex users or migrate to e-mail, Goldfax "brought us a huge amount of business and we were dealing with a massive amount of fax conversion".[76] Like the telex service, this fax facility also convinced some subscribers to become users of the e-mail network. The third service, Goldtransfer, provided several file transfer facilities.[77] By the time these services became available on Telecom Gold, people were increasingly using PCs to access the network. As the number of PCs grew within companies, people invariably used these computers to access the network and as many people became PC users, they often chose Telecom Gold as their e-mail service. As software companies and PC manufacturers improved the facilities of their software and hardware, this not only benefited the users of these products, but the Telecom Gold service as a whole.

To access the network using a terminal, subscribers paid several fees, all of which were expensive. During 1987, Telecom Gold decided to charge customers for the e-mails they sent and received, at a cost of 4 pence for every 512 characters.[78] It also started to charge users for storing files on their computers, meaning that if a person saved a file containing approximately 200 words on a Telecom Gold computer, the subscriber would have to pay 21.5 pence a month, excluding VAT.[79] The fees for accessing third party databases were also high. Depending on the database that a person used, it could cost them up to £2.50 a minute to access information. These high prices did little to encourage small companies and individuals to become subscribers. BT's complicated charging structure was also not attractive. By the end of the 1980s, a subscriber was obliged to pay six different charges: an initial registration fee, a time-based access charge, transmission costs, storage expenses, a monthly £5 charge, and the cost of a telephone call or connection to the PSS. These depended on the time of day that the user established a connection to Telecom Gold and on how much data

[75] *Telecom Gold User Guide* (London: British Telecom, 1990), pp. 7/1-7/42 and 8/3-8/21.
[76] D. Sexton, Interview by D. Rutter, 27 February 2002.
[77] These enabled users to transmit e-mails prepared offline to the online service as well as transmitting files between computers using BT's network.
[78] J. Schofield, "Panning for Gold," *The Guardian*, 9 July 1987, p. 15.
[79] B. Fox, *Out of Sight, Out of Mind*, New Scientist, 1992, Available from: http://archive.newscientist.com/archive.jsp?id=18195300, Accessed on: 15 January 2002.

they transmitted, received, and/or stored. If a subscriber used BT's Packet Switched Stream instead of the PSTN, the situation was even more complex, requiring the user to know the data transfer rate of their connection to the PSS.[80]

As well as the costs associated with using Telecom Gold, security breaches did not endear existing and new subscribers to the service. In 1983, hackers gained unauthorised access to a user's mailbox to prove that Telecom Gold was an inherently insecure e-mail network.[81] During the Microlive BBC television programme, the presenters received a message from the hackers drawing attention to how easy it was for a password-cracking program to discover the password used by the presenters' mailbox. However, the hackers had not actually cracked the password, as someone had given it to the perpetrators. While no one had breached the security of Telecom Gold through hacking, the incident did undermine confidence in the security of the system. Of course, Telecom Gold assured its subscribers that the security of its e-mail service was not in doubt, although in reality it was less secure than other systems such as X.400.[82] A hacker reinforced this view when he obtained unauthorised access to a user's account in 1986. As a result, BT started to monitor the account that the hacker was accessing, after which the hacker left the service. Unfortunately for BT, it failed to remove the monitoring, with the result that the subscriber in question, a journalist, drew attention to this infringement of his privacy in a magazine column.[83]

Although security breaches were a problem, they did not seriously affect Telecom Gold's ability to attract new users. From 200 users in 1982, the network grew to 53,000 subscribers by 1986, which was quite a large growth rate when compared to competitors such as COMET and Cable & Wireless Easylink.[84] To cope with the

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[80] Packet Switched Stream was the new name for BT's Packet Switching Service. On Telecom Gold's charges see P. Ennor, "BT Gold," *Which Computer?* September 1987, pp. 79-80 and 85.
[81] J. Kavanagh, "Electronic Vandals Strike at the BBC's Live Gold," *Computer Weekly*, 6 October 1983, p. 1.
[82] For example, X.400 could encrypt e-mails and provide digital signatures. See J. King, "X.400 Security," *Computers & Security*, vol. 11, no. 8, 1992, pp. 707-710 and N. Swain, "Getting the Message Safely: Security and X.400 Systems," *Computer Fraud & Security Bulletin*, vol. 1992, no. 3, 1992, pp. 10-15.
[83] R. Schifreen, "Someone's Watching You," *Personal Computer World*, July 1987, p. 76.
[84] Three years after launching COMET in 1981, BL Systems' public e-mail service had only 400 users and by 1986, this had increased to only 2,000. By 1985, it had taken Cable & Wireless two years to attract 3,000 customers. Other companies, such as the Computer Sciences Corporation, also took time to attract new users. For example, CSC had set up its Notice e-mail service in 1977. Eight years later,

increasing number of users, Telecom Gold installed more minicomputers. As Sexton remembers, "we were putting in a new machine every three weeks to keep pace with the growth which was great fun" (see Figure 5.5).[85] By 1987, Telecom Gold had attracted a critical mass of 76,000 subscribers, making it the market leading electronic mail network in the UK.[86] As BT was the largest provider of telecommunications in Britain, this had helped to legitimate the e-mail market and encourage users to subscribe to BT's service.[87] As the subscriber base grew in size, the utility of belonging to the network also expanded, for both existing users and potential adopters. This situation became self-sustaining, attracting more and more users to the service until it became the largest public e-mail service in the UK. As Telecom Gold had become the e-mail network with the largest number of subscribers, this was attractive to potential adopters. After all, if a company wanted to communicate with another firm that used a public e-mail network, the chances were that they too used Telecom Gold, because of the service's prominence in Britain. Because Telecom Gold was part of the Dialcom network, this was also attractive for companies that wanted to communicate with companies in other countries. By 1986, there were 15 Dialcom licensees throughout the world in countries such as the US, the UK, France, Italy, and Australia. Dialcom interconnected the services in these countries to form an international e-mail network.[88] This network interested British Telecom which had been trying to become one of the premier providers of telecommunications services throughout the world for some time.[89]

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this only had 1,000 subscribers. See P. Wilson, "Let's Get Mailboxes Moving," *Computer Weekly*, 1 March 1984, p. 26 and Chang and Hitchcock eds., *The VANS Handbook*, pp. 63-64 and 75-76.

[85] Sexton, Interview.

[86] On critical mass see D. Allen, "New Telecommunications Services: Network Externalities and Critical Mass," *Telecommunications Policy*, vol. 12, no. 3, 1988, pp. 257-271.

[87] As BT was the UK's main provider of telecommunications services, potential adopters saw the Corporation as a credible supplier of electronic mail. This situation helped to convince people that e-mail was a useful service and that BT was the organisation to provide that service. BT, as one of the pioneers of public e-mail in the UK, therefore helped to legitimate the concept of e-mail and maximise its early entry into this new market. On the concept of pioneer brand advantage see F.H. Alpert and M.A. Kamins, "Pioneer Brand Advantage and Consumer Behaviour: A Conceptual Framework and Propositional Inventory," *Journal of the Academy of Marketing Science*, vol. 22, no. 3, 1994, pp. 244-253.

[88] J. Schofield, "Dialcom Purchase Adds Lustre to the Telecom Goldmine," *The Guardian*, 20 March 1986, p. 15.

[89] Prestel was part of this strategy and when this failed to help BT become a worldwide premier provider of telecommunications services, the company looked for other opportunities that might achieve its goal. On BT and Dialcom see P.W. Barnes, "British Telecom Agrees to Acquire ITT Dialcom Inc," *Wall Street Journal*, 10 March 1986, p. 1.

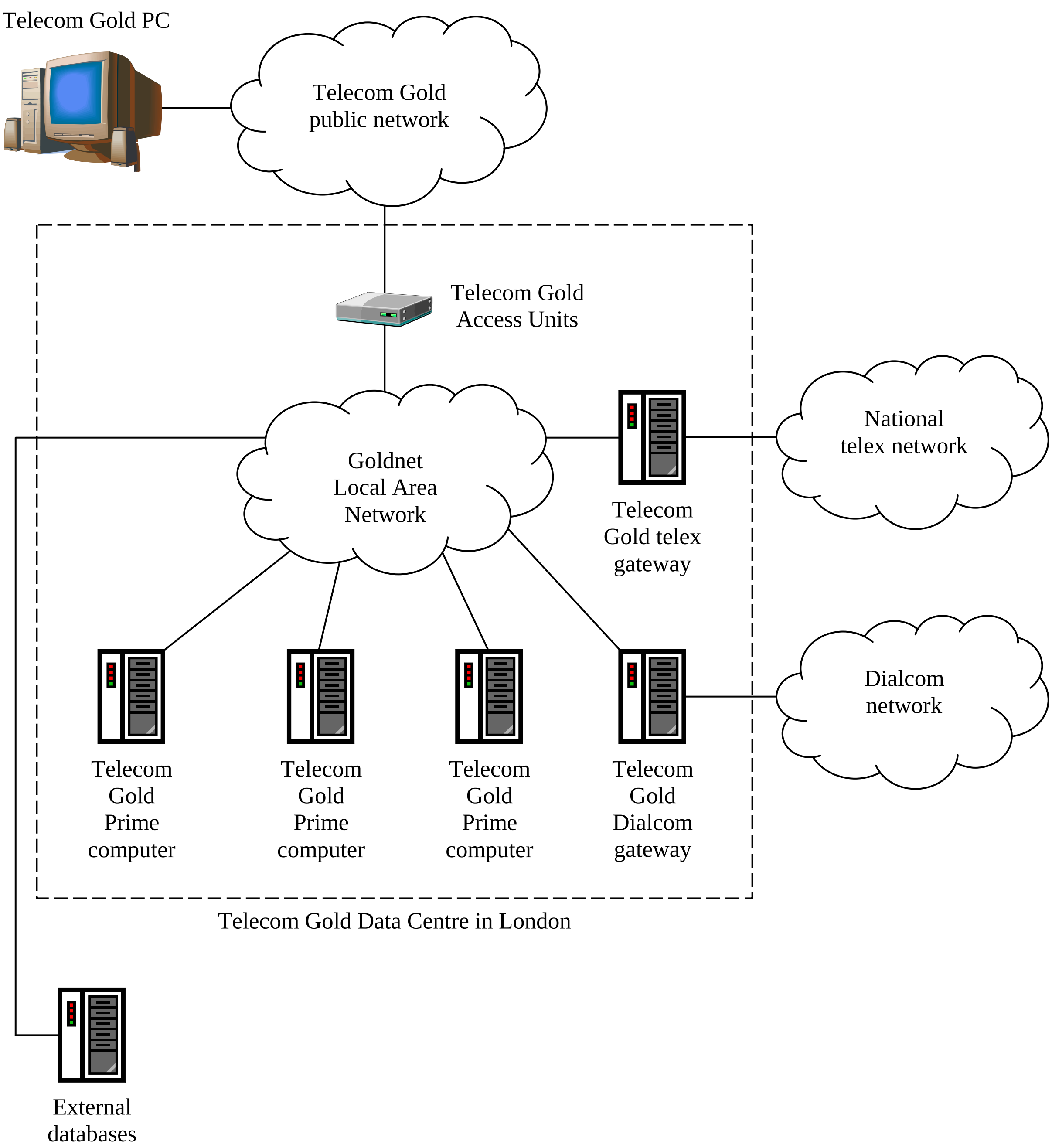

Figure 5.5. The Telecom Gold Data Centre in London during 1986.[90]

Dialcom presented British Telecom with this opportunity and during 1986 BT therefore purchased the company from ITT.[91] BT therefore controlled an international

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[90] When British Telecom had launched Telecom Gold in 1982, there were only two Prime computers. As demand for the service increased, BT installed new Prime computers and interconnected them using the Goldnet LAN. People established connections with these machines using terminals connected to the Telecom Gold public network, which then connected them to Goldnet using Access Units. See B. Fox, "The Electronic Mail is Getting Through," *New Scientist*, 17 October 1985, pp. 61-64.

[91] The ITT Corporation had purchased Dialcom during 1982. See "British Telecom Announces Completion of ITT Dialcom Acquisition," *British Telecom News release*, 9 May 1986, pp. 1-2.

electronic mail network that within three years would contain 270,000 subscribers in 19 countries (see Figure 5.6).[92]

5.5.2 Mercury Link 7500

As part of the government's liberalisation of the UK telecommunications industry, it had issued Mercury Communications with a licence in 1982 to operate as the main competitor to British Telecom which it did by offering circuits to businesses and consumers.[93] As BT and Mercury began to compete, Cable & Wireless Easylink had to address a problem in connection with its user base. By 1985, there were only 3,000 subscribers and as Flinter remembers, the service "was struggling, as it was a marginal business that didn't make any money".[94] While Cable & Wireless Easylink offered similar facilities to the market leader, Telecom Gold, and while subscribers could communicate with the larger Western Union Easylink community of about 117,000 users, the service did not offer anything that its competitors did not also provide.[95] To attract new users, Barbara Davies, the development manager, therefore "brought in a solution sales team and the whole sales and marketing effort went towards a number of industry types, so that Easylink became part of a solution for a customer rather than a single service".[96]

As Cable & Wireless began to ascertain which type of industry it should target, something happened which would ultimately make Easylink one of the most successful e-mail services in the UK. During 1986, Flinter noticed that a few journalists at News International were using Easylink and he wondered, "why would a company that size be using our service?

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[92] "As Good as Gold?" *Mind Your Own Business*, October 1988, p. 60.
[93] A consortium, consisting of Cable & Wireless, Barclays Merchant Bank, and British Petroleum, had formed Mercury Communications during 1981. See *Events in Telecommunications History*.
[94] Flinter, Interview.
[95] For example, Easylink was not part of an international network and Cable & Wireless had not licensed the software for use on company LANs, because Easylink did not have the resources to support such an endeavour.
[96] B. Davies, Interview by D. Rutter, 4 March 2002.

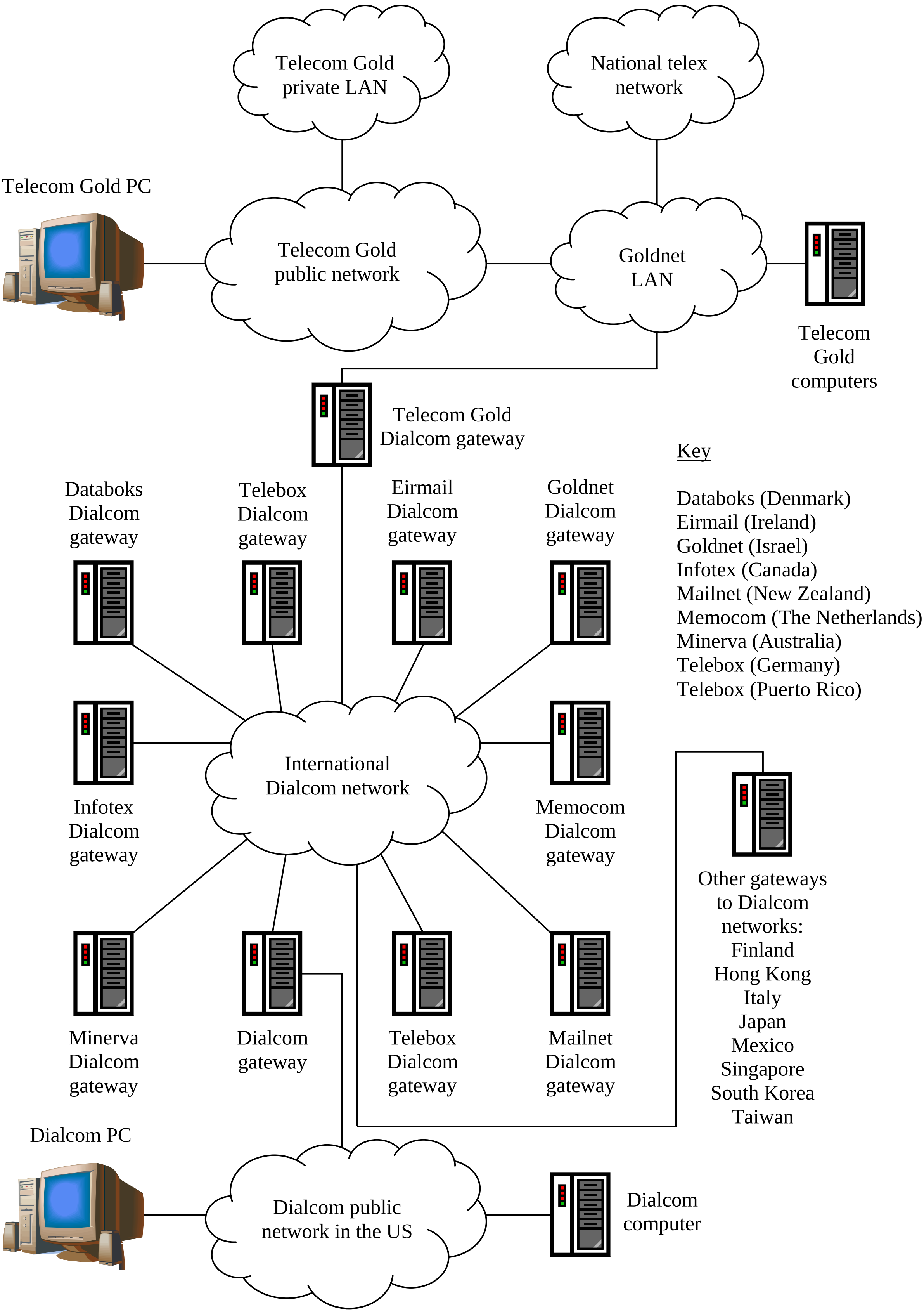

Figure 5.6. The international Dialcom e-mail network at the end of the 1980s.[97]

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[97] The information in this figure came from several sources. See Schofield, "Dialcom purchase adds lustre," p. 15, J. Angel, "How BT Serves the President," *The Guardian*, 18 September 1986, p. 13, and J. Schofield, "Gold Grows Up," *Practical Computing*, July 1987, p. 27.

There had to be a business opportunity there and so we made contact with them".[98] During the mid 1980s, News International wanted to create a new editing and publishing system which would enable journalists and press agencies to submit news stories electronically.[99] This system would replace the inefficient copy taking system and help to prevent press agencies from submitting worthless stories. To address these needs, Cable & Wireless launched the Easylink e-mail service, Newslink, during 1986. News International dictated that its employees, freelance journalists, and press agencies had to use this e-mail service to file news stories. News International focused particularly on the press agencies, stating, "we'll take any story you've got and every time we use it Newslink will immediately force deliver it direct into our publishing systems".[100] The company would then charge the press agencies for every story received, therefore preventing useless stories. A year after these facilities became available Newslink had increased the number of Easylink mailboxes by 2,000. While a total user population of 5,000 Easylink subscribers seemed low, especially when compared with Telecom Gold's 76,000 customers, the 2,000 new mailboxes did not truly reflect the number of people that used Newslink. Newspapers and broadcasters may have single accounts with a few e-mail addresses, but thousands of employees used these mailboxes.[101]

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[98] News International was the UK subsidiary of the News Corporation. News Corp purchased the British newspapers The Times and the Sunday Times during 1981, following this with the acquisition of Twentieth Century Fox in 1985. Twenty years later, this global multimedia corporation owned many publishing and broadcasting entities including 175 newspapers, HarperCollins Publishers, Fox and Sky News, and Classic FM. See B. Barnard, "Murdoch's Empire," *Europe*, December 1994/January 1995, pp. 32-33 and *Newspapers*, News Corporation, 2005, Available from: http://www.newscorp.com/operations/newspapers.html, Accessed on: 3 May 2005. Additional information from Flinter, Interview.

[99] As part of this initiative, News International planned to move its publishing facilities out of Fleet Street and into a new plant built at Wapping in London's docklands. The newspaper unions in Fleet Street were apprehensive about this transfer and the modernisation of the newspaper publication process using new technology, because it threatened their control over the publication of newspapers, control they had often exercised in the past. For example, they had censored stories they disagreed with and stopped the publication of papers, demanding bonuses or pay rises in return for continued newspaper production. Ignoring these demands, News International established the new printing plant and encouraged the workers at newspapers such as The Times in Fleet Street to move to this new facility. Most did and this move ultimately helped to broaden the freedom of the press and modernise the publication process of newspapers in Britain. See H. Greer, "Murdock Strikes a Blow for British," *Wall Street Journal*, 30 April 1986, p. 1.

[100] Flinter, Interview.

[101] Davies, Interview.

As the number of Easylink users increased, so too did the revenues from the telexes sent through Easylink's successor, Mercury Link 7500.[102] By the late 1980s, the telex facility was generating between one and two million pounds of telex traffic every year. With 110,000 telex subscribers in the UK and 1.5 million worldwide by the late 1980s, the telex was still a significant communications medium, although many believed that its successor, teletex, would soon supersede the older technology.[103] As telecommunications companies began to market teletex, another technology, facsimile, began to attract new users. Initially, companies had only sold about 5,000 fax machines during 1980, but by 1986, this had increased to 86,000, with 7 million machines worldwide.[104] The benefits of interconnecting the e-mail networks with this large user community were obvious. By providing the ability to send faxes from an e-mail account, this would preclude customers from having to buy fax machines, and increase the value of belonging to an e-mail network because of the fax connection. As a result, all of the leading e-mail networks provided a fax outbound facility including Mercury Link 7500. Cable & Wireless charged users 25 pence to send a fax containing 60 lines of text.[105] Because Cable & Wireless' customers did not need to buy a fax machine, the cost of using the e-mail service to send faxes was inexpensive.[106] Facsimile therefore complemented the e-mail networks by providing access to a large community of users. Mercury Link 7500 and Telecom Gold chose to view the technology like this, although during the late 1980s it was not clear whether this was true and which technology, out of teletex, fax, or e-mail, would become the dominant communications medium.

[102] In 1987, Cable & Wireless renamed Easylink as Mercury Link 7500.
[103] The Deutsche Bundespost had invented teletex during the mid 1970s and the CCITT had ratified the teletex standard in 1980. Teletex enabled people to use word processors to transmit text directly to other terminals. It could also communicate with the telex network and, as it was faster than telex, people referred to it as 'supertelex'. People within the telecommunications industry believed that by the year 2000 there would be 400,000 teletex terminals in use throughout the world. However, by 1987, there were little more than 18,000 terminals worldwide. Teletex therefore never superseded telex or challenged e-mail. See A. Kumar, "Annals of Messaging: The Telex Foundation," *Data Communications*, March 1987, pp. 271-272, 275-276, 279-280, 283-284, and 287, R.J. Firth, *Implementing Teletex* (Manchester: NCC Publications, 1985), pp. 1-3, D. Danks, "European Disharmony Snarls up a Standard," *Computing*, 21 October 1982, pp. 28-29, and J. Williamson, "Text Transmission In Europe: Telex, Teletex and Facsimile All Share a Piece of the Pie," *Telephony*, 25 April 1988, pp. 26-27.
[104] "Why the UK Loves Fax," *Communicate*, May 1987, p. 48.
[105] E. Fordham, "Global Comms Network," *Business Equipment Digest*, February 1989, p. 20.
[106] The average cost of a fax machine in the UK during the mid to late 1980s was almost £600. See J. Williamson, "Not Just The Fax," *Telephony*, 25 September 1989, pp. 33-34.

5.6 Interconnection, Proprietary E-mail, and the Internet

5.6.1 X.400: Expectations and Reality

By the late 1980s, four e-mail interconnection systems had emerged which could interconnect incompatible networks. These were X.400, proprietary systems, Internet solutions, and commercial conversion services. When British Telecom had announced its Gold 400 Message Handling System during 1986, it had been the first indication that a large telecommunications company supported the CCITT's X.400 standard. The following year, two demonstrations of X.400 occurred which illustrated the level of commitment for the Red Book from other companies within the industry. In 1987, 14 companies conducted a large demonstration of X.400 internetworking at CeBIT in Hannover. Organisations such as the Deutsche Bundespost, IBM, DEC, Hewlett-Packard (HP), ICL, Xerox, and British Telecom illustrated how incompatible computers throughout Europe could successfully send and receive e-mails using X.400.[107] The demonstrations attracted 20,000 visitors and the participants agreed to promote X.400 later that year at Telecom 87 in Geneva.[108] Twenty-one companies contributed to the displays at this show, including BT, AT&T, Dialcom, the Deutsche Bundespost, IBM, and Telenet. BT together with e-mail companies from the US, France, Switzerland, and Japan demonstrated the feasibility of interconnecting incompatible networks and therefore the potential of developing a global electronic mail network.[109]

If the 21 participants at Telecom 87 could have permanently interconnected their networks using X.400, then this would have created a community of over 6.5 million users. However, demonstrations were not enough. Support from the leading telecommunications companies and computer firms would be necessary for X.400 to become a success.[110] BT was one of the leading firms to support the standard, believing that X.400 was central to every type of electronic messaging, especially e-mail.[111] After BT had announced that it would establish a Message Handling System

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[107] "Firms Link Up In X.400 Display," *Computer Weekly*, 20 March 1986, p. 11.
[108] I.R. Valentine, "Why X.400?" *Telecommunications*, October 1987, pp. 83-84 and 92.
[109] P.L. Guidi, "Electronic Mail Begins a New Era," *Telecommunications Products & Technology*, December 1987, pp. 16-20.
[110] Green-Armytage, "X.400 Could Link Islands at Last," p. 26.
[111] As well as interconnecting e-mail networks, X.400 could interconnect e-mail services with telex and facsimile systems. See Betanov, *Introduction to X.400*, pp. 227-234 and 240-242.

in 1986, it began a series of trials of the X.400 software provided by Dialcom, which included using the MHS on Telecom Gold's computers.[112] When BT had completed these yearlong trials, it launched its Gold 400 service during June 1987. British Telecom charged users £700 a year to become users of its Message Handling Service, with usage charges of 20 pence for every 2,048 characters transmitted. BT was the first company to use the Gold 400 service, establishing links between Prestel and Telecom Gold, as well as using the system within the Corporation.[113] British Telecom announced that it would also establish connections with X.400 services in 11 countries.[114] By 1990, about one hundred companies in the UK had subscribed to Gold 400. Most of these were large international corporations which used the service for intra-company communications between incompatible private networks.[115] Although BT would have liked Gold 400 to become the centre of the e-mail universe, it remained essentially a UK-based service. Other companies also pledged their support for the standard during the late 1980s. Dialcom licensed its X.400 software to interested companies in 15 countries and created a link with AT&T Mail. This connection enabled Dialcom's 270,000 worldwide users to communicate with AT&T Mail's 40,000 subscribers.[116] Citibank planned to implement X.400 on a new global e-mail network that would interconnect its locations throughout the world, and, in the process, migrate away from its existing proprietary communications services.[117] And networks such as CompuServe, MCI Mail, and Western Union Easylink also used

[112] "Trials Start for Message Service," *Electronic and Optical Publishing Review*, vol. 6, no. 4, 1986, pp. 225-226.

[113] See R. Wakeling, "Intermail," *British Telecommunications Engineering*, January 1988, pp. 262-264. BT also established a link with Sprint International's SprintMail and set up Gold 400 telex and fax gateways. See J. Green-Armytage, "BT and Sprint Join X400 Systems for National Backbone," *Computer Weekly*, 9 May 1991, p. 16 and C.F. Wilkinson, "X.400 Electronic Mail," *British Telecommunications Engineering*, October 1989, pp. 164-171.

[114] "Comms Briefs," *Computer Weekly*, 15 November 1990, p. 16.

[115] D. Jones, "X400 – Jam Today?" *Open Systems*, September 1990, pp. 32-34.

[116] "AT&T and Unit of British Telecom Plan Link for Mail," *Wall Street Journal,* 19 January 1989, p. 1.

[117] By 1992, Citibank had become the largest bank in the US and had branches and offices in more than 90 countries worldwide. It operated two international messaging systems, the Global Communications Network and Citimail, both of which used proprietary protocols. See E. Messmer, "Citibank Commits to OSI with Global X.400 Net Plan," *Network World,* 26 October 1992, pp. 1 and 130 and *Citigroup - History*, Citigroup, 2005, Available from: http://www.citigroup.com/citigroup/corporate/history/citibank.htm, Accessed on: 3 May 2005.

X.400 to establish links between their networks, potentially creating a community of 620,000 users who could communicate with each other.[118]

As many within the electronic mail industry seemed to move inexorably towards the goal of the X.400 global network, other services started to establish connections between themselves using both proprietary protocols and the Internet. For instance, in 1987 Mercury Link 7500 and RCI-Calvacom in France established a connection which enabled Calvacom's 4,200 users and Cable & Wireless' 6,000 subscribers to exchange e-mails.[119] In addition, Datalinx launched an e-mail service that allowed users to send and receive e-mails with Telecom Gold and Mercury Link 7500 users.[120] Many networks also connected themselves to the Internet during the late 1980s, using gateways between the networks to handle the necessary protocol conversions. A software company called Net-Tel set up a link, Goldgate, between Telecom Gold and the Joint Academic Network.[121] As the Joint Network Team had connected JANET to the Internet many years before, this link enabled BT's customers to send and receive Internet e-mails. Other networks, such as CompuServe, MCI Mail, Western Union Easylink, and the Compulink Information eXchange (CIX), also created connections to the Internet during this period. To help these services communicate using the Internet as a network backbone, computer scientists, such as Jonathan Postel, developed the experimental Intermail system.[122] Intermail connected Telemail, Dialcom, and MCI Mail to the Internet, allowing subscribers of these networks to exchange e-mails. The rationale behind this system was that it should make communication between incompatible networks transparent, meaning that people

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[118] See *CompuServe DOS Information Manager Supplement Version 1.36* (Columbus, Ohio: CompuServe, 1992), p.17, B. Brown, "AT&T, MCI to link with Telenet Telemail via X.400," *Network World*, 8 May 1989, pp. 9-10, and Brodsky, "Online Services," p. 15.

[119] "European Email Service Links Britain and France," *Communicate for the Telecommunications User*, May 1987, p. 10.

[120] Although Datalink allowed its users to send e-mails to another incompatible network, the service had limited impact because it did not allow subscribers of say Telecom Gold to send e-mails to Mercury Link 7500 customers using Datalink as the form of interconnection. Only Datalink customers and people who wanted to communicate with these users could therefore benefit from the interconnections. See S. Gold, "Inter-system Email: The Datalinx Approach," *Communicate for the Telecomms and Datacomms User*, December 1989, pp. 14-15.

[121] B. Fox, *Catching on to Hidden Gold on the Net*, New Scientist, 1995, Available from: http://archive.newscientist.com/archive.jsp?id=19643400, Accessed on: 15 January 2002.

[122] On Postel see Appendix E.

should be able to send e-mails to any network, without worrying about the complexities of translation.[123]

In addition to experimental conversion systems such as Intermail, commercial versions emerged during the late 1980s and early 1990s. Instead of purchasing, say, an X.400 gateway and attaching it to a corporate LAN in order to communicate with other systems, companies could pay a company to convert e-mails for them. In 1992, Cable & Wireless launched a service called MultiMessage which it based on its predecessor, Mercury Link 7500.[124] MultiMessage provided several conversion facilities which enabled companies to transmit messages in one format and then have the service deliver them in a different format.[125] Using gateways, MultiMessage could convert communications between MultiMessage, X.400, Lotus cc:Mail, Internet e-mail, telex, and fax.[126] As Mark Preston, Cable & Wireless' technical design authority, explains, "the philosophy in those days was very much anywhere connecting to anything".[127] In 1999, a new service, Intranet Messenger, superseded MultiMessage, and added a direct connection to the Internet via an SMTP server and a Short Message Service (SMS) conversion facility for mobile phone users (see Figure 5.7).[128] Organisations such as Shell and the Met Office used Cable & Wireless' conversion service extensively which generated significant revenues for the company.

[123] As users had to enter extra header information before e-mail addresses before Intermail could deliver messages, the system was not as transparent as its designers would have hoped. See A. Westine, et al., "Intermail & Commercial Mail Relay Services," *Proceedings of the 18th Annual ACM SIGUCCS Conference on User Services, Cincinnati, Ohio* (New York: ACM Press, 1990), pp. 407-414.
[124] By the time Cable & Wireless introduced MultiMessage in 1992, the company had effectively stopped selling Mercury Link 7500. Customers that still had accounts could continue to use them, although Cable & Wireless did not use the name Mercury Link 7500 any more, replacing it with the name MultiMessage. Information from M. Preston, Interview by D. Rutter, 14 March 2002.
[125] Other companies developed similar systems at this time. For example, during the late 1980s, AT&T developed a universal messaging platform, which could convert messages from many formats including AT&T Mail, X.400, and SMTP e-mail, telex, and fax. See A.L. Fryefield and P.V. Guidi, "AT&T Premises Messaging Products," *AT&T Technology*, vol. 4, no. 2, 1989, pp. 28-37.
[126] Cable & Wireless were able to establish a connection with the Internet, as the X.400 software that it used had this capability.
[127] Preston, Interview.
[128] M. Preston, *MultiMessage Technical Reference Guide* (London: Cable & Wireless, 1997), p. 19.

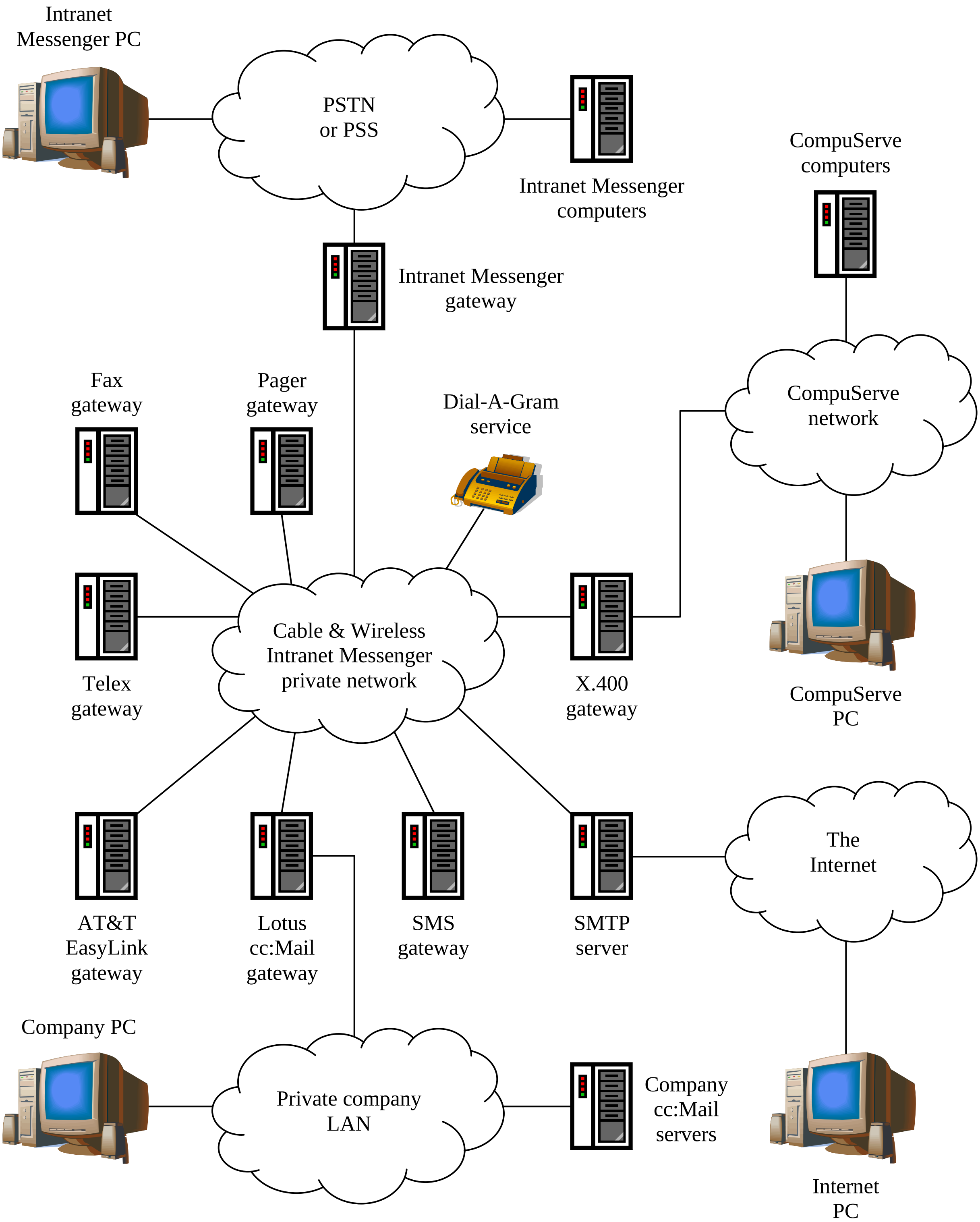

Figure 5.7. The Cable & Wireless Intranet Messenger system in 1999.[129]

[129] Companies could connect to Intranet Messenger using several terminals, devices, and connections, including PCs, telex machines, mobile phones, the PSTN, the PSS, and leased lines. The Dial-A-Gram service was a MultiMessage service that enabled customers to telephone or fax messages to MultiMessage, which Cable & Wireless staff would then enter into the system and deliver to their destinations. The Intranet Messenger computers stored MultiMessage accounts, which had originally been Mercury Link 7500 accounts. The X.400 gateway could connect to any other X.400 gateway, a potential example being CompuServe. See Preston, *MultiMessage Technical Reference Guide*. Additional information from Preston, Interview.

By the late 1980s and early 1990s, services such as MultiMessage and the interconnections created by X.400, proprietary links, and the Internet allowed people to communicate with users on other incompatible networks. These links enabled, for instance, a Telecom Gold subscriber to send and receive e-mails with Prestel, users on the Internet, and Western Union Easylink customers. However, these global interconnections were not ones that people wanted to use. There were simply too many networks, interconnection options, conversion facilities, address formats, and complexities to encourage thousands of users to attempt internetwork communication. In addition, by the late 1980s, it was clear that the influence of potential solutions such as Datalinx and Intermail had been limited.[130] And services such as MultiMessage, while enabling internetwork communication for a limited number of companies in the UK, did not offer a lasting resolution to the global incompatibility issue. What people needed was a single solution to the problem of interconnectivity. Many people believed that this was where X.400 was the natural choice.[131] If every network gradually migrated away from proprietary protocols and the Internet towards X.400, this would realise the objective of creating a global interconnected e-mail network. Signs of this migration did exist.[132] However, for this transitional strategy to work every network would need to migrate to X.400. By the early 1990s, it was clear that this was not happening. Most networks, such as Telecom Gold, had only provided access to the CCITT's standard in the form of a gateway between the networks. This option was a less radical approach to a global e-mail network, but it could have worked if enough companies had installed the X.400 gateways between their networks, and adopted a uniform addressing mechanism supplied as part of the CCITT's standard.

[130] This fact is not surprising. Datalinx only interconnected a few networks, Telecom Gold and Cable & Wireless Easylink, and to benefit from these links, people needed to become subscribers of the service. Intermail never became as successful as it perhaps could have done because it did not connect hundreds of networks, only a few such as Dialcom and MCI Mail. It also required users to enter extra header information before e-mail addresses, something that many users would not want to do as they wanted a truly transparent solution to the incompatibility problem.

[131] Flinter, Interview.

[132] For example, in the academic community, the JNT was migrating away from its Grey Book protocol towards X.400 and in the US, the government had decided in 1986 to replace TCP/IP with OSI. In addition, a similar thing was happening with the proprietary Citibank networks. See M. Witt, "Moving from DoD to OSI Protocols: A First Step," *Computer Communication Review*, vol. 16, no. 2, 1986, pp. 2-7.

Several problems were impeding X.400's progress. When the CCITT had ratified X.400 in 1984, it had defined a comprehensive standard for a Message Handling System.[133] X.400 was a very complex standard which like most standards contained voluminous amounts of detail making it too complex for any company to implement fully, especially on personal computers which lacked the power to execute many of the features provided by the standard.[134] The standards were also open to interpretation which meant that, for instance, BT might implement certain features as part of its Gold 400 Message Handling System, while Citibank might employ a different range of facilities for its MHS. This situation could create incompatibilities between the systems, and therefore cause problems for users.[135] Disappointing demand for X.400 was also a problem. This lacklustre support came from computer manufacturers and the network providers themselves. Computer companies were nervous about investing in a market for X.400 products that did not seem to exist. After all, no one was certain if users would be willing to pay for X.400 systems. So few products materialised which did little to create the seamless connections between networks. The conflicting motivations of the public e-mail providers compounded these problems. In particular, British Telecom's intentions with its Gold 400 service seemed disingenuous.[136] BT wanted its MHS to become the universal clearinghouse for every e-mail transmitted in the UK. This clearinghouse would enable it to control a crucial component of the e-mail internetwork that would exist in Britain and generate substantial revenues for every e-mail transmitted through its Message Handling System. However, by interconnecting every service using X.400, this would mean that, say, a Mercury Link 7500 user could potentially access the services provided by Telecom Gold, such as access to databases. This situation could therefore provide little incentive for potential adopters to become customers of BT's network as opposed to its competitors. As a result, most public e-mail providers were adamant

[133] In 1988 and 1992, the standards organisation updated X.400 to solve problems and improve the services it offered. See Betanov, *Introduction to X.400*, pp. 71-75.
[134] Ibid., p. 2.
[135] "X.400: No Guarantees for Interoperability," *Data Communications*, 21 May 1993, p. 62.
[136] Other companies were also guilty of this charge. For example, during the late 1980s, IBM announced that it would support X.400 by interconnecting its Distributed Office Support System (DISOSS) and Profs e-mail office solutions to X.400-based services. However, IBM initially only intended to sell these X.400 compatible systems in Europe, therefore protecting its installed base of DISOSS and Profs users in the US, where they were more widely diffused compared to Europe. See Kerr, "X.400 E-Mail Standard Picks Up Steam in the U.S.," p. 24.

that they would retain control of their user bases which they had worked hard to attain.[137]

By the mid 1990s, it was clear that several factors had seriously affected X.400's chance of becoming the central component in a global e-mail network. Although X.400 had interconnected one million mailboxes on many networks by 1994, this number was insignificant when compared to the potential number of users it could have linked at that time.[138] In addition, most subscribers did not use X.400 on a frequent basis because they were either not aware of its existence or not familiar with its relatively complicated addressing format.[139] As a result, most people did not use the X.400 links that did exist between the networks which meant that most e-mail users remained isolated from each other. X.400 had therefore failed to fulfil the promise set for it by its proponents. As Brunnen remembers, "X.400 was a dangerous and stupid diversion because there was a thing called the IP protocols. X.400 was supposedly an important step, but it was a cul-de-sac".[140] However, with several networks, such as Dialcom and CompuServe, having hundreds of thousands of subscribers, many of whom would have liked to communicate with each other, there was still a need for a solution to the problem of interconnection.[141]

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[137] J. Rickard, "Electronic Mail Call — Getting There Is Getting Easier," *Online*, September 1990, pp. 37-40.

[138] This number seems large initially especially considering the problems that had affected X.400. However, it was insignificant when compared to the total number of e-mail users it could have connected by the mid 1990s. By the end of 1995, there were more than 26 million Internet users. See *Nua Internet How Many Online*, Nua, 2003, Available from: http://www.nua.ie/surveys/how_many_online/world.html, Accessed on: 13 May 2004.

[139] Companies such as BT did not help to promote X.400 to their customers. While a manual for a network would be a suitable publication to explain what X.400 was and how subscribers could use this facility, BT failed to do this with Prestel. Consulting four Prestel manuals from the late 1980s and early 1990s reveals that while these publications mention the Prestel Telex Link and/or the gateways to third party databases, they do not mention the link that existed between Prestel and Telecom Gold via Gold 400 or X.400. Problems such as these and other issues, including users not seeing the value of X.400 and the promise of a global interconnected e-mail network, prevented such a network from materialising. Convergence around X.400 therefore did not occur. If people did not see the value of X.400 on individual networks, companies could not expect them to see the value of an X.400 global interconnected e-mail network. See *Prestel Customer Handbook* (London: British Telecom, 1988), *Prestel Mailbox User Guide* (Hemel Hempstead: British Telecom, 1989), *Prestel User Guide* (Hemel Hempstead: British Telecom, 1990), and *Prestel User Guide* (London: British Telecom, 1991). On e-mail and X.400 see Appendix L.

[140] Brunnen, Interview.

[141] By the late 1980s and early 1990s, Dialcom had 270,000 users and CompuServe had 750,000 subscribers. See "As Good as Gold?" p. 60 and "CompuServe Puts the Whole World at Your Fingertips," *Personal Computer World*, April 1991, pp. 160-161.

5.6.2 The Demise of Proprietary Public E-mail Networks

By the end of the 1980s, British Telecom had decided to reintegrate Telecom Gold and Dialcom back into the main Corporation. As Peter Bury, the second managing director, remembers, "Telecom Gold had got onto the corporate radar and had been noticed".[142] This decision damaged both services. As Martin Turner, a former Telecom Gold product manager remembers, it had been "very innovative of BT to fund these start-ups but the one thing that BT got wrong was when they became reasonably successful and tried to pull them back into the mother ship and installed bureaucrats to run them which meant that all of the entrepreneurial and inspirational people began to leave".[143] By incorporating Telecom Gold back into British Telecom, the network became one of many services and therefore lost its identity. Although BT continued to market the service, it decided not to develop its successor, Mailbox, into an Internet Service Provider when it became clear that people wanted to connect to the Internet during the early to mid 1990s.[144] Instead, BT decided to launch a new Internet Service Provider, called BTnet, in 1994, and within two years, Mailbox had ceased to exist.[145] Morris reflects on the demise of Mailbox saying "I think Telecom Gold disappeared on the basis people probably lost sight of what it really was, to a point where it fell off the back of a ship and nobody knew that we had lost it."[146]

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[142] P. Bury, Interview by D. Rutter, 27 February 2002.
[143] M. Turner, Interview by D. Rutter, 26 February 2002.
[144] BT re-launched Telecom Gold as Mailbox during 1992 and then focused on developing MS-DOS and Microsoft Windows client software for its service, instead of focusing on the Internet. Although the Goldgate gateway between Mailbox and the Internet existed, BT never supported this facility and therefore did not upgrade it even when traffic through the gateway increased, as the popularity of the Internet grew. It was during this period when BT could have connected its 120,000 Mailbox customers to the Internet using a new gateway, provided text-based access to services such as the World Wide Web, and then developed its service into a full ISP. However, BT did not do this, unlike other companies, such as GeoNet, which were offering these services at this time. See *MailStation User Guide* (London: Soft Solution, 1994), pp. 49-50.
[145] During the previous decade, BT had become increasingly aware of how best to respond effectively to the market in order to operate a successful electronic mail network, by incrementally improving its service in response to the demands of its subscribers. However, by the mid 1990s, this success began to impede British Telecom's ability to assess effectively the emerging issues, challenges, and opportunities of another network, the Internet. On technological discontinuities see R.N. Foster, *Innovation: The Attacker's Advantage* (London: Macmillan, 1986).
[146] Other Mailbox-based networks also ceased to exist. For example, in 1989 BT had integrated the TTNS with Prestel Education to form the Campus 2000 service. In addition, in 1991, AT&T bought Istel and Microlink as part of a deal and then closed the latter, believing that this service did not concur with its global telecommunications strategy. AT&T offered CompuServe subscriptions to former Microlink customers. See Cawson, et al., *The Shape of Things to Consume* p. 160. Additional information from Morris, Interview.

As BT turned its attention to the Internet, the traffic through Cable & Wireless' MultiMessage X.400 service started to decrease, while the use of Newslink continued to increase. The level of X.400 traffic had never been high, but for those companies that used this facility, their need for the service reduced towards the end of the 1990s. As Preston remembers, "X.400 was starting to become less important and strategic, with some of our big X.400 customers moving to the Internet".[147] This trend occurred across the electronic mail world at this time. For instance, several organisations terminated support for X.400 including Sprint International, UKERNA, the National Health Service (NHS), and BACS.[148] Meanwhile, the popularity of Newslink among publishers and journalists grew. When Cable & Wireless had launched its e-mail-based service in 1986, it had only one customer, News International. By the year 2000, many companies used the services provided by Cable & Wireless' system. These included all national and most regional newspapers, press agencies such as Associated Press (AP) and Reuters, and television and radio stations such as BBC 1 and Radio 4. What had begun as one service among several in the Cable & Wireless Easylink portfolio, had become a very successful independent e-mail-based service, with thousands of users throughout the publishing and broadcasting industries. By then, Cable & Wireless had decided that it was no longer interested in operating the

[147] Preston, Interview.

[148] GTE bought Telenet during 1979 and in 1986 Telenet merged with US Telecom to form the Sprint Communications Company. By 1988, SprintMail had 200,000 users. See "GTE Sprint and US Telecom Will Merge," *Across the Board*, 24 January 1986, p. 3 and Brodsky, "Online Services," p. 15. Sprint closed their X.400 ADMD in the UK during 2001. With the closure of SprintMail's service, this isolated JANET from commercial management domains. However, this event was not significant because most people who used JANET did not access X.400. The following year UKERNA terminated the JANET X.400 service. During November 2003, the NHS closed its X.400 service and replaced it with a new, more secure electronic mail service that used Internet protocols to serve almost 10,000 NHS organisations, with a total user population of 1.2 million. In March 2005, BACS withdrew support for X.400, meaning that BACS customers had to migrate to BACSTEL-IP the new system for online payment and collection. See *Warning of the Termination of the Sprintmail X.400 Service*, UKERNA, 2001, Available from: http://www.ja.net/mail/x400/sprintmail.html, Accessed on: 14 April 2005, *JANET Mail Services*, UKERNA, 2002, Available from: http://www.ja.net/mail/x400/J-400.html, Accessed on: 14 April 2005, *X.400 Service Ends*, NHS, 2003, Available from: http://www.nhsia.nhs.uk/nhsnet/pages/emailmessaging/x400smtp/closure.asp, Accessed on: 14 April 2005, *Roll-out of NHS Messaging Service Completed*, NHS, 2003, Available from: http://www.informatics.nhs.uk/cgi-bin/item.cgi?id=380, Accessed on: 1 April 2005, *About NHSnet & the New National Network (N3)*, NHS, 2004, Available from: http://www.nhsia.nhs.uk/nhsnet/pages/about/intro/nhsnet.asp, Accessed on: 1 April 2005, and *What is a Direct Submitter?* BACS Payment Schemes Limited, 2005, Available from: http://www.bacs.co.uk/BPSL/bacstelip/directsubmittters/Whatisadirectsubmitter, Accessed on: 14 April 2005.

system, and subsequently sold it to a company, Newslink Limited, which re-launched the service using Internet technology.[149]

5.6.3 The Ascendancy of Internet E-mail

In parallel with the development of proprietary electronic mail networks and the X.400 standard, Internet e-mail continued to evolve. After Tomlinson had implemented e-mail on the ARPANET during 1971, a small number of users had utilized the messaging programs. However, for e-mail to diffuse throughout the network, the community would need to develop standards that would define how the ARPANET should format and transmit messages. By 1981, the Internet community had prepared several standards, one of the most important of which, the Simple Mail Transfer Protocol (SMTP), allowed servers to transmit e-mails throughout the ARPANET.[150] As PCs became popular during the 1980s, people wanted to be able to connect to a server that stored their e-mails, download their messages, and read them offline. In response to this need, the Internet community therefore developed two standards, the Post Office Protocol (POP) and the Internet Message Access Protocol (IMAP), in 1984 and 1988 respectively. POP and IMAP established connections with remote e-mail servers that contained users' mailboxes. With the invention of the World Wide Web, companies, such as Hotmail, extended access to electronic mail from within Web browsers (see Figure 5.8).[151]

From the mid 1990s onwards, millions of people used electronic mail on the Internet which forced services such as CompuServe to interconnect their networks with the Internet, and as a result adopt the Internet Protocol suite.

[149] Newslink Limited therefore replaced the old proprietary Newslink hardware and software with Internet-based technology.
[150] See Appendix L.
[151] Hotmail invented Webmail when it launched its service on the Web during 1996. In 1997, Microsoft bought Hotmail and renamed it MSN Hotmail. By 1999, the number of users had reached 30 million and by 2005 there were over 200 million active accounts, making Hotmail the largest e-mail provider in the World. In 2005, people send 100 e-mails a day using MSN Hotmail. See *MSN Hotmail: From Zero to 30 Million Members in 30 Months*, Microsoft Corporation, 1999, Available from: http://www.microsoft.com/presspass/features/1999/02-08hotmail.mspx, Accessed on: 20 October 2005, *MSN Historical Timeline: A Brief History of Milestone Events in the Life of MSN from the Past Ten Years*, Microsoft Corporation, 2005, Available from: http://www.microsoft.com/presspass/press/2002/nov02/11-08MSN8GlobalTimeLine.mspx, Accessed on: 20 October 2005, *MSN Advertising: Hotmail*, Microsoft Corporation, 2005, Available from: http://advertising.msn.com/msnsites/msnindividualsite.asp?showmore=true&siteid=siteid43, Accessed on: 20 October 2005, and Appendix L.

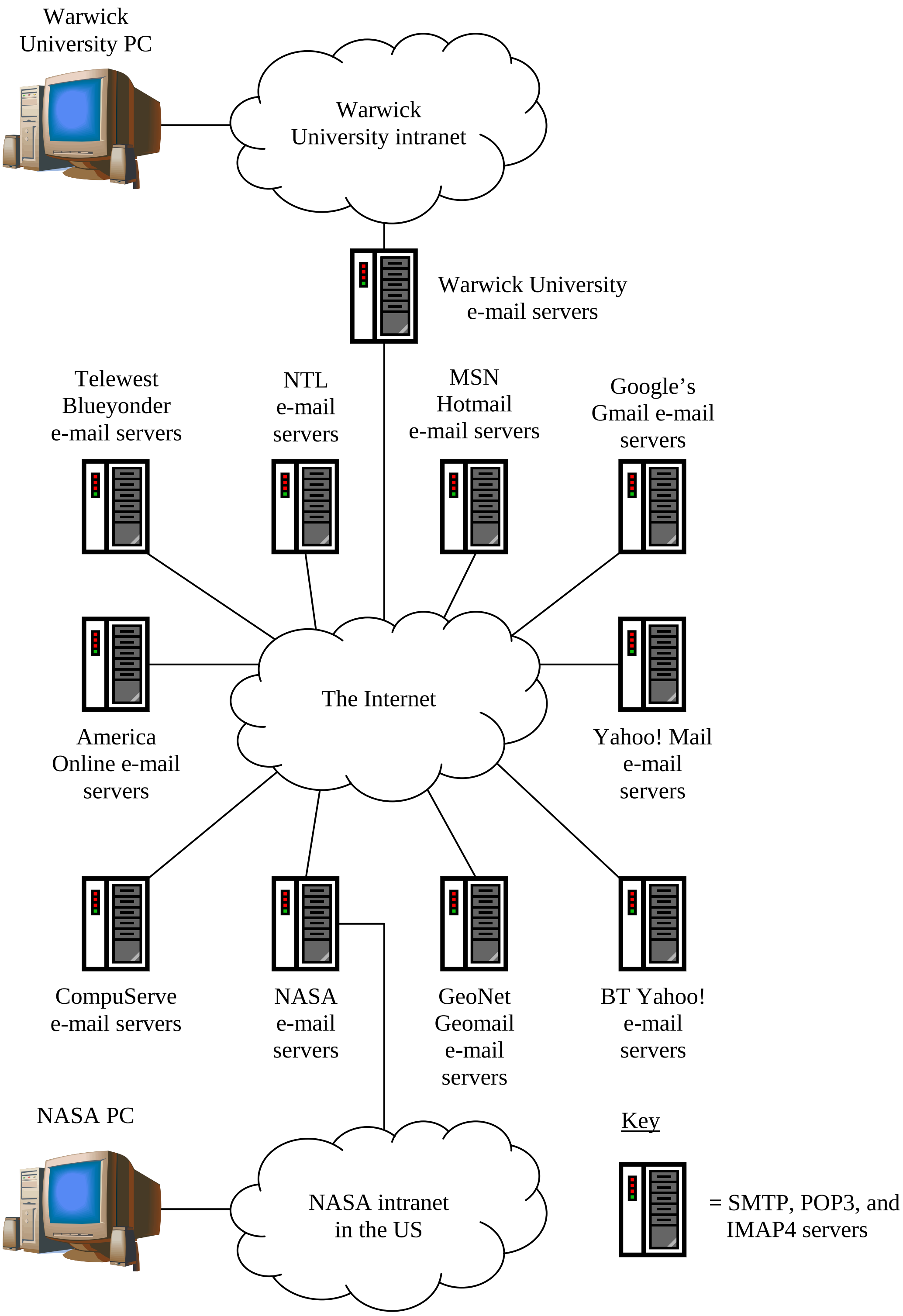

Figure 5.8. A simplified representation of Internet e-mail.[152]

By then, it was no longer sufficient to improve the proprietary e-mail networks gradually in response to the needs of users, because customers also valued the ability

[152] The figure illustrates how the Internet interconnects different e-mail networks, enabling users to communicate. Several types of organisation provide e-mail services including academic institutions, commercial companies, and government agencies. See Appendix L.

to send and receive e-mails to anyone on the Internet. An important shift had therefore occurred from the old, closed world of the proprietary networks to the new, open world of the Internet.[153] By resolving the problem of how to interconnect incompatible networks, the Internet had enabled anyone with a connection to the Internet and an e-mail account to communicate. The Internet had also contributed to the decline of X.25 and the higher-layer proprietary protocols. Throughout the 1980s, many companies had used X.25 as a fundamental component of their networks. These firms had also used higher-layer protocols for services such as e-mail, file transfer, and other facilities. Some, such as the academic community's Grey Book standard, had been open for everyone within academia to implement, while others, such as Telecom Gold's e-mail protocol, were proprietary. The telecommunications industry intended that every company would replace both types of protocol with their OSI equivalents. X.25 would form the basis for a global OSI network. However, the ascendancy of the Internet superseded most proprietary protocols, OSI standards such as X.400 and X.500, and the underlying X.25 technology.[154] For this reason, the closure of X.25-based proprietary e-mail networks, such as Telecom Gold, reduced the reliance on X.25, and helped to contribute to the decline of this protocol and the rise of TCP/IP as the standard of choice for internetworking. This convergence around the Internet Protocol suite also extended to other forms of messaging, such as the ability to transmit telexes and faxes over the Internet.[155] The Internet had therefore become what many had hoped X.400 would become: a global e-mail network. This is

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[153] The older networks had solved a specific set of problems, namely how to provide network services and facilities using proprietary technologies. With the emergence of the Internet, the problems faced expanded to include the issue of interconnection. On technological paradigms and trajectories see G. Dosi, "The Nature of the Innovative Process," in *Technical Change and Economic Theory*, G. Dosi, et al. eds. (London: Pinter, 1988), pp. 221-238.

[154] Ibid.

[155] No single authority controlled this convergence. As governments, companies, organisations, and individuals valued TCP/IP's ability to interconnect incompatible networks and especially to connect to the Internet, they directed the convergence around the Internet Protocol suite. As people converged around TCP/IP and the Internet, another form of convergence started to occur. Companies added new facilities to the Internet, which enabled people to transmit telexes and faxes over IP. These services increased the value of using the Internet for the companies and individuals who needed these facilities. One of the companies to offer these services was EasyLink. During 2000, Swift Telecommunications acquired AT&T's EasyLink business. Swift provide a service called Internet Telex, which enables customers to send telexes using e-mail and the Internet. In addition, the company offers a service, Integrated Desktop Messaging, which enables subscribers to use EasyLink to send and receive faxes using e-mail. See *Swift Telecommunications Acquires AT&T EasyLink Business*, AT&T, 2000, Available from: http://www.att.com/news/2000/12/15-3562, Accessed on: 15 April 2005, *Integrated Desktop Messaging*, EasyLink Services, 2002, Available from: http://www.easylinkservices.co.uk/idm.cfm, Accessed on: 15 April 2005, and *EasyLink Internet Telex*, EasyLink Services, 2002, Available from: http://www.easylinkservices.co.uk/internettelex.cfm, Accessed on: 15 April 2005.

not to say that the public e-mail networks and X.400 were failures. The e-mail networks had provided useful services for subscribers and X.400 had interconnected several networks enabling people to exchange e-mails, albeit on a limited basis. By the late 1990s, X.400 had also become useful as a reference model for electronic mail.[156] By introducing people, such as database users and journalists, to the concept of electronic mail, the e-mail networks had helped to influence many peoples' perception of what e-mail was, and what it could do for them.[157] In addition, by the time the Internet became popular, many former customers of proprietary e-mail networks owned PCs which they used for Internet e-mail.[158] And as networks such as Telecom Gold closed, their users naturally turned to the Internet as the communication network of choice for e-mail, which helped to contribute to the increasing number of Internet users. With the disappearance of proprietary e-mail networks, this helped to consolidate TCP/IP as the standard used to transmit electronic mail on networks such as the Internet.[159]

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[156] For example, a description of how X.400 works, in terms of system components such as UAs and MTAs, can be useful as a model for understanding how e-mail works in general. On the X.400 model see Betanov, *Introduction to X.400*, pp. 15-22.

[157] Because the public e-mail networks did not attract millions of users, unlike the Internet, and as most no longer exist, people can consider them failures. However, this is too simplistic, ignoring the influence these networks had on their users. A similar situation occurred with the NNTT in Arizona during the 1980s. Many considered the NNTT to be a failure, but its influence over the design and construction of subsequent telescopes was important. See W.P. McCray, "What Makes a Failure? Designing a New National Telescope, 1975–1984," *Technology and Culture*, vol. 42, no. 2, 2001, pp. 265-291.

[158] This trait was a pre-adaptive advance, because the original diffusion of PCs was unconnected with the Internet, but later gained adaptive value when previous customers of proprietary e-mail networks wanted to access the Internet to send and receive e-mails. The concept of pre-adaptation comes from evolution. See V. Schneider, "Evolution in Cyberspace: The Adaptation of National Videotext Systems to the Internet," *Information Society*, vol. 16, no. 4, 2000, pp. 319-328 and R. Dawkins, *The Ancestor's Tale: A Pilgrimage to the Dawn of Life* (London: Weidenfeld & Nicolson, 2004), pp. 82-83.

[159] It is, of course, more complicated than this. SMTP transmits e-mails by using the lower-layer services provided by TCP/IP. See Appendix L.

6. From Time-sharing to the Web

6.1 Introduction

The time-sharing systems of the 1960s became the basis for a new type of service. Known as computer bureaus, these enabled customers to establish connections with central data centres in order to access several facilities, such as performing calculations and writing interactive programs using languages such as FORTRAN.[1] Several companies established computer bureaus throughout the decade, including IBM, with its Quiktran service, and Bolt, Beranek and Newman's Telcomp bureau.[2] However, there was an alternative for companies that did not want to use the facilities provided by computer bureaus. Towards the end of the decade, corporations such as IBM started to sell time-sharing systems which customers could install in-house.[3] One of these companies was the Golden United Life Insurance Company which would set up the first online service, CompuServe. This chapter will focus on CompuServe and show how this developed from being a time-sharing system, to an online service accessed by personal computer users. It will describe how, by the mid 1980s, the network offered many of the services and facilities that the Internet of the 1990s would provide. It will show how CompuServe became the largest online service in the world by the end of the 1980s and explain why this occurred. The chapter will place CompuServe into context by discussing the online service phenomenon, focusing on competitors such as America Online, Prodigy, and the Microsoft Network (MSN). The chapter will explore why CompuServe underestimated the significance of the Internet, and how the commercialisation of this network, and the subsequent emergence of Internet Service Providers, affected the company.

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[1] Computer bureaus could support anything from 20 to 200 simultaneous users. Charges varied. For example, GE Systems' service cost users $30 an hour, whereas Tymshare billed customers at up to $375 a month. By 1967, there were 20 companies in the US offering computer bureau services. See C.C. Barnett, Jr., et al., *The Future of the Computer Utility* (New York: American Management Association, 1967), p. 50 and A.L. Norberg and J.E. O'Neill, *Transforming Computer Technology: Information Processing for the Pentagon, 1962-1986* (Baltimore: Johns Hopkins University Press, 1996), p. 105.

[2] D.F. Parkhill, *The Challenge of the Computer Utility* (Reading, MA: Addison-Wesley Publishing Co., 1966), pp. 76-79.

[3] J.E. O'Neill, "'Prestige Luster' and 'Snow-Balling Effects': IBM's Development of Computer Time-Sharing," *IEEE Annals of the History of Computing*, vol. 17, no. 2, 1995, pp. 50-54.

6.2 Early Network Developments

6.2.1 From Time-sharing to Online Service

The Golden United Life Insurance Company was a financial services firm based in Ohio. In 1969, it wanted to modernise its operations by installing computers.[4] It decided to establish an internal time-sharing system, and allocated $1.5m to the project. At this time, the Digital Computer Corporation supplied several computers which companies could use as the basis for time-sharing systems. These included the PDP-15 and the Time Share-8, based on a PDP-8.[5] As many successful time-sharing firms used PDP-10s, Golden United decided to purchase one of these computers, at a cost of $700,000. While this machine was more expensive than both a PDP-15 and a PDP-8, the extra processing power that it offered would enable the company to establish a computer bureau service, the revenues from which would cover the cost of the machine.[6] To run the service, Golden United set up a subsidiary called Compu-Serv Network Inc. According to Barry Berkov, a former senior vice president of the information services division at Compu-Serv, the objective of the subsidiary "was to copy other time-sharing companies such as GE and IBM's service bureau".[7] However, as Sandy Trevor, a past chief information officer, remembers "it was a terrible time to get into this business, because General Electric (GE), Tymshare, Cyphernetics, and First Data were already established".[8] To help encourage potential adopters to become subscribers of its computer bureau service, Compu-Serv attempted to reduce the switching costs by adapting the interface of its system to emulate the interface of GE Systems' service.[9] It also developed a new application designed to appeal to insurance companies which wanted to exploit the potential of time-sharing services, without having to develop internal systems. Known as the Life Insurance Data Information System (LIDIS), this was a back office information processing application which clients could access using teletypes and the PSTN, to process insurance-related information.

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[4] R. Levering, et al., *The Computer Entrepreneurs: Who's Making It Big and How in America's Upstart Industry* (New York: New American Library, 1984), pp. 415-420.
[5] "DEC's Time Share-8," *Datamation*, September 1968, p. 71.
[6] For example, a Time Share-8 cost between $55,000 and $150,000 in 1968, depending on the amount of memory and number of peripherals purchased. See Ibid., p. 71.
[7] B. Berkov, Interview by D. Rutter, 2 December 2002.
[8] S. Trevor, Interview by D. Rutter, 2 December 2002.
[9] On switching costs see P. Klemperer, "Markets with Consumer Switching Costs," *Quarterly Journal of Economics*, vol. 102, no. 2, 1987, pp. 375-394.

LIDIS helped to attract users to Compu-Serv's new computer bureau service. Within three years, the time-sharing system was generating $250,000 on sales of $2m. However, by then, the long-term future of Compu-Serv's service had started to become uncertain. Like Golden United, many companies had started to buy time-sharing systems for in-house use. If Compu-Serv was to survive, it would need to develop new applications. In 1970, Compu-Serv had developed an electronic messaging service for General Motors. It then developed a similar product, InfoPlex, which it sold to firms who could install it on their minicomputers for intra-company communications. Compu-Serv also sold InfoPlex as a service for companies that wanted to pay a third party company to handle their electronic communications for them. As Compu-Serv started to develop a network throughout the US, establishing centres in several cities, accessing InfoPlex for the cost of a local telephone call became attractive to firms. In addition to this service, Compu-Serv developed new facilities, such as financial programs and experimental modelling applications.

Compu-Serv's range of services helped to contribute to the subsidiary's $10m in revenues by 1977. With hundreds of clients accessing several computer centres throughout the US, Compu-Serv had become a successful computer bureau. However, like every time-sharing service, the company suffered from the fundamental problem of underutilisation. Companies generally only accessed the bureau during office hours which meant that Compu-Serv did not capitalise on its investment in its hardware and software during the evenings and at weekends. In addition, the emerging market for personal computers troubled time-sharing firms. These offered relatively inexpensive computing power and could run financial programs, a task that time-sharing systems had traditionally handled.[10] PCs could therefore threaten Compu-Serv's business. In addition, they could also represent an opportunity for the company, and if it did not exploit this, a competitor would. It therefore decided to surpass its existing computer bureau service, while this was still popular, in an attempt to secure future expansion for the company.[11] As a result, CompuServe examined ways in which PCs might not

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[10] For instance, in 1977, an organisation could buy a 48 Kb Altair personal computer, dumb terminal, 2 floppy disk drives, a printer, and accounting software for $16,000. In comparison, minicomputers cost $25,000 or more for a basic system and hundreds of thousands of dollars for more sophisticated machines. See E.K. Yasaki, Sr., "Microcomputers: For Fun and Profit?" *Datamation*, July 1977, pp. 66-71.

[11] On creative destruction and product cannibalism see J.A. Schumpeter, *Capitalism, Socialism and Democracy* (London: Allen and Unwin, 1976), pp. 81-86.

displace its time-sharing network, determining that it could offer substantial amounts of electronic information to potential adopters. To test the feasibility of this idea, Compu-Serv approached the Midwestern Association of Computer Clubs during 1978 with the offer of a PC-based online service called MicroNET. Hobbyist computer users were enthusiastic about being able to use the time-sharing network, and this convinced Compu-Serv that it should establish the service on a nationwide basis.

6.2.2 The CompuServe Information Service

In 1979, CompuServe launched MicroNET throughout the US.[12] CompuServe targeted the service at hobbyist computer users who might want to access its facilities. By using a personal computer, such as a Tandy TRS-80 or an Apple II, subscribers could access several services, including programming languages such as FORTRAN and BASIC, electronic mail, software that they could download, multi-player games, and applications such as business, personal, and educational programs. As MicroNET used CompuServe's time-sharing network, subscribers could only use the PC-based service during off-peak hours which complemented the load placed on the network during the day, generated by the corporation's time-sharing customers. CompuServe charged users a $9 registration fee and then $5 an hour. MicroNET provided inexpensive access to the resources of centralised computers which appealed to potential hobbyist computer users.[13] In addition, CompuServe provided local call access to its computer centres in 27 cities and people could connect to MicroNET from an additional 153 cities at a cost of an extra $4 an hour.[14] Everyone connected to the system using 300 bps modems.[15] By the end of 1979, MicroNET had 1,000 subscribers.[16] CompuServe had recognised early the opportunity presented by the PC and created the first "online service" that offered facilities which personal computer users were willing to pay to access.[17] As the 1980s began, the concept of an online service began to diffuse throughout the US and other countries.

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[12] Compu-Serv became CompuServe Inc. during 1977.
[13] MicroNET was inexpensive when compared to time-sharing services which typically charged $20-$30 an hour.
[14] See "MicroNET: Big-system Performance for Your Personal Computer," *Byte*, October 1979, p. 51 and "MicroNET: It's Off and Running and Delivering as Promised," *Byte*, January 1980, p. 103.
[15] See Appendix B.
[16] J. Carey and M.L. Moss, "The Diffusion of New Telecommunication Technologies," *Telecommunications Policy*, vol. 9, no. 2, 1985, pp. 145-158.
[17] CompuServe was therefore a technological pioneer, an innovator that had perceived the personal computer as an opportunity and exploited it. See R.S. Rosenbloom and M.A. Cusumano,

By late 1980, CompuServe had renamed MicroNET as the CompuServe Information Service (CIS). By then, the corporation had started to expand its network in several ways. Subscribers could access the CIS during the daytime, at a cost of $22.50 an hour.[18] Business customers could use the CompuServe computer network to interconnect their offices. CompuServe agreed a deal with Tandy to sell starter kits for the online service through 14,000 Radio Shack stores throughout the US.[19] By the end of 1980, customers in nearly 200 cities could access the online service using CompuServe's network, Telenet, Tymnet, or British Telecom's International Packet Switching Service (IPSS). CompuServe developed a new system for quickly accessing facilities. Instead of navigating through ASCII menus to find a facility, subscribers could use the GO command. By entering GO followed by a keyword, CompuServe would display any facility provided by the online service. Subscribers could use the new keyword feature to access an increasingly large range of services, including forums, the National Bulletin Board, and the Citizens Band (CB) Simulator. Of these, forums, which were a form of Bulletin Board System (BBS), would become crucial to the success of CompuServe. BBSs were similar to noticeboards, meaning that people could leave messages about different topics which other people could then view.[20] CompuServe divided its forums into Special Interest Groups (SIGs) which covered several subjects, including computing, literature, music, and space.[21] When CompuServe launched this facility, it soon became very popular with subscribers. Two other facilities, the National Bulletin Board and the CB Simulator, also became popular. The National Bulletin Board was a free classified advertisements service which subscribers could use to post notices advertising items for sale. CompuServe invented the other new service, the Citizens Band Simulator, during 1980. It believed that people would want to use real-time conferencing to communicate with other

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"Technological Pioneering and Competitive Advantage: The Birth of the VCR Industry," *California Management Review*, vol. 29, no. 4, 1987, pp. 51-76.

[18] J. Silverstein, "Videotext in the United States," in *The Future of Videotext*, E. Sigel ed. (London: Kogan Page, 1983), pp. 51-79.

[19] Levering, et al., *The Computer Entrepreneurs*, p. 419.

[20] Bulletin Board Systems were an asynchronous technology, which meant that a user who read a message on a BBS, did not need to be online at the same time as the person who created the message. In this respect, BBSs were similar to electronic mail. See T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 436-437 and Appendix I.

[21] C. Bowen and D. Peyton, *How to Get the Most out of CompuServe* (New York: Bantam Books, 1984), pp. 117-169.

users.[22] Most people used the CB Simulator to communicate in public. However, by establishing a private channel, known as TALK, two individuals could communicate in private. As young people used CompuServe, this raised concerns that were similar to the apprehension surrounding chat rooms on the Internet today. Because a person could pretend to be whoever they wanted to be and, as they were anonymous, the potential for deception existed.

By the end of 1980, CompuServe's range of services and facilities had encouraged 4,000 people to become members of the network. Two years previously, H&R Block, a tax preparation firm, had become interested in the company, because it wanted to diversify.[23] In 1980, it acquired CompuServe for $22.8m.[24] The following year, CompuServe's users had increased to 18,000. By 1982, there were 35,000 subscribers.[25] CompuServe was growing at an annual rate of about 20 percent and had revenues of $37m. The growth of the service pleased both H&R Block and CompuServe. However, according to Berkov "initially no one had really expected the CIS to take off the way it did, but the idea reflected CompuServe's realization that the advent of the PC was going to change the landscape dramatically".[26] CompuServe's early success helped to legitimate the online services market. Other companies soon recognised the potential of online services and the PC, including the Telecomputing Corporation of America (TCA). TCA had set up The Source during 1979, with the aim of providing a similar range of facilities to CompuServe.[27] By 1980, the service had 7,000 subscribers. As a result, The Source had more users than CompuServe at this time, although this achievement was transitory.[28]

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[22] The CB Simulator was a synchronous technology, which meant that both parties who wanted to converse had to be online at the same time for real-time communication to occur. The CB Simulator was therefore similar to a telephone. See Sheldon, *McGraw-Hill Encyclopedia*, pp. 436-437.
[23] W.M. Grossman, "On-line and On Form," *Personal Computer World*, December 1994, pp. 385-388 and Silverstein, "Videotext in the United States," p. 60.
[24] Silverstein, "Videotext in the United States," p. 60.
[25] Carey and Moss, "The Diffusion of New Telecommunication Technologies," p. 153.
[26] Berkov, Interview.
[27] P. Tootill, "Commercial Trip," *Personal Computer World*, August 1987, pp. 178-179.
[28] Carey and Moss, "The Diffusion of New Telecommunication Technologies," p. 153.

6.3 Evolution of CompuServe

6.3.1 Consolidation

By 1983, CompuServe had nearly doubled its subscriber base from 35,000 to 65,000. It offered many services to its users and charged them $6 an hour to access the network. However, with the emergence of competitors such as The Source, CompuServe continued to expand the number of facilities to consolidate its position as a provider of online information services. It announced that the Columbus Dispatch would launch an electronic edition of its newspaper, followed by 11 other periodicals, such as The New York Times and the Washington Post. CompuServe also added an online shopping facility, known as the Electronic Mall. A person could browse products from over 50 companies including Kodak and Sears which would then deliver goods to the customer’s home. As well as focusing on consumers, CompuServe also continued to address the needs of business users. In 1983, it launched the Executive Information Service (EIS).[29] The EIS offered a similar range of facilities to the CIS, with additional services tailored to executives who used personal computers. These included conferences, based on the CB Simulator, programs, such as statistical and investor applications, and the business e-mail service, InfoPlex, which firms could access using the EIS or install on their own networks. In addition to these distinct services, CompuServe added two new facilities that would be attractive to both types of user. The first was online databases. By the mid to late 1980s, CompuServe subscribers could access many databases, including the Dow Jones News/Retrieval Service, the Official Airline Guides (OAG), and Grolier’s Academic American Encyclopedia. As access to databases became available on CompuServe, this often encouraged potential adopters, especially business users, to become subscribers of the online service to use these information sources, and as people became users of CompuServe, they accessed the databases provided by other companies.[30] In addition, as the third party companies improved their databases, this benefited the external firms and CompuServe as well, which created new capabilities for both types of company. CompuServe and the databases provided by third party

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[29] Bowen and Peyton, *How to Get the Most out of CompuServe* p. 189.
[30] On technological interrelatedness see C. Antonelli, “The Dynamics of Technological Interrelatedness: The Case of Information and Communication Technologies,” in *Technology and the Wealth of Nations: The Dynamics of Constructed Advantage*, D. Foray and C. Freeman eds. (London: Pinter, 1993), pp. 194-207.

companies therefore corresponded to a platform.[31] With both types of company investing in their services in order to improve them, this helped to increase the attractiveness of the platform for both existing customers and potential adopters.[32] The second facility that CompuServe developed was the ability for subscribers to send and receive e-mails to several networks. In addition, they could also send and receive telexes and send faxes (see Figure 6.1). It was during this period that a "number of Internet advocates" within CompuServe tried to persuade the company to provide e-mail access to this network.[33] When its customers also expressed an interest in an e-mail link to the Internet, CompuServe decided to provide this service. Although the company interconnected its network with the Internet, it was not interested in enhancing this connection to provide access to other services, such as telnet and FTP, as the Internet was an academic network which was of little interest to the online service. CompuServe's attitude was a reasonable one to adopt at this time. After all, only academic institutions and other select organisations could connect to the Internet during the 1980s. CompuServe and other companies such as BT therefore viewed the Internet as a curiosity, a network that was irrelevant to their business. Some, such as OSI advocates, went further, describing the Internet as a "toy academic network".[34] For these reasons, CompuServe and other companies ignored the Internet at this time.

By the mid 1980s, CompuServe represented different things to different people.[35] To some, it was a communications medium, through which people conversed with other subscribers using e-mail, the forums, and the CB Simulator. To others, it was a business tool which they could use to access programs, download stock market data, and check flight details. And to others, it was a way to play online games and have fun. While CompuServe meant different things to different people, there were two services that many agreed were very useful.

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[31] On platforms see T.F. Bresnahan and S. Greenstein, "Technological Competition and the Structure of the Computer Industry," *Journal of Industrial Economics*, vol. 47, no. 1, 1999, pp. 1-40.
[32] On endogenous sunk costs see J. Sutton, *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration* (Cambridge, MA: MIT Press, 1991), pp. 11-12 and 45-81.
[33] Berkov, Interview.
[34] K. Hafner and M. Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon & Schuster, 1996), p. 247.
[35] On interpretative flexibility see W.E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (Cambridge, MA: MIT Press, 1995), pp. 73-75.

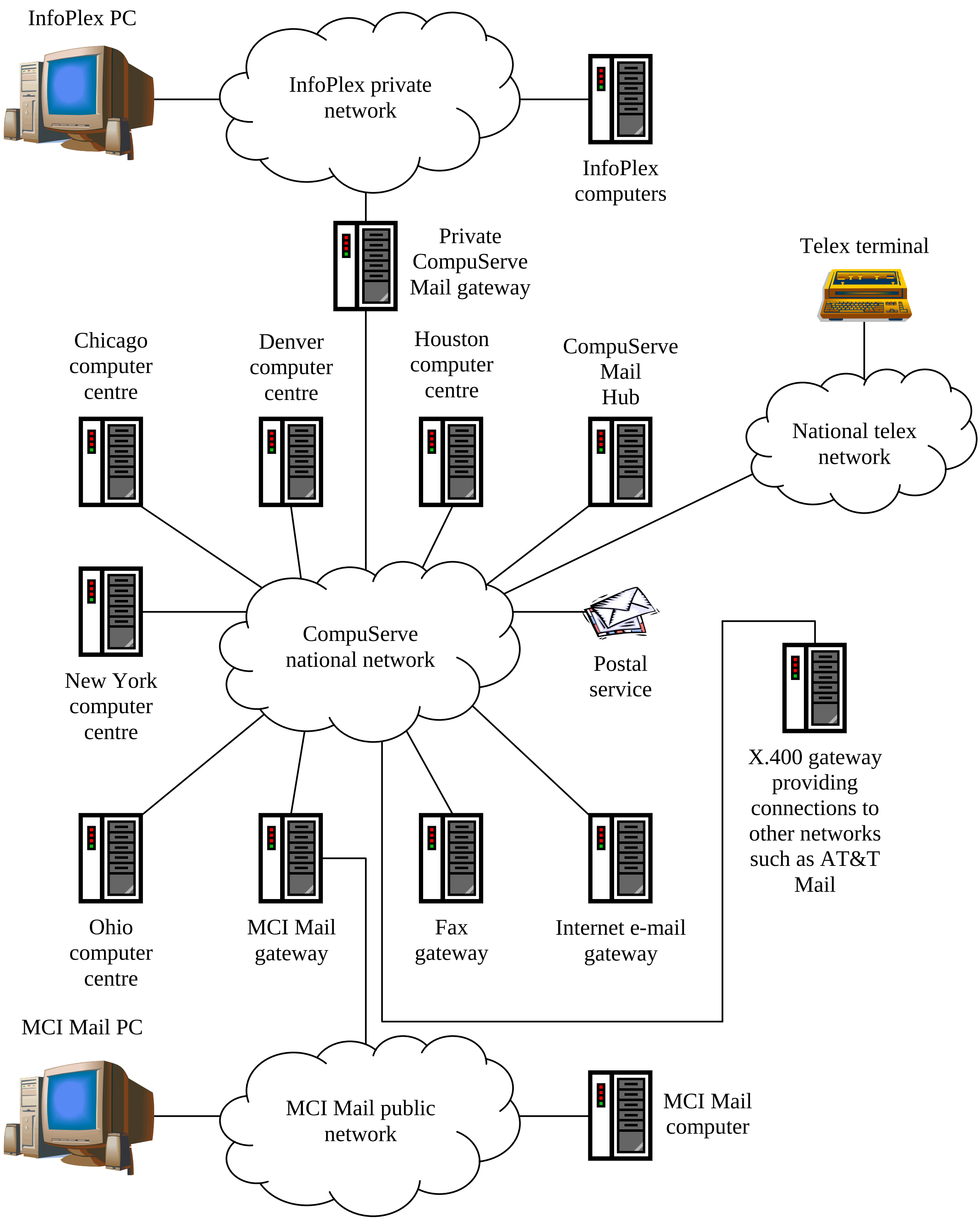

Figure 6.1. The CompuServe network circa late 1980s.[36]

[36] This figure only shows five of the over 200 CompuServe computer centres throughout the US. The CompuServe Mail Hub enabled users of the Novell NetWare network operating systems to exchange e-mails, using the NetWare Message Handling System version 1.5C. The postal service offered by CompuServe, allowed users to send e-mails to the online service organisation, which would then laser print the messages and deliver them like a letter using the US Postal service. See *CompuServe DOS Information Manager Supplement Version 1.36* (Columbus, Ohio: CompuServe, 1992).

Electronic mail had always been popular, but by the end of the 1980s, the same also applied to the forums. By 1988, CompuServe contained over 150 forums on many subjects, including computers, entertainment, and astronomy.[37] The computer support forums provided by companies were especially popular. Companies such as IBM, Microsoft, and Apple supplied news about software and assistance with solving hardware and software problems.[38] Users could also download updated drivers, patches, and other types of software to their PCs. These forums started to become synonymous with CompuServe. As David Gilroy, a former customer services director at CompuServe, remembers, "people came for e-mail, but stayed for the forums".[39]

As the 1980s ended, the CIS and the EIS had become sophisticated services. People used personal computers to establish connections to CompuServe's computer centres using CompuServe's network, Telenet, Tymnet, and IPSS.[40] CompuServe charged users $6 an hour to connect at 300 and 450 bps, and $12.50 an hour to access the service at 1,200 and 2,400 bps.[41] CompuServe provided hundreds of services using its proprietary protocols for facilities such as its EasyPlex e-mail service and its CompuServe B file transfer protocol, all of which ran over the company's X.25 network or external X.25 networks provided by other companies including Telenet.[42] By the end of the 1980s, there came a point when CompuServe's rate of adoption became self-sustaining, creating a critical mass of users.[43] This situation occurred when the CIS had encouraged over 550,000 users to become members. CompuServe had become the largest online service for PC users in the world.[44] It offered many of the facilities that existed on other networks at that time, such as videotex and e-mail networks. It also provided facilities that would exist on the Internet of the 1990s. In essence, CompuServe had become what British Telecom had hoped Prestel would become during the 1980s: a large, successful, online service offering hundreds of

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[37] See *CompuServe Information Service Users Guide* (Columbus, Ohio: CompuServe, 1988) and *CompuServe Quick Reference* (Columbus, Ohio: CompuServe, 1988).
[38] *CompuServe* (Columbus, Ohio: CompuServe, 1988).
[39] D. Gilroy, Interview by D. Rutter, 22 November 2002.
[40] *CompuServe Information Service Users Guide*, pp. 247-251.
[41] *CompuServe*.
[42] See Appendix I.
[43] On critical mass see E.M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Free Press, 1995), p. 313.
[44] By the end of the 1980s, the Télétel network in France had more than 3 million users. However, as this was a videotex network, which most people accessed using the custom-built Minitel terminals, it was not an online service for PC users.

services to thousands of users. There were several reasons for CompuServe's success. First, as an increasing number of potential adopters became aware of CompuServe and understood what it was and what the service could do for them, they became subscribers.[45] Second, as more customers adopted the service, the more they learnt about it, and the more CompuServe attempted to improve its network.[46] And, third, as an increasing number of users joined the network for these and other reasons, this enhanced the value of belonging to the service for both potential adopters and existing subscribers.[47] By the end of the 1980s, CompuServe had become the market leading online service for PC users.[48]

Despite CompuServe's success, by the end of the 1980s it faced increasing competition in the online services market. These competitors included The Source, America Online, Prodigy, and Delphi. Towards the end of the 1980s, The Source had over 150,000 users. While it had started not long after CompuServe and for a while looked as though it might rival this network, it had never seriously challenged CompuServe, once this network had become very successful. In 1989, CompuServe bought The Source, and increased its user base.[49] Quantum Computer Services Inc. launched America Online for the Apple Macintosh during 1989. CompuServe initially perceived America Online to be a poor imitation of its service – a clone without any distinguishing features. This view would persist into the 1990s. In the meantime, Sears, Robuck & Co and IBM launched Prodigy during 1990 targeted at consumers.[50] As Berkov remembers, "[we] initially considered Prodigy to be a big threat but it turned out to be a plus for CompuServe. They spent a lot on promotion and effectively legitimated the market".[51] CompuServe was "not impressed with Prodigy's service

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[45] Closure had therefore occurred. People now regarded CompuServe as an online service, which offered many services and facilities. On closure see R. Kline and T. Pinch, "The Social Construction of Technology," in *The Social Shaping of Technology*, 2nd ed., D. MacKenzie and J. Wajcman eds. (Buckingham: Open University Press, 1999), pp. 113-115. On informational increasing returns see W.B. Arthur, "Competing Technologies: An Overview," in *Technical Change and Economic Theory* G. Dosi, et al. eds. (London: Pinter, 1988), pp. 590-607.

[46] On the concept of learning by doing see K.J. Arrow, "The Economic Implications of Learning by Doing," *Review of Economic Studies*, vol. 29, no. 3, 1962, pp. 155-173.

[47] On network externalities see O. Shy, *The Economics of Network Industries* (Cambridge: Cambridge University Press, 2001).

[48] On technological lock-in see W.B. Arthur, "Competing Technologies and Economic Prediction," in *The Social Shaping of Technology*, 2nd ed., D. MacKenzie and J. Wajcman eds. (Buckingham: Open University Press, 1999), pp. 106-112.

[49] "The Source Bows Out Unmourned," *Personal Computer World*, September 1989, p. 100.

[50] J.L. Viescas, *The Official Guide to the PRODIGY Service* (Redmond, WA: Microsoft Press, 1991).

[51] Berkov, Interview.

which seemed to be too limiting and more toy-like".[52] Another competitor was Delphi. Launched by the General Videotex Corporation during 1983, Delphi offered a similar range of facilities to the other online services, but it was the smallest of the five, with only 40,000 subscribers by 1988.[53] Despite the emergence of four competing networks, CompuServe remained the largest US service during the late 1980s.

6.3.2 Expansion

Throughout the 1980s, CompuServe's success was mainly limited to the US, where most of its subscribers lived. Although people could access the service from other countries, using public packet-switched networks to connect to CompuServe's computer centres in the US, the cost of using these networks often discouraged most from doing so. For example, during the 1980s, customers in the UK could use the IPSS or the Computer Sciences Corporation's (CSC‘s) Infonet network to establish connections to CompuServe. However, as it cost $50 an hour to connect to Infonet, the amount of international traffic remained low.[54] Clearly, there was potential to expand CompuServe outside of the US. The company had decided to start to exploit this potential during 1986, by introducing licences to operate CompuServe on a local basis, in a similar way to how Dialcom expanded its network. In 1986, CompuServe granted a licence to Nissho Iwai and Fujitsu Ltd to develop a service in Japan. These companies established the Network Information Forum (NIF), to operate their network, called NIFTY-Serve. NIF launched this service during 1986. By 1992, there were 350,000 members. Encouraged by the success of the CIS in the US and NIFTY-Serve in Japan, CompuServe licensed its service in many countries including Argentina, Australia, Chile, Mexico, New Zealand, South Korea, and Taiwan.[55] All of these would use international public packet-switched networks, based on X.25, for intercontinental communication.

In addition to licensing its service in the Far East, South America, and Australia, CompuServe also wanted to establish its network throughout Europe. It approached

[52] Ibid.
[53] A. Brodsky, "Online Services: A Buyer's Guide," *Link-Up*, May/June 1988, pp. 14-15.
[54] B. Knox, "At Your Service in Europe," *CompuServe Magazine*, June 1990, pp. 16-17.
[55] D.W. Jackson, et al., "The Un American Story," *CompuServe Magazine*, June 1992, pp. 8-15.

Radio-Schweiz in Switzerland with the proposition of launching the service in Europe. As Radio-Schweiz operated its own computer network and the DataStar database services, CompuServe believed that it would be an ideal partner. Initially, the licensee established a switching centre in Berne, through which customers could establish connections to the host computers in the US. However, this was only a temporary solution, as countries in Europe would need their own computer centres. CompuServe and Radio-Schweiz soon followed this by setting up the first subsidiary in Britain, the headquarters of which were in Bristol. CompuServe decided to use the services of a network in the UK, Istel's Infotrac, which offered subscribers access to the US online service for £5.63 an hour (see Figure 6.2). While still expensive, this was considerably less than connecting to CompuServe using a network such as CSC's Infonet.

With an access network in place, CompuServe UK began to prepare for the launch of the service in Britain. It started to install host computers in the UK, localised the sign-up materials and manuals, established a telephone support service, and began to market CompuServe with advertisements in magazines such as Personal Computer World.[56] Launched as the CompuServe/Forum service during 1990, it provided access to the full range of facilities of the US network for a registration fee of £29.95 and usage charges of £7.11 an hour.[57] The total hourly charge, including the cost of connecting to CompuServe using the Infotrac network, was £12.74.[58] CompuServe was not the first network to appear in the UK. However, as it was the largest online service in the world, it did not perceive other networks, such as Prestel and Telecom Gold, to be significant and therefore ignored them. However, it soon became clear that in order for CompuServe to retain its market-leading position, it would have to use another network instead of Infotrac, because of its slow speed. CompuServe UK therefore decided to establish its own network.

[56] "Welcome to a World of Information," *Personal Computer World*, October 1990, pp. 128-129.
[57] "CompuServe Maps a European Connection," *MacUser*, 20 April 1990, pp. 16 and 19.
[58] S. Gold, "A Clear Line," *Personal Computer World*, June 1990, pp. 182-184 and 186.

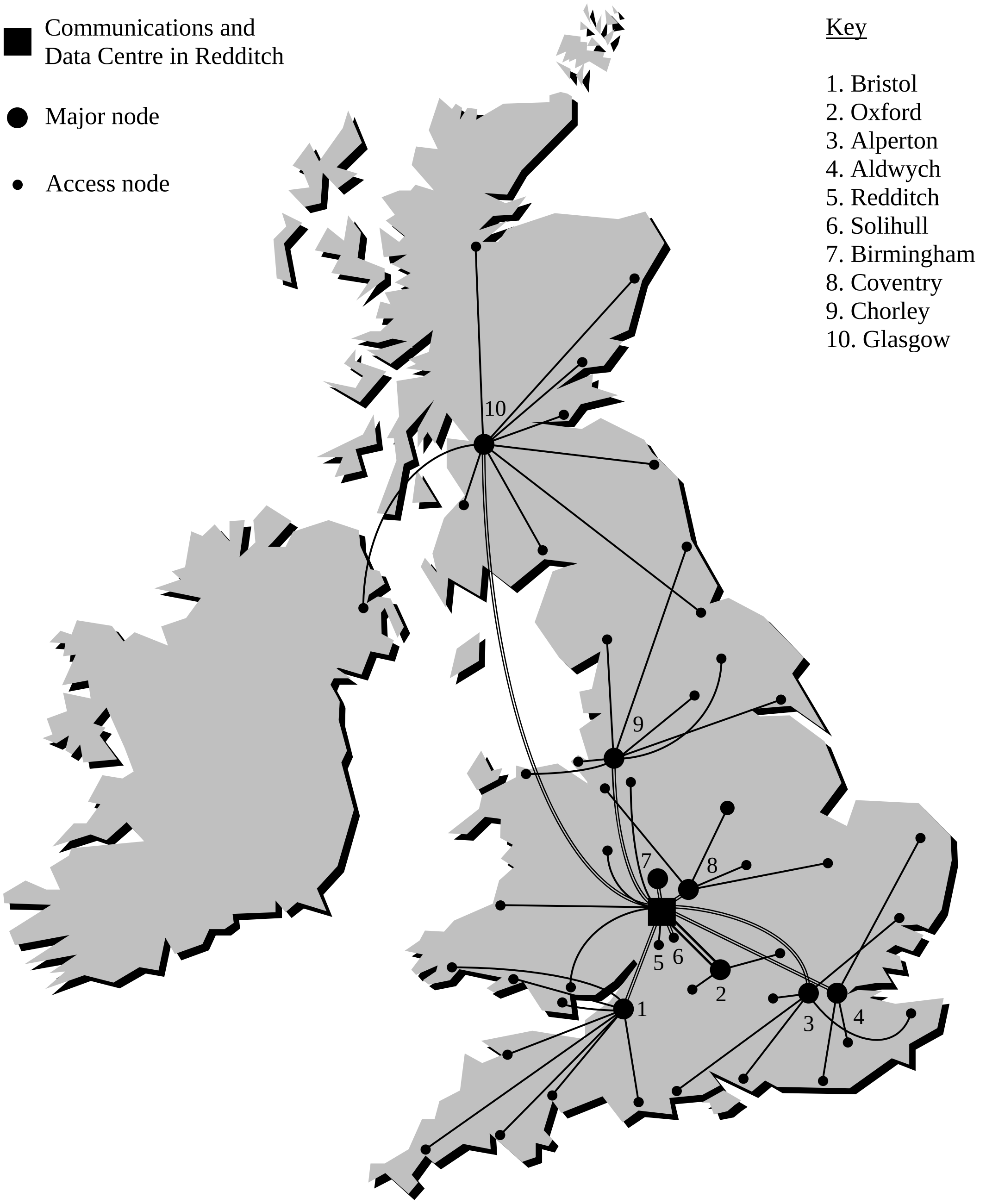

Figure 6.2. Istel's Infotrac network in 1985.[59]

To do this, it set up Points of Presence (PoPs) throughout the country.[60] These connected users to the CompuServe network, enabling them to dial a local node which then routed their call to the British or US host computers. Customers could also later

[59] J.P. Leighfield, "Implementing and Operating a Value Added Network," *Computer Communications*, vol. 8, no. 4, 1985, pp. 199-202.

[60] Points of Presence were network access points, which contained modems connected to the PSTN. Users established dial-up connections to a PoP, which then enabled them to access the desired network. On PoPs see Sheldon, *McGraw-Hill Encyclopedia*, pp. 993-995.

use other networks, such as BT's GNS Dialplus and Mercury Communications, to connect to the UK service and therefore CompuServe in the US (see Figure 6.3).[61]

Having set up its own network in Britain, CompuServe UK needed to localise the content of the service. Initially, subscribers could access only US facilities, but gradually new UK and European specific information and services appeared. These included the UKShare Forum, which enabled people to download European shareware, and for business users, the UK Company Library which provided financial details for over a million companies in the United Kingdom.[62] In addition, by the end of 1991, CompuServe and other firms had added further UK-specific services to the network. These included the UK Newspaper Library, which people could use to read the full text of newspapers such as The Financial Times, and the PC Plus Online! Forum, which subscribers could use to access computing news and download software.[63] To attract new computer users to the service, CompuServe agreed a deal with PC Magazine during 1992. Initially this meant that the magazine maintained a forum on the service, called ZEUS, which provided laboratory reports about hardware and software, programs that users could download, and a place for users to discuss topics.[64] PC Magazine followed this with the launch of ZiffNet. For £9.00 an hour, subscribers could access many facilities, including news, software, e-mails, and databases.[65] As ZiffNet used the CIS as the basis for its service, subscribers to PC Magazine's network could also access CompuServe. In this sense, it was similar to networks such as Microlink which used Telecom Gold as the basis for its service.

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[61] "New for U.K.: Mercury Network, Shareware Forum," *CompuServe Magazine*, November 1992, p. 6.

[62] See "International Update," *CompuServe Magazine*, July 1991, p. 6, W.M. Grossman, "Bring on the Brits," *CompuServe Magazine*, March 1992, pp. 20-22, and "Getting the Business from the UK and Europe," *CompuServe Magazine*, October 1991, p. 6.

[63] See "Access the Text of Britain's Dailies," *CompuServe Magazine*, November 1991, p. 7 and "PC Plus Opens, London Node Expands," *CompuServe Magazine*, April 1992, p. 8.

[64] R. Goodwins, "Communication Lines: ZEUS Opens PC Magazine's Editor's Forum," *PC Magazine*, April 1992, pp. 373-376.

[65] See R. Goodwins, "ZEUS and CompuServe: An Update on Services and Prices," *PC Magazine*, April 1993, p. 261 and R. Goodwins, "Way to GO," *PC Magazine*, June 1994, pp. 314-315.

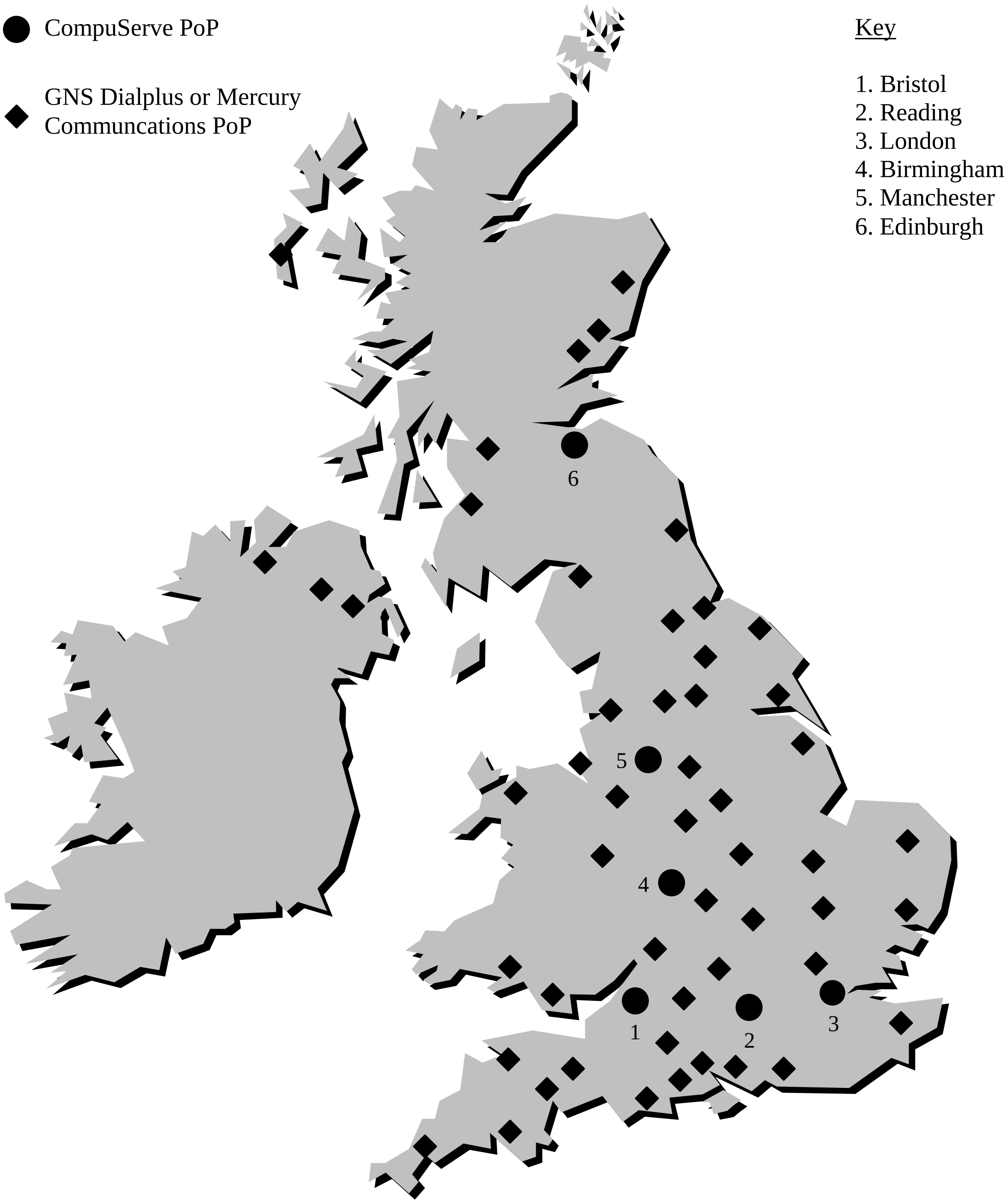

Figure 6.3. CompuServe's PoPs and other Points of Presence in 1994.[66]

CompuServe's expansion throughout the world helped to increase the number of subscribers. By 1992, there were 1.1 million subscribers. By then, consumers as well as hobbyist and business users had joined the service.[67] Despite the efforts of

[66] For clarity, the figure only shows a limited number of the 120 PoPs, which existed in 1994. Both the CompuServe PoPs and the Points of Presence of other networks, such as GNS Dialplus and Mercury, operated at one or more data transfer rates: 300, 1,200, 2,400, and 9,600 bps. See *CompuServe* (Bristol: CompuServe, 1994).

[67] As CompuServe contained many services and lots of information, much of it tailored to certain types of user, this helped to attract different people and organisations to the CIS and EIS. For example, the legal LAWSIG forum, which contained several services such as information about computer law and

competitors, such as America Online and Prodigy, to attract users, CompuServe remained the market-leading online service in the world. However, while CompuServe continued to concentrate on improving its facilities, in an attempt to consolidate its position as the market leading online service, it did not focus on the Internet. Although the company advertised that its users could send and receive e-mails with the Internet, it listed this network with several others, including MCI Mail and technologies such as the telex and fax.[68] E-mail access to the Internet was just one of the hundreds of services that CompuServe provided, and from its point of view, not an important one at that. As a result, it ignored this network during the first few years of the 1990s. Many others did the same. For example, throughout the early 1990s, Microsoft believed that the Internet was not relevant to its business. British Telecom also did not consider it important, and instead focused on marketing its proprietary networks, Prestel and Telecom Gold. The actions of these companies were justified at the time. During the early 1990s, it was not obvious that the Internet was going to become popular. Even in 1994, when people had started to express an interest in the Internet, many still underestimated the importance and impact that it would have on hundreds of millions of people. For example, Simon Rockman, a journalist employed by the magazine Personal Computer World, wrote in 1994 "while having an Internet address might be the coolest thing [to] have on a business card today, tomorrow it will be about as popular as CB radio".[69] However, within a couple of years, CompuServe and many other companies would have to respond to the threats and opportunities posed by this network.

6.4 The Commercialisation of the Internet

Since it's inception in 1983, the Internet, like its predecessor the ARPANET, had been a network that restricted access to certain types of user. Only universities and research organisations that the Defense Advanced Research Projects Agency (DARPA) funded could therefore access the network. When the National Science Foundation (NSF) created the NSF network (NSFNET) during 1986 and interconnected it with the Internet, this enabled any academic and research

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legal software that people could download, attracted the interest of lawyers and other legal personnel. See G. Irwin, "CompuServe Information Services," *Computers and Law*, March 1992, pp. 23-24.

[68] "Your Introduction to a World of Information," *Personal Computer World,* September 1990, p. 127.

[69] S. Rockman, "Losing Interest in the Internet," *Personal Computer World*, October 1994, p. 451.

organisation to use the Internet, whether DARPA funded or not. When the NSF decided to upgrade the NSFNET during 1987, it awarded the contract to Merit, IBM, and MCI.[70] This was the first time that commercial organisations had become involved in the Internet. However, the NSF's Acceptable Use Policy prohibited the use of the Internet for commercial applications, such as advertising and selling products and services.[71] By the 1990s, this situation had started to change. Networks such as PSINet provided services to academic institutions, as well as operating their own commercial networks. As a result, the Internet created a link between these networks. However, as these networks could not transmit commercial information via the NSFNET backbone, they decided to create their own backbones. In 1991, three commercial network providers, PSINet, CERFNet, and Alternet decided to interconnect their networks, by forming the Commercial Internet eXchange (CIX).[72] As a result, two backbones were in operation in the US: the restrictive NSFNET and CIX. Privatisation of the Internet had therefore begun. By this time, the National Science Foundation wanted to transfer the operation of its backbone to the commercial sector, as it no longer wanted to operate a network backbone and enforce the Acceptable Use Policy. As a result, the NSF announced in 1991 that by 1994 commercial Internet Service Providers (ISPs) would operate their own network backbones which subscribers could use to access the Internet. By 1995, Merit had decommissioned the old NSFNET backbone, completing the privatisation of the Internet.

6.4.1 PIPEX

The first Internet Service Providers to provide commercial access to the Internet, targeted companies that wanted to connect to this network. The most successful company to provide access in the UK was PIPEX. In 1979, Peter Dawe, an accountant, joined Cambridge Micro Computers (CMC).[73] CMC provided computers to government and other clients. During the early 1980s, Dawe became interested in internetworking when it became clear that CMC's clients were experiencing difficulties linking their personal computers to the UNIX machines provided by CMC.

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[70] J. Abbate, "Government, Business, and the Making of the Internet," *Business History Review*, vol. 75, no. 1, 2001, pp. 147-176.
[71] S. Greenstein, "Commercializing the Internet," *IEEE Micro*, vol. 18, no. 6, 1998, pp. 6-7.
[72] J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), pp. 198-199.
[73] F. Byrne and J. Bates, *Unipalm (A)* (London: London Business School, 1996).

For many companies, the natural solution to this problem in the 1980s was OSI. However, Dawe preferred TCP/IP which he believed could solve the problems experienced by CMC's clients and which had a lot of potential as a tool to internetwork incompatible systems.[74] As a result, he left CMC during 1986 to found his own company, called Unipalm Limited. Dawe agreed a deal with a US supplier of TCP/IP software, FTP, to resell its products in the UK. The existence of Unipalm and PSINet helps to correct the often misunderstood perception that after TCP/IP emerged during the 1970s, it diffused only throughout the Internet, before being commercialised during the 1990s. There is more to TCP/IP than just being the suite of protocols used on the Internet. During the 1980s and into the 1990s, companies such as Unipalm sold TCP/IP software and services to companies which needed solutions to their internetworking problems. Although the Internet was the largest network to use TCP/IP, other networks also adopted these protocols during this period.

Having established Unipalm, Dawe marketed the US software to UK corporations that needed to interconnect their incompatible networks. These networks were usually from three main suppliers: IBM, with its System Network Architecture (SNA) system; Digital, with its Digital Equipment Corporation network (DECnet); and Novell, with its Novell NetWare network operating system. By 1990, Unipalm was generating £750,000 sales and £140,000 pre-tax profits, and had become the market-leading internetworking provider in the UK. However, by then, companies such as DEC and Novell had started to launch multi-vendor solutions which could interconnect incompatible systems. These companies therefore challenged Unipalm's position as an internetworking provider. As Dawe remembers "we were in trouble. If we didn't create a market or a market was created for Wide Area Networking, we were going to be obliterated by NetWare". Unipalm therefore approached British Telecom and Mercury about developing a market for WANs using TCP/IP. However, the response was always the same: use X.25. Both companies were simply not interested in TCP/IP. It was at this point, that Dawe visited the US and learnt about the Internet. When he returned, he had become convinced that the rapid diffusion of TCP/IP throughout the Internet in the US would no doubt occur in the UK which would help Unipalm's sales. In addition, if the company became an Internet Service Provider, this

[74] P. Dawe, Interview by D. Rutter, 26 November 2002.

would maximise the chance of it capitalising on the diffusion of TCP/IP on the Internet in the UK. Unipalm agreed, but it did not share Dawe's view that the company should become an ISP. Convinced he was right, Dawe therefore left the company during 1991 to set up a subsidiary, the Public Internet Protocol EXchange (PIPEX). To become an Internet Service Provider, PIPEX would need to rent a leased line to the Internet from BT, at a cost of £150,000 a year which it would then share between its customers. To access the Internet, these users would then pay £11,500 a year to establish leased line connections to PIPEX's single Point of Presence in Cambridge. Within one year, PIPEX had 60 customers, including large corporations such as British Petroleum (BP) which meant that thousands of people were using PIPEX's connection to the Internet. Bill Thompson, PIPEX's 'Internet Ambassador', remembers this period, saying "there was a general sense that we were pioneering something that was very important; that getting a network connection would change the way businesses operated and open up new opportunities to them".[75]

6.4.2 Demon Internet

PIPEX had always targeted business customers which wanted to connect to the Internet. However, as PIPEX charged customers £11,500 a year for this facility, this precluded individuals and companies from connecting to the Internet who could not afford the charges. This attitude would influence the development of the first ISP to launch an affordable service, Demon Internet. During 1985, Cliff Stanford, an accountant, and a friend, Grahame Davies, set up Demon Systems to sell programs for the MS-DOS operating system. As the company started to become quite successful, Stanford and Davies decided to diversify by becoming a reseller for U.S. Robotics modems. To help sell these devices, both Stanford and Davies joined a Bulletin Board System called the Compulink Information eXchange towards the end of the 1980s. Set up during 1987, this contained hundreds of conferences on many different topics.[76] By the time Stanford had joined CIX, he had become interested in the Internet, learning that Netcom, an ISP, had recently launched access to the Internet in the US for $25 a month. At this time, someone had posted a message on a US BBS saying that inexpensive access to the Internet would never exist in the UK. Stanford

[75] B. Thompson, Interview by D. Rutter, 13 November 2002.
[76] See Appendix I.

disagreed, believing that people would be willing to pay a reasonable fee to connect to the Internet. Many CIX users wanted to access the Internet, but as CIX provided an e-mail only connection at this time, they also wanted a service that provided access to other services such as telnet and FTP. Stanford realised that if he divided the £20,000 a year charged by one of PIPEX's competitors, EUnet GB, by 200 people, then these users could share the cost of a leased line to the US for about £10 a month.[77] As a result, he set up the tenner.a.month conference on CIX, and asked if people would be willing to pay for a complete year's access up front, at £120.[78] Many people expressed an interest and so Demon Systems started to collect subscriptions.

By the time that Demon Systems had received 75 subscriptions during 1992, Stanford and Davies thought, "right, let's go for it".[79] By then, EUnet GB had reduced its charges to £10,000 a year and PIPEX had launched its service, so it was feasible to establish Demon's Internet access service with fewer than 200 members. Demon Systems launched its Internet service, Demon Internet, during June 1992. It advertised the ISP as an inexpensive way of accessing the Internet for home computer users.[80] Customers paid a £12.50 registration fee and then £10 a month to connect to the Internet. Subscribers could use programs such as telnet, FTP, and electronic mail. To access these utilities, Demon Internet provided programs for MS-DOS which established a connection with the ISP using TCP/IP, and then enabled a subscriber to access a remote host or service.[81] However, the user interface of this software was not friendly as it presented users with different interfaces for the applications. However, Demon Internet was not worried about this issue. As Steve Kennedy, a founder member of the company, reflects, the ISP "was a techie service for techies, and the techies loved it".[82] As Stanford remembers, "we never saw the Internet as mainstream – we saw it as a hobby club. We had a projection at the beginning to aim for 200 users on start-up, rising to 400 within six months and maybe 1,000 users at two years".[83] He

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[77] B. Tisdall, "The Daemon from Demon," *Personal Computer World*, November 1995, pp. 138-139 and 141. The first organisation to do provide commercial access to the Internet in the UK was EUnet GB, which was part of the European UNIX network (EUnet). See D. Karrenberg, "EUnet and OSI Transition Plans," *Computer Networks and ISDN Systems*, vol. 16, no. 1 and 2, 1988, pp. 94-100.
[78] S. Kennedy, Interview by D. Rutter, 12 November 2002.
[79] G. Davies, Interview by D. Rutter, 12 November 2002.
[80] "Internet," *The Guardian*, 9 July 1992, p. 33.
[81] On the Serial Line Internet Protocol (SLIP) and the Point-to-Point Protocol (PPP) see Appendix E.
[82] Kennedy, Interview.
[83] Tisdall, "The Daemon from Demon," p. 138.

adds "we never really saw where the Internet was going. We just decided to give people access to download files".[84] However, Demon Internet soon started to attract people who were not hobbyist computer users. Within a short space of time, hundreds of new users were joining the service every month. As Stanford remembers, "we suddenly realised what was happening and diverted every resource we had to the Internet business".[85] Demon Internet therefore had to provide a service that catered for the needs of consumers, who were customers that were not familiar with how to connect to the Internet. By introducing people to a technology that they were not familiar with, the company also had to help educate its customers, something its support department helped to do when users inevitably telephoned the firm with queries.[86]

6.5 Survival in an Internet World: CompuServe and Online Services

As people began to subscribe to Demon Internet's service, CompuServe's focus remained firmly on improving its network. Throughout the 1980s, CompuServe's users had accessed the CIS using ASCII menus. These were not easy to learn and use. CompuServe therefore decided to develop a new program called the CompuServe Information Manager (CIM) which enabled a person to use a mouse to access menus. Having released a version of this software for MS-DOS, CompuServe ported this program to three additional operating systems: Microsoft Windows, Mac System 6.x, and OS/2 (see Figure 6.4). CompuServe users therefore had a graphical environment in which to navigate the resources provided by the CIS which was similar to the Web.

By 1992, CompuServe had become a graphical online service. In comparison, the programs in use on the Internet at this time were mainly character-based (see Figure 6.5). CompuServe did not perceive the text-based Internet as a threat to its graphically rich online service.

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[84] C. Stanford, Interview by D. Rutter, 26 November 2002.
[85] Tisdall, "The Daemon from Demon," p. 138.
[86] On technological mediation see S. Greenstein, "The Commercialization of Information Infrastructure as Technological Mediation: The Internet Access Market," *Information Systems Frontiers*, vol. 1, no. 4, 2000, pp. 329-348.

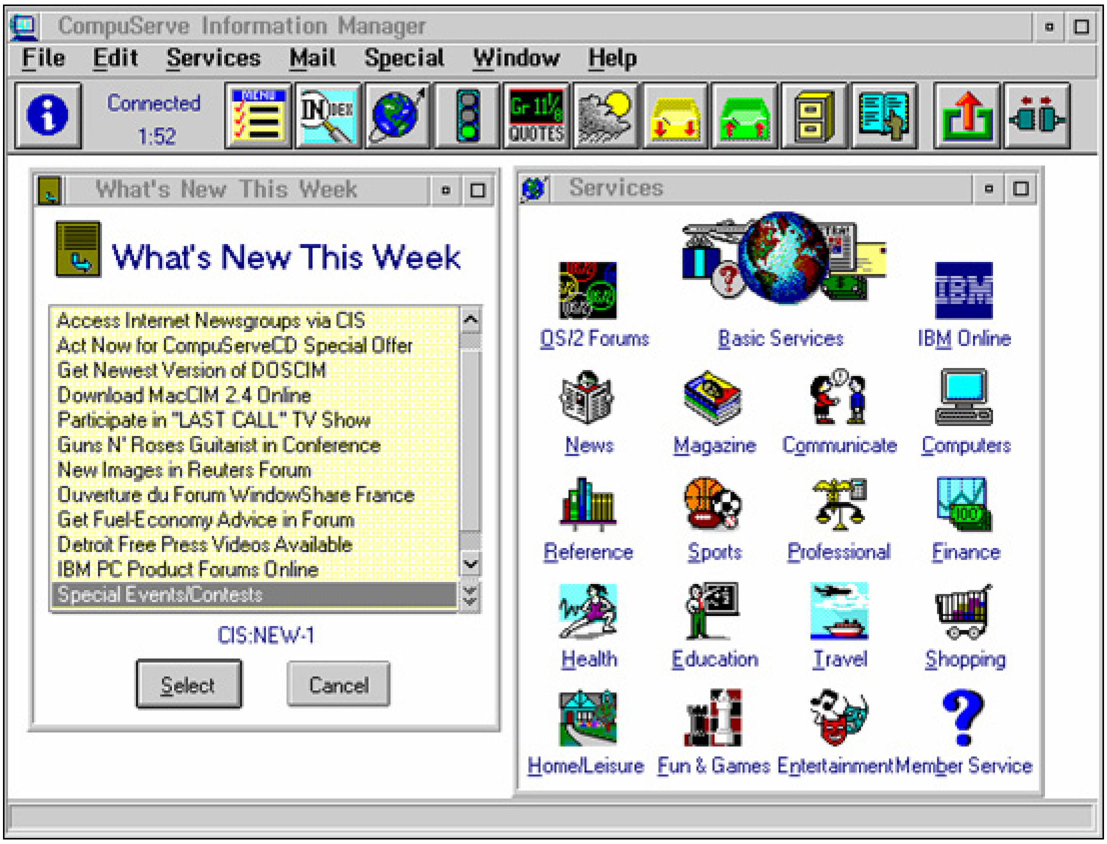

Figure 6.4. The CompuServe Information Manager for OS/2 Warp in 1994.[87]

However, it was at this point, when Demon Internet started to attract users and other ISPs did the same, that CompuServe could have capitalised on the emerging demand for Internet access. Instead of continuing to provide an e-mail only link to the Internet, CompuServe could have supplied access to other tools, such as telnet and FTP, which people wanted to use. Some of CompuServe's European managers wanted the company to do this, but they encountered resistance from the US managers, who were more concerned with the increasing threat posed by America Online. This network had attracted 500,000 users by 1993, which was over a third of CompuServe's total user base at that time.[88] CompuServe was adamant that it would protect its proprietary online service that had brought it success.

[87] *CompuServe*, Stellar Online, 1995, Available from: http://www.stellar.org/pa/ibm/cserve.gif, Accessed on: 3 June 2005.
[88] *AOL History*, AOL, 2004, Available from: http://www.corp.aol.com/whoweare/history.html, Accessed on: 11 September 2004.

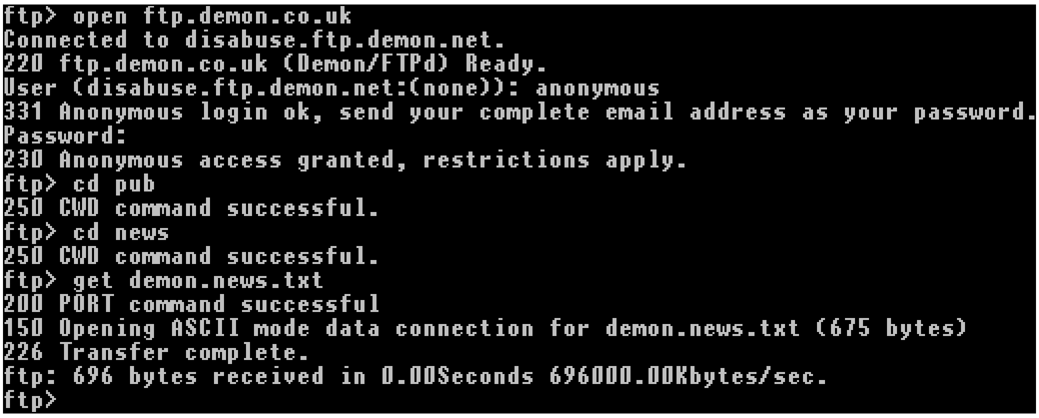

Figure 6.5. An example of the Internet's interface during the early 1990s.

With 1.35 million subscribers by 1993, thousands of services, and global coverage, CompuServe was still the market leading online service in the world. During this period, CompuServe stressed that it provided quality information from many suppliers, in an attempt to differentiate itself from other networks, including the Internet.[89] However, providing a service that satisfied the information and communications needs of over a million users was not enough. What CompuServe needed to do was to replace its CIS while it was still successful, something that it had done once before with its computer bureau service. CompuServe therefore needed to transform its proprietary architecture in order to adapt to the changing world of information and communications technologies; a world that was becoming increasingly Internet-centric by 1993.[90] However, CompuServe continued to ignore the Internet at this time.[91]

As CompuServe's attention remained focused on improving its network and deciding how it should respond to the threat of America Online, new ISPs emerged in Britain. These included CityScape, the BBC Networking Club, and BTnet. As Demon Internet started to attract hundreds of users, PIPEX decided that it too should invest in the consumer access market, by acquiring a 25 percent shareholding in a new, small ISP

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[89] On differentiation see C. Shapiro and H.R. Varian, *Information Rules: A Strategic Guide to the Network Economy* (Boston, MA: Harvard Business School, 1999), pp. 19-51.
[90] On architectures see C.R. Morris and C.H. Ferguson, "How Architecture Wins Technology Wars," *Harvard Business Review*, vol. 71, no. 2, 1993, pp. 86-96.
[91] During the previous decade, CompuServe had become increasingly aware of how best to respond effectively to the market in order to operate a successful online service, by incrementally improving its network in response to the demands of its subscribers. However, by the mid 1990s, this success began to impede CompuServe's ability to assess effectively the emerging issues, challenges, and opportunities of another network, the Internet. On technological discontinuities see R.N. Foster, *Innovation: The Attacker's Advantage* (London: Macmillan, 1986).

called CityScape.[92] CityScape used PIPEX to provide access to the Internet, and acted as a reseller for Internet access. CityScape charged subscribers £50 to join the service and then £15 a month to access the Internet.[93] Having acquired a stake in CityScape, PIPEX later tried to purchase the company. When it did not succeed, it launched PIPEX Dial, aimed at consumers. The BBC also decided to establish itself as an ISP during 1994.[94] Like CityScape, the BBC Networking Club used PIPEX's backbone to connect its users to the Internet. For a registration fee of £25 and then £12 a month, subscribers could access the Internet, including the World Wide Web, and the BBC's Bulletin Board System, which provided information about the Corporation's television programmes and other information.[95] Although the BBC Networking Club did not last for long, the BBC helped to legitimate this market.[96] British Telecom had the same effect. In 1994, it launched BTnet, targeted at businesses, and set up BT Internet for consumers during 1996.[97] BT Internet customers paid a £20 registration fee and then £15 a month to access the Internet.[98]

By the end of 1994, Demon Internet had nearly 180,000 subscribers, most of whom had joined the service during 1994.[99] Compared to the growth of other networks, such as Prestel and Telecom Gold, this was a substantial growth rate. After all, it had taken both of BT's services between eight and ten years to approach 100,000 users. The popularity of the Internet in the UK was part of a larger global phenomenon. For example, the number of people on the Internet had increased from about 500,000, in 1991, to more than 26 million by the end of 1995.[100] With growth such as this, CompuServe could not ignore the Internet any longer. By improving the capabilities of its interconnection with the Internet, this would increase the value of the network

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[92] F. Byrne and J. Bates, *Unipalm (C)* (London: London Business School, 1996).
[93] W.M. Grossman, "Service Stations," *Personal Computer World*, November 1994, pp. 464-466, 468, and 470.
[94] M. Acey, "BBC Networking Club Puts Auntie at Your Disposal," *Computer Weekly*, 14 April 1994, p. 6.
[95] D. Brake, "Auntie on the Line," *Personal Computer World*, July 1994, pp. 520-523.
[96] The BBC closed its Internet access service during February 1996 in response to competition from other ISPs. See "BBC Closes Networking Club," *Personal Computer World*, February 1996, p. 22.
[97] N. Titley, "BTnet: The BT Internet Service Architecture," *UK UNIX Systems User Group (UKUUG) IP Workshop '94, 11-13 October 1994, The Zoological Society, London* (Buntingford: UKUUG, 1994), pp. 71-77.
[98] *Events in Telecommunications History - 1996*, BT, 2005, Available from: http://www.btplc.com/Thegroup/BTsHistory/1996.htm#1996, Accessed on: 8 June 2005.
[99] D. Winder, "Threats to the Internet," *PC Pro*, July 1995, pp. 162-168.
[100] *Nua Internet How Many Online*, Nua, 2003, Available from: http://www.nua.ie/surveys/how_many_online/world.html, Accessed on: 13 May 2004.

for its subscribers, by providing a link to the larger network.[101] Of course, by 1994, CompuServe's users had been accessing the Internet, in the form of electronic mail, since the late 1980s. This link was more capable than it at first might have seemed. Subscribers were able to use electronic mail to remotely access programs such as FTP and other services and tools such as Usenet, Archie, Gopher, Veronica, and WAIS.[102] Users could also access the World Wide Web using e-mail which would retrieve Web pages without any associated graphics (see Figure 6.6). These services were possible because special servers' interpreted commands embedded within electronic mails, retrieved information, and then sent it to users within e-mails. However, using e-mail in this way was an inefficient and indirect method of accessing the Internet. It also restricted a person's experience of the network, especially when it came to the World Wide Web. Using e-mail for this purpose could also be quite expensive. CompuServe charged subscribers 8 pence for every Internet e-mail sent and received.[103] For these reasons, users wanted direct access to the resources available on the global network at reasonable prices.[104] However, CompuServe could not immediately provide full access to the Internet, as it operated a proprietary network that was incompatible with TCP/IP. As a result, the company decided to work towards providing full access in separate stages. It began this process by enabling users to access Usenet's newsgroups towards the end of 1994.[105]

CompuServe was not the only online service that had to respond to the popularity of the Internet during the early to mid 1990s. The Internet affected both existing and new services, including Delphi, CIX, Apple's eWorld, and the Microsoft Network.[106]

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[101] CompuServe would need to install gateways between its network and the Internet for its users to access the larger network. On adapters see J. Farrell and G. Saloner, "Converters, Compatibility, and the Control of Interfaces," *Journal of Industrial Economics*, vol. 40, no. 1, 1992, pp. 9-35.

[102] See E. Krol, *The Whole Internet: User's Guide and Catalog*, 2nd ed. (Sebastopol, California: O'Reilly, 1994), pp. 146-148, P. Gilster, *The New Internet Navigator* (New York: Wiley, 1995), pp. 255-265, P. Gilster, *Finding It on the Internet: The Essential Guide to Archie, Veronica, Gopher, WAIS, WWW (Including Mosaic), and Other Search and Browsing Tools* (New York: Wiley, 1994), pp. 243-260, and Appendix M.

[103] R. Sluman, *CompuServe for Europe: A Guide to the Information Superhighway* (London: International Thomson Publishing, 1995), p. 7.

[104] On disruptive technologies see J.L. Bower and C.M. Christensen, "Disruptive Technologies: Catching the Wave," *Harvard Business Review*, vol. 73, no. 1, 1995, pp. 43-53.

[105] R. Goodwins, "Gateway to the Stars: Accessing the World's News with Usenet," *PC Magazine*, October 1994, p. 292.

[106] Another service that had to respond to the Internet was Poptel. Poptel had launched its service during 1986, targeted at non-commercial organisations such as charities. To supply this service it used the facilities provided by the German network, GeoNet, which had a presence in several countries. By the end of the 1980s, nearly 400 subscribers used facilities such as e-mail, Bulletin Board Systems, and

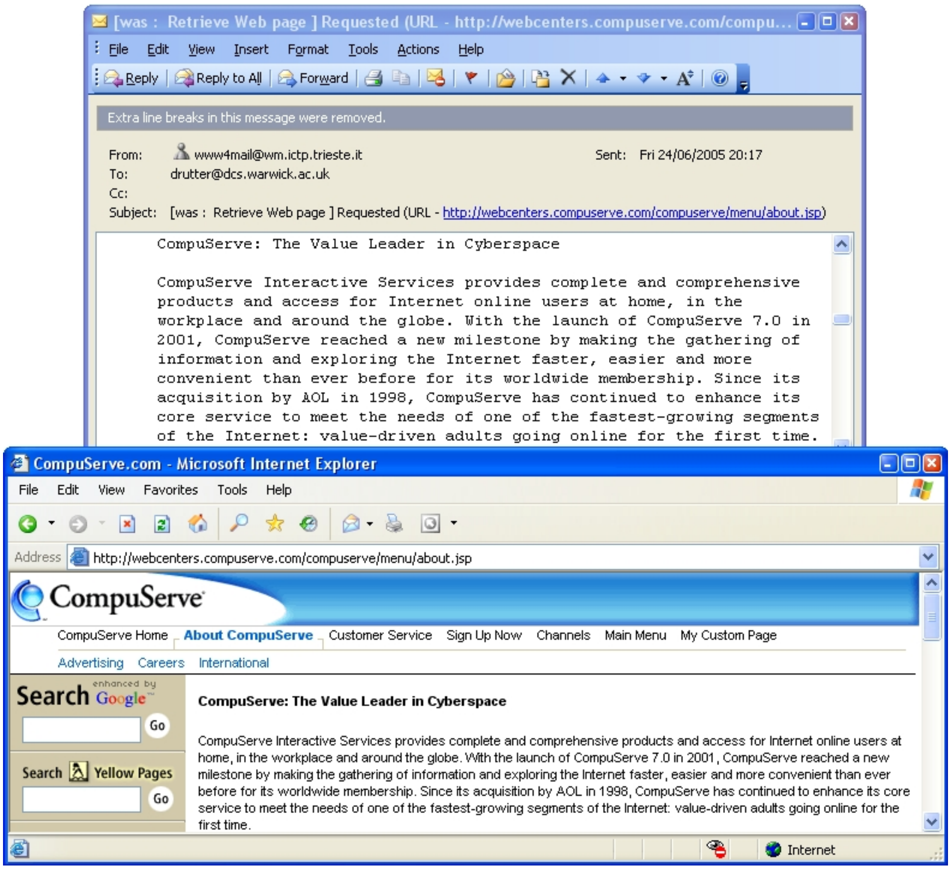

Figure 6.6. How the Web looked to CompuServe's users in 1994.[107]

Delphi was one of the first online services in the US to provide telnet and FTP access to the Internet.[108] The following year Delphi launched its service in the UK, and therefore provided access to the Internet for its British customers.[109] The UK's largest Bulletin Board System, the Compulink Information eXchange, also started to provide access to the Internet, during 1995. CIX's 15,000 subscribers could use applications such as telnet, FTP, and the World Wide Web.[110] In 1994, Apple decided to set up a

databases. During the early 1990s, Poptel ignored the Internet as many did, but according to one of the organisation's co-founders, Shaun Fensom, by 1993 "we knew we had to get serious about the Internet". Poptel therefore started to provide full access to this network. Information from S. Fensom, Interview by D. Rutter, 15 November 2002. Additional information from *Poptel: The Alternative Access to the New Communications Technology* (London: Poptel, 1986) and J. Green, "Heard It on the Grapevine," *Computing*, 16 November 1989, pp. 28-29.

[107] The figure shows a Web page retrieved using e-mail and the same page displayed within a Web browser. Although it was possible to access the World Wide Web using e-mail, most CompuServe users waited until a full connection became available, so that they could browse the Web using a browser, and therefore navigate the Web using hyperlinks and view images as well as text.

[108] "Delphi Grants Internet Access; Includes FTP and Telnet," *Link-up*, January/February 1993, pp. 1 and 9.

[109] D. Winder, "All the Right Signals," *PC Pro*, November 1994, pp. 217-220.

[110] See Appendix I.

network called eWorld.[111] Apple's service provided access to e-mail, bulletin boards, information, and other services (see Figure 6.7). Apple predicted that within one year eWorld would have 400,000 users.[112] Apple's eWorld was a self-contained online service which did not have a full link to the Internet. However, by mid 1995, pressure from users had forced Apple to upgrade its network to provide access to telnet, FTP, and the World Wide Web.[113] While Apple responded to the demands for Internet access, Microsoft planned its service known as the Microsoft Network (MSN) in the US.[114] MSN provided a similar range of facilities to Apple's eWorld, but it did not provide full access to the Internet (see Figure 6.8). However, by the end of 1995, the demand for this facility from MSN's users had forced Microsoft to supply a full connection to the network.[115]

With the launch of new ISPs and online services, CompuServe faced competition from many companies. By the beginning of 1995, America Online had 2 million customers which was only 1 million less than CompuServe. In addition, CompuServe's users were not satisfied with e-mail and Usenet only access to the Internet. CompuServe responded to these challenges in three ways. First, it began to lower its prices to help retain its users and compete effectively with its competitors. By 1995, CompuServe had reduced the cost of accessing the service from about £12.74 an hour in 1990, to a monthly membership fee of £6.38 and access charges of £3.08 an hour.[116] In response to the threat posed by America Online, CompuServe decided to launch a new "AOL killer" service called WOW! in the US.[117] CompuServe targeted WOW! at people who were not connected to the Internet. As well as accessing content that was similar to the information provided by the CIS, people could also use the Web. Users could join the service for $17.95 a month or $14.95 if they were already a CompuServe subscriber.[118]

[111] "Apple Serves Up eWorld as AppleLink Successor," *MacUser*, 21 January 1994, p. 19.
[112] G. Sneesby, "A Brave New eWorld," *MacUser*, 4 February 1994, pp. 68-69.
[113] J. Smith, "eWorld 1.1," *MacUser*, 1 September 1995, p. 57.
[114] "Microsoft to Go Global with Online Network," *MacUser*, 9 December 1994, p. 28.
[115] "Microsoft Embraces the Net," *Internet World*, April 1995, p. 15.
[116] "CompuServe Cuts Charges," *PC Pro*, March 1995, p. 27.
[117] A. Gray, E-mails to D. Rutter, 29 January 2003.
[118] R. Aguilar, *CompuServe Tries to Wow the Rest of Us*, CNET News.com, 1996, Available from: http://news.com.com/2100-1023_3-207291.html, Accessed on: 7 March 2003.

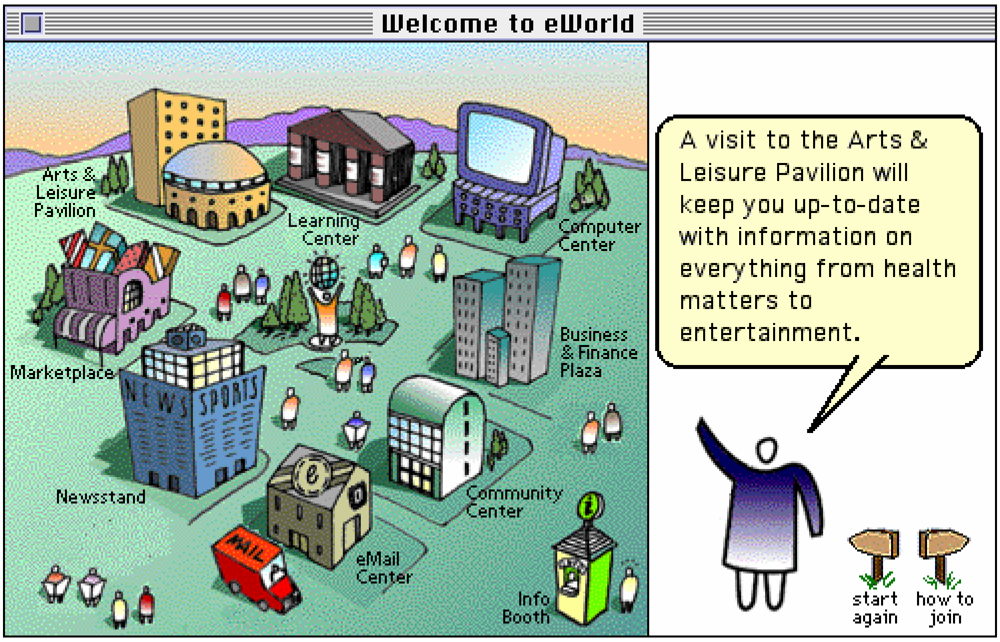

Figure 6.7. Apple's eWorld.[119]

To address the concerns of its users that wanted full access to the Internet, CompuServe provided access to FTP, telnet, and the World Wide Web during 1995.[120]

With the launch of World Wide Web access in 1995, CompuServe redirected its marketing away from being the largest online service in the world, to being the best way to connect to the Internet.[121] However, by then more than 40 ISPs, such as Demon Internet and PIPEX Dial, had capitalised on the popularity of the Internet, and as a result had naturally become associated with the task of connecting to the Internet. In comparison, CompuServe was an online service which also offered connections to the Internet. However, when compared to ISPs, it was not attractive. For example, towards the end of 1995, it charged users £6.20 for 5 hours access to the Internet. Potential adopters could instead pay £10 a month to an ISP, such as Demon Internet, for unlimited time online. If a person chose to use CompuServe to connect to the Internet, they would have to use two different programs.

[119] S.G. Converse, *Apple Computer's eWorld: What AOL Could Have Been*, S.G. Converse, 1998, Available from: http://www.scottconverse.com/apple's_eworld.htm, Accessed on: 16 October 2005.
[120] See D. Winder, "Chat-Up Lines," *PC Pro*, March 1995, pp. 229-232, R. Goodwins, "Netsurfing by Remote: Exploring the Internet with Telnet," *PC Magazine*, May 1995, p. 281, and R. Goodwins, "Many a SLIP: The New Generation of Internet Connectivity Protocols," *PC Magazine*, June 1995, p. 295.
[121] "Free.Net.Surfing@Compuserve," *Personal Computer World*, December 1995, p. 234.

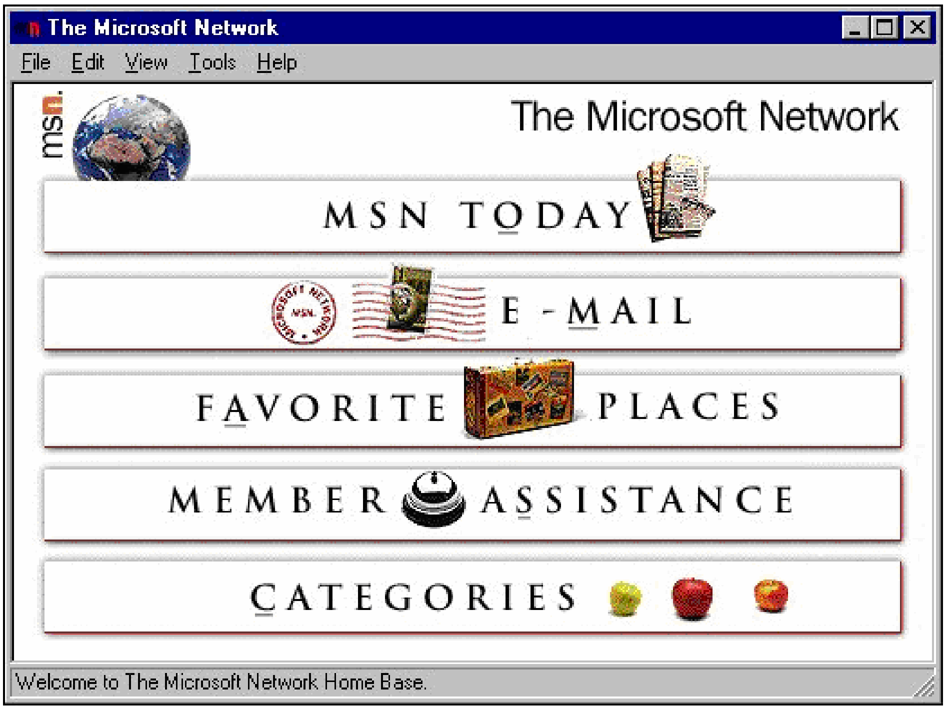

Figure 6.8. The Microsoft Network.[122]

The CompuServe Information Manager provided access to the CIS, and applications such as Usenet, telnet, FTP, and e-mail. To access the World Wide Web, subscribers needed to log off from the CIS, and then use another program, the CompuServe NetLauncher, to establish a dial-up connection to the Internet.[123] From a user's point of view, this made connecting to the Internet unnecessarily complicated, although this was an unavoidable consequence of CompuServe trying to integrate the open Internet Protocol suite, into its closed, proprietary architecture.

In addition to competing with Internet Service Providers in the UK, CompuServe also had to contend with the emergence of American Online (AOL) into the European market during 1996.[124] By then, American Online had become the largest online service and ISP in the world with 5 million customers. One year later, it had 10 million users. No computer network or online service had attracted so many users in

[122] S.D. Guthrie, *The Microsoft Network – What it is and What it Offers*, Duke University, 1995, Available from: http://www.duke.edu/eng169s2/group4/sguthrie/what.htm, Accessed on: 16 October 2005.
[123] D. Winder, "Ready to Run," *PC Pro*, November 1995, pp. 198-202 and 205-211. CompuServe upgraded the CompuServe Information Manager for Windows (WINCIM) in 1996. Subscribers could then access the CIS and the Web at the same time. See S. Cobb, "A Winner or a Wince?" *Personal Computer World*, February 1996, pp. 344-345 and 347.
[124] When America Online launched itself in Europe, it marketed its service using the initialism AOL. See J. Schofield, "Uncle Sam Wants You," *Personal Computer World*, February 1996, p. 32.

such as short space of time, and this was attributable to the popularity of the Internet. It was clear that America Online was therefore dominating both the online service and ISP markets. While America Online continued to attract significant numbers of subscribers, other services struggled to survive. CompuServe closed its WOW! service towards the end of 1996. It had cost the company $50m to develop and operate and had only attracted 102,000 users since its launch.[125] Apple followed this by announcing that it would close eWorld, after it had failed to attract a critical mass of users.[126] In early 1997, News International stopped operating Delphi, because it could no longer compete with the Internet.[127] Two years later Prodigy Communications also closed its online service, deciding instead to focus on its Internet access service, Prodigy.net, which had 433,000 subscribers by then.[128]

The closure of online services such as Apple's eWorld, Delphi, and Prodigy helped to increase the number of users accessing the Internet, as many of these former subscribers naturally turned to this network to satisfy their information and communications needs. These closures left two main online services, CompuServe and America Online. During 1997, America Online approached CompuServe with an offer to buy the company for $1.2 billion, and during 1998 it acquired the firm. CompuServe therefore became a division of its former competitor.[129] Although this acquisition consequently reduced CompuServe's status, its prominence as the original and, for many years, the largest online service, was important. CompuServe had influenced many peoples' perception of what an online service was, and what it could do for them.[130] In addition, people used their personal computers, with which they had

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[125] D.S. Lindsey, *CompuServe Fails to WOW! Consumers*, Wired News, 1996, Available from: http://www.wired.com/news/business/0,1367,584,00.html, Accessed on: 7 March 2003.
[126] R. Aguilar, *Apple Turns off eWorld, Turns to Net*, CNET News.com, 1996, Available from: http://news.com.com/Apple+turns+off+eWorld,+turns+to+Net/2100-1023_3-206546.html, Accessed on: 18 March 2003.
[127] News International had bought Delphi from the General Videotex Corporation during 1993. See D. Brake, "Chicago to Delphi," *Personal Computer World*, August 1994, pp. 536-540.
[128] During 1996, Prodigy had migrated away from the NAPLPS videotex display standard to HTML. However, this transition was not enough to retain its 1.13 million subscribers. By 1999, the number of users had decreased to 208,000. See M. Kane, *Y2K Bug Claims Prodigy Service*, ZDNet News, 1999, Available from: http://zdnet.com.com/2100-11-513499.html?legacy=zdnn, Accessed on: 24 March 2003.
[129] D. Lorimer, *CompuServe is Sold*, vnunet.com, 1997, Available from: http://www.vnunet.com/News/35367, Accessed on: 18 March 2003.
[130] Although the Internet had become more popular and successful than CompuServe had been, and despite the fact that America Online had acquired CompuServe, the original online service was not a failure. On the concept of failure and how a technology can influence the design and development of

accessed CompuServe, to connect to the Internet.[131] Although CompuServe and America Online existed within the open world of the Internet, their proprietary architectures could not survive, as TCP/IP had become the de facto suite of protocols for internetworking and networking, both on the Internet and on many other networks as well. Both online services recognised this, and therefore started to migrate away from their old architectures towards TCP/IP, just as UKERNA and France Télécom had done with their networks. As they began this transition, this reduced the reliance on the national and international X.25 circuits which they had both used for communication. As a result, this helped to consolidate TCP/IP's dominance as the internetworking protocol of choice. With 2 million AOL users in the UK by 2002 and 35 million worldwide, this also helped to consolidate TCP/IP as the standard used on the largest online service in the world.

subsequent technologies see W.P. McCray, "What Makes a Failure? Designing a New National Telescope, 1975–1984," *Technology and Culture*, vol. 42, no. 2, 2001, pp. 265-291.

[131] This trait was a pre-adaptive advance, because the original diffusion of PCs was unconnected with the Internet, but later gained adaptive value when previous customers of CompuServe wanted to access the Internet to send and receive e-mails, and therefore used CompuServe to achieve this objective or became a subscriber of an ISP. The concept of pre-adaptation comes from evolution. See V. Schneider, "Evolution in Cyberspace: The Adaptation of National Videotext Systems to the Internet," *Information Society*, vol. 16, no. 4, 2000, pp. 319-328 and R. Dawkins, *The Ancestor's Tale: A Pilgrimage to the Dawn of Life* (London: Weidenfeld & Nicolson, 2004), pp. 82-83.

7. Conclusions

7.1 Summary of the Thesis

The thesis began in Chapter 2 by looking at academic networks in the UK. During the 1970s, several academic networks, such as SWUCN and SRCnet, emerged, but as they were incompatible with each other, this limited their utility. To rationalise the situation, the Computer Board decided to set up a new national network, which would use the X.25 standard and the interim Coloured Book protocols. Known as the Joint Academic Network (JANET), the formation of this network occurred during 1984. Within a period of about two years, every academic network in the country had converged around X.25 and the Coloured Books and become part of JANET. Once this convergence had occurred, JANET evolved during the 1980s, with new services and facilities emerging on the network. To support the increasing traffic on JANET, the funding bodies decided to plan a two-phase upgrade of the network, known respectively as JANET Mark II and SuperJANET.

In Chapter 3, the thesis continued to focus on the evolution of British academic networks. The JANET Mark II upgrade became operational during 1990 and the JNT followed this with the SuperJANET initiative, which became the backbone of the national academic network JANET. Upgraded four times during a ten-year period, this network helped to satisfy the demands placed on it by its users. In parallel with these developments, pressure emerged from the academic community for a TCP/IP service on JANET. Within six months of the JNT launching the JANET IP Service, 80 percent of universities had switched from using X.25 to using TCP/IP. As a result, the academic community migrated way from X.25, the Coloured Books, and OSI to TCP/IP.

In Chapter 4 attention moved to the Prestel videotex network. During 1979, the General Post Office launched Prestel, predicting that 90,000 people would become subscribers by the end of 1980. This situation did not occur. However, by the early 1980s, Prestel did offer services and facilities, such as information retrieval, e-mail, and online banking and shopping, which people now use on the Internet. After the Post Office had launched Prestel, companies set up their own private viewdata networks which attracted customers, especially in the travel industry. However, Prestel did not share this success. By the mid 1980s, the network only had 62,000 subscribers. In parallel with these developments, other countries set up videotex networks, the most successful of which was Télétel in France. However, as most of these networks were incompatible with each other, this limited their utility. To solve this problem, the videotex community needed some form of internetworking solution. Several possible solutions appeared which had the potential to create a videotex internet. However, this did not occur and by the mid 1990s, most videotex networks did not exist. Those that did had to adapt their networks to co-exist with the Internet, which meant either installing gateways between the older networks and the Internet, or migrating to TCP/IP.

Chapter 5 introduced electronic mail networks. During the 1980s, Telecom Gold and Cable & Wireless Easylink became two of the largest networks in Britain. The chapter looked at how these services developed throughout the 1980s and into the 1990s. It also explored the problem of interconnectivity. By the mid 1980s, there were many incompatible e-mail networks throughout the world. Several solutions to the problem of interconnectivity appeared including the X.400 standard. X.400 had the potential to form a global interconnected e-mail network. However, problems such as the complexity of the standard and the lack of demand prevented X.400 from becoming widely diffused. By the mid 1990s, most proprietary e-mail networks had disappeared and people subsequently converged around the Internet and its e-mail protocols in order to communicate with people throughout the world using e-mail.

In Chapter 6, the thesis focused on CompuServe, other online services, and the Internet. CompuServe launched its PC-based service during 1979. By the mid 1980s, it offered many of the services and facilities that the Internet of the 1990s would provide. One of these services was an e-mail connection to the Internet. CompuServe could have chosen to expand access to the Internet at this time, but it chose not to believing that the network was irrelevant to its business. By the end of the 1980s, CompuServe had become the largest online service in the world. In 1990, CompuServe launched its network in the UK, which enabled people in Britain to access thousands of services and facilities. As interest in the Internet started to emerge during the early to mid 1990s, CompuServe again decided to ignore the Internet, preferring to focus on its main competitor, America Online. Meanwhile, Internet Service Providers, such as PIPEX and Demon Internet, started to provide access to the Internet. By 1994, CompuServe could not ignore the Internet any longer. Its competitors, including Apple's eWorld and the Microsoft Network, had to do the same. By the end of the 1990s, most of the proprietary online services had disappeared, which left only CompuServe and America Online. As TCP/IP had become the de facto suite of protocols for internetworking and networking by this time, both CompuServe and America Online had to migrate away from their old proprietary architectures towards TCP/IP.

7.2 Analysis

7.2.1 From Diversity to Convergence

From the 1970s onwards, many computer networks emerged in the UK, all of which used either proprietary or open protocols. The standards used on JANET were open: X.25, the Coloured Books, and the OSI protocols. The videotex networks that appeared during the 1970s and 1980s also used open standards. These included Prestel, Télétel, and CAPTAIN. In contrast, e-mail networks such as Telecom Gold and Cable & Wireless Easylink used proprietary protocols. The same was true for online services, including CompuServe, The Source, America Online, and the Microsoft Network. As the networks used different protocols, this meant that they were incompatible with each other, which limited the utility of the networks for their users. By the mid 1980s, the problem of interconnectivity had become acute. However, as most of the literature that looks at the development of the Internet does not consider many networks, this problem is not immediately apparent to the reader. The literature therefore does not focus on the potential solutions that emerged to solve the problem of interconnectivity. Some sources do consider the Open Systems Interconnection seven-layer reference model, but most usually only devote a small section to this subject. This approach suggests that alternative internetworking solutions were not significant and can leave the reader with the impression that the world of networking started with the ARPANET and ended with the Internet. However, inspection of the literature from the 1980s and 1990s reveals a different story. Throughout the 1980s, there were several potential solutions to the problem of interconnectivity. These included the Videotex Internetworking (VI) set of standards and Intermail. However, the one that became dominant, at least on paper, was OSI. Protocols such as X.400 had the potential to interconnect every computer network. The International Organization for Standardization (ISO), the CCITT, the UK and US governments, companies such as BT, the Joint Network Team, and many industry practitioners all believed that OSI was the only solution to the problem of internetworking. Some OSI advocates went further, referring to the Internet as a "toy academic network".[1] Many believed that TCP/IP was a transitory solution to a problem that only OSI could ultimately solve. Proponents of TCP/IP disagreed. David Clark, the chairman of the Internet Activities Board from 1981 to 1989, remarked that "we reject: kings, presidents, and voting. We believe in: rough consensus and running code".[2] They therefore rejected the approach adopted by the advocates of OSI, specifically that committees should design protocols.

And so the protocol wars began during the 1980s, with proponents on both sides refusing to accept the arguments presented by their opponents. Many believed passionately in their protocols and it seemed as though a consensus between the rival groups would never occur. As one person remarked at a meeting that discussed the protocols, "unanimity might be achieved—if we shoot a few people".[3] However, by the early 1990s, the war had ended. By then, it was clear that TCP/IP had prevailed. The failure of OSI to diffuse throughout the world occurred for several reasons, including the way the ISO specified standards, the standards themselves, and lack of demand. The International Organization for Standardization specified the OSI standards before implementing them. As the ISO's study periods lasted for four years, it took a long time for the organisation to ratify the standards. In comparison, during these years, people were actually using TCP/IP to conduct real work. The OSI standards themselves did not help. As Vint Cerf, who had developed the Transmission Control Protocol with Robert Kahn during 1974, remembers, "the language they used was turgid beyond belief. You couldn't read an OSI document if your life depended on it."[4] In addition, by the time that implementations did emerge, during the early

[1] K. Hafner and M. Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon & Schuster, 1996), p. 247.
[2] A.L. Russell, *From "Kitchen Cabinet" to "Constitutional Crisis": Politics of Internet Standards, 1969-1992*, Andrew L. Russell, 2002, Available from: http://www.arussell.org/papers/russell-icohtec2002.pdf, Accessed on: 29 June 2005.
[3] R.d. Jardins, "Opinion: OSI is (Still) a Good Idea!" *ConneXions*, June 1992, pp. 33-35.
[4] Hafner and Lyon, *Where Wizards Stay Up Late*, p. 247.

1990s, support for TCP/IP was strong and OSI could not displace this. As John Quarterman, who wrote a book about computer networks, remarks “OSI and IP started at about the same time. OSI wandered off into the weeds and IP won the race. Those that backed OSI, bet on the wrong horse”.[5] For these reasons, many considered OSI to be a failure. However, this is too simplistic. Although OSI was not a success, it became useful as a pedagogical model used by lecturers to teach students how computer networks worked. In addition, during the early 1990s, the Internet Engineering Task Force established working groups to integrate OSI-based protocols into the Internet, such as X.500.

As the popularity of OSI declined during the early 1990s, TCP/IP and its associated protocols became the natural solution to the problem of internetworking. The rise of TCP/IP occurred in association with the increasing popularity of the Internet. In a period of about 5 years, from 1990 to 1995, TCP/IP became the de facto protocol for internetworking and networking in general. It also became the protocol of choice on most computer networks in the UK. For example, by the mid 1990s, both JANET and SuperJANET used TCP/IP and other protocols such as SMTP. Videotex networks, including the Thomson Open-line Programme, either migrated to TCP/IP or established internetwork connections between the obsolete videotex technology and the Internet. The Internet Protocol suite also affected the e-mail services such as MultiMessage and Newslink. In addition, online services, such as CompuServe, America Online, and the Microsoft Network had to adopt TCP/IP in response to the demands of their users. As many of these networks had used X.25, reliance on this protocol declined as organisations adopted TCP/IP. The speed of the convergence around TCP/IP and the subsequent scale of the millions of Internet users are important, not just in the UK, but throughout the world.[6]

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[5] See P.H. Salus, “Protocol Wars: Is OSI Finally Dead?” *ConneXions*, August 1995, pp. 16-19 and J.S. Quarterman, *The Matrix: Computer Networks and Conferencing Systems Worldwide* (Bedford, MA: Digital Press, 1990).

[6] It took just five years, from 1990 to 1995, for many networks to converge around TCP/IP. In addition, it only took 4 years for the Internet to attract 50 million users. In comparison, the telephone took nearly 75 years to reach the same number of subscribers. And by 2005, the Internet would have approximately 934 million users. No single authority directed the convergence around TCP/IP and the Internet. Users valued what TCP/IP and its associated protocols could do for them, in terms of interconnecting incompatible networks and especially connecting them to the Internet. They therefore decided to adopt these protocols. No one planned this convergence and most people did not predict that it would happen. See P. Norris, *Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide* (Cambridge: Cambridge University Press, 2001), p. 32.

The convergence around the Internet Protocol suite was not the only convergence to occur during the 1990s. For most of the 1980s, users on the Internet had used tools such as telnet and FTP. By the 1990s, several new applications had emerged, including Archie, Gopher, Veronica, WAIS, and the World Wide Web. By the mid to late 1990s, the World Wide Web had displaced Gopher, to become the dominant service on the Internet, second only to e-mail in popularity. As people could use Web browsers to perform several activities including accessing Web sites, sending and receiving e-mails, and connecting to FTP servers, people associated the Web with the Internet. Although people continued to use other programs, such as e-mail clients and FTP programs, no other interface offered the same level of access to so many tools. By the late 1990s, the Internet community had therefore converged around the Web as the unified user interface of the Internet.[7]

During the 1980s, the gradual process of ratifying and refining OSI standards, did not present a significant threat to proprietary networks. This situation allowed companies, such as British Telecom, to endorse OSI while still competing with networks such as Cable & Wireless Easylink. When the Internet became popular during the 1990s, TCP/IP and protocols such as SMTP assumed the responsibilities of network communication and services such as e-mail. Proprietary protocols had traditionally supplied these services, so this reduced the extent to which companies could compete in these areas. Companies did of course find ways of competing. For example, America Online, Yahoo!, and Microsoft all developed instant messaging applications which used proprietary protocols that ran on top of TCP/IP (Figure 7.1). Proprietary protocols could therefore co-exist in the open world of the Internet, although as the protocols were incompatible with each other, this recreated the problem of interconnectivity that existed during the 1980s and early 1990s to a certain extent, albeit on top of the open standard TCP/IP.[8]

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[7] No one controlled the convergence around the Web. Users valued what the Web could do for them and therefore adopted it. No one planned this convergence and most did not predict that it would happen.

[8] Proprietary protocols, such as those used by the instant messaging applications, operate at the applications layer of the TCP/IP reference model, using the services provided by the lower layers, specifically TCP/IP. These protocols therefore co-exist within the open world of the Internet. Although the protocols are incompatible with each other, there are signs that things are changing. In 2005, Microsoft and Yahoo! announced that they would interconnect their instant messaging services in 2006, in order to compete more effectively with AOL's Instant Messenger (AIM), which has 41.6 million users. This interconnection will enable the 19.1 million Yahoo! Messenger users and the 14.1

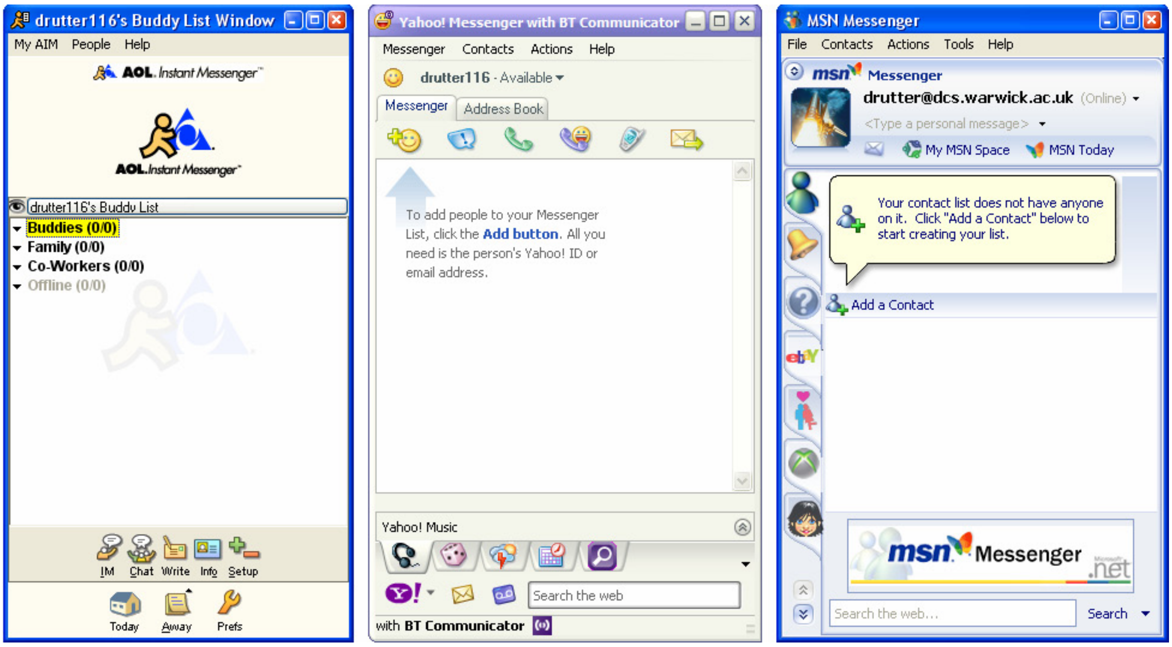

Figure 7.1. Instant messaging applications that use proprietary protocols.

However, there is a limit to which online services such as America Online will integrate their networks into the Internet. Although America Online has been migrating away from its proprietary architecture towards the Internet, this transition is not yet complete. For instance, in 2005 subscribers still use a proprietary program, AOL 9.0, to access services and facilities, such as e-mail and the World Wide Web (see Figure 7.2). Although there are signs that AOL is continuing to integrate its services into the Internet, it is questionable whether it will ever fully embrace this network or still seek to impose some form of proprietary control.[9]

million MSN Messenger users to communicate with each other, something that has not been possible before as both companies restricted communication to their own communities of users, forcing users to use both applications if they wanted to communicate with people who used the two services. This situation is reminiscent of the interconnectivity problems encountered by users of the electronic mail networks in the UK during the 1980s and early 1990s. See *Instant Message Providers Hook Up*, BBC News, 2005, Available from: http://news.bbc.co.uk/1/hi/business/4335932.stm, Accessed on: 16 October 2005, *Group Hug! Friends on Yahoo! and MSN Can Soon Share Instant Messages*, Yahoo! 2005, Available from: http://messenger.yahoo.com/partners_msn.php;_ylt=Asb4cwOaHZ.7bTxsgB_OS5ZwMMIF, Accessed on: 16 October 2005, and *Microsoft, Yahoo Reportedly Ready to Link Instant-Messaging Services*, InternetWeek, 2005, Available from: http://www.internetweek.com/news/172300323, Accessed on: 16 October 2005.

[9] For instance, AOL now has a beta of a standalone Web browser, the AOL Explorer, which people can use to access the Web instead of AOL 9.0. During early 2005, it announced that it would allow third party developers to create applications that could integrate with its Instant Messenger application. America Online also distributes an open source Web server, AOLserver. See *AOL Explorer Beta*, AOL, 2005, Available from: http://beta.aol.com/projects/aolexplorer/index.html? Accessed on: 19 June 2005, D. Worthington, *AOL Opens Up its AIM Community*, BetaNews, 2005, Available from: http://www.betanews.com/article/AOL_Opens_Up_its_AIM_Community/1109603183, Accessed on:

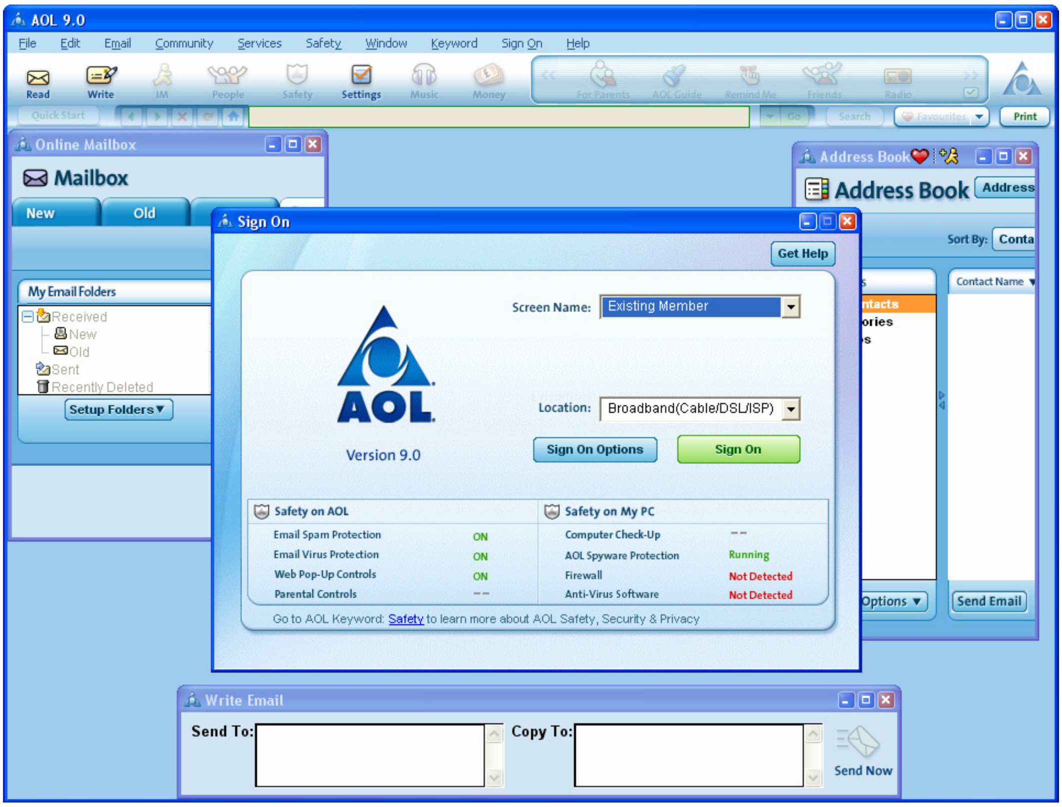

Figure 7.2. The proprietary AOL 9.0 application.

7.2.2 From Convergence to Pervasive Computing

The convergence of computer networks around TCP/IP forms the basis for a larger form of convergence, known as pervasive computing, which started to occur during the late 1990s.[10] In the 21st century, several technologies can access the Internet. These include computers, mobile phones, landline telephones, Personal Digital Assistants, laptops, cameras, camcorders, televisions, game consoles, and cars.[11] In addition, during the last 15 years new mobile networks have emerged. These include Wireless Local Area Networks, commonly known as Wireless-Fidelity (Wi-Fi)

19 June 2005, and *What is AOLserver*, AOL, 2005, Available from: http://www.aolserver.com, Accessed on: 19 June 2005.

[10] No single authority controlled these forms of convergence, no one planned for them, and most did not predict that it would happen. Users directed both types of convergence because of what the technology could do for them.

[11] There are initiatives to extend the idea of IP-connected devices to entire buildings, embedding IP-aware devices into technologies, including lighting and air conditioning systems, as well as home appliances such as cookers and washing machines. MIT's The Center for Bits and Atoms' Internet 0 project is an example of this embedded IP technology. See B. Daviss, "The Net Comes Home," *New Scientist*, 15 February 2003, pp. 26-29 and R. Krikorian and N. Gershenfeld, "Internet 0 — Inter-device Internetworking," *BT Technology Journal*, vol. 22, no. 4, 2004, pp. 278-284.

networks, and Bluetooth, for mobile phones and other devices.[12] During the last 5 years, Wi-Fi networks have emerged in places such as offices, hotels, universities, the British Library, and airports. By paying an access fee, people can use laptops with Wi-Fi network cards in them to connect to the Internet. For the first time, people can use nodes within the Internet that are not fixed which liberates individuals from having to access the Internet using a desktop PC. People can use any IP-aware technology to use the Internet wherever and whenever it suits them. The fixed Internet has therefore become the mobile Internet. In addition, Voice over IP (VoIP) technology is enabling companies such as British Telecom to use TCP/IP as the basis for all of their services, including telephony. TCP/IP is therefore at the core of this emerging convergence revolution.[13]

7.3 Further Research Questions

This thesis poses several important questions that are worthy of further research, the first three of which the chapter will consider briefly below. To what extent was security an issue in the computer networks of the 1980s and early 1990s? Why did many governments, companies, organisations, and individuals fail to predict the popularity of the Internet and how important this network would become? How did the convergence around TCP/IP influence the emergence of pervasive computing? Did time-sharing systems affect the development of computer networks and if so how? What forces and influences lead to the development of a diverse range of networks that used incompatible protocols? What were the advantages and disadvantages of each protocol from the point of view of the participants and, looking back, were these views reasonable and have attitudes now changed? How much effort did people expect to have to undertake in order to develop protocol converters or gateways, and where their expectations right? Was incompatibility between protocols as significant with Local Area Networks as it was with public Wide Area Networks? To what extent did LANs play a role in the general diffusion of networks in the UK?

[12] A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 292-317.

[13] See J. Burkhardt, et al., *Pervasive Computing: Technology and Architecture of Mobile Internet Applications* (Boston: Addison-Wesley, 2001), U. Hansmann, et al., *Pervasive Computing: The Mobile World*, 2nd ed. (Berlin: Springer, 2003), and P. Day, *In Business - Connections*, BBC Radio 4, 2004, Available from: http://www.bbc.co.uk/radio4/news/inbusiness/ram/inbusiness_20040930.ram, Accessed on: 3 October 2004.

How the did different types of terminal, such as televisions, telephones, dumb and intelligent terminals, and especially the Personal Computer, influence the development and adoption of networks? How important were users in the adoption and diffusion of networks? Why did people create Bulletin Board Systems and what was their impact? Did the World Wide Web supersede all Bulletin Board Systems, or was the situation more complicated than this? To what extent did incompatibility limit the usefulness of networks for users? Why did governments, companies, organisations, and individuals believe that OSI would solve the problem of incompatibility, when this never occurred? Why did TCP/IP succeed where OSI failed and is it accurate to consider OSI to be a complete failure?

Throughout the 1980s, many networks did not consider security to be of paramount importance. Security breaches did occur on networks such as JANET and Telecom Gold, but they were not that common. However, as millions of people adopted the Internet from the mid 1990s onwards, the issue of security became of crucial concern to companies and individuals alike, forcing firms such as Microsoft to respond. Why did people not consider security as important in the 1980s as it subsequently became from the mid 1990s onwards? Is it simply because millions of people used the Internet and this created problems, in terms of the number of hackers and naïve users, or was the situation more complicated than this? Several other aspects about the diffusion and implications of computer networks need additional attention. During the 1980s, most networking companies outside of academia ignored the Internet, as they did not consider it relevant to their business. They therefore focused their attention on their proprietary networks and OSI. However, when the Internet became very popular during the mid 1990s, this success surprised them. Companies such as CompuServe and British Telecom had to respond quickly and decisively to the popularity of a network that they had ignored for years. The same was also true of Microsoft. While Bill Gates' 1995 book, The Road Ahead, did mention the Internet, it did so only in passing, devoting about 12 pages to the subject. Within a year, Gates had to amend his book to acknowledge the significance of the Internet and how Microsoft would make "the Internet its central focus".[14] Why were so many governments, companies,

[14] See B. Gates, *The Road Ahead* (London: Viking, 1995), p. ix and G. Gooday, "Taking Apart the 'Roads Ahead': User Power Versus the Futurology of IT," *Convergence: The Journal of Research into New Media Technologies*, vol. 4, no. 3, 1998, pp. 8-16.

organisations, and individuals unable to predict the popularity of the Internet? In addition, the topic of pervasive computing and the convergence of technologies such as the telephone around TCP/IP need closer attention. For example, how and why did TCP/IP become the basis for a new form of convergence, which enables people to interconnect many technologies with the Internet?

7.4 Concluding Remarks

This thesis has attempted to correct the misconception that the world of networking started with the ARPANET and ended with the Internet. It did this by looking at how a diverse range of incompatible computer networks emerged in Britain during the 1970s, 1980s, and 1990s. It considered why many people assumed OSI was the natural choice to solve the problem of interconnectivity, therefore dismissing TCP/IP which the Internet and other networks used. The thesis looked at the context and background for the protocol wars, which emerged during the late 1980s, by means of detailed reference to significant British networks. The thesis also considered why most people did not adopt OSI in the UK, how and why TCP/IP became the de facto protocol for internetworking in Britain, and how most of the networks that still existed by the mid 1990s converged around the Internet Protocol suite during this decade.

People can draw several conclusions from an analysis of the emergence and diffusion of computer networks in the UK, and the subsequent convergence around the Internet Protocol suite. These include the importance of users in the evolution of the technology, the possibility of several potential outcomes and therefore how the teleological approach can be misleading, and how users influenced the convergence around the technology. No single authority controlled the evolution of networks in the UK, which meant that the networks naturally evolved on their own in response to the needs of users and other factors such as interconnectivity and standards. Users were often at the centre of this evolution. They dictated what services they wanted networks to provide, and the network operators therefore responded by providing these facilities or, in some cases, the users provided the services themselves. Users were therefore crucial to the evolution of the technology. As no single authority controlled the evolution of the networks, there did not seem to be an overarching plan for the future direction of networks in the UK. However, such a plan did exist in the form of OSI. Many organisations, such as the Joint Network Team, believed that OSI was the natural choice to solve the problem of interconnectivity, and that it would ultimately become the dominant set of standards for networking. Commercial companies, such as British Telecom, also acknowledged that OSI would become important. Organisations and companies therefore planned to migrate away from interim and proprietary protocols towards OSI. If this had occurred it could have potentially created an OSI internet. In addition, other potential outcomes could have occurred, including the idea of a videotex internet. It is therefore misleading to suggest that the world of networking started with the ARPANET and ended with the Internet, when the Internet was only one of several potential outcomes. This teleological approach retrospectively imposes a direction or a purpose and ultimate outcome onto the emergence, diffusion, and evolution of networks when no such direction or purpose existed. If a reader looks at materials from the secondary literature of the 1980s, he or she will be able to discern four main trends.[15] First, most industry practitioners, analysts, and commentators believed in OSI and predicted that this set of standards would become a success and ultimately dominate the world of networking. Second, although many people saw OSI as the natural solution to solve the problem of internetworking, uncertainty surrounded the set of standards. For example, people were unsure how long it would take the ISO to ratify a complete set of OSI protocols; whether computer hardware and software manufacturers would implement the standards; if commercial networks such as Telecom Gold would fully embrace the protocols; and whether users would adopt OSI solutions. Third, although some writers did mention TCP/IP and the Internet, they did so usually in passing and often dismissed them as temporary solutions which OSI would ultimately supersede. Finally, when it became clear that TCP/IP had the potential to rival OSI, many people still believed that OSI would prevail and that networks using TCP/IP would eventually migrate to OSI protocols. When it became clear that this might not happen, many people assumed that OSI and TCP/IP would co-exist.[16] The main point is that

[15] For example, it is instructive to scan through issues of the newspaper Computer Weekly from the 1980s and early 1990s. Doing so will help a reader to become familiar with peoples' thoughts about the future direction of computer networks at that time.

[16] See for example B. Sales, "TCP/IP–X.25/OSI Interoperation: From the Medium Term to the Long Term," *Computer Networks and ISDN Systems*, vol. 23, no. 1-3, 1991, pp. 171-176, D. Wallace, "How to Interwork Between TCP/IP and OSI," *Telecommunications*, April 1989, pp. 46 and 51-54, R. Hunt, "The Future of TCP/IP and ISO/GOSIP - Migration or Coexistence?" *Networks '93: Integrating Networks with Business Objectives, Birmingham, June 1993* (London: Blenheim Online, 1993), pp.

uncertainty about the future existed and it was therefore not obvious that TCP/IP would become dominant. This situation did not change until the Internet started to become popular during the early to mid 1990s. Retrospectively implying a direction or a purpose and ultimate outcome to the evolution of a technology and therefore adopting a teleological approach can therefore be unwise and misleading.

If network practitioners and operators underestimated the significance of TCP/IP and the Internet, they also underestimated how important users would become in the convergence around this protocol and network. Many companies, such as BT, and organisations, such as the JNT, believed that they had the responsibility to specify which standards their networks should use. People would then use these protocols transparently in their daily interactions with the networks. However, when the Internet became popular during the early to mid 1990s, many users started to recognise that TCP/IP could solve the problem of interconnectivity, and connect them to the Internet, which offered many services and facilities that they wanted to use. As a result, users started to demand access to TCP/IP and the Internet and it was therefore users, and not a single authority, which drove the convergence around this protocol and the global network of networks. Users were therefore central to the convergence around the technology. Many failed to predict that this would happen and were unable to envisage the speed and scale of this convergence. They also failed to predict how, from the early 21st century, the adoption of the Internet Protocol suite would form the basis for a form of convergence that extends the influence of TCP/IP to devices other than personal computers. This phenomenon is creating the mobile Internet, and users are again essential to this form of convergence, which has TCP/IP at its core.

423-437, and M. Ward, “Internet Must Win the Numbers Game,” *Computer Weekly*, 22 April 1993, p. 12.

Appendix A. Packet Switching and Protocols

A.1 Packet Switching

Paul Baran invented packet switching at the Research and Development (RAND) Corporation during the early 1960s. He initially proposed a distributed message switching system which meant that the network would transmit complete messages between computers.[1] Baran later refined this idea by splitting data into discrete units called message blocks. A few years later, Donald Davies at the UK's National Physical Laboratory (NPL) also invented packet switching. Davies was not aware of Baran's work, but his proposal was similar to Baran's distributed communications system. He referred to the message blocks as packets, and this lead to the term packet switching.[2]

Packet switching works by dividing, say, an e-mail into a series of packets. Each packet contains the address information that a packet-switched network uses to deliver the packet to its destination. Packets also contain data which in this example contain sections of the e-mail. In the example shown in Figure A.1, User A wants to transmit an e-mail to User B. User A's PC divides the e-mail into a series of packets and then transmits them to the packet-switched network, which in this case is the Internet. Telecommunications companies connect networking devices called routers to the Internet. Routers operate on a store-and-forward basis. Routers receive packets, store them, and then transmit the packets to other routers, using the address information contained within each packet. When User B's computer has received the entire series of packets, the computer reassembles the e-mail from the packets received. An analogy is to think of packets as being similar to envelopes, with the address on the outside and the data on the inside.[3]

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[1] Message switching networks transmit entire messages, instead of individual packets, between routers, and people therefore refer to them as store-and-forward networks. An alternative technology, known as circuit switching, establishes a circuit or path within a network between a sender and a receiver, which both parties use to communicate. An example of a circuit switched network is the PSTN. See A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 147-149.

[2] J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), pp. 7-35.

[3] On packet switching, including the envelope analogy, see T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 957-962.

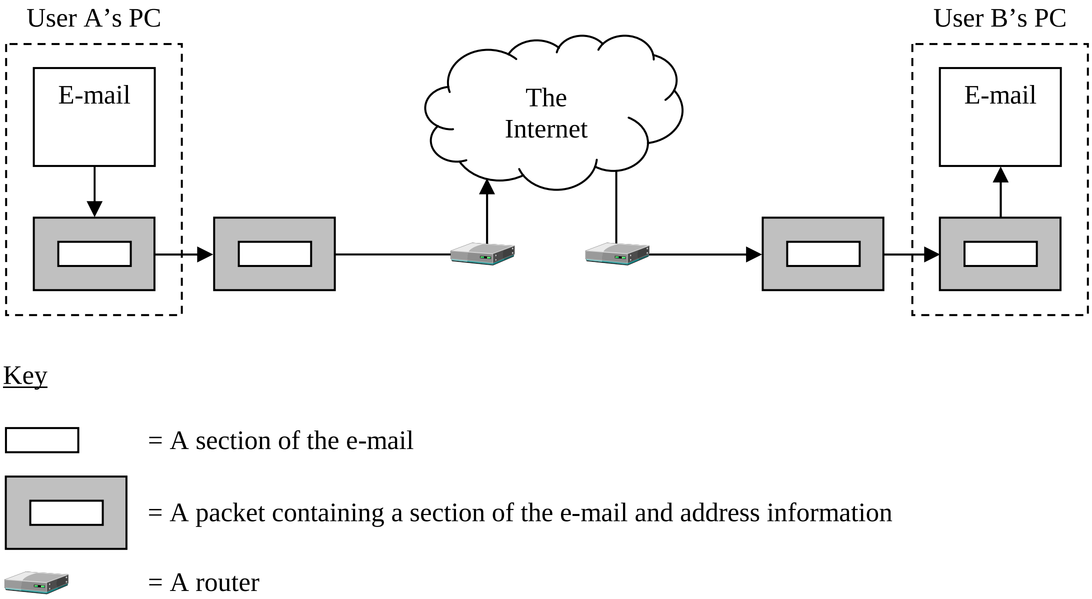

Figure A.1. Packet switching.

If a person wanted to send a large document to someone that did not fit into a single envelope, they might split the document into sections and then place each section into a separate envelope. They would then post the envelopes and when they arrived, the recipient would reassemble the separate sections into the original document.

A.2 Protocols

Designers of communication protocols agree on the rules and procedures that control the interactions involved in computer communication. Protocols organise how two computers establish contact with each other, transmit information, detect and correct errors, and then terminate communication. In the example shown in Figure A.2, the user wants to download a file that is stored on a server. To achieve this, the client PC and server transmit and receive a series of packets. These packets contain instructions and the file that the user wants to access. When either the client or the server transmits a packet, the other computer transmits an acknowledgement, indicating the successful receipt of the packet involved. However, when the server transmits the second segment of the file, the client does not send an acknowledgment, indicating that the network may have corrupted or lost the packet. After a pause, the server therefore retransmits the packet. When the server has successfully transmitted the file, both computers terminate the connection.

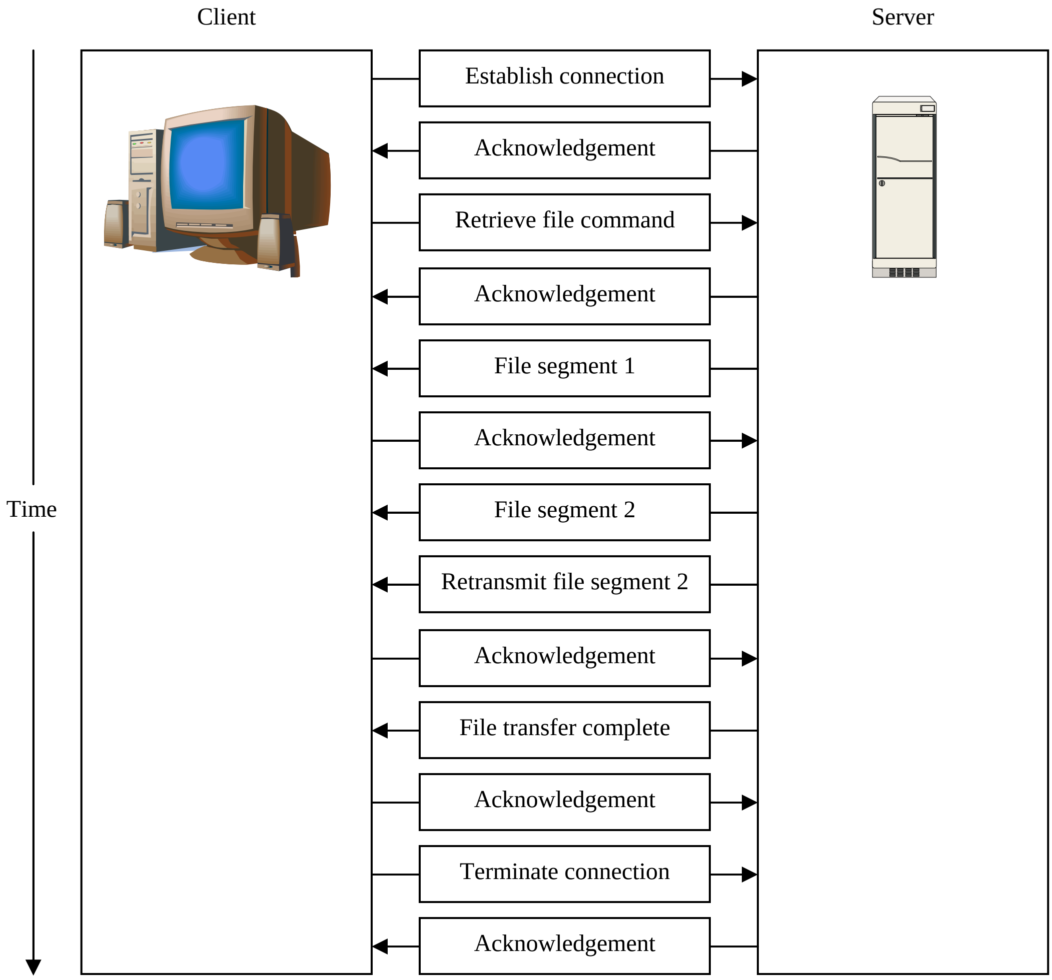

Figure A.2. Downloading a file from a server.

There are many different types of protocol, ranging from low-level protocols that are responsible for network-specific functions, to higher-level protocols involved with applications such as e-mail. Two network-specific protocols include X.25 and TCP/IP. A file transfer protocol is an example of an application protocol. These protocols provide the rules and procedures that are necessary to transmit a file from one computer, across a network, to another computer. Examples include the Blue Book protocol, which people used on JANET, and the File Transfer Protocol (FTP) used on the Internet.

Appendix B. Bandwidth and Data Transfer Rates

B.1 Overview and Example Systems and Data Transfer Rates

The bandwidth of a communication channel refers to the range of frequencies that the channel uses, which means that the bandwidth determines the quantity of information that the channel can transmit during one second, referred to as the data transfer rate or data rate. Common units include bits per second (bps), Kilobits per second (Kbps), Megabits per second (Mbps), and Gigabits per second (Gbps). People often refer to the data transfer rate of a channel as the channel's bandwidth or speed. The original leased lines used in the early networks of the 1970s operated at slow speeds such as 2,400 and 4,800 bps. If a person wanted to connect to a remote computer to download a 1 Mb file, which is approximately the size of two 300-page books stored in plaintext format, then it would take nearly 70 minutes to transmit the file using a line that operated at 2,400 bps. As the data transfer rates of networks improved, the time it took to transmit data therefore improved. For example, once networks operated at, say, 256 Kbps during the late 1980s, this meant that transmitting the same 1 Mb file across a network would take only 65 seconds. An analogy is to think of the bandwidth of a communication channel as being similar to the diameter of a water pipe, with the water representing the data, and the flow of water representing the data transfer rate. As the diameter of the pipe increases, the quantity of water that flows through the pipe every second also increases. Table B.1 provides an overview of the bandwidths of different communication systems.

Table B.1. Communications systems and associated data transfer rates.[1]

Communication system	Data transfer rate
Dial-up modem	From 300 bps to 56 Kbps
Cable modems	From 512 Kbps to over 10 Mbps
Digital Subscriber Line (DSL)	From 512 Kbps to over 50 Mbps
T1 leased line	1.544 Mbps
Ethernet LANs	10 Mbps
FDDI	100 Mbps
Fast Ethernet	100 Mbps
T4 leased line	274.176 Mbps
Gigabit Ethernet	1 Gbps
Synchronous Digital Hierarchy (SDH)	51.9 Mbps to 2.5 Gbps
10-Gigabit Ethernet	10 Gbps
Dense Wave-Division Multiplexing (DWDM)	10 Gbps to 40 Gbps

[1] On bandwidth, including the water pipe analogy, see T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 102-107.

Appendix C. Standards Organisations

C.1 General Standards Organisations

The two types of standards, de facto and de jure, have influenced the development of computer networks, since the introduction of this technology during the late 1960s. Examples of de facto standards include TCP/IP, SMTP, and HTTP. These standards emerged through consensus among computer scientists and other users who helped to develop the ARPANET and the Internet. In comparison, de jure standards emerged through official standardisation bodies, which ratified international standards, based on the work of many committees. Examples include X.25, X.400, and X.500. Several organisations participated in the development of both types of standard (see Table C.1). See Figure C.1 for the relationship between the United Nations, the ITU, and the IEEE. See Figure C.2 for the relationship between the ITU, the ISO, and national standards organisations such as the British Standards Institute (BSI).

C.2 Internet Standards Organisations

In addition to the organisations mentioned above, several additional bodies are involved with the standardisation of the Internet (see Table C.2). While no one controls the Internet, these volunteer organisations influence the Internet's development. See Figure C.3 for the relationship between the Internet organisations and the ITU.

Table C.1. General standards organisations.[1]

Organisation	Description
BSI	The British Standards Institute is the UK's national standards body. Founded as the Engineering Standards Committee in 1901, it began to introduce standards for technologies such as the gauges of trams. Since then, it has produced standards for many products including the three-pin plug and seat beats. During 1976, the BSI began to develop an internetworking architecture which later became the Open Systems Interconnection seven-layer reference model. The BSI is a member of the ISO.[2]
CEPT	The European Conference of Postal and Telecommunications Administrations (CEPT) is an organisation that deals with postal and telecommunications issues in Europe. Founded in 1959 by 19 countries, the membership increased to 26 Post, Telegraph, and Telephone (PTT) operators within its first ten years. By 2005, there were 46 member countries. CEPT undertakes work in several areas including influencing developments within the ITU and standardisation. The CEPT ratified the European standard for videotex networks in 1981.[3]
CCITT	The Comité Consultatif International Télégraphique et Téléphonique (CCITT) was the predecessor to the ITU-T.[4] In 1956, the CCITT replaced two earlier committees, the International Telegraph Consultative Committee (CCIT) and the International Telephone Consultative Committee (CCIF). The CCITT ratified many standards relating to telecommunications, including X.25, X.400, X.500, and the V-series of standards for modems such as V.21. The CCITT chose to designate each standard with a letter, representing a series such as X, and a number, which represented the series number, such as 400. In 1993, the CCITT became the ITU-T.[5]
IEEE	The Institute of Electrical and Electronics Engineers (IEEE) undertakes a broad range of activities, including the standardisation of electrical engineering and computer systems. Founded as the American Institute of Electrical Engineers (AIEE) in 1884, it was interested in standards relating to power systems and wire communication systems such as the telegraph. By 1963, this institute had merged with the Institute of Radio Engineers (IRE) to form the world's largest professional organisation. The IEEE develops draft standards which it forwards to the American National Standards

[1] A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 71-77.
[2] *History of the BSI Group*, BSI, 2004, Available from: http://www.bsi-global.com/News/History/index.xalter, Accessed on: 16 August 2004.
[3] *About CEPT*, CEPT, 2004, Available from: http://www.cept.org, Accessed on: 22 February 2005.
[4] In English, people referred to the CCITT as the International Telephone and Telegraph Consultative Committee.
[5] *ITU Overview - History*, ITU, 2002, Available from: http://www.itu.int/aboutitu/overview/history.html, Accessed on: 13 May 2004.

	Institute (ANSI) and the ISO. An example of an IEEE standard is the 802.3 set of standards for Ethernet LANs.[6]
ISO	The International Organization for Standardization (ISO) is an international organisation which ratifies standards. The ISO contains members from 148 countries, some of which are from governments and others from companies. In 1946, 25 countries established the ISO, and set up its secretariat in Geneva. Experts participate in Technical Committees which develop standards for use within both the public and private sectors. For example, the JTC 1/SC6 committee developed standards relating to the lower layers of the OSI seven-layer reference model. The ISO is a member of the ITU.[7]
ITU	The International Telecommunication Union (ITU) is an international organisation that ratifies standards. In 1865, members from 20 countries founded the organisation with the aim of standardising international telegraphic communications. With the invention of the telephone in 1876 and the subsequent development of wireless communications, the ITU ratified standards that governed these new forms of communication. In 1947, the ITU became an agency of the United Nations. With the launch of Sputnik I in 1957, this prompted the ITU to organise conferences to discuss the implications of satellite communications. In 1989, the ITU reorganised the Union into three sectors, based on the principal work undertaken: ITU-Telecommunications Standardization (ITU-T), for the standardisation of telecommunications; the ITU-Radiocommunication (ITU-R), for the characteristics and procedures relating to radio communications; and ITU-Telecommunication Development (ITU-D), for the development of telecommunication infrastructures in countries that lack these facilities. The ITU's headquarters is in Geneva, which, in addition to providing central administrative facilities for the 189 member states, also holds international conferences relating to the ITU's work.[8]

[6] *What is the IEEE?* IEEE, 2003, Available from: http://www.ieee.org/portal/index.jsp?pageID=corp_level1&path=about/whatis&file=index.xml&xsl=generic.xsl, Accessed on: 16 August 2004.
[7] *Introduction*, ISO, 2004, Available from: http://www.iso.org/iso/en/aboutiso/introduction/index.html, Accessed on: 16 August 2004.
[8] *ITU Overview - History*.

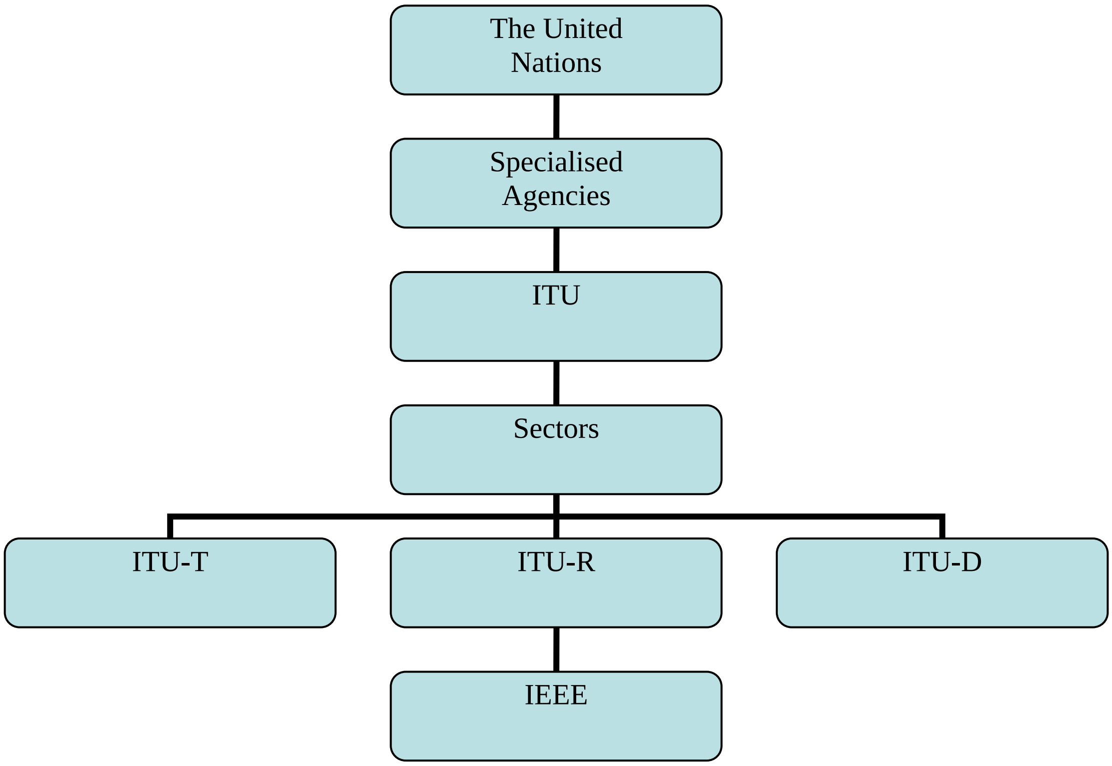

Figure C.1. The United Nations, the ITU, and the IEEE.[9]

[9] *The United Nations system*, United Nations, 2004, Available from: http://www.un.org/aboutun/unchart.pdf, Accessed on: 30 September 2004.

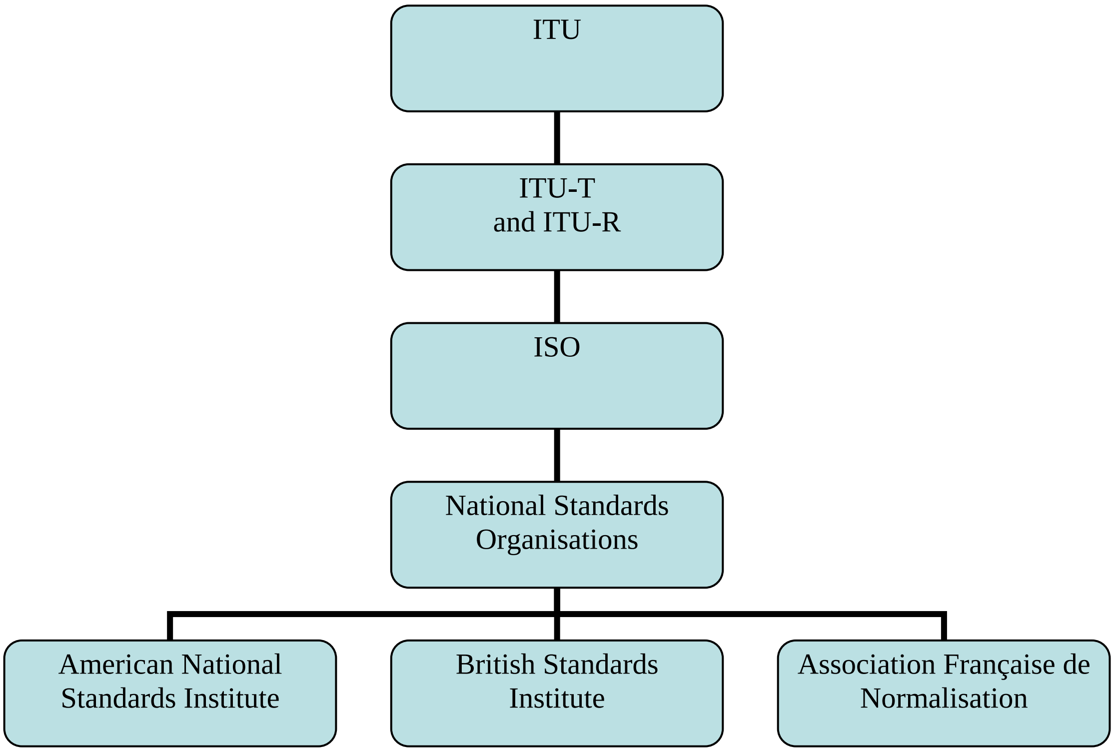

Figure C.2. The ITU, ISO, and national standards organisations.[10]

[10] For simplicity, this figure only shows three national standards organisations.

Table C.2. Internet organisations.[11]

Organisation	**Description**
IAB	The Internet Architecture Board (IAB) has several responsibilities including overseeing the IETF's architectural activities. One of the tasks undertaken by the IAB is to maintain and publish the Request for Comments (RFCs) standards documents which are central to the development of the Internet.
ICANN	The Internet Corporation for Assigned Names and Numbers (ICANN) is responsible for the Internet Protocol addresses used on the Internet. In 1998, ICANN replaced the Internet Assigned Numbers Authority (IANA).
IESG	The Internet Engineering Steering Group (IESG) manages the Internet standardisation process, including the approval of standards.
IETF	The Internet Engineering Task Force (IETF) is composed of members who wish to contribute to the Internet's development. Working groups focus on specific areas of the Internet's architecture, including e-mail, the DNS, and IPv6.
IRTF	The Internet Research Task Force (IRTF) is involved with the research that can contribute to the development of the Internet. The IRTF is organised into research groups which deal with topics such as protocols, applications, and technologies.
ISOC	The Internet Society (ISOC) is an international organisation that is involved with the future of the Internet. It contains 16,000 members from over 180 countries. It delegates responsibility for the standards relating to the Internet's infrastructure to the IAB. ISOC is a member of the ITU.

[11] T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications,* 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 650-653.

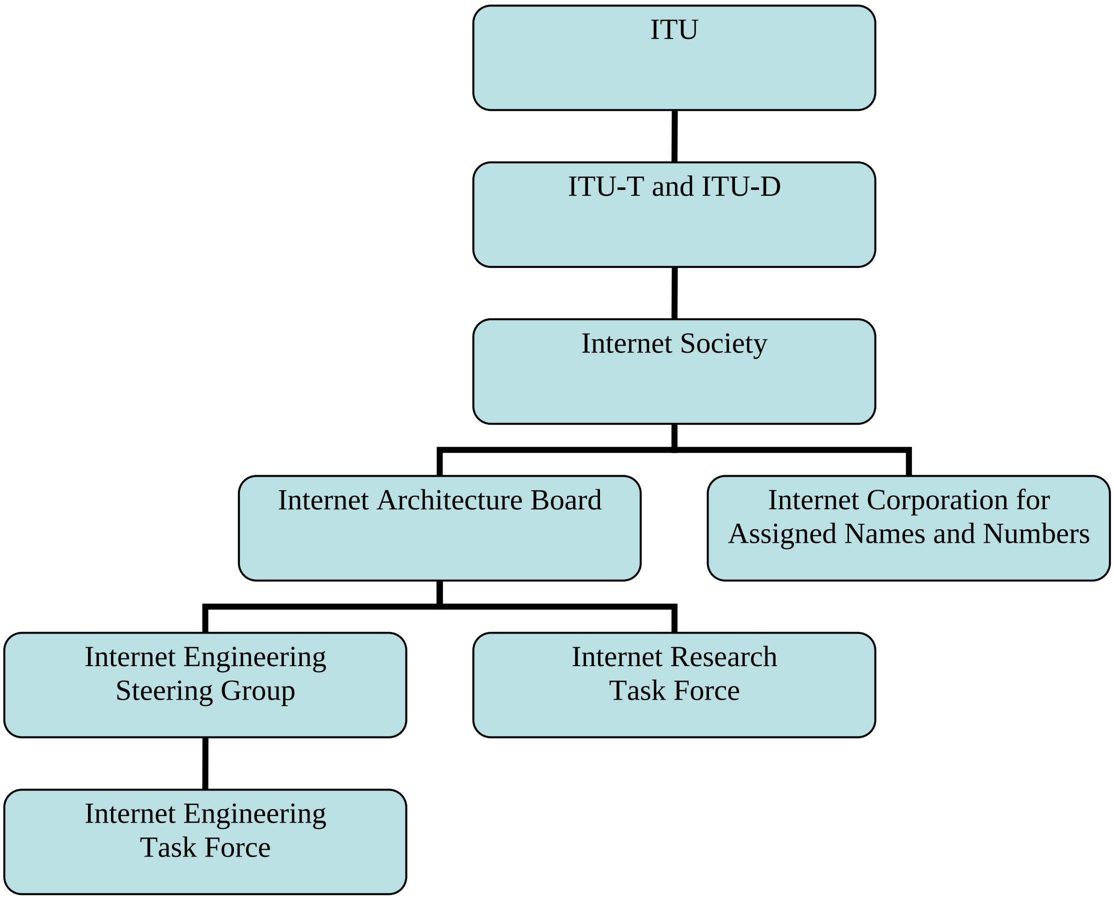

Figure C.3. The Internet organisations and the ITU.

Appendix D. OSI, X.25, and the Coloured Book Protocols

D.1 The OSI Seven-layer Reference Model

The Open Systems Interconnection (OSI) seven-layer reference model defines a layered architecture for understanding network communication. Each layer within the protocol stack is responsible for a different element of the transmission process, and is independent of the other layers. Every layer provides services to the layer above, and each layer is not aware of how the layer beneath it operates. In theory, every layer is independent, so that an engineer could change an aspect of a layer without affecting the other layers.[1]

In the example shown in Figure D.1, a user (client) wants to send an e-mail to another person. When the user clicks the 'Send' command in their e-mail program on their client PC, the layers insert the data from the e-mail into packets, include error checking as part of the data, and then transmit the packets over the network to the destination e-mail server. On receipt of the packets, the layers of the architecture on the server reverse the process undertaken by the layers on the client, to check the data for errors, and extract and recompose the e-mail from the packets. A similar process occurs when the recipient receives the e-mail.

[1] J. Henshall and S. Shaw, *OSI Explained: End-to-end Computer Communication Standards* (Chichester: Ellis Horwood, 1988).

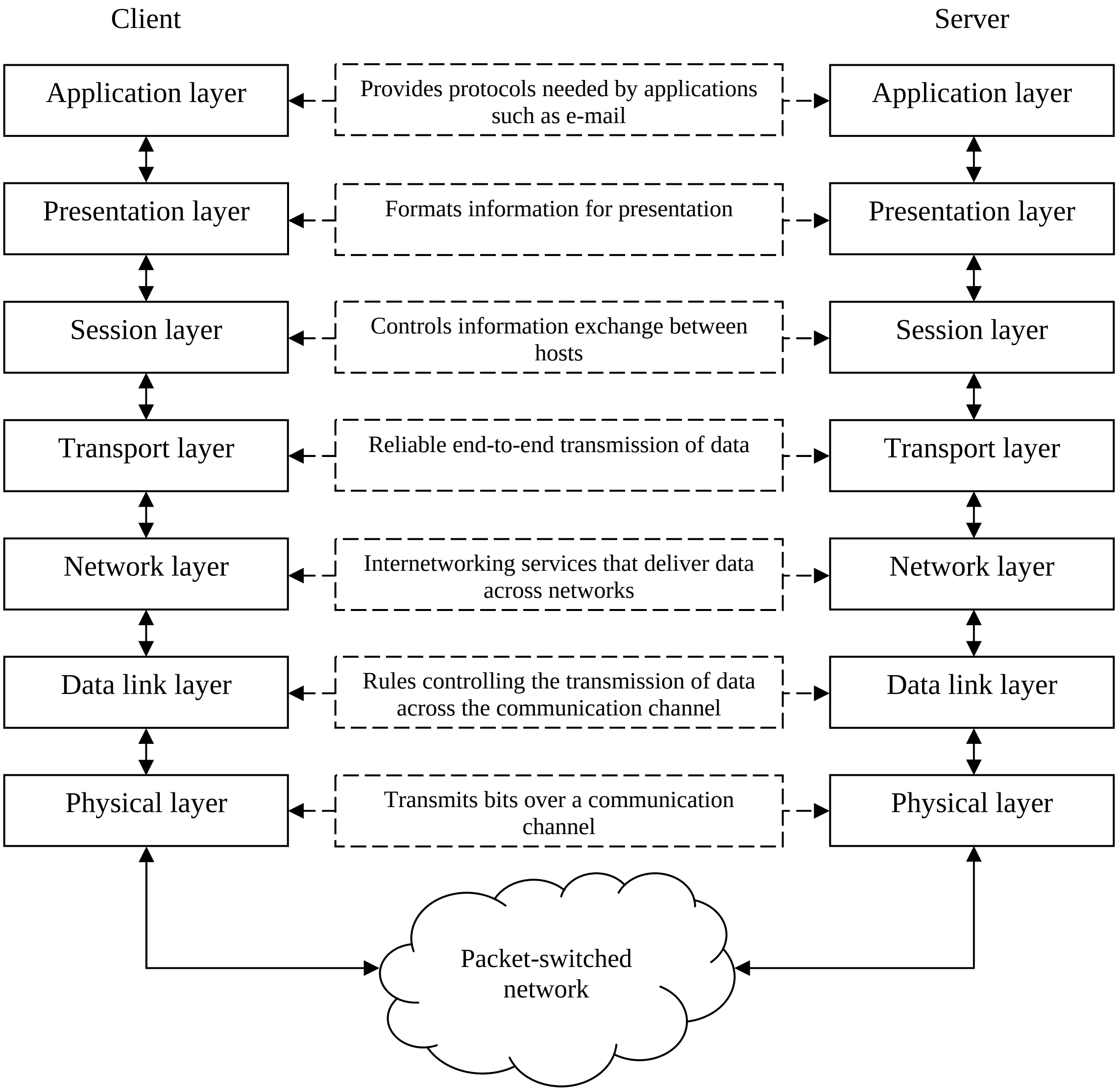

Figure D.1. The OSI seven-layer reference model.

D.2 X.25

X.25 defines the interface between a terminal, such as a PC, and a packet-switched network. In Figure D.2, X.25 defines how the client PC and server interface with the packet-switched network using modems.[2]

[2] R.J. Deasington, *X.25 Explained: Protocols for Packet Switching Networks*, 2nd ed. (Chichester: Ellis Horwood, 1990).

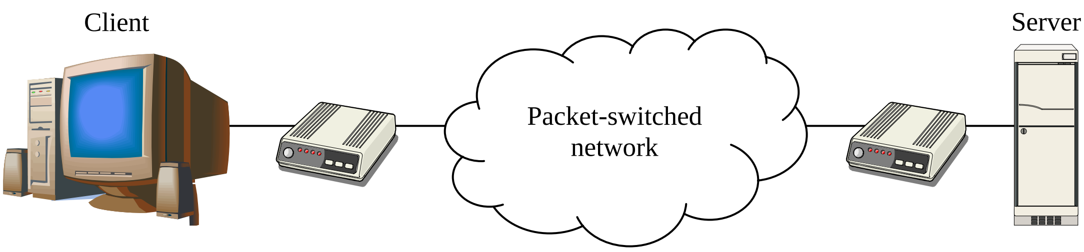

Figure D.2. X.25.

X.25 defines the physical, data link, and network layers of the OSI seven-layer reference model (see Figure D.3).

There were several revisions of the X.25 standard, including 1976, 1980, and 1984.[3]

D.3 The Coloured Book Protocols

For a network to be of use to people, it needs more than a standard, such as X.25, which only defines how computers connect to packet-switched networks. Networks need higher layer protocols to perform tasks including exchanging information between computers, handling presentation issues relating to information, and providing the services needed by applications such as e-mail.

The UK academic community attempted to solve this problem by developing a set of Coloured Book protocols (see Table D.1). Each book corresponded to a particular function. For example, the Blue Book defined how JANET transmitted files and the Grey Book used this protocol to send and receive e-mails (see Figure D.4). The Coloured Books were interim solutions which the community intended to replace when their OSI equivalents became available. For example, the OSI FTAM protocol would therefore replace the Blue Book in the architecture.[4]

[3] M.A. Sirbu and L.E. Zwimpfer, "Standards Setting for Computer Communication: The Case of X.25," *IEEE Communications Magazine*, vol. 23, no. 3, 1985, pp. 40-42.
[4] J. Larmouth and R.A. Rosner, "Networking Protocols in the UK Academic Community," in *Network Architectures*, C. Solomonides ed. (Maidenhead: Pergamon Infotech, 1982), pp. 9-21.

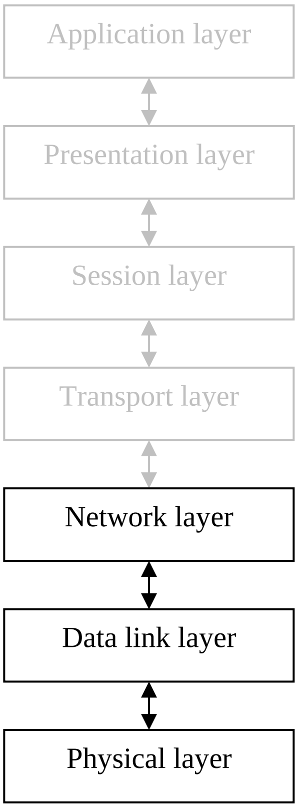

Figure D.3. X.25's position within the OSI seven-layer reference model.

Table D.1. The Coloured Book protocols.

Coloured Book	**Description**
Blue Book	File transfer protocol
Fawn Book	Use of interactive terminals
Green Book	Packet assembly and disassembly
Grey Book	Electronic mail
Orange Book	Cambridge Ring LANs
Pink Book	Ethernet LANs
Red Book	Job Transfer and Manipulation Protocol (JTMP)
White Book	Transition strategy to OSI
Yellow Book	Transport service

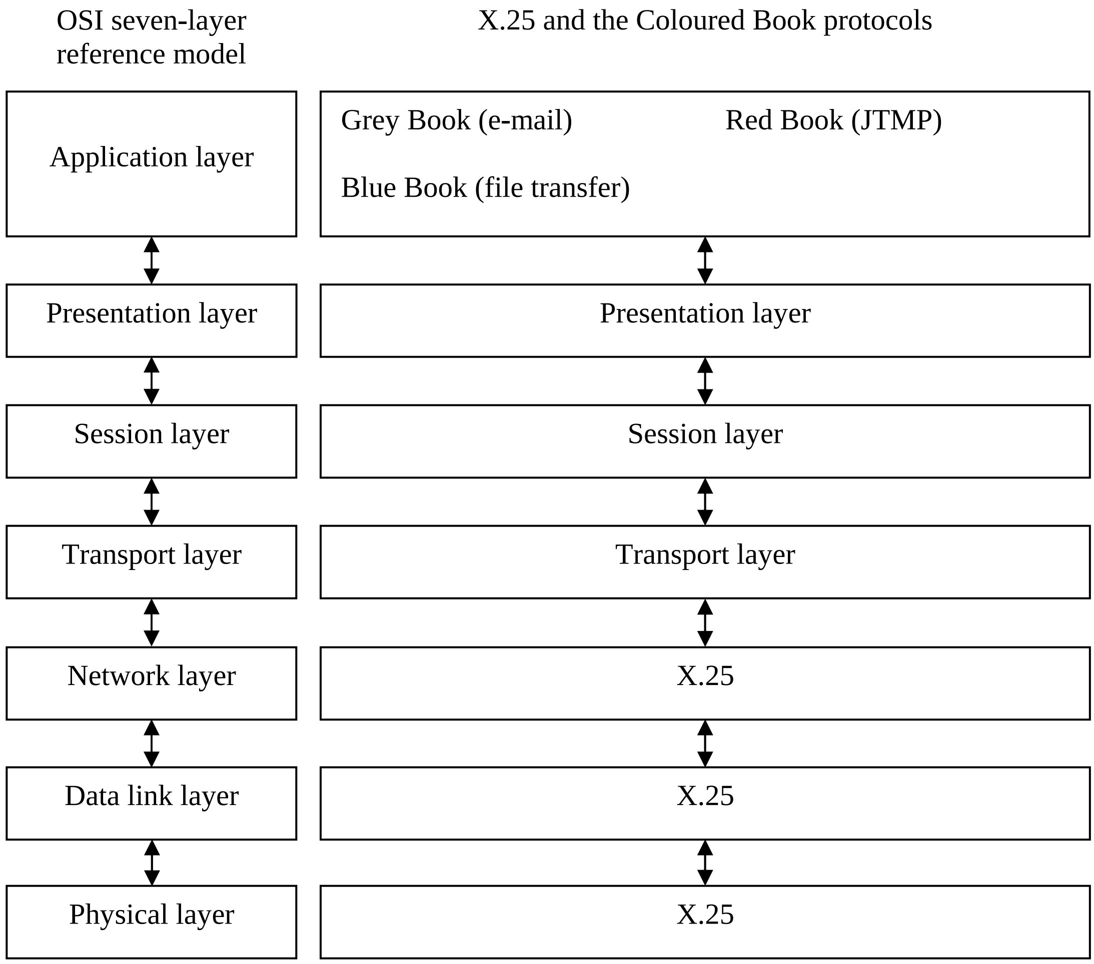

Figure D.4. The relationship between X.25 and the Coloured Book protocols.[5]

[5] For clarity, this figure omits some of the lower layer Coloured Books.

Appendix E. TCP/IP and the Internet Protocol Suite

E.1 TCP/IP

During the early to mid 1970s, the Defense Advanced Research Projects Agency (DARPA) operated three networks: the ARPANET, the Packet Radio Network (PRNET), and the Satellite Network (SATNET). SATNET linked two sites in the US with University College London (UCL) in the UK and the Norwegian Seismic Array (NORSAR) in Norway. The networks used incompatible protocols and this therefore created a problem for the DARPA's Information Processing Techniques Office (IPTO) which wanted to interconnect the networks. During 1973, an IPTO program manager, Robert Kahn, approached Vint Cerf, a computer scientist, with the problem of how to interconnect the incompatible packet-switched networks. Cerf had chaired the International Conference on Computer Communications (ICCC) during 1972 which had considered how to interconnect computer networks. Cerf and Kahn's work resulted in a solution to the interconnection problem called the Transmission Control Protocol (TCP).[1] During 1978, Cerf, Kahn, and Jonathan Postel split TCP into two separate protocols, TCP and the Internet Protocol (IP), to simplify the design of the gateways that would interconnect networks.[2] DARPA wanted the ARPANET's sites to adopt the new standard, and therefore funded Bolt, Beranek, and Newman (BBN) to incorporate the standard into the UNIX operating system. The University of California at Berkeley (UC Berkeley) later did the same with its Berkeley Software Distribution (BSD) of UNIX.[3] As TCP/IP came with UNIX, this helped to diffuse the protocol throughout the ARPANET and other networks that used UNIX on their computers. By 1983, DARPA stipulated that any site connected to the ARPANET must use TCP/IP. People subsequently referred to the Internet as any network that used TCP/IP.[4]

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[1] V.G. Cerf and R.E. Kahn, "A Protocol for Packet Network Intercommunication," *IEEE Transactions on Communications*, May 1974, pp. 637-648.

[2] During the 1970s and 1980s, Postel become actively involved with the Internet. As well as helping to separate TCP into TCP/IP, he defined the Simple Mail Transport Protocol. See J.B. Postel, *Simple Mail Transfer Protocol*, IETF, 1982, Available from: http://www.ietf.org/rfc/rfc0821.txt?number=821, Accessed on: 13 May 2004.

[3] J. Abbate, *Inventing the Internet* (Cambridge, MA: MIT Press, 1999), pp. 118-130 and 133.

[4] C.J.P. Moschovitis, et al., *History of the Internet: A Chronology, 1843 to the Present* (Oxford: ABC-Clio, 1999), pp. 109-110.

TCP/IP and the Open Systems Interconnection reference model are similar in several ways. In particular, both provide layered architectures for understanding network communication. OSI contains seven layers, while TCP/IP contains anything from three to five layers. A consensus regarding the number of layers does not therefore exist. For example, the protocol specification for TCP published in 1981 defined four layers, while the US DoD referred to three layers in 1985.[5] In addition, universal agreement about the names for each layer does not exist. Despite these ambiguities, many people agree that the TCP/IP architecture contains three main layers (see Figure E.1). Diagrams often include a fourth layer, the Network Access layer, for completeness. This layer corresponds to the physical and data link layers of the OSI reference model. However, TCP/IP does not specify the protocols for this layer. The reason for this is that Cerf et al designed TCP/IP so that it could run over any type of network, which means that people can use TCP/IP over networks such as Ethernet, ATM, and fibre-optic networks.

The transport layer of the TCP/IP reference model is responsible for the reliable end-to-end transmission of data. It therefore performs a similar function to the equivalent OSI transport layer. The transport layer contains two main protocols: the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP). TCP is a reliable connection-oriented protocol which means that it establishes a connection with the destination computer, transmits data, and then terminates the connection. In contrast, UDP is an unreliable connectionless protocol which means that it just transmits packets, each of which contains the address of the destination computer. UDP therefore lacks the facilities of TCP, such as ensuring that the source computer transmits packets in the correct order, that error checking finds and corrects errors, and that flow control prevents the receiver from overloading which can happen when the transmitter sends packets too quickly. Applications, such as file transfer, use TCP, as they need to ensure that a computer delivers every packet reliably. Other applications, such the Domain Name System (DNS), use UDP because they do not need the services provided by TCP and this therefore improves performance.[6]

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[5] See J. Postel, *Transmission Control Protocol: DARPA Internet Program Protocol Specification*, IETF, 1981, Available from: http://www.ietf.org/rfc/rfc0793.txt?number=793, Accessed on: 3 August 2004 and *DDN Protocol Handbook Volume One: DoD Military Standard Protocols* (Menlo Park, California: DDN Network Information Center, 1985), pp. 1/21-1/22 and 1/81.

[6] A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 42-43.

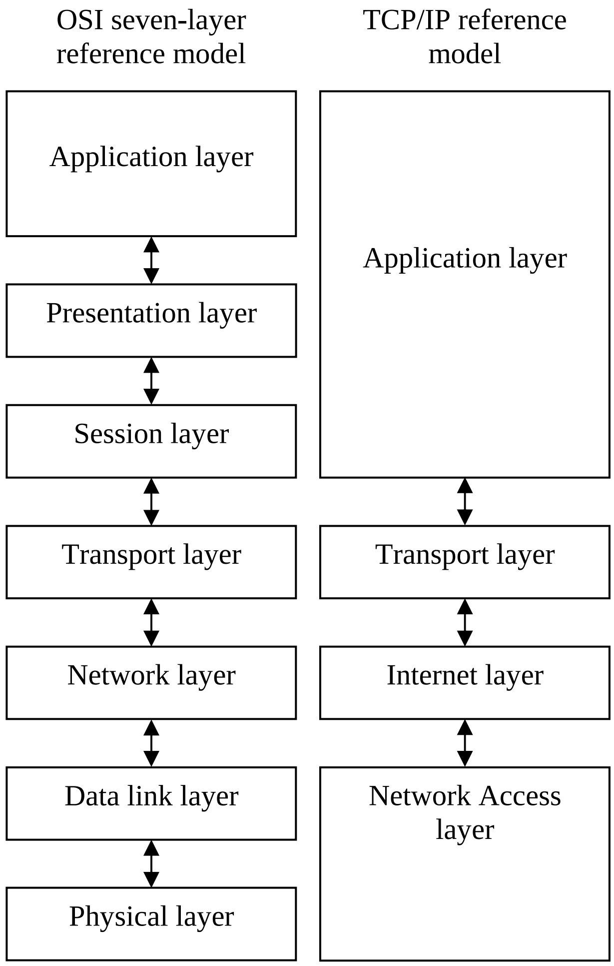

Figure E.1. The TCP/IP reference model.

Both TCP and UDP use the services of the Internet layer to deliver packets. The Internet layer is responsible for the internetworking services that deliver data across networks. It therefore performs a similar function to the equivalent OSI Network layer. The Internet layer contains several protocols, the most important of which is the Internet Protocol (IP). The Internet Protocol is responsible for routing data from a source computer to the correction destination, a process that often involves transmitting packets across several networks. IP uses unique addresses called IP addresses which relate to networks and the hosts on that network. An IP address is composed of four fields, separated by three periods, for example 204.200.223.156.[7]

TCP/IP works by encapsulating the data generated by the different layers of the TCP/IP reference model. Each layer encapsulates the data from the layer above it, adds header information, and then passes the data to the layer beneath it in the

[7] T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 669-676.

protocol stack. Headers contain a variety of data including address and error checking information. Once TCP/IP has encapsulated the data, routers transmit the packets to the destination computer via a packet-switched network such as the Internet. The layers on the destination computer then reassemble the packets by removing the header information and passing the data to the layers above.

In the example shown in Figure E.2, an application wants to transmit information, such as an e-mail, across the Internet to another computer. The application creates a message containing the stream of data that TCP/IP and the Internet will transmit, and then passes this data to TCP within the transport layer of the TCP/IP reference model. TCP then encapsulates the data and adds a TCP header to form a TCP segment. It then passes this segment to IP within the Internet layer which then encapsulates the TCP segment and adds an IP header to form an IP datagram.[8] As different network technologies, such as Ethernet and FDDI, have different Maximum Transmission Units (MTUs) for their frame sizes, this often necessitates fragmenting the IP datagram into individual datagram fragments. Once this process is complete, IP passes the IP packets to the Network Access layer. The Network Access layer then inserts the datagram fragments into frames and adds frame headers. The source computer then transmits the frames to the Internet and routers transmit the frames to their destination using the address information contained within the frames.

The above overview of TCP/IP describes how this protocol works over fixed connections, such as leased lines, which telecommunications companies and other firms use to help construct computer networks. Companies interconnect computers to these networks, which are often LANs, using Network Interface Cards (NICs) contained within computers. However, to establish a connection to the Internet from a PC to an Internet Service Provider (ISP), a user and the ISP need another protocol. The reason for this is that Cerf et al designed TCP/IP so that it could run over any network. They therefore did not specify the protocols that people could use in the Network Access layer. To solve this problem, several computer scientists developed the Serial Line Internet Protocol (SLIP) during the early 1980s.[9]

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[8] Computer scientists often use the words packet and datagram interchangeably.
[9] J. Romkey, *A Nonstandard for Transmission of IP Datagrams over Serial Lines: SLIP*, IETF, 1988, Available from: http://www.ietf.org/rfc/rfc1055.txt?number=1055, Accessed on: 05 June 2005.

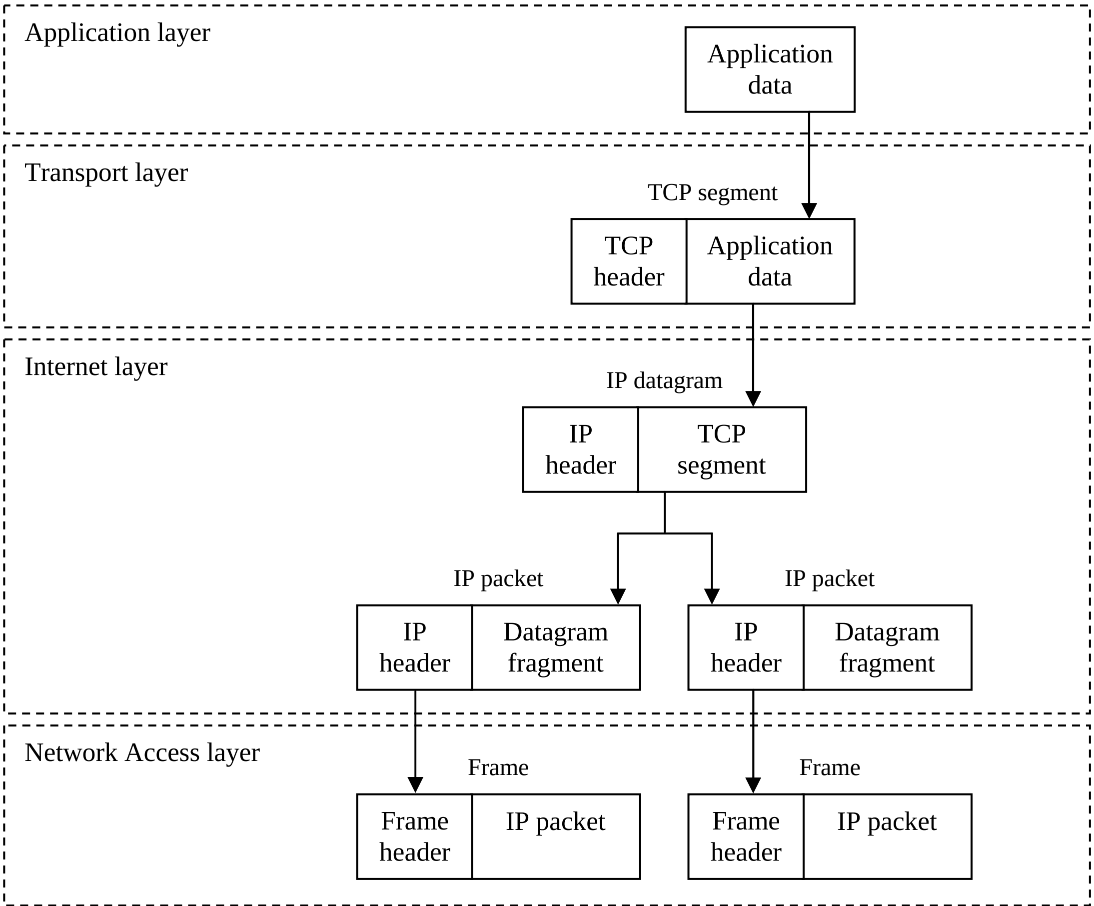

Figure E.2. TCP/IP encapsulation.

SLIP encapsulated IP datagrams into data link layer frames which a user's computer then transmitted over the serial PSTN.[10] A successor to SLIP, the Point-to-Point Protocol (PPP), emerged during 1993. PPP added several new features, including the ability to transmit other types of protocol such as DECnet packets.

When an increasing number of people became interested in the Internet during the early 1990s, the most widely diffused operating system on personal computers was MS-DOS. However, this did not have built-in support for the TCP/IP protocol stack and neither did MS-DOS's successor, Microsoft Windows. To rectify this situation, companies developed and sold TCP/IP compatible programs for MS-DOS and

[10] Although people mainly used SLIP, and its successor PPP, to establish temporary dial-up connections over the analogue PSTN using modems, people could use both protocols to set up permanent links between computers. See K. Dowd, *Getting Connected: The Internet at 56K and Up* (Sebastopol, CA: O'Reilly & Associates, 1996), pp. 83-92. During the early 1990s, OSI advocates intended to develop a standard, the Asynchronous Protocol Specification (APS), which would enable people to use their PCs to establish connections over the PSTN in order to send and receive e-mails using X.400. People would therefore not need X.25 or leased lines to use X.400, potentially opening up access to X.400 systems to users without these links. See M. Moeller, "X.400 Over Dial-Up," *Communications International*, February 1993, pp. 14 and 16.

Windows. For example, Demon Internet provided the KA9Q, PCElm, and SNews programs which all used TCP/IP to send and receive data over the PSTN to the ISP.[11] In addition, IBM launched software for MS-DOS which enabled people to use command line utilities, such as FTP, to connect to remote hosts over TCP/IP connections.[12] In addition, Microsoft, in association with networking companies, developed the Windows Sockets (WinSock) standard which enabled companies to port utilities for the UNIX operating system, such as ping and traceroute, to Windows. Before the introduction of Microsoft Windows 95 in 1995, operating systems such as Microsoft Windows did not contain the TCP/IP protocol stack. During 1995, Microsoft therefore provided this software, known as Microsoft TCP/IP for Windows for Workgroups 3.11, on floppy disk at a cost of £10. Other companies, including Leaf Distribution, launched products that people could buy in order to install the TCP/IP protocol stack on Windows, and therefore access the Internet. Leaf sold a product called Chameleon NFS 4.0 which in addition to providing the protocol stack for Windows, also supplied GUI utilities for applications such as FTP. With the launch of Microsoft Windows 95 in 1995, Microsoft included the TCP/IP protocol stack with the operating system. Every subsequent version of Windows also had this built-in, together with several UNIX utilities such as telnet, ping, and traceroute.

E.2 The Internet Protocol Suite

TCP/IP is part of a larger set of protocols known as the Internet Protocol suite, commonly known as just TCP/IP (see Figure E.3). This suite contains a variety of protocols that operate at different layers of the TCP/IP reference model. While some protocols are located in layers such as the transport layer, most protocols are located in the application layer. People use programs that interface with these protocols to perform several tasks. For example, people use applications to send and receive e-mails, browse the Web, read newsgroups, connect to remote hosts, and manage networks.

[11] W.M. Grossman, "Into the Internet," *Personal Computer World*, April 1993, pp. 388-390, 392, and 394.

[12] R. Goodwins, et al., "TCP/IP: Your Road to Internet Wizardry," *PC Magazine*, pp. 224-229, 232-236, and 238-244.

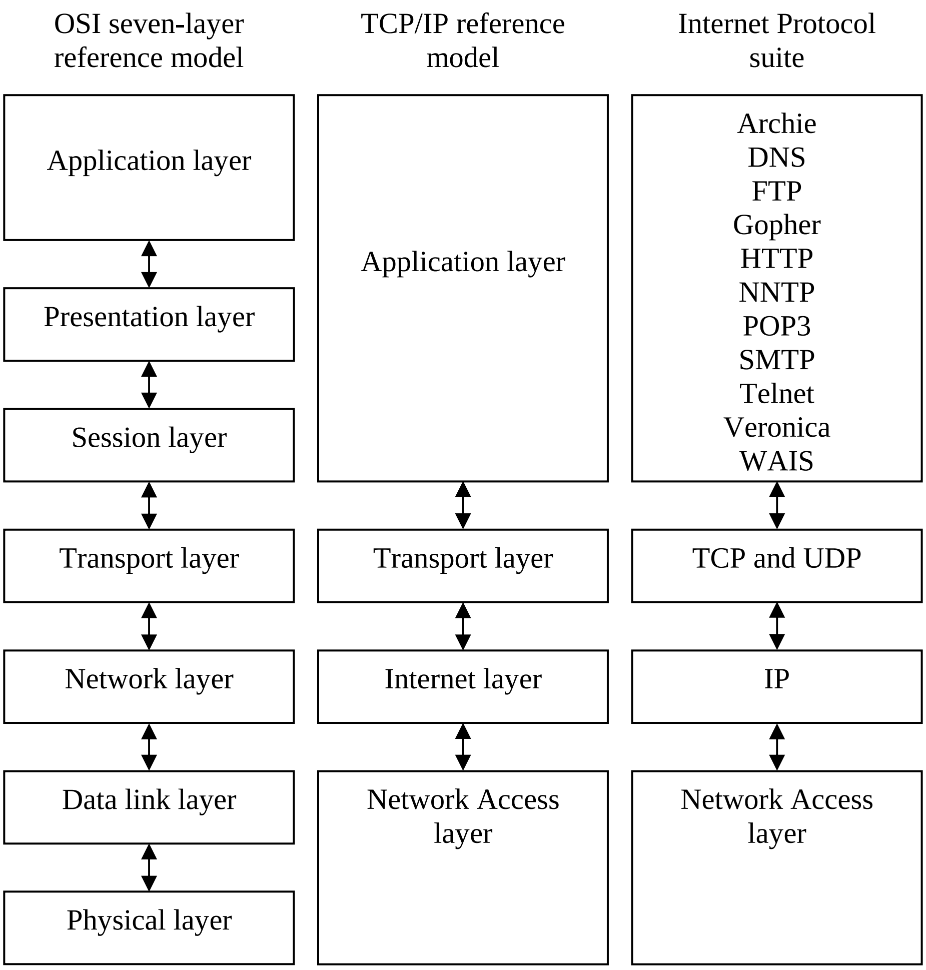

Figure E.3. The Internet Protocol suite.[13]

After the ARPANET became operational in 1969, work began on the first application protocol: the Telecommunications network protocol (Telnet). Other protocols, such as the File Transfer Protocol (FTP) and the original electronic mail protocol soon followed telnet. Throughout the 1970s and into the 1980s, people developed several protocols for the ARPANET, and this trend continued on the Internet during the 1980s, the 1990s, and into the 21st century. See Table E.1 for a subset of the Internet Protocol suite.

[13] For clarity, this figure contains a subset of the complete Internet Protocol suite.

Table E.1. A subset of the Internet Protocol suite.[14]

Protocol	Description
Archie	A tool for searching anonymous FTP archives.
ARP	The Address Resolution Protocol maps an Internet Protocol address on to the address stored within a Network Interface Card used by networks such as LANs.
DHCP	The Dynamic Host Configuration Protocol dynamically assigns Internet Protocol addresses to client computers when they logon to a network.
DNS	The Domain Name System is a hierarchical system which translates Internet names into IP addresses.
Finger	Finger is a tool that determines if a person has an account on a local or remote host, and then retrieves information about that person such as their full name.
FTP	The File Transfer Protocol transmits files between computers. A person uses an FTP client program to download a file to their computer from a remote host. FTP programs originally required the user to type commands to retrieve files, but Graphical User Interface (GUI) clients later complemented these command-based programs.
Gopher	A client-server system that enabled people to navigate through a hierarchy of menus to find the information that they wanted.
HTML	Web developers use the Hypertext Markup Language to create Web pages.
HTTP	The Hypertext Transfer Protocol transmits Web pages between servers and clients on the Internet.
Hytelnet	Hytelnet improved the usability of telnet's user interface, by using menus instead of commands.
ICMP	If a problem occurs on a network, the Internet Control Message Protocol reports the error to the source computer and provides diagnostic services.
IGMP	The Internet Group Message Protocol controls communication between groups of host computers which want to participate in a multicast. Multicasting transmits data, such as audio or video, to a list of network users.
IMAP	The Internet Message Access Protocol is a standard used to store and retrieve e-mails on a server.
IP	The Internet Protocol routes data from a source computer to its destination.
IPP	The Internet Printing Protocol is a standard for controlling the use of printers over the Internet.
IRC	The Internet Relay Chat system enables people to communicate in real time with other people.
Jughead	The Jonzy's Universal Gopher Hierarchy Excavation And Display system enabled people to search a single Gopher server for information.
Knowbot	Knowledge robots are tools used to search for information across several sources. An example is using Knowbot to search for information about a

[14] See P. Gilster, *Finding It on the Internet: The Essential Guide to Archie, Veronica, Gopher, WAIS, WWW (Including Mosaic), and Other Search and Browsing Tools* (New York: Wiley, 1994) and Sheldon, *McGraw-Hill Encyclopedia*, pp. 654-658.

	person, where Knowbot interacts with tools, such as WHOIS and finger, to complete its task.
LDAP	The Lightweight Directory Access Protocol is a client-server directory service that people can use to locate information relating to many entities such as computers, printers, and people. LDAP was originally a client for X.500.
LISTSERV	LISTSERV is a program for maintaining mailing lists. Using e-mail, people can subscribe and unsubscribe from lists which cover many subjects.
MIME	The Multipurpose Internet Mail Extensions enable people to attach files to e-mails which networks, such as the Internet, then deliver to their destination using SMTP.
NFS	The Network File System is a distributed file system which enables servers to share files on the Internet and other networks. NFS allows people to access and update the contents of files on a server using a client program.
NNTP	The Network News Transfer Protocol transmits Usenet newsgroups.
OSPF	The Open Shortest Path First protocol enables a router to develop a localised topology of a network, based on the connections that exist between the router, other routers, servers, and clients.
Ping	The Packet Internet Gopher checks if a host is online and if so returns information such as the time it took the network (s) to transmit and receive the packets involved in the ping enquiry.
POP	The Post Office Protocol is a standard used to store and retrieve e-mails on a server.
PPP	The Point-to-Point Protocol enables computers to transmit packets across serial connections and telephone networks. PPP has superseded SLIP.
RIP	The Routing Information Protocol enables routers to transmit and receive information relating to routes within a network such as the Internet.
SLIP	The Serial Line Internet Protocol enables computers to transmit packets across serial connections and telephone networks. PPP has superseded SLIP.
SMTP	The Simple Mail Transfer Protocol forwards e-mails between servers.
SNMP	The Simple Network Management Protocol enables a network manager to manage a network by gathering information from devices such as routers.
SSL	The Secure Sockets Layer enables clients and servers on the Internet to communicate securely, using encryption and authentication. When a browser and a Web server establish a secure connection using SSL or another secure connection technology, they use Secure HTTP (HTTPS).
TCP	The Transmission Control Protocol is responsible for the reliable end-to-end transmission of data.
Telnet	The Telecommunications network protocol enables users to control remote host computers. For example, it enables people to run programs on a host.
TFTP	The Trivial File Transfer Protocol is a functionally reduced version of FTP.

Traceroute	Traceroute enables a person to determine the route taken by packets between a source computer and a destination.
UDP	The User Datagram Protocol is a functionally reduced version of TCP.
Veronica	The Very Easy Rodent-Oriented Net-wide Index to Computerised Archives enabled people to search Gopher servers for information.
WAIS	The Wide Area Information Server was a search engine which enabled people to search databases for information.
WHOIS	WHOIS is a service which enables users to locate information about people and companies from directories.
XHTML	eXtensible Hypertext Markup Language is the successor to HTML.
XML	The eXtensible Markup Language is a more sophisticated version of HTML.

Appendix F. SMDS, ATM, PDH, and Fibre-optic Networks

F.1 Switched Multimegabit Data Service

Switched Multimegabit Data Service (SMDS) is a service that enables companies to extend their Local Area Networks across larger geographical areas. MANs and WANs therefore use SMDS as a low-level service. Bellcore developed SMDS and based it on the IEEE 802.6 Distributed Queue Dual Bus (DQDB) MAN technology. SMDS uses DQDB as the basis for communication between a customer's computers and network interconnection devices and the telecommunication company's equipment. SMDS operates at two speeds, 1.544 Mbps and 44.736 Mbps, which correspond to the speeds of T1 and T3 leased lines respectively.[1] SMDS can run over copper and fibre-optic cables. SMDS is located in the Network Access layer of the TCP/IP reference model, as shown in Figure F.1.[2] Companies can use SMDS to route several protocols, such as TCP/IP, across an SMDS network (see Figure F.2).

F.2 Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) is a technology that enables companies to build high-speed networks that can transmit a variety of information including data, voice, and video. ATM operates at several data transfer rates including 25 Mbps, 45 Mbps, and 155 Mbps, depending of a variety of factors including the underlying network technology used by a network. ATM can operate over different technologies including FDDI, PDH, and SDH. Telecommunications operators developed ATM during the mid 1980s and founded the ATM Forum in 1991 to ratify ATM standards.[3] ATM is a connection-oriented technology which means that it establishes a dedicated path, known as a virtual circuit, between the source and destination computers, transmits data, and then terminates the virtual circuit. As companies can use ATM in LANs, MANs, and WANs, telephone companies marketed ATM as a network technology that could establish end-to-end connections throughout a company.

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[1] In the UK, the top speed is 34 Mbps, not 45 Mbps as in the US.
[2] *Switched Multimegabit Data Service*, Cisco Systems, Inc., 2002, Available from: http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/smds.htm, Accessed on: 10 August 2004.
[3] See G. Held, *Understanding Data Communications*, 7th ed. (Indianapolis, IN: Addison-Wesley, 2002), p. 588 and *History*, ATM Forum, 2002, Available from: http://www.atmforum.com/aboutatm/history.html, Accessed on: 6 September 2004.

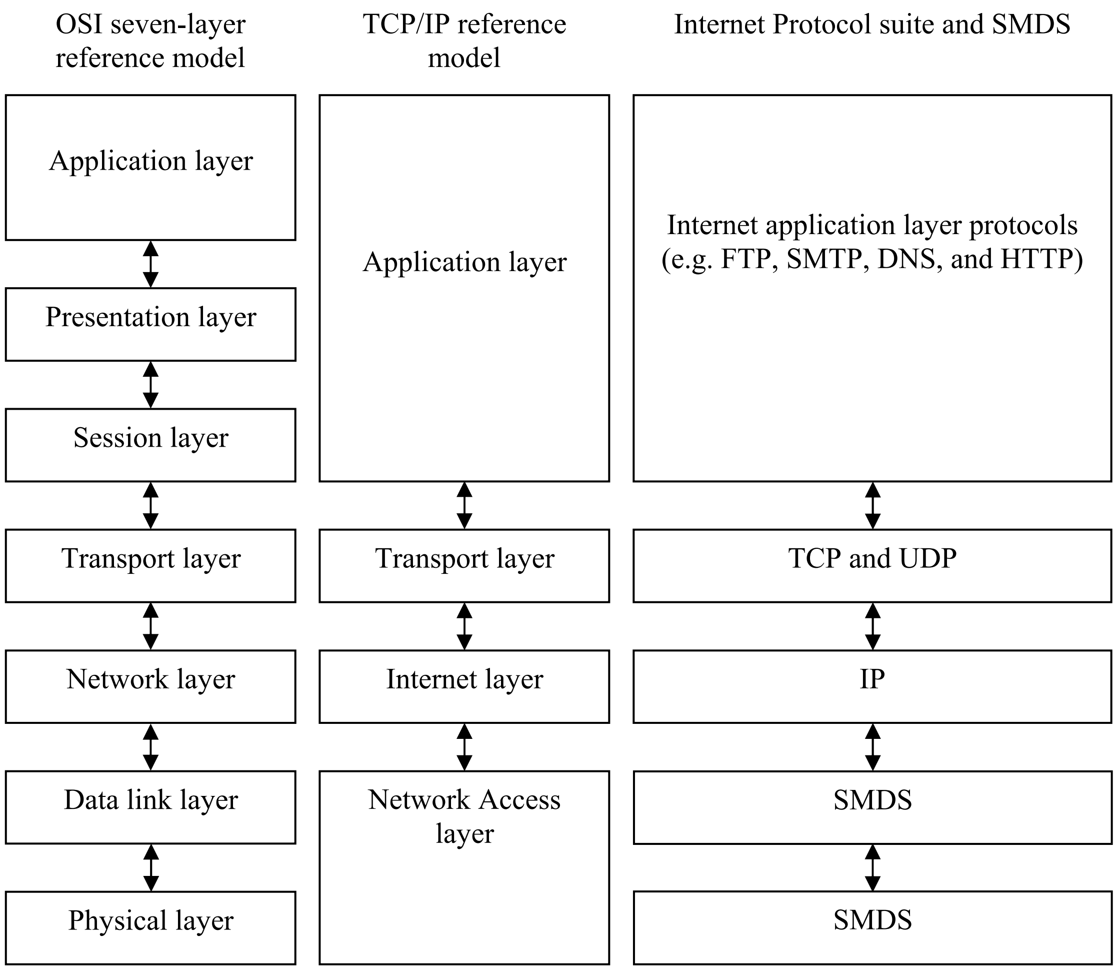

Figure F.1. The Internet Protocol suite and Switched Multimegabit Data Service.

As ATM can also transmit voice as well as data, companies can use the technology to combine their telephone and data networks. During the early to mid 1990s, many companies believed that ATM would fulfil its potential. However, new technologies, such as Gigabit Ethernet, 10-Gigabit Ethernet, and Dense Wave-Division Multiplexing (DWDM), have affected ATM's diffusion.[4]

ATM is located in the Network Access layer of the TCP/IP reference model. The ATM reference model splits the functionality of the technology into three layers: the Physical layer, the ATM layer, and the ATM Adaptation layer (AAL) (see Figure F.3). These layers work together to create and transmit fixed-length cells that contain data from the higher layers of a compatible protocol such as TCP/IP.[5]

[4] T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 65-66.
[5] A cell is similar to a frame. However, the term frame is usually only used to describe the unit of data that an underlying network technology, such as SDH, transmits to its destination.

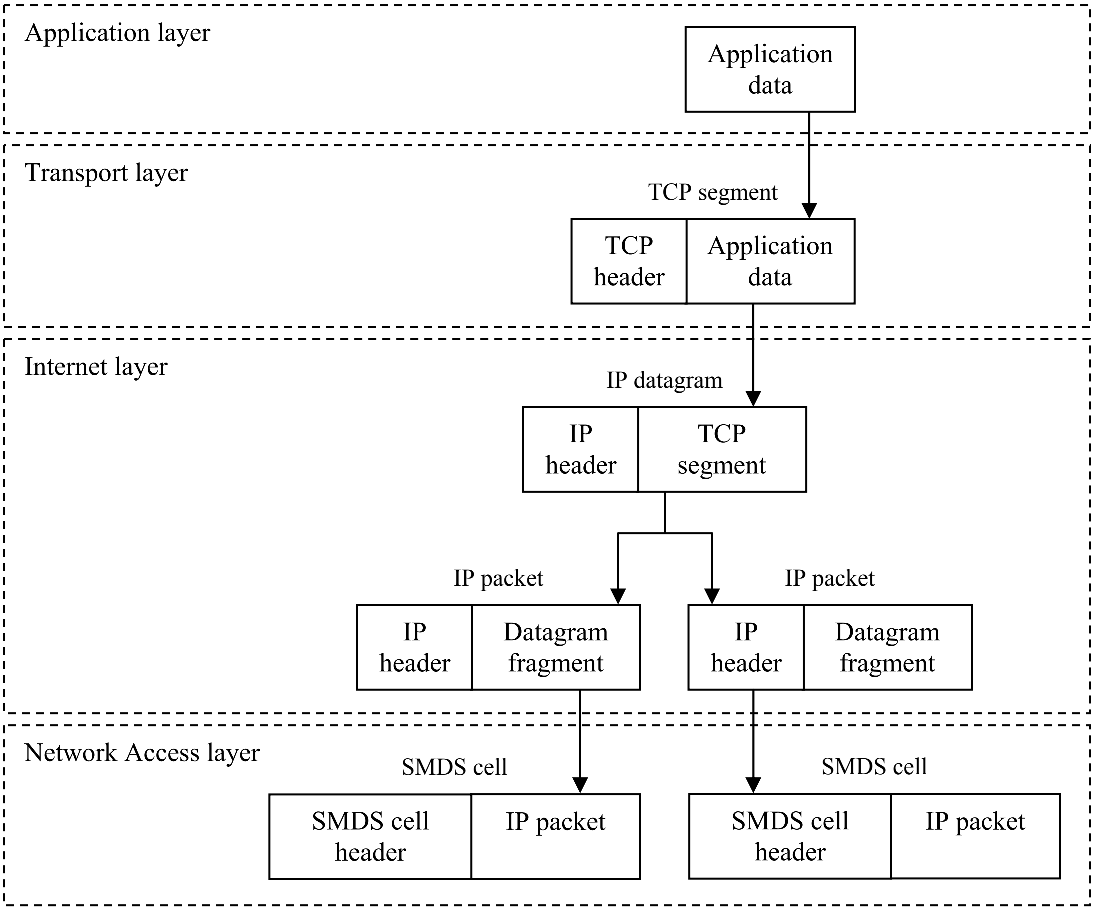

Figure F.2. Encapsulation of IP packets within SMDS cells.

However, as ATM is a connection-oriented technology this means that it is not compatible with connectionless systems. Connectionless networks just transmit packets, each of which contains the address of the destination computer. Two examples of connectionless network technologies include Ethernet and TCP/IP. To solve these problems, several solutions emerged. The LAN Emulation (LANE) standard enabled ATM to operate as a backbone that interconnected Ethernet networks. The ATM Adaptation layer was involved in this process. This layer also enabled ATM to encapsulate TCP/IP packets and then transmit them across an ATM network (see Figure F.4). However, this solution was not as effective as two connectionless network technologies working together.

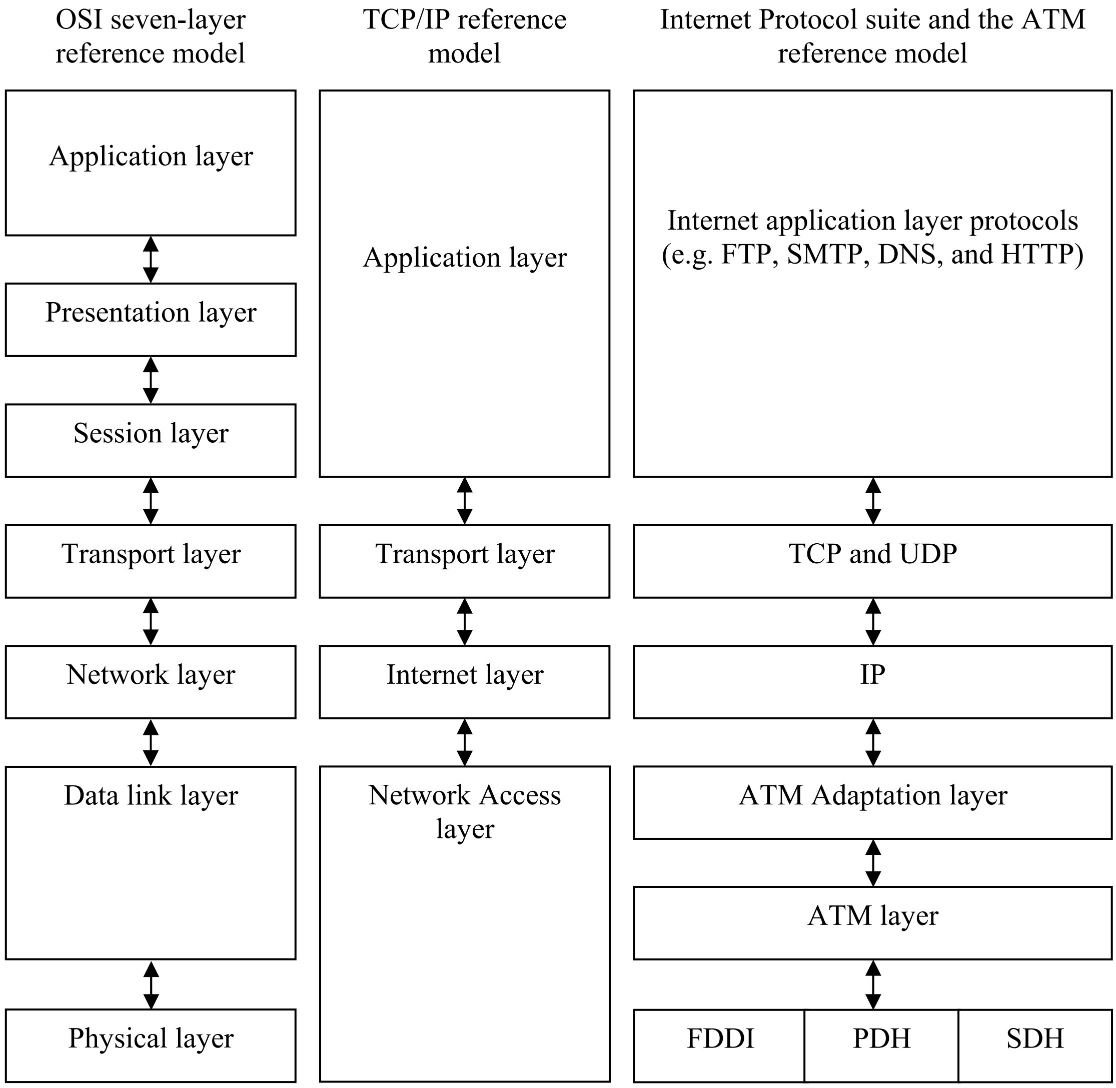

Figure F.3. Internet Protocol suite and the ATM reference model.

This symbiosis helped both TCP/IP's and Ethernet's mutual diffusion, but it did not help the adoption of ATM.[6]

[6] *Asynchronous Transfer Mode Switching*, Cisco Systems, Inc., 2002, Available from: http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/atm.htm, Accessed on: 10 August 2004.

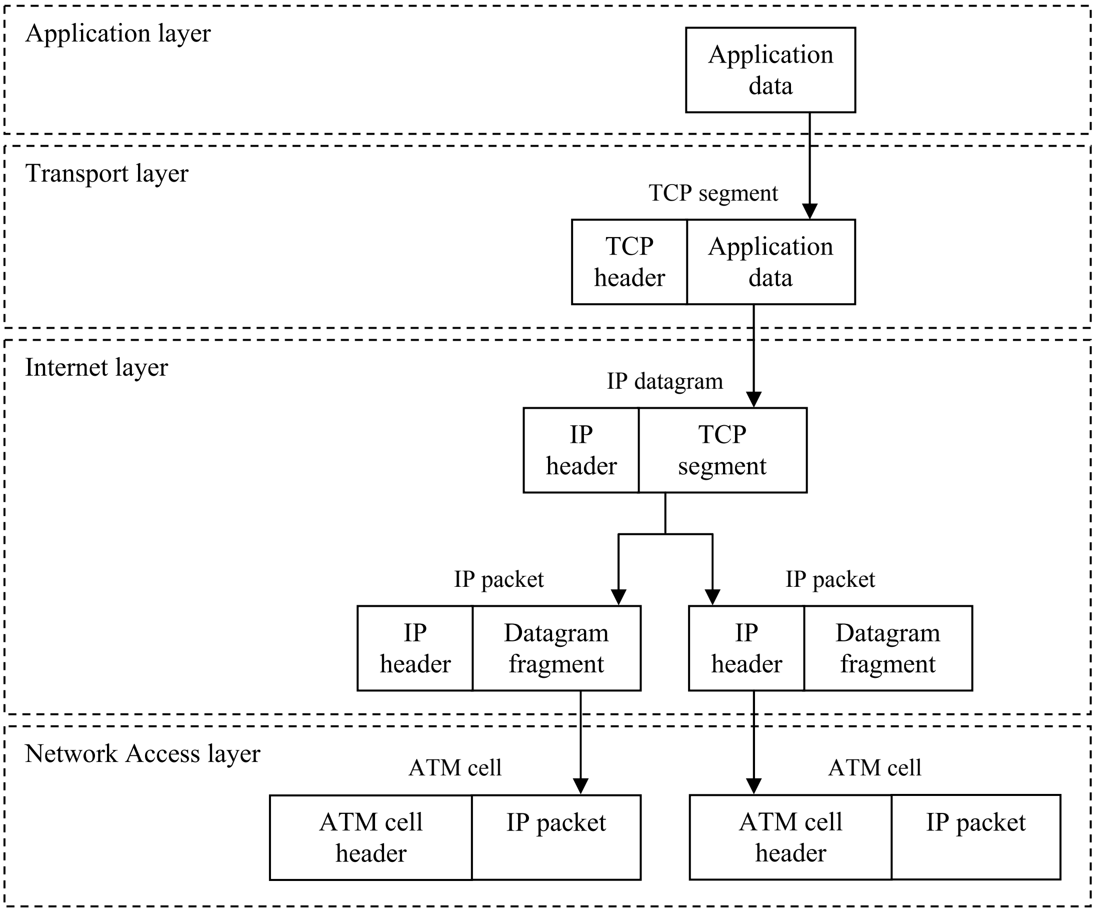

Figure F.4. Encapsulation of IP packets within ATM cells.

F.3 Plesiochronous Digital Hierarchy

Plesiochronous Digital Hierarchy (PDH) is a system that telecommunication operators use to combine several channels of data into one or more higher-level channels. Known as the North American Digital Hierarchy (NADH) in the US, AT&T invented the technology during the 1960s as a replacement for earlier communication facilities. PDH uses digital leased lines to transmit data. These leased lines are part of a digital hierarchy which are composed of the T Carrier services in the US and the E Carrier services in Europe. Both services provide a hierarchy of leased lines at a variety of data transfer rates (see Table F.1).

Table F.1. T and E Carriers.[7]

T Carrier	Data transfer rate	E Carrier	Data transfer rate
DS0	64 Kbps	E0	64 Kbps
T1 (DS1)	1.544 Mbps	E1	2.048 Mbps
T1C (DS1C)	3.152 Mbps	E2	8.448 Mbps
T2 (DS2)	6.312 Mbps	E3	34.368 Mbps
T3 (DS3)	44.736 Mbps	E4	139.268 Mbps
T4 (DS4)	274.176 Mbps	E5	565.148 Mbps
T5 (DS5)	400.352 Mbps		

The telecommunication companies originally designed both the T and E Carriers to transmit digitised voice. However, as the carriers transmit digital information they can also transmit data. Leased lines transmit varying amounts of voice calls and data, depending on the category of line. For example, a DS0 circuit can transmit one phone call or data at a data transfer rate of 64 Kbps, while a T3 circuit can transmit 672 voice calls or data at 44.736 Mbps. If a telecommunication company did not combine the separate phone calls and then transmit them through a single T3 circuit, this would mean that it would need 672 separate copper wires, one for each voice call.

PDH combines several channels into one or more higher-level channels using a technology known as Time Division Multiplexing (TDM). TDM divides the circuit of a leased line into several channels based on time. TDM uses an interleaving technique which means it allocates the bandwidth of the circuit to each of the separate channels for a fraction of time. In the example shown in Figure F.5, four LANs share a T1 leased line using two multiplexers. Multiplexers combine several channels into one channel, and in the example, they use Time Division Multiplexing to achieve this objective.

The leased lines that companies use in, say, PDH networks are either private or public. The above example illustrates a simple point-to-point link between the multiplexers using a T1 leased line. Companies hire such circuits to connect, say, two offices together. They also hire leased lines to connect their office LANs to a WAN provided by a telecommunication operator.

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[7] DS stands for Digital Signal-X (DSx) and refers to the hierarchy of digital data transmission rates that the T and E Carriers use. Both the T and E Carriers transmit digital signals, which operate at different data transfer rates, which the DSx hierarchy defines. See Sheldon, *McGraw-Hill Encyclopedia*, pp. 282-283, 409, 413-414, 828-834, 843-844, 1209-1211, and 1221-1224.

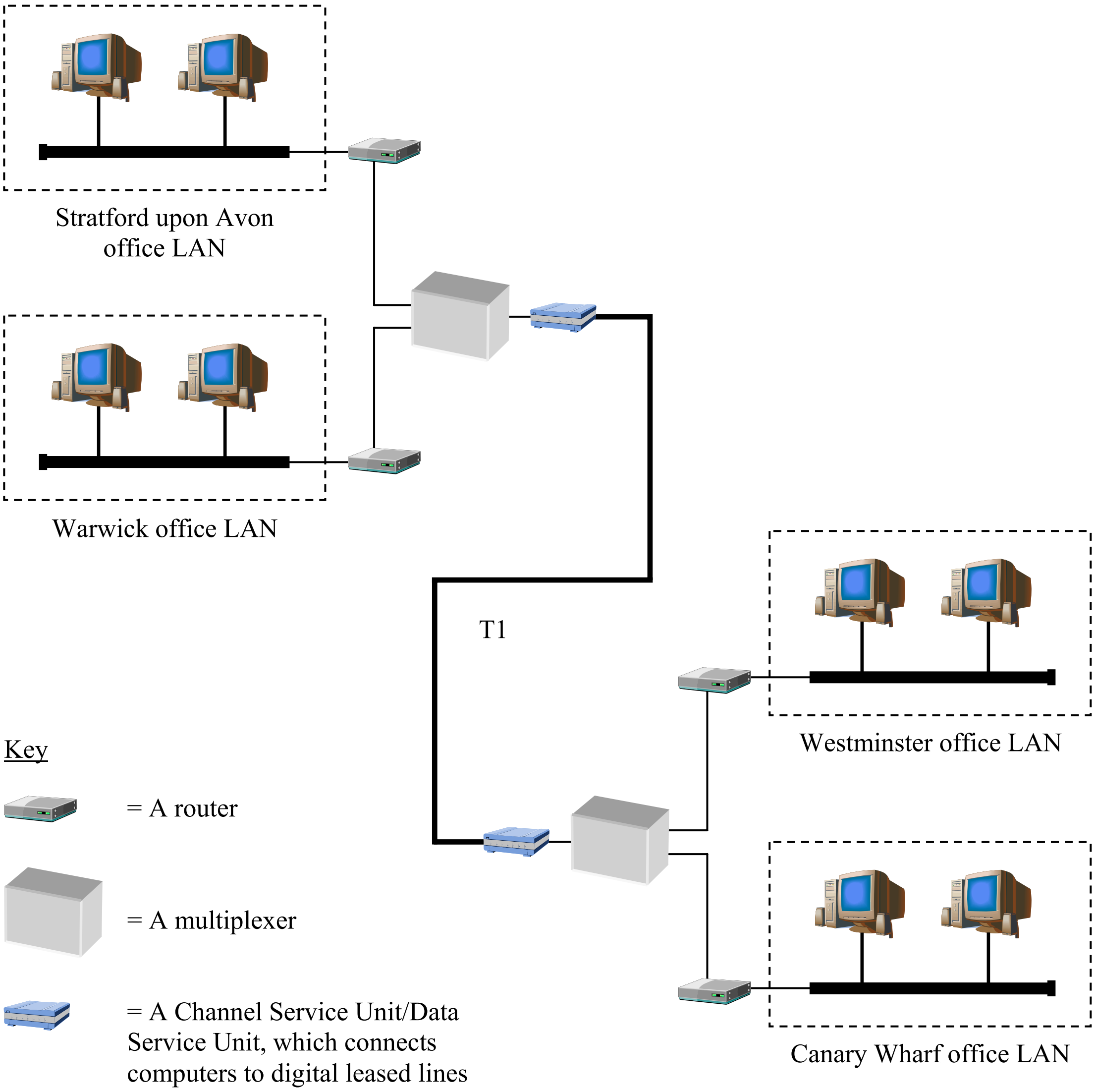

Figure F.5. Four LANs sharing a T1 leased line using two multiplexers.

A company's leased lines are private because no one else shares the circuits. Telecommunication companies charge firms based on the distance that the leased line covers and the bandwidth of the line. Leased lines are permanent circuits with a fixed bandwidth. Service Level Agreements (SLAs) cover topics such as the supported data transfer rates of a line and remedies for circuit problems. A company's leased lines can employ a variety of network topologies including point-to-point and multipoint links. Telecommunication companies also use leased lines to provide networks such as WANs. These networks are public which means that the company uses the leased lines to transmit traffic from many companies. Telecommunication operators use leased lines to develop WANs, using a variety of topologies including star, ring, and meshes.

PDH can transport many different types of protocols. In the example shown in Figure F.6, PDH supports the higher-layer protocols ATM and TCP/IP, which means that PDH frames can encapsulate ATM cells which in turn can encapsulate TCP/IP packets (see Figure F.7).

F.4 Fibre-optic Networks

The invention of fibre-optic cables occurred during the 1970s. By the early 1980s, the first fibre-optic systems emerged. Several telecommunication operators used proprietary systems that were incompatible, and for the systems to interconnect standardisation was needed. During 1985, Bellcore started to develop a standard for fibre-optic networks called Synchronous Optical Network (SONET). When the CCITT became involved in the development of SONET, this resulted in a compatible standard known as Synchronous Digital Hierarchy (SDH). While there are differences between the two standards, they are essentially the same. SONET became a subset of SDH, and telecommunication companies throughout the world adopted them for their fibre-optic networks.[8]

Fibre-optic networks function in the infrared range of the electromagnetic spectrum. Light-Emitting Diodes (LEDs) or lasers generate signals that then propagate through a fibre-optic cable by internal reflection. Signals travel through glass, plastic, or silica fibres which are approximately the width of a human hair or smaller.[9] Several layers of material surround a strand of fibre, each of which performs a different function (see Figure F.8). For example, the cladding that encloses the fibre reflects the infrared waves, therefore keeping the signals within the fibre and helping them to travel the length of the cable. The original fibre-optic cables contained one strand of fibre which could transmit only one signal at a time. By combining several fibres into one cable this increased the amount of infrared waves that fibre-optic networks could transmit, which therefore increased the number of signals per cable meaning that the cables could transmit more information. For example, an early AT&T fibre-optic system transmitted 80,000 simultaneous phone calls using 144 fibres.

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[8] A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), p. 144.
[9] Ibid., p. 96.

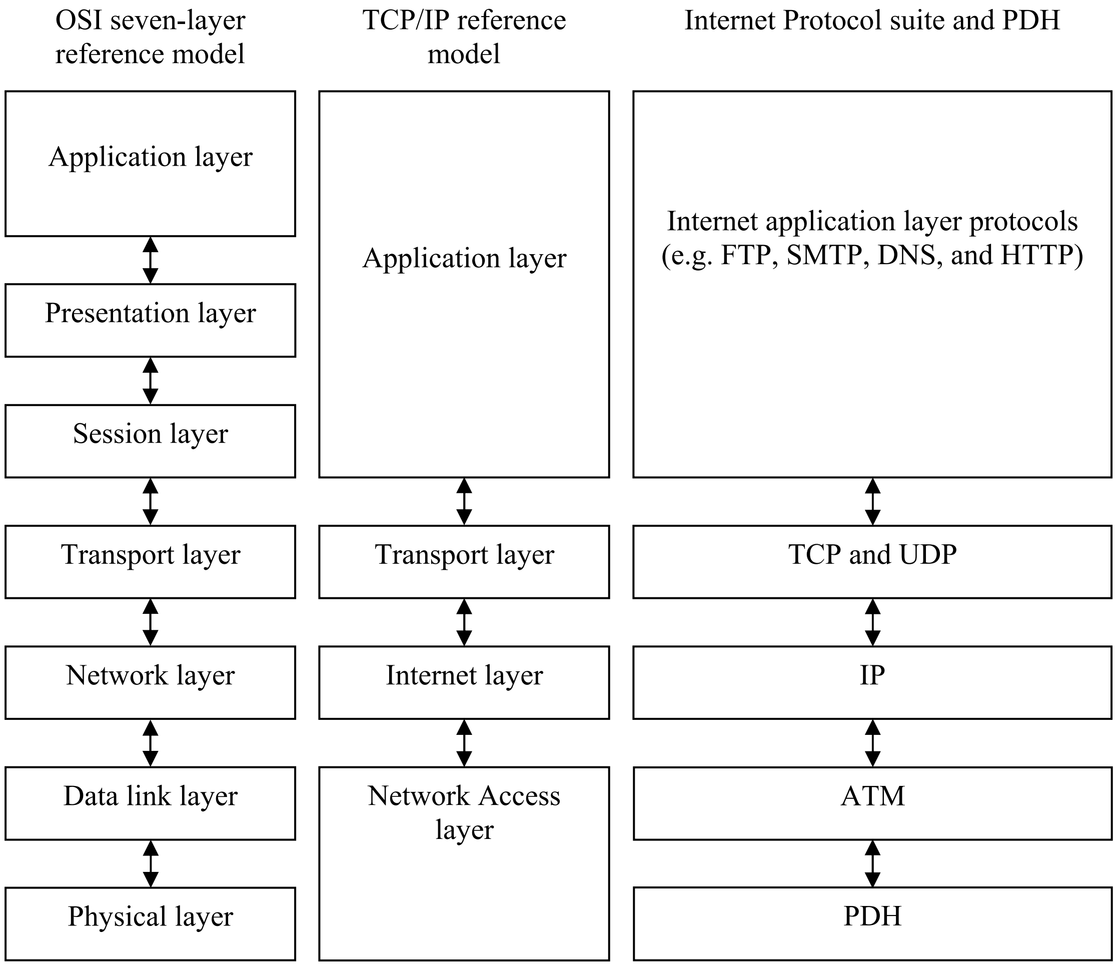


Figure F.6. Internet Protocol suite and PDH.

However, the cable only used 72 strands of fibre, the remaining fibres being available for redundancy purposes.[10]

To increase the information that each fibre could transmit, telecommunication companies employed Time Division Multiplexing technology which divides a strand of fibre into several channels based on time. Another technology employed for the same purpose is Wavelength Division Multiplexing (WDM). Instead of dividing a fibre into several channels using time, WDM divides a fibre into different wavelengths. An analogy is to imagine each wavelength as a different colour within the infrared range of the electromagnetic spectrum.[11]

[10] Held, *Understanding Data Communications*, p. 104.
[11] On fibre-optics, including the colour analogy, see Sheldon, *McGraw-Hill Encyclopedia*, pp. 497-504.

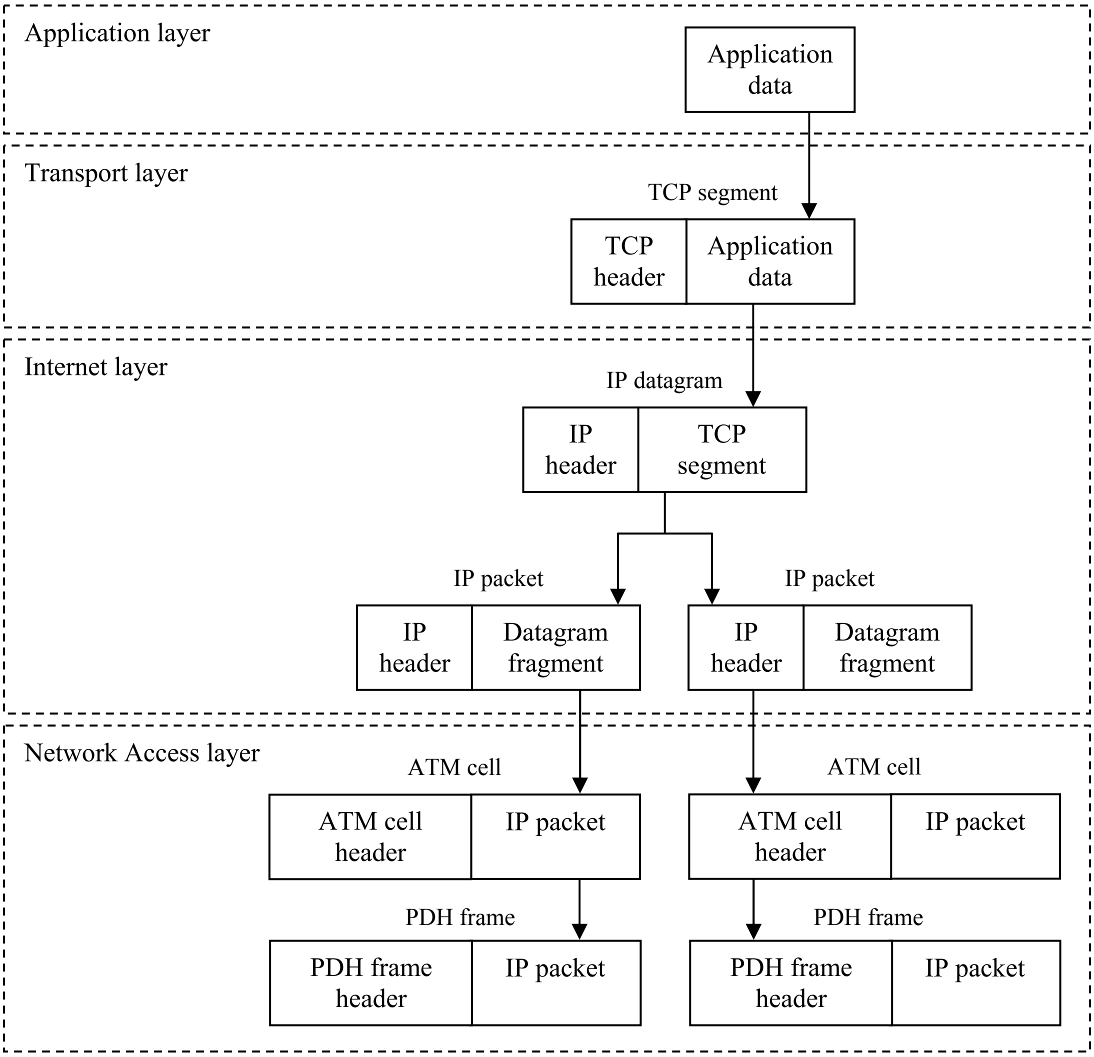
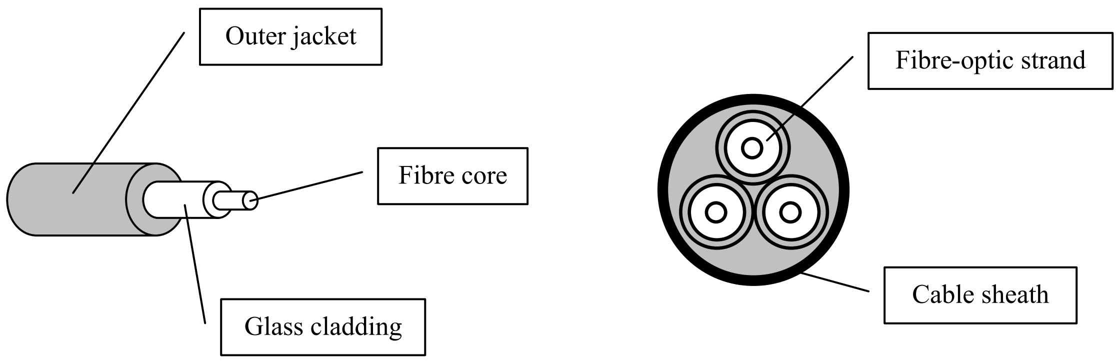


Figure F.7. Encapsulation of IP packets and ATM cells within PDH frames.

These wavelengths correspond to individual channels, known as lambda circuits, which the fibre-optic network uses to transmit data.[12] When WDM emerged during 1990, the first commercial networks contained eight channels per fibre, each of which could transmit 2.5 Gbps. The single fibre-optic cable could therefore transmit 20 Gbps. By 2001, there were commercial systems that contained 96 channels, each of which transmitted 10 Gbps. Each fibre-optic cable could therefore transmit 960 Gbps. To put this into perspective, the cable could transmit 30 movies a second.[13]

[12] Physicists use the Greek letter lambda, λ, to denote the wavelength of a wave, hence the term 'lambda circuit'. See H.D. Young, et al., *Sears and Zemansky's University Physics with Modern Physics*, 11th international ed. (San Francisco: Pearson, Addison Wesley, 2004), p. 550.
[13] Tanenbaum, *Computer Networks*, p. 139.



A single fibre-optic strand and cable

Cross section of a fibre-optic cable containing three strands of fibre

Figure F.8. Fibre-optic cables.

By employing lasers that are more precise, increasing the number of channels, and decreasing the space between wavelengths, Dense Wavelength Division Multiplexing technologies can create fibre-optic cables that contain hundreds of channels and possibly thousands of signals.[14]

Telecommunications companies divide transmission facilities into categories, based on factors such as the data transfer rates of circuits. These categories are part of digital hierarchies. For example, for leased lines there are the T and E Carriers which are part of the NADH and the PDH respectively. For fibre-optic systems, there is the hierarchy of Optical Carrier (OC) circuits (see Table F.2). SDH and WDM operate at the Network Access layer of the TCP/IP reference model. SDH supports several higher-layer protocols such as ATM and TCP/IP (see Figure F.9). ATM encapsulates IP packets into ATM cells which SDH then encapsulates into frames, transmitting them across fibre-optic cables (see Figure F.10). However, there is an overhead associated with using several protocols such as running IP over ATM over SDH. For example, there is an ATM ‘cell tax’ associated with every ATM cell. Each ATM cell is 53 bytes long: 48 for the payload, containing the IP datagram, and 5 for the cell’s header. As the header constitutes nearly 10 percent of a cell’s size, this means that when a network uses IP over ATM it only utilises 79.6 percent of the data transfer rate available.

[14] S.V. Kartalopoulos, *DWDM: Networks, Devices, and Technology* (Piscataway, NJ. IEEE Press, 2003).

Table F.2. Optical Carriers.[15]

Optical Carrier level	Data transfer rate	Number of phone calls
OC-1	51.84 Mbps	672
OC-3	155.52 Mbps	2,016
OC-6	311.04 Mbps	4,032
OC-9	466.56 Mbps	6,048
OC-12	622.08 Mbps	8,064
OC-18	933.12 Mbps	12,096
OC-24	1.244.16 Gbps	16,128
OC-36	1.866.24 Gbps	24,192
OC-48	2.488.32 Gbps	32,256
OC-96	4.976.00 Gbps	64,512
OC-192	9.952.00 Gbps	129,024
OC-256	13.271 Gbps	172,032
OC-768	40 Gbps	516,096

However, when a network uses IP over SDH, it uses 95.4 percent of the data transfer rate.[16] As ATM imposes a protocol overhead, and as this affects line utilisation and therefore performance, these factors affect the traffic on networks that use ATM such as the Internet. In addition, using ATM to support IP adds to the complexity of an overall network and duplicates functionality.[17] There is therefore a gradual trend away from running IP over ATM over SDH, towards running IP over SDH.[18] In the long-term, there is an aim to remove SDH as well and therefore run IP directly over the high capacity Dense Wavelength Division Multiplexing (see Figure F.9).[19] By removing both ATM and SDH from communication systems, this will therefore remove the protocol overheads and improve the efficiency of communications. However, as ATM controls processes such as quality of service and the creation of virtual circuits, networks need a new protocol to assume these responsibilities. The IETF proposes the Multiprotocol Label Switching (MPLS) for these tasks.[20]

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[15] On optical carriers see Ibid., pp. 918-920.
[16] *Comparison of IP-over-SONET and IP-over-ATM Technologies*, Trillium Digital Systems, Inc., 1997, Available from: http://www-t.zhwin.ch/it/ksy/Block01/IPATM-Trillium/wp_ip.html, Accessed on: 13 August 2004.
[17] P. Newman, et al., "IP Switching—ATM Under IP," *IEEE/ACM Transactions on Networking*, vol. 6, no. 2, 1998, pp. 117-129.
[18] D. Clark, "Heavy Traffic Drives Networks to IP over SONET," *Computer*, December 1998, pp. 17-20.
[19] Sheldon, *McGraw-Hill Encyclopedia*, pp. 934 and 1000.
[20] On MPLS see Ibid., pp. 808-813.

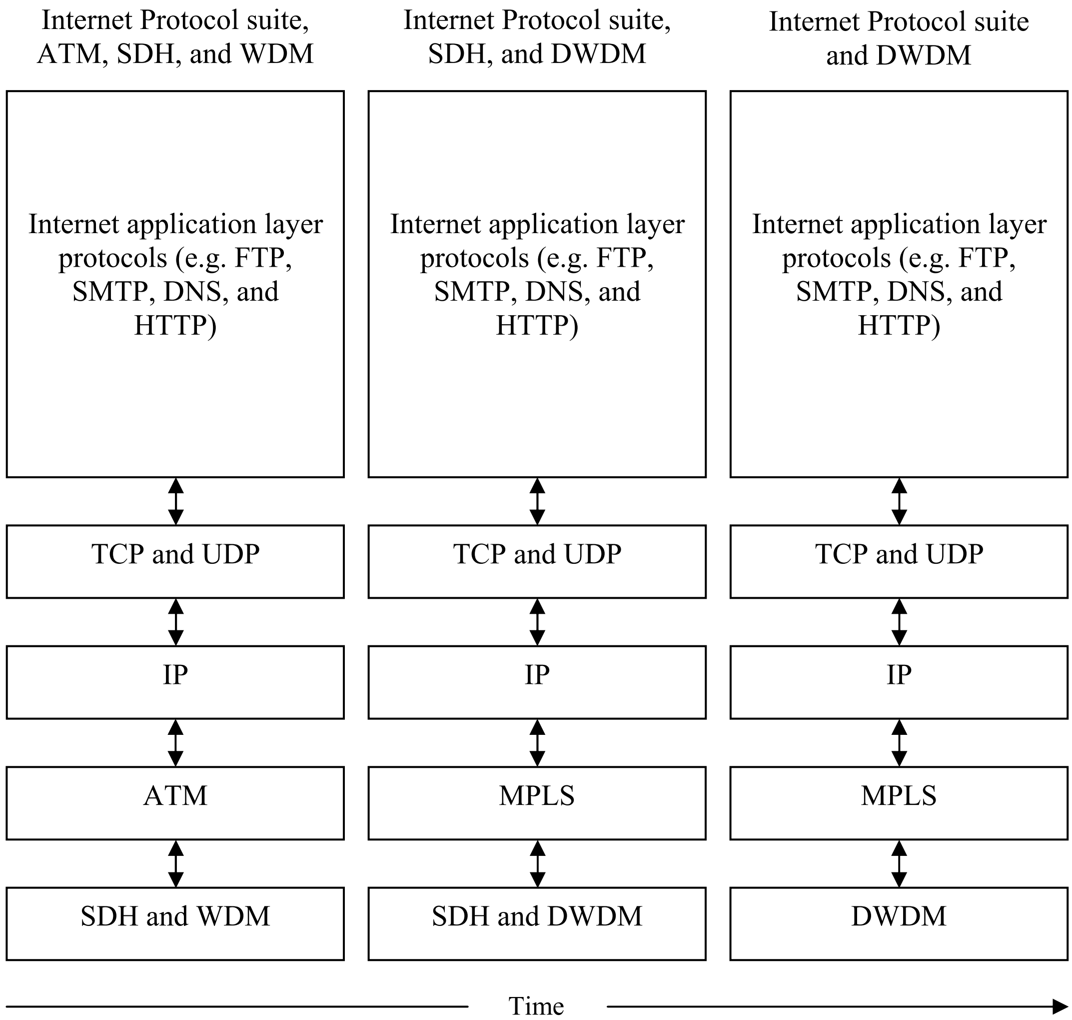

Figure F.9. Transition from IP over ATM over SDH to IP over DWDM.

In addition, in order for companies to adopt IP over DWDM, networks need a new technique to encapsulate IP datagrams for transmission over the DWDM fibre-optic networks. The ITU-T proposes the G.709 Digital Wrapper (DW) standard for this purpose (see Figure F.11).[21]

[21] *Next Generation Networking Technologies*, Xilinx, 2003, Available from: http://www.xilinx.com/esp/networks_telecom/optical/collateral/ngn.pdf, Accessed on: 13 August 2004.

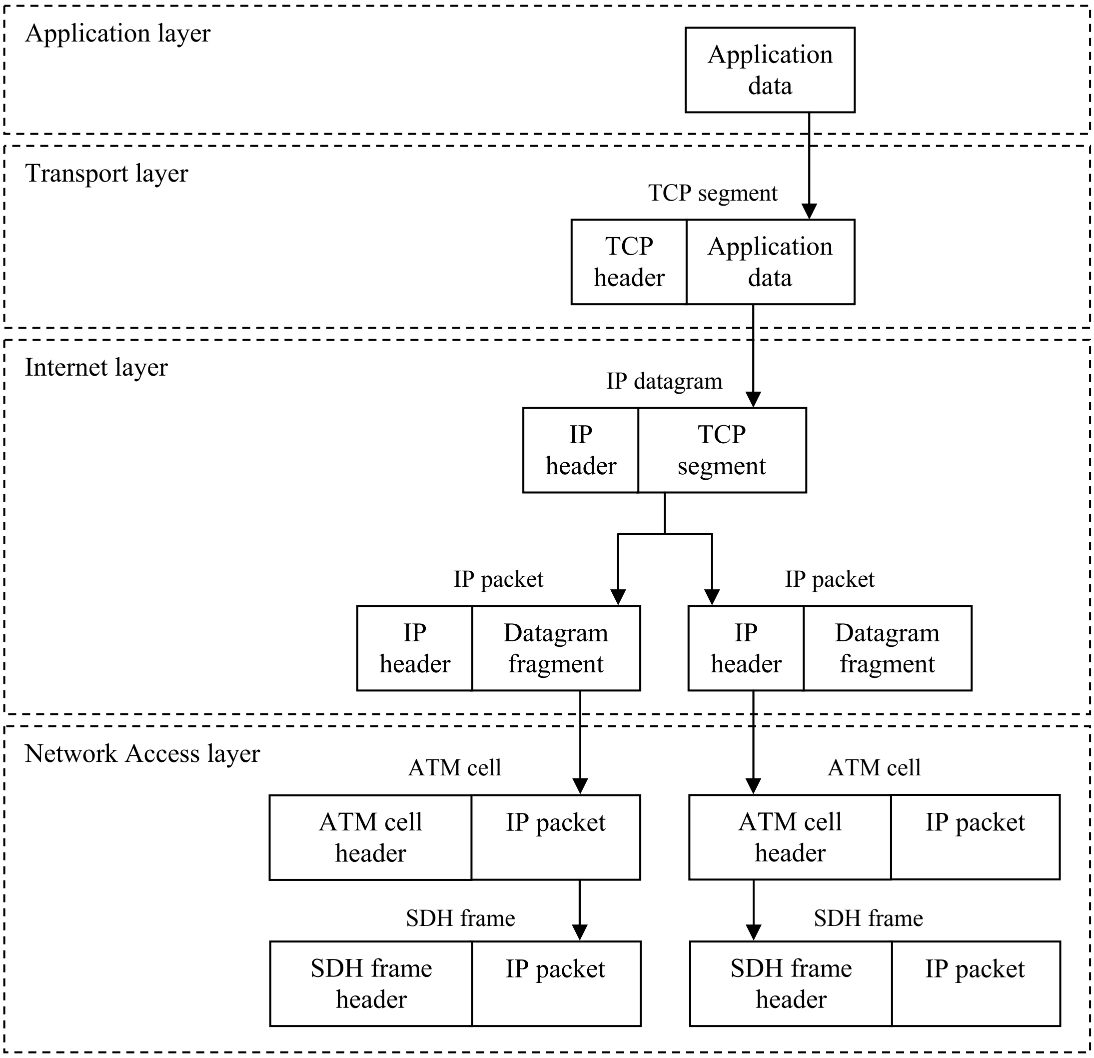

Figure F.10. Encapsulation of IP packets and ATM cells within SDH frames.

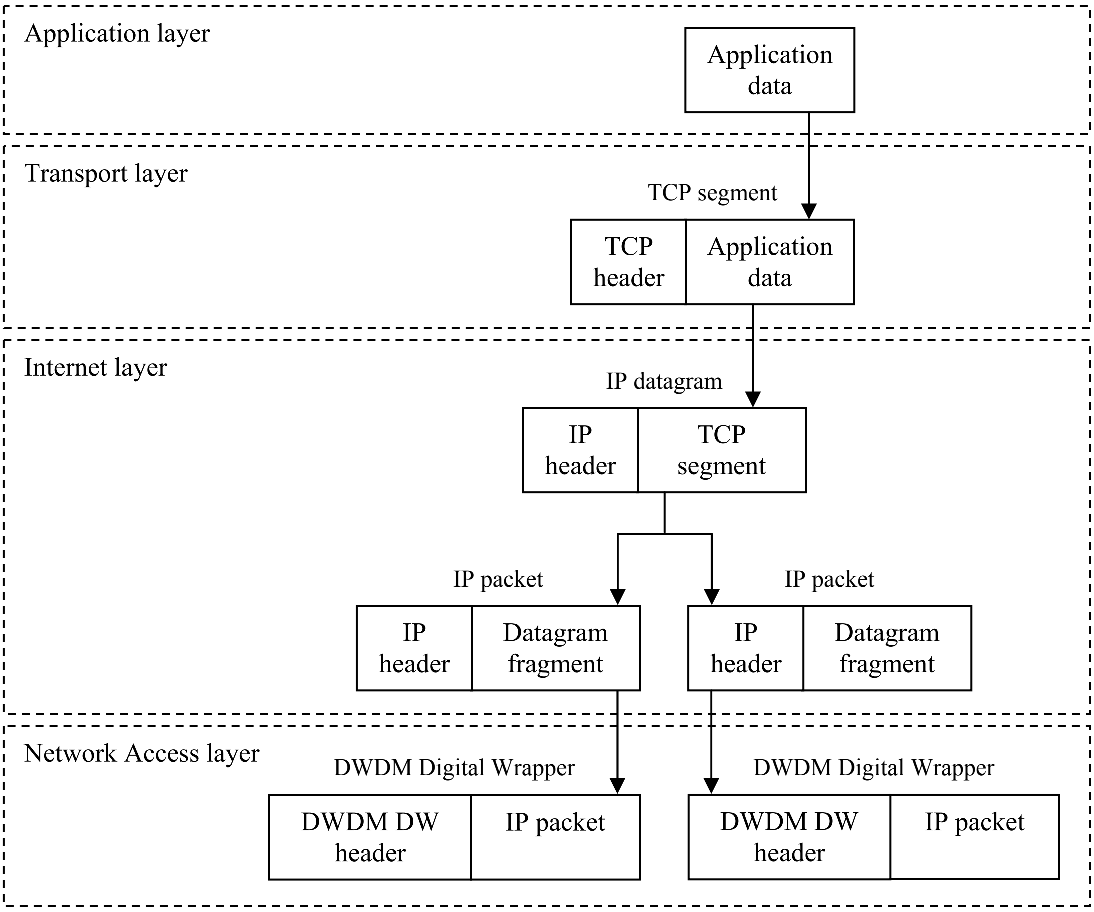

Figure F.11. Encapsulation of IP packets within DWDM Digital Wrappers.

Appendix G. LANs, MANs, and WANs

G.1 Local Area Networks

Local Area Networks (LANs) cover a small geographical area such as an office within a building or a university department. They are smaller than both Metropolitan Area Networks (MANs) and Wide Area Networks (WANs). People use LANs to share resources, such as files and printers, and to communicate. The invention of LANs occurred during the early 1970s. They evolved from point-to-point connections which consisted of a single cable that usually connected two computers together. In the example shown in Figure G.1, there is a point-to-point connection between the terminal and the mainframe. Companies either established these connections locally between a terminal and computer within the same building, or between a terminal at one site and a mainframe at another site, using the Public Switched Telephone Network (PSTN) or a leased line to link the nodes.

By sharing the connection between two computers, the concept of a Local Area Network emerged. As no two computers could use a connection to transmit data at the same time, LANs needed arbitration mechanisms. People developed several mechanisms including token passing and contention resolution. In a token-passing LAN, only the computer that possesses a token can transmit frames of data over the Local Area Network. Examples of token-passing LANs include token ring, token bus, Cambridge Ring, and Fiber Distributed Data Interface (FDDI).[1] In a contention-based LAN, computers compete for access to the LAN. They do this by transmitting packets and, when a collision of packets occurs, they wait for a random period and then retransmit the packet again. The main contention-based LAN standard is Ethernet.[2]

Figure G.2 illustrates the topology of a Local Area Network. Three computers share the cable and use this it to communicate.

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[1] On Cambridge Ring LANs see R.M. Needham and A.J. Herbert, *The Cambridge Distributed Computing System* (London: Addison-Wesley, 1982), pp. 24-40.

[2] T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 460-476, 480-485, 494-497, 560-568, 722-725, 1253-1254, and 1256-1257.

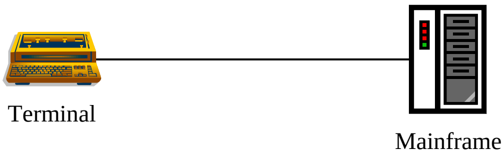

Figure G.1. A point-to-point connection.

Using a variety of network connection devices, companies can expand LANs to form internetworks.[3] In the example shown in Figure G.3, there are two Local Area Networks: LAN segment 1 and LAN segment 2. A device known as a bridge links the two LANs. Bridges transmit frames between LAN segments.

As companies set up LANs and internetworks, they adopted several LAN technologies. During the 1980s, several LAN standards competed. These included token ring, FDDI, and Ethernet. By the end of the 1980s, Ethernet had become the dominant LAN standard. During the 1990s, FDDI became quite popular in LANs and as a backbone for campus networks, as it offered greater bandwidth compared to Ethernet. However, when Fast and Gigabit Ethernet emerged during the 1990s, they superseded FDDI and consolidated Ethernet's market leading position.[4]

Robert Metcalfe invented Ethernet during the early 1970s. Metcalfe learnt about the ALOHA Hawaiian network and believed that he could improve the design of this network. His work resulted in Ethernet which was the first Local Area Network standard. LAN technologies, such as Ethernet, are located in the Network Access layer of the TCP/IP reference model (see Figure G.4). Ethernet encapsulates IP packets received from the Internet layer, adds headers, and then transmits the frames across the LAN using the underlying network cables and networking devices (see Figure G.5).[5]

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[3] Ibid., pp. 136-144, 151, 464-466, 558-560, 1049-1050, and 1071-1075.

[4] At the beginning of the 21st century, a new type of LAN technology emerged: the Wireless LAN (WLAN). Ratified by the IEEE as the 802.11 series of standards, people commonly refer to them as Wireless-Fidelity (Wi-Fi) networks. See A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 68-71 and 292-302.

[5] As well as encapsulating and transmitting TCP/IP packets, LAN standards such as Ethernet can also perform the same functions for other higher-layer protocols such as the Novell NetWare operating system and underlying protocols. NetWare provides a variety of LAN-related facilities including messaging, file and print services, and directory services. During the 1980s and early 1990s, NetWare provided these services using the proprietary internetworking protocols SPX and IPX. These protocols operated at the Transport and Network layers of the OSI reference model. With the rise of the Internet during the 1990s, Novell incorporated support for TCP/IP into its protocol suite, replacing SPX and IPX. See Sheldon, *McGraw-Hill Encyclopedia*, pp. 688-690 and 907-908.

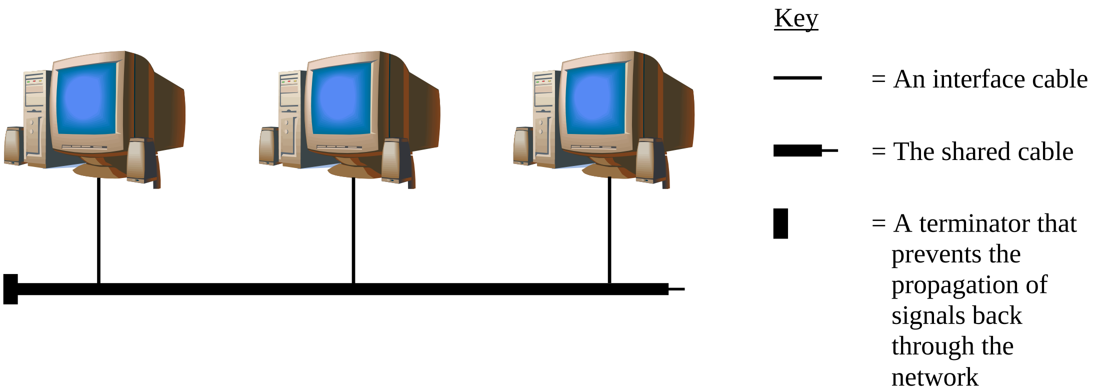


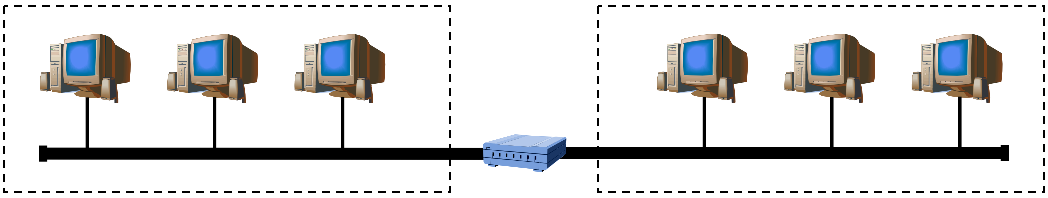
Figure G.2. A Local Area Network.

Ethernet, Fast Ethernet, and Gigabit Ethernet can use a variety of network cables, including coaxial, twisted-pair, and fibre-optic. For an overview of some of the Ethernet standards see Table G.1.

G.2 Metropolitan Area Networks

Metropolitan Area Networks cover a large geographical area such as a city or a small region of a country. They are larger than LANs, but smaller than Wide Area Networks. Companies use Metropolitan Area Networks as backbones to interconnect their LANs, and to connect their LANs to WANs. For example, a business can use a MAN to interconnect their offices within a city, and universities can interconnect campus LANs to regional MANs. Metropolitan Area Networks emerged during the late 1980s and evolved from Community Antenna Television (CATV) systems.[6] Companies, such as telecommunications operators, provide MANs using a variety of technologies. These include FDDI, ATM, and Switched Multimegabit Data Service (SMDS). These technologies often use underlying circuits based on fibre-optic connections such as the Synchronous Digital Hierarchy (SDH) technology.[7] Newer developments include the IEEE's 802.16 Broadband Wireless Access technology that companies can use for wireless MANs and WANs.[8] MAN technologies are located in the Network Access layer of the TCP/IP reference model (see Figure G.6).

[6] W.E. Bracker, Jr., et al., "Metropolitan Area Networking: Past, Present, and Future," *Data Communications*, January 1987, pp. 151-152, 155-156, and 159.
[7] J.F. Mollenauer, "Metropolitan Area Network Update: The Global LAN is Getting Closer," *Data Communications*, December 1989, pp. 111-112, 115-116, 119-120, and 123.
[8] Tanenbaum, *Computer Networks*, pp. 302-310.



Key

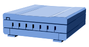
 = A bridge

Figure G.3. Two LAN segments interconnected by a bridge.

In the example shown in Figure G.7, a company interconnects two of its LANs within London using the MAN provided by a telecommunication operator.

G.3 Wide Area Networks

Wide Area Networks cover a very large geographical area such as a country or a continent. They are therefore larger than both LANs and MANs. WANs interconnect MANs and LANs to form a large interconnected network. WANs are either private or public. Private WANs interconnect MANs and LANs and therefore enable companies to create a country or continent-wide private network. Companies, such as telecommunications operators, provide public WANs which companies can use. Public WANs use packet-switched network technologies, such as X.25, SMDS, ATM, Frame Relay, and TCP/IP, which means that many companies share the WAN circuits, unlike in a private WAN. Companies can use a variety of circuits to build a Wide Area Network including leased lines, microwave links, satellite links, and fibre-optic connections. Companies can also use the new IEEE 802.16 Broadband Wireless Access technology, to provide wireless WANs as well as MANs. Wide Area Networks emerged during the 1960s and one of the earliest examples of a WAN was the ARPANET. WANs can have several network topologies, including star, ring, and mesh (see Figure G.8). WAN technologies are located in the Network Access layer of the TCP/IP reference model (see Figure G.9).[9]

[9] Tanenbaum, *Computer Networks*, pp. 19-21 and 302-310.

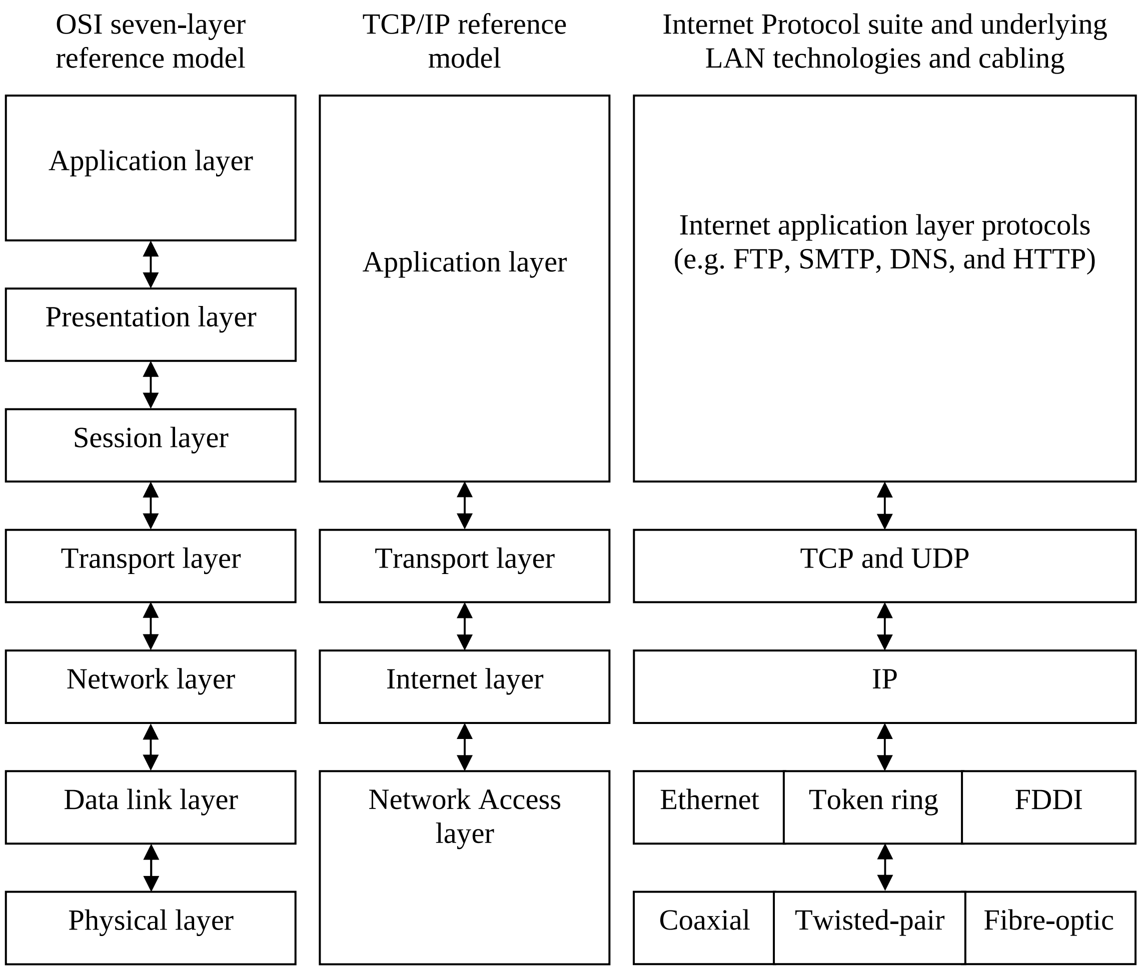


Figure G.4. Internet Protocol suite and underlying LAN technologies and cabling.[10]

In the example shown in Figure G.10, a company interconnects four of its LANs using two MANs and a WAN. A telecommunications operator provides the MANs and WANs.

[10] FDDI also operates in the physical layer. However, for simplicity the figure does not show this detail.

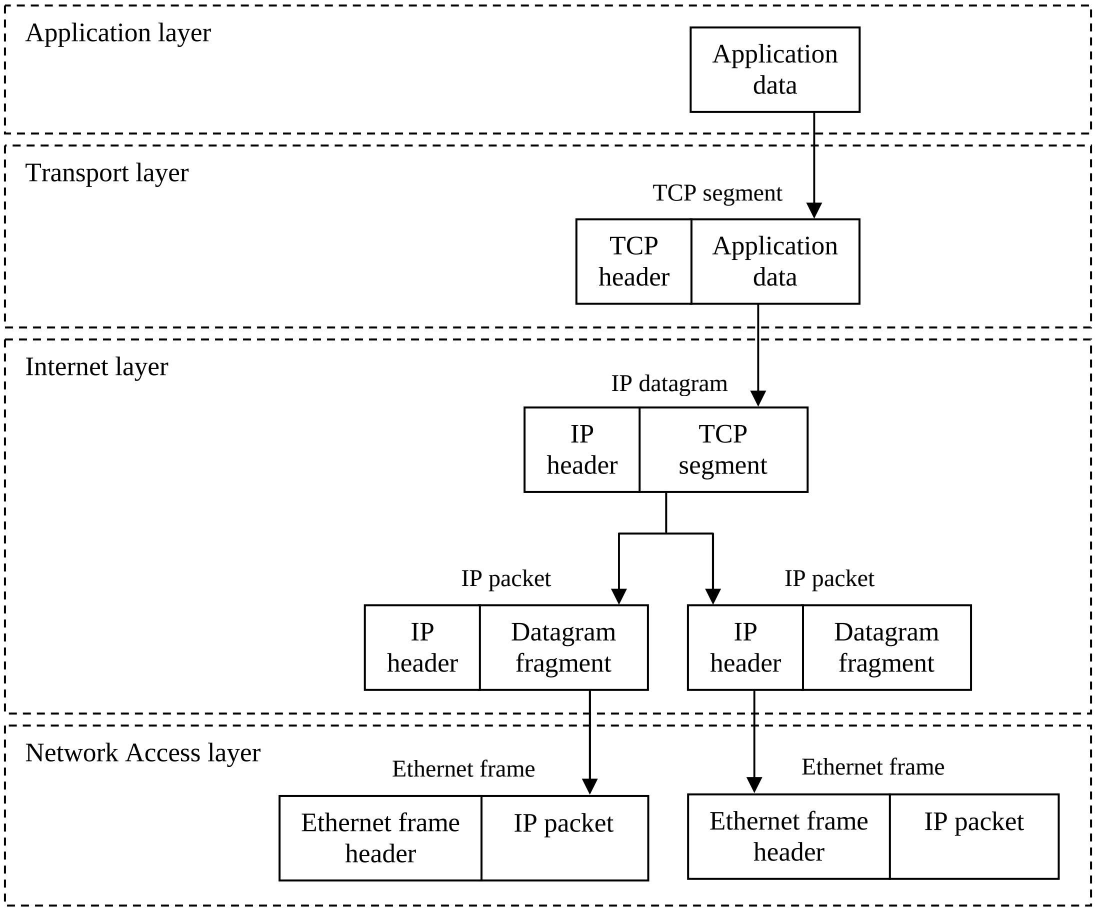


Figure G.5. Encapsulation of IP packets within Ethernet frames.

Table G.1. A subset of the Ethernet standards.[11]

Standard	Description
10Base-5	10 Mbps Ethernet using coaxial cables
10Base-T	10 Mbps Ethernet using uses twisted-pair cables
100Base-TX	100 Mbps Fast Ethernet using uses twisted-pair cables
1000Base-T	1 Gbps Gigabit Ethernet using uses twisted-pair cables
10GBase-SR	10 Gbps 10-Gigabit Ethernet using uses fibre-optic cables

[11] See G. Held, *Ethernet Networks: Design, Implementation, Operation, Management*, 3rd ed. (Chichester: John Wiley, 1998), B.A. Forouzan, *Data Communications and Networking*, 3rd ed. (Boston: McGraw-Hill Higher Education, 2003), pp. 339-354, and Sheldon, *McGraw-Hill Encyclopedia*, pp. 566-567.

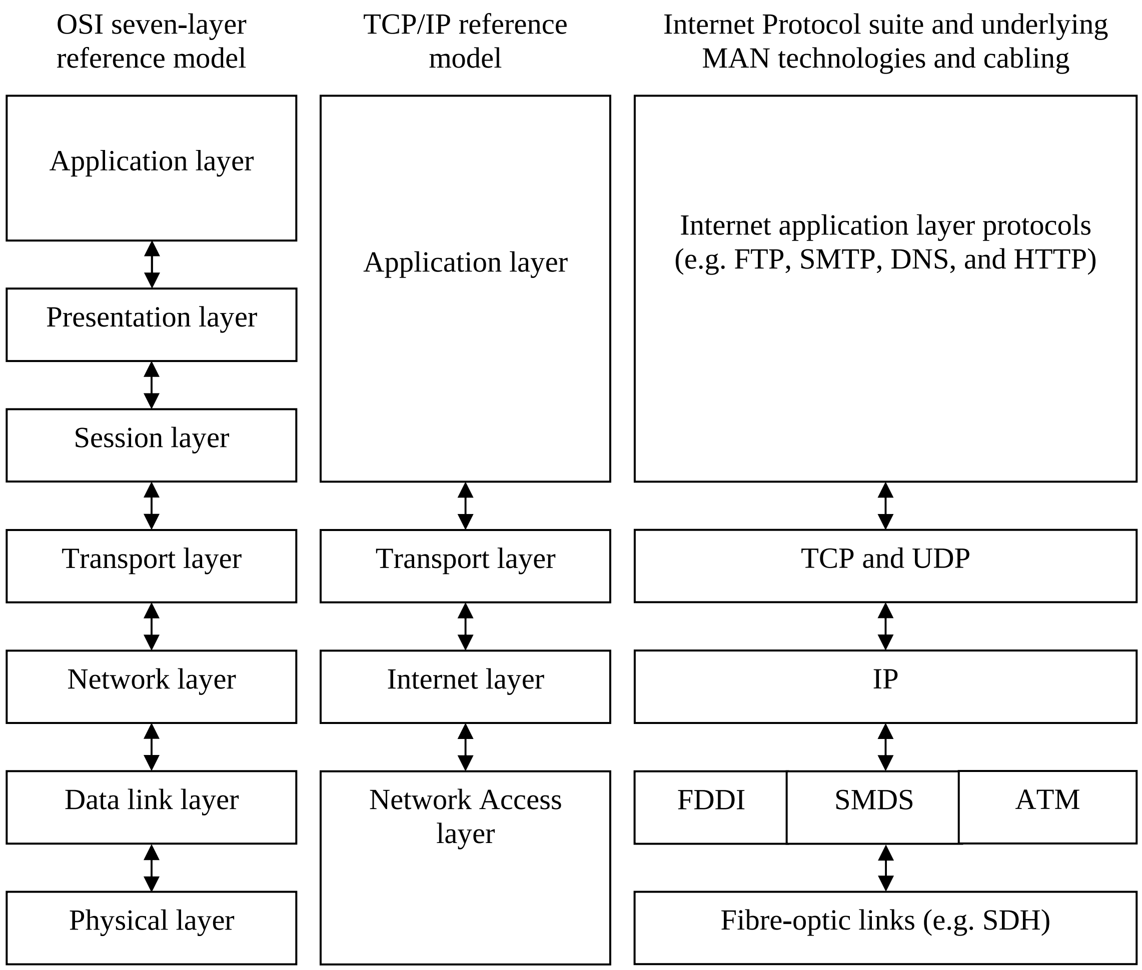


Figure G.6. Internet Protocol suite and underlying MAN technologies.[12]

[12] FDDI, SMDS, and ATM also operate in the physical layer. However, for simplicity the figure does not show this detail.

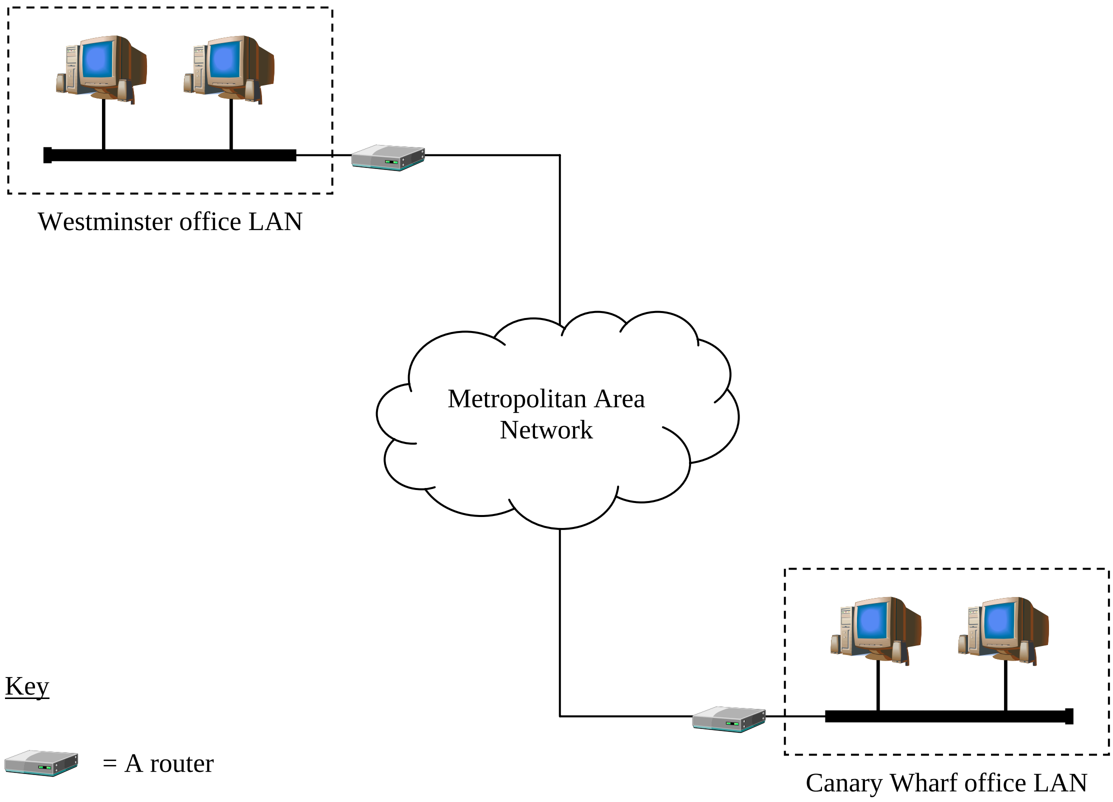


Figure G.7. A Metropolitan Area Network.

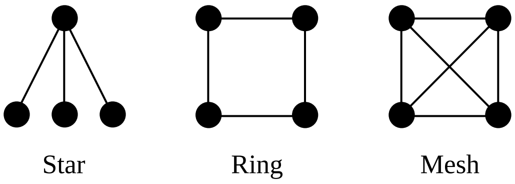


Figure G.8. Different WAN topologies using leased lines.

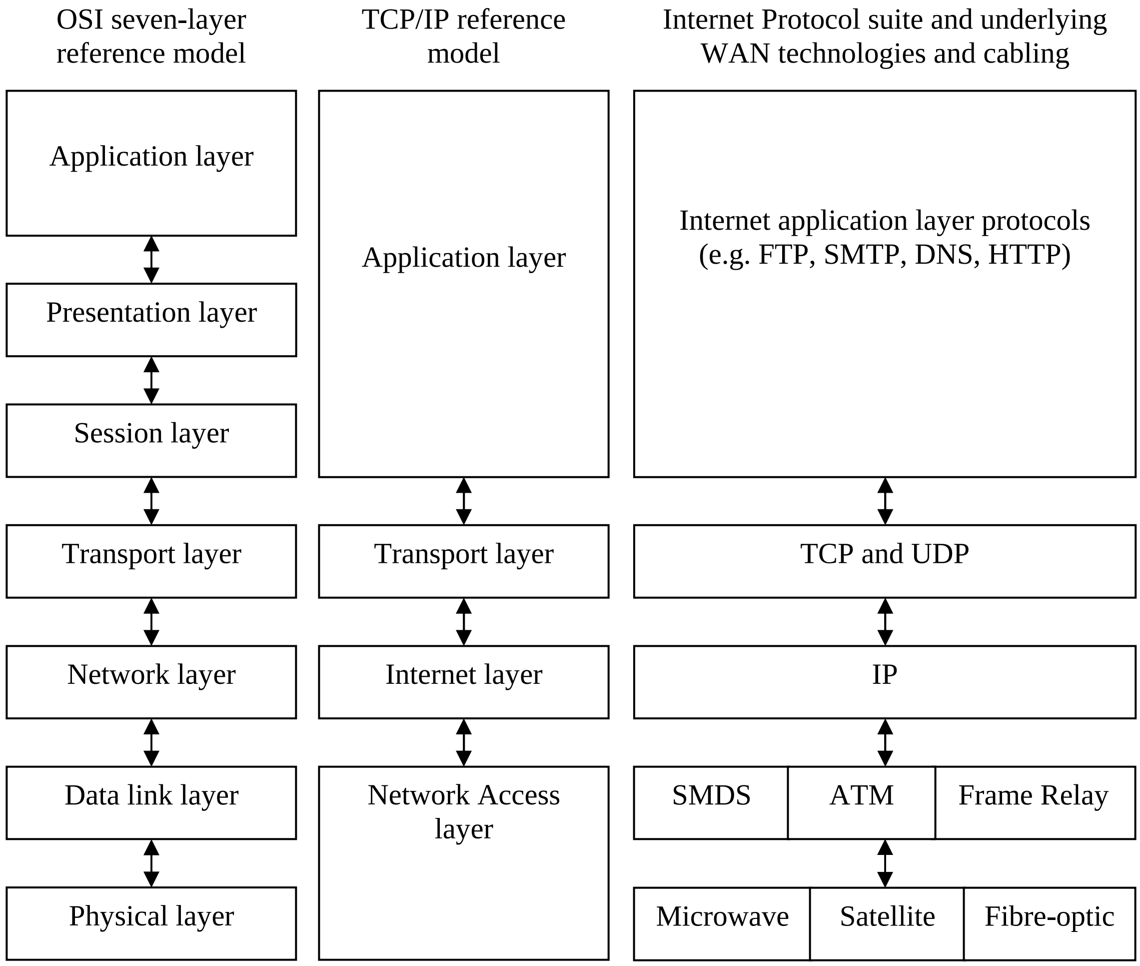
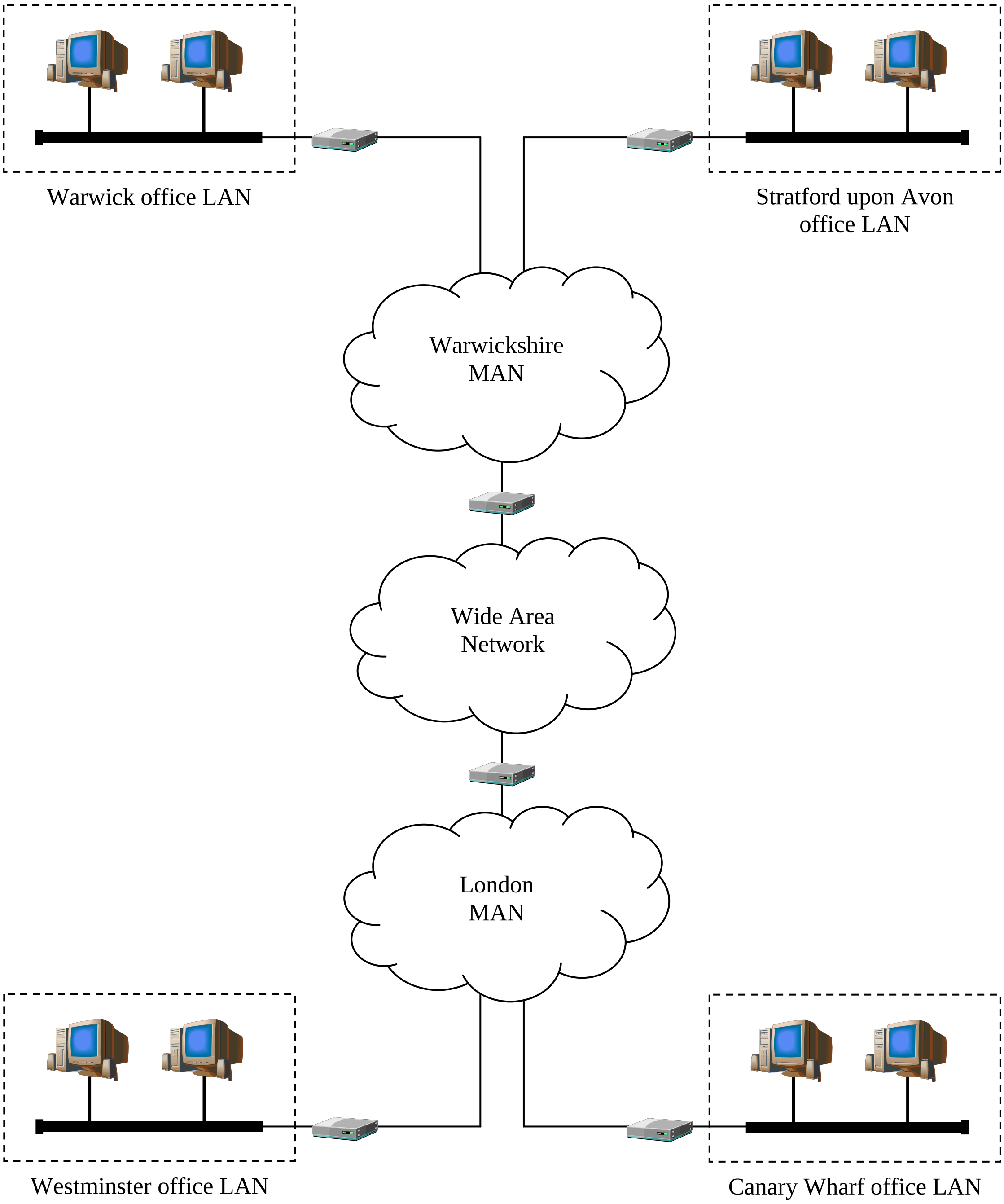


Figure G.9. Internet Protocol suite and underlying WAN technologies.[13]

[13] SMDS, ATM, and Frame Relay also operate in the physical layer. However, for simplicity the figure does not show this detail. An example of a fibre-optic network technology that companies use in WANs is SDH.



Key

 = A router

Figure G.10. A Wide Area Network.

Appendix H. The Technology of Videotex Networks

H.1 OSI, X.25, and Videotex Networks

Videotex display standards, such as Prestel, Antiope, and S.100, defined how frames of information should be stored, formatted, and displayed on terminals.[1] The presentation layer of the OSI seven-layer reference model therefore contained important protocols for all videotex services (see Figure H.1). Display standards such as Prestel provided display functions to applications, including information retrieval, e-mail, and telesoftware. To perform their task, these presentation layer protocols used the services of the layers below, in particular the X.25 lower layer protocols, to transmit information from a videotex computer to a terminal.

H.2 How Teletext Works

Teletext works by inserting data in to the Vertical Blanking Interval (VBI) of a television picture (see Figure H.2).[2] For example, the British Broadcasting Corporation's (BBC's) Ceefax services insert frames of information into four lines of the 625-line television frame. Each frame contains 24 rows of 40 characters and the BBC assembles these frames into magazines of pages which it continuously broadcasts to teletext compatible televisions. It takes about 25 seconds to broadcast a magazine containing 100 pages. The Corporation broadcasts every page once except for the index pages which it broadcasts more frequently. A data inserter at the BBC inserts the serial teletext data into the television signal which a transmitter then broadcasts to aerials. A decoder within a television set then receives the broadcast signal, isolates the teletext signal embedded within the VBI, stores a frame of information within memory, and then uses a character generator to display the page of information. A person then uses a remote control to select the page that they want to view and the decoder then selects and displays this page when the BBC next broadcasts it.

[1] J. Gecsei, *The Architecture of Videotex Systems* (Englewood Cliffs: Prentice-Hall, 1983), pp. 28-30.
[2] S.A. Money, *Teletext and Viewdata* (Sevenoaks: Newnes Technical Books, 1979).

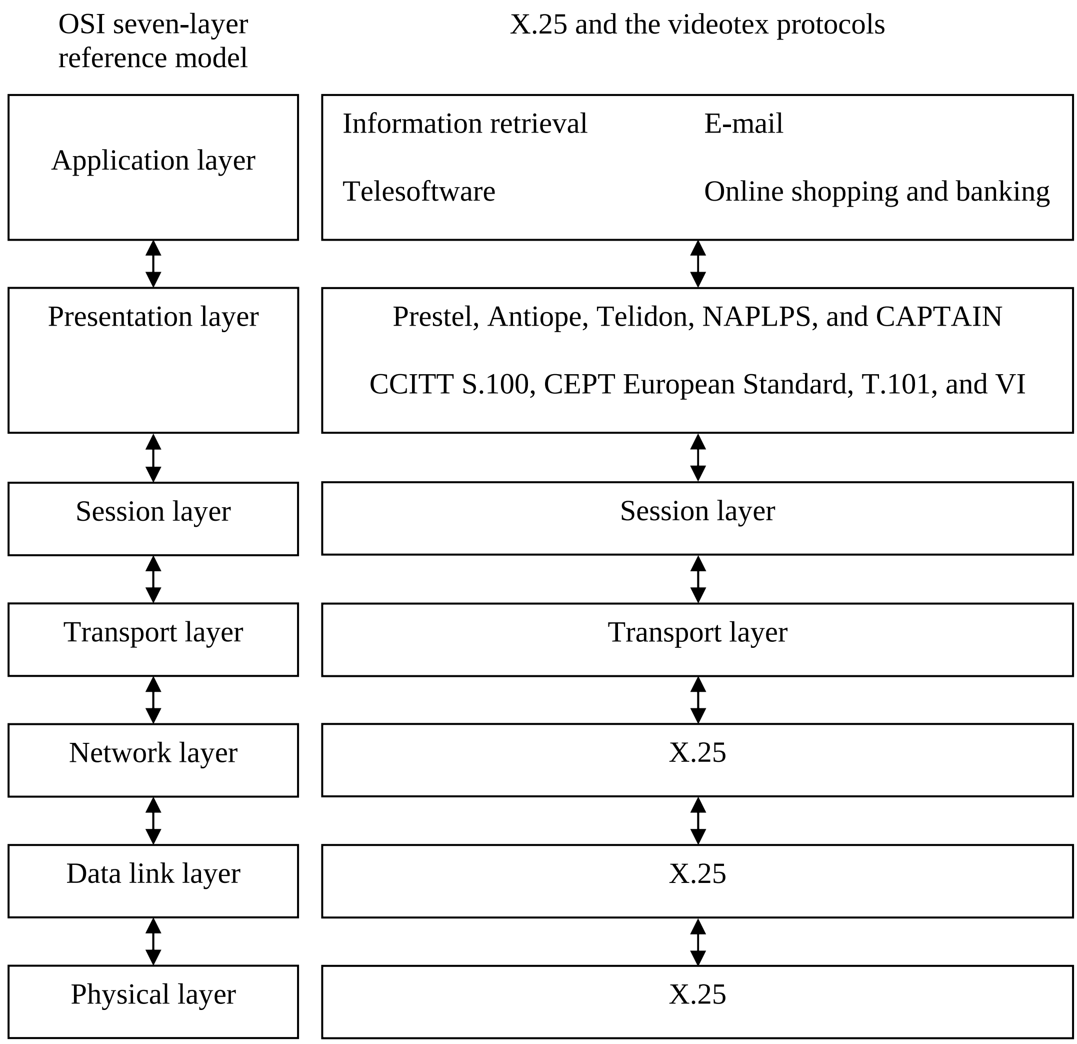


Figure H.1. The relationship between OSI, X.25, and videotex.[3]

H.3 How Viewdata Worked

Viewdata worked by using the Public Switched Telephone Network to transmit frames of information from a computer to a viewdata compatible terminal. Frames contained 24 rows of 40 characters and a unique page number such as page 10. Pages always contained at least one frame and could contain up to 26 frames. Each frame contained the number of the associated page together with a lowercase letter, for example page 10111a.

[3] The figure is a simplified representation of how videotex protocols worked. In reality, standards such as T.101 transcended the presentation layer to provide functions for multiple layers.

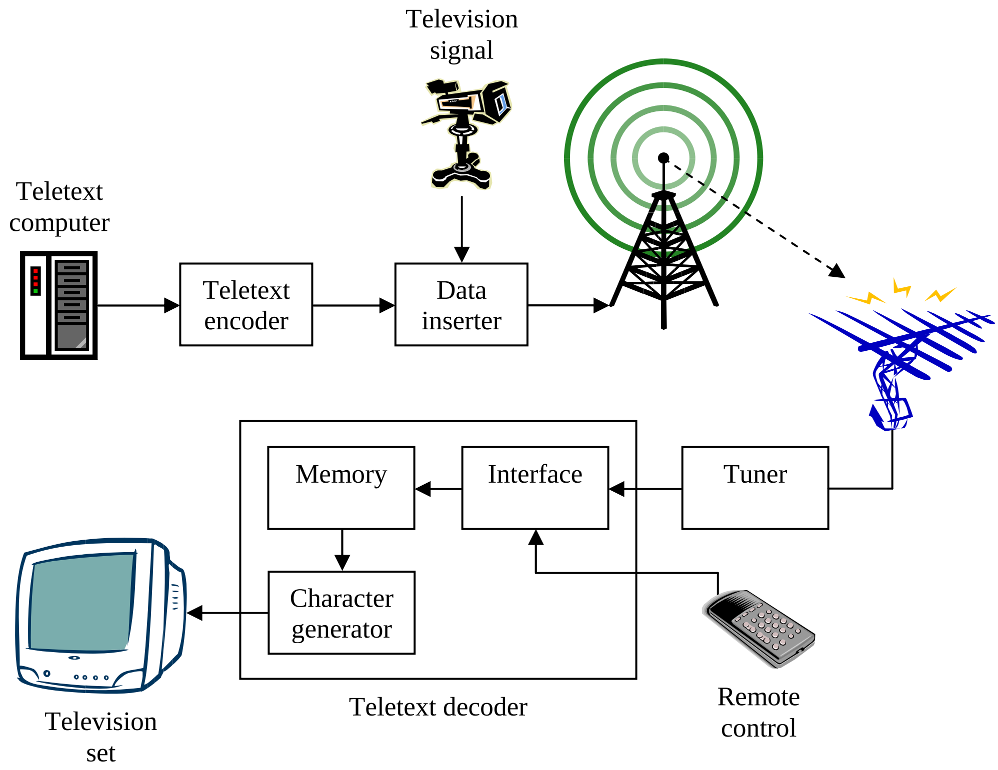


Figure H.2. A simplified illustration of how teletext works.[4]

Viewdata arranged these pages and frames into an inverted tree hierarchy, containing the main topics at the top of the tree and the sub-topics underneath (see Figure H.3).[5] Users would navigate down through this hierarchy of routeing pages in search of information, in the form of end pages, which interested them. Alternatively, users could enter the page number of a page to view that page, instead of navigating through the intermediate routeing pages. As the hierarchy could contain perhaps up to 10 levels and as each page in the system could contain up to 26 frames of information, represented by the letters of the alphabet, this meant that viewdata had the potential to display millions of pages of data.

People would use viewdata compatible terminals, such as television sets, business terminals, editing terminals, and Personal Computers to connect to the viewdata computer using the PSTN (see Figure H.4).[6]

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[4] For clarity, the figure shows the tuner separately from the television when it would, of course, be integral to the receiver. In addition, the figure shows the decoder separately, although manufacturers would usually incorporate this as a printed circuit board inside the television set.
[5] G.E. Field, *Navigation of Menu-Accessed Information Space: Psychological Experimentation in Human Computer Interaction*, Ph.D. thesis (London: Department of Electrical Engineering, Imperial College, 1988), pp. 28-51.
[6] Money, *Teletext and Viewdata*, pp. 113-123.

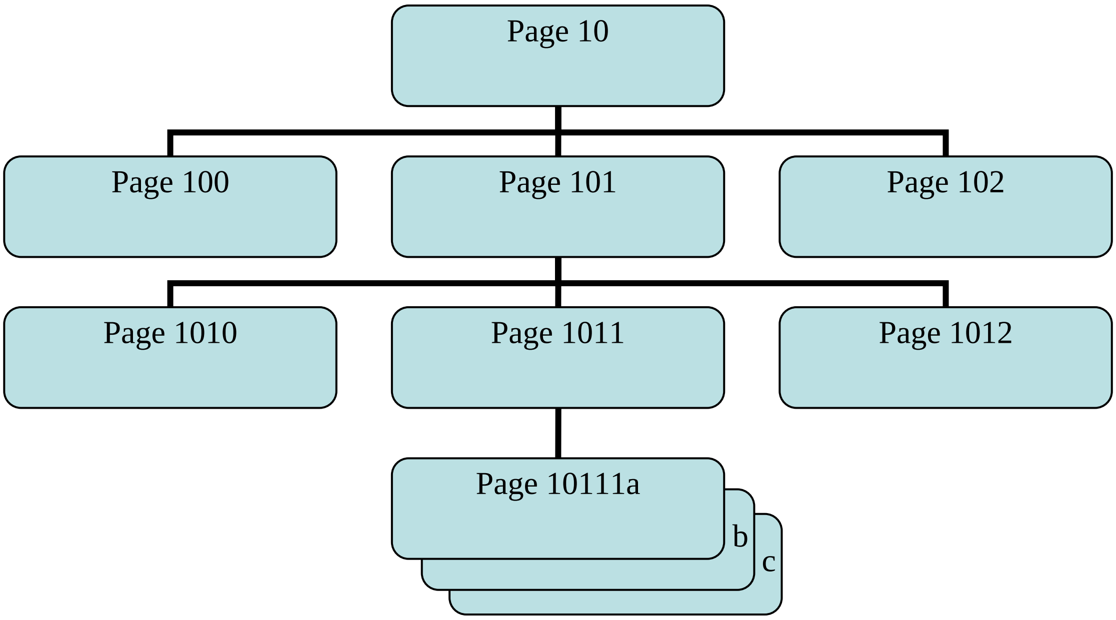

Figure H.3. An inverted tree hierarchy.

Each terminal would contain a viewdata decoder which included a modem that usually enabled the terminal to download data from the remote computer at 1,200 bps, with an upload speed of 75 bps. Terminals would dial the telephone number of their nearest viewdata computer and establish a connection. The network would then transmit the index page of the system, which the decoder would store in memory, using the display control logic to display the information on-screen. Users would enter page numbers using a remote control.

H.4 Prestel Gateway

Prestel Gateway enabled External Information Providers (EIPs) to establish connections with the Prestel network to enable users to access information and services provided by external computers (see Figure H.5).[7] Users would navigate to a gateway frame within the Prestel database which would then enable them to access information stored on an external computer. The third party company would either store its information in a Prestel compatible format, or use special software to translate this information into the Prestel format as and when users requested this data. The Prestel computer and external computer would communicate with each other using the Prestel Gateway (PG) protocol.

[7] *Welcome to Gateway* (London: British Telecom, 1981).

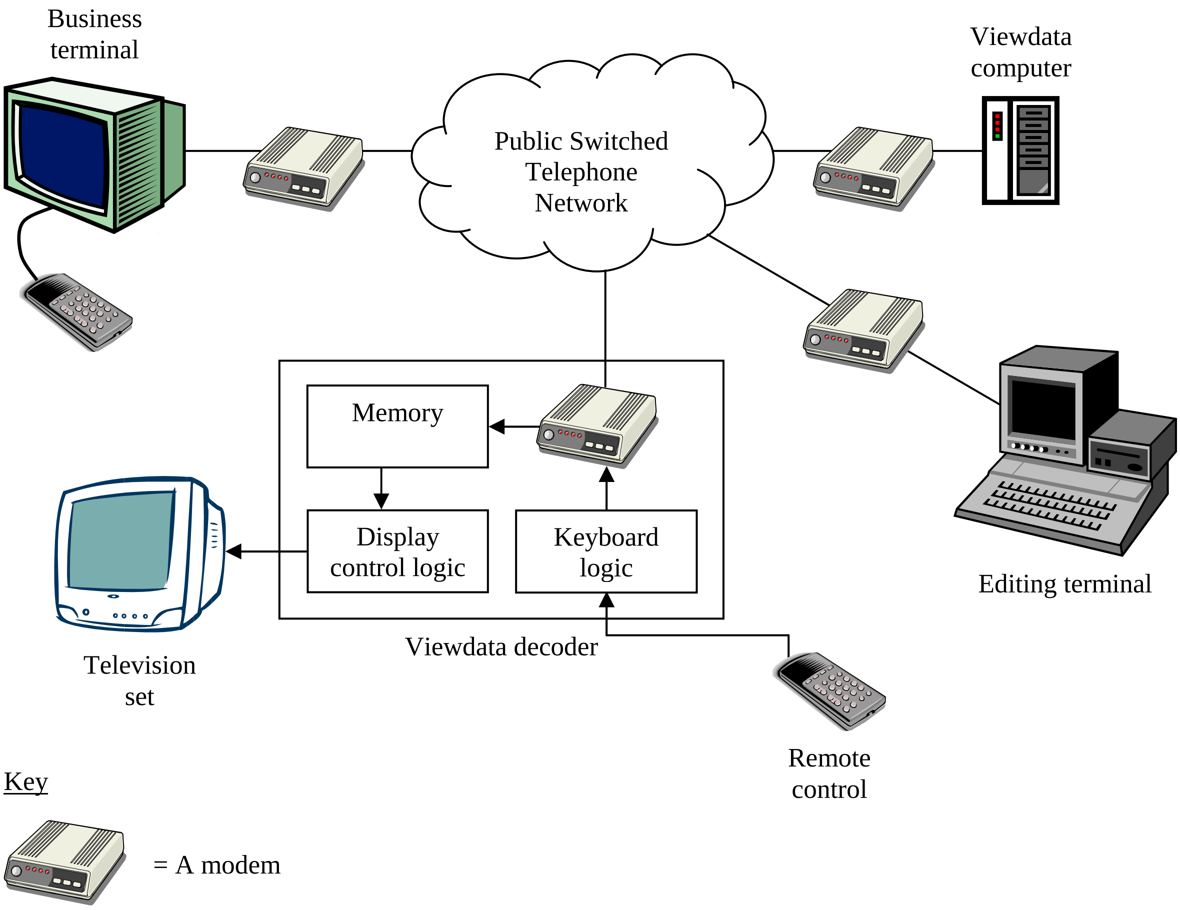

Figure H.4. A simplified illustration of how viewdata worked.[8]

This protocol defined how both computers should interact, and PG used the underlying services provided by the X.25 Packet Switching Service (PSS) for this purpose. The Prestel computer would initiate every transmission with external computers and handle billing. In addition to information retrieval, external computers could also provide data collection facilities and this could help to form the basis for transactional applications such as online shopping and banking.

H.5 Videotex Display Standards

There were several videotex display standards.[9] These included alphamosaic, alphageometric, and alphaphotographic (see Figure H.6).[10]

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[8] For clarity, the figure shows the modems separately from the terminals when they would, of course, be integral to the terminals. In addition, the figure shows the decoder separately, although manufacturers would usually incorporate this as a printed circuit board inside a terminal. For simplicity, the figure only shows the decoder for the television.

[9] R. Woolfe, *Videotex: The New Television-Telephone Information Services* (London: Heyden, 1980), pp. 26-36.

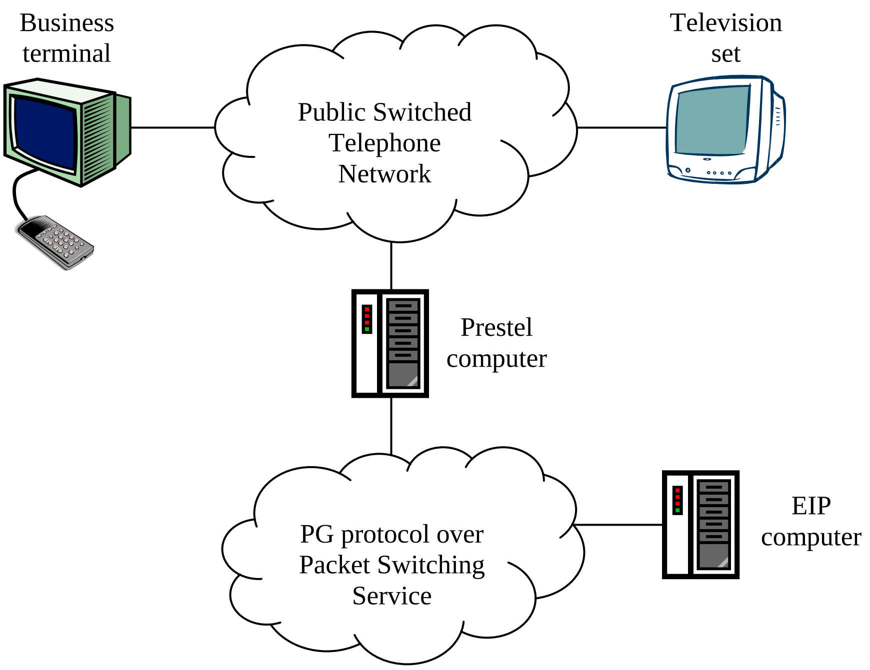

Figure H.5. Prestel Gateway.

Alphamosaic systems used a matrix of cells covering the screen of a terminal to display characters and basic graphics. Every character could have attributes associated with it, such as single or double height, and a viewdata system could encode these attributes either serially or in parallel. Both Prestel and Télétel were alphamosaic systems. However, they were both incompatible because they each used serial or parallel encoding and different amounts of memory for each character. Prestel used 8 bits, while Télétel's standard, Antiope, used 16 bits.

Alphageometric systems, such as Telidon, were more sophisticated than the alphamosaic systems. Instead of transmitting the graphics, which could be part of a viewdata frame, a viewdata operator could transmit instructions which the terminal could then use to generate an image. As the instructions were not dependent on the capabilities of the viewdata terminals, the resolution of the images and text increased as the terminals became more sophisticated. An example alphageometric system was Telidon.

[10] Another technology, known as Dynamically Redefinable Character Set, enabled videotex operators to extend the set of characters that a terminal could display, downloading these to DRCS compatible terminals. A terminal could therefore display a wider variety of symbols and graphics.

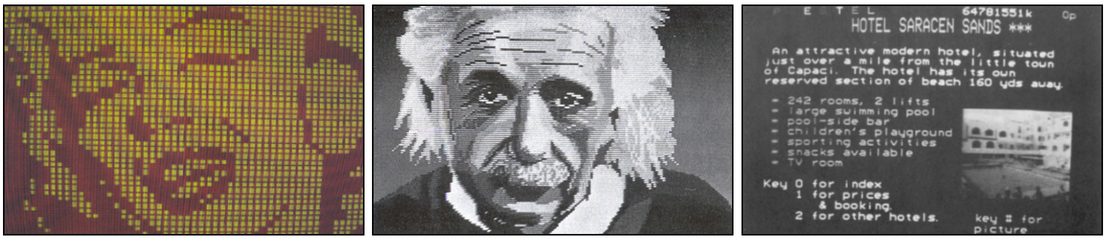

Figure H.6. Alphamosaic, alphageometric, and alphaphotographic display standards.

Alphaphotographic systems, such as Picture Prestel, transmitted every pixel within a frame, enabling companies to display photographs in stages.[11] A Picture Prestel frame would take about one minute to transmit.[12] Although this type of videotex display standard was more sophisticated than the alphamosaic and alphageometric alternatives, it meant that a videotex operator needed to transmit a lot of information to display a photograph. Transmission times were therefore slower with this display standard. To help improve transmission speeds, companies could reduce the size of photographs relative to the size of the videotex frame, and use alphamosaic and alphageometric elements within the frame.

H.6 Videotex Over IP

In the example shown in Figure H.7, a user runs a Minitel emulator on their PC. This software establishes a connection to a Télétel gateway using TCP/IP over the Internet.[13] The gateway then establishes a connection with a Télétel computer. A user can then use the Minitel emulator terminal to navigate through the inverted tree hierarchy of information frames stored on the videotex computer. As the communication between the PC and the remote Télétel computer begins, the gateway translates packets of data between TCP/IP and the X.25 Télétel videotex standard used on the Télétel network. It does this by obtaining the instructions from the user as to which videotex page they want to view which the system embeds within TCP/IP packets.

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[11] E.J.K. Bisherurwa, *Picture Coding Techniques for Videotex and Facsimile*, Ph.D. thesis (Colchester: Department of Electrical Engineering Science, University of Essex, 1983), p. 1.19.

[12] K.N. Ngan, *Picture Coding in Viewdata Systems*, Ph.D. thesis (Loughborough: Loughborough University of Technology, 1982), p. 37.

[13] People could also user TCP/IP to transmit videotex packets across a Local Area Network. See D. Mavrakis, et al., *Videotex URL Specification*, University of California, Irvine, 1997, Available from: http://ftp.ics.uci.edu/pub/ietf/uri/draft-mavrakis-videotex-url-spec-01.txt, Accessed on: 19 February 2004 and S.T. Jones, *Distributed Videotex on a Local Area Network*, Ph.D. thesis (Colchester: University of Essex, 1987), pp. 86-88 and 92-93.

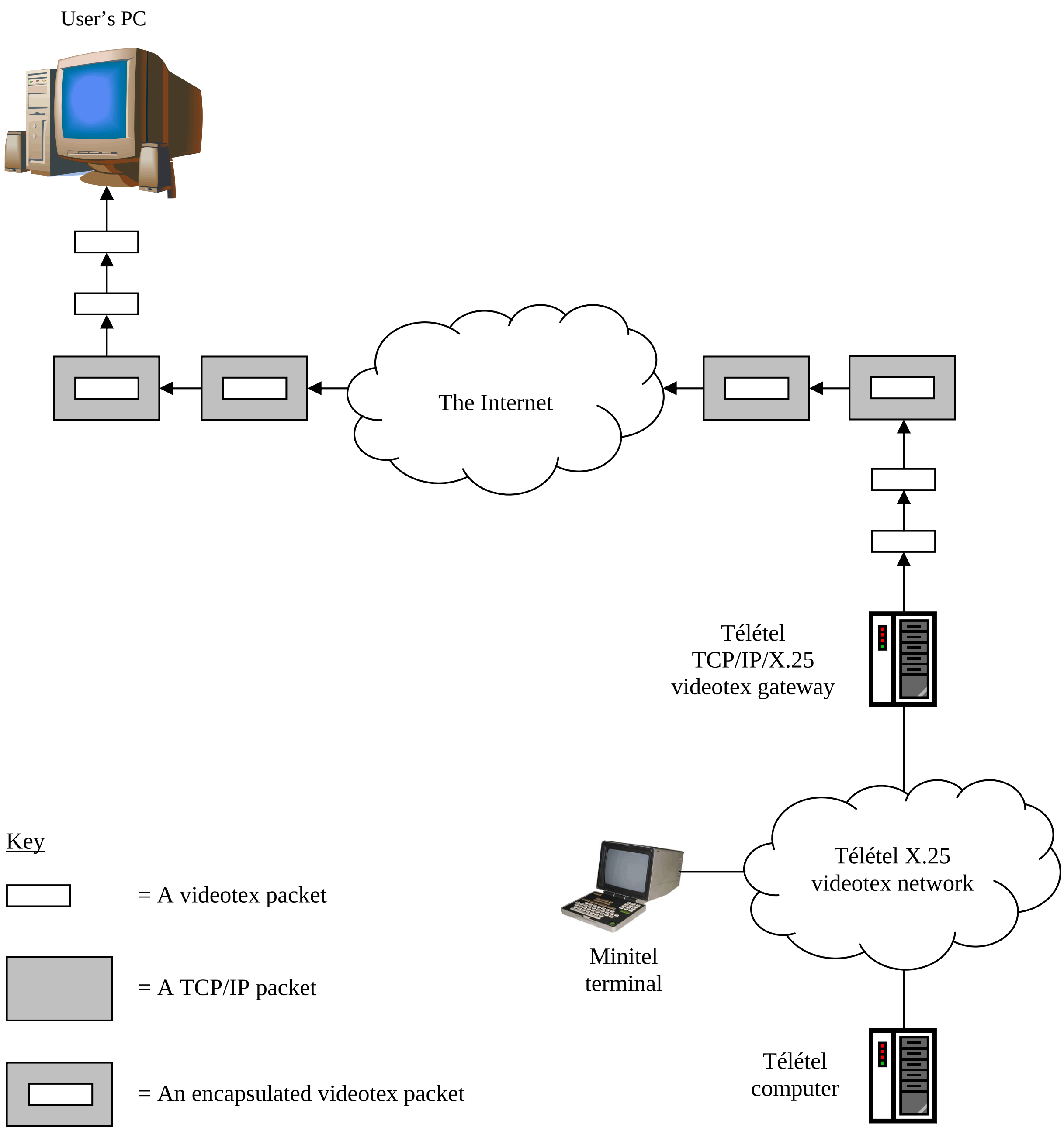

Figure H.7. Videotex over IP.[14]

It then passes this information onto the videotex computer which responds by transmitting the desired videotex frame. The Télétel gateway then encapsulates the videotex packets, which make up the information for the frame, within TCP/IP packets and then transmits these across the Internet. When the packets reach their destination, the Minitel emulator reverses this encapsulation process to extract the videotex data which it then displays on-screen.

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[14] For clarity, the figure shows the videotex packets as being separate from the encapsulated videotex packets, when in reality the encapsulated videotex packets are the only types of packet that exist on the Internet between the gateway and the Minitel emulator running on the PC.

Figure H.8 illustrates the layers involved in this process. The videotex data is composed of the underlying videotex display standard specifications and the data from the application, such as an information retrieval program, which a person is using. These layers use the services provided by the lower TCP/IP layers to transmit videotex packets across the Internet from the Télétel videotex gateway to the Minitel emulator running on a PC.

In addition to using an emulator, such as the Minitel emulator provided by France Télécom, companies could potentially provide access to their videotex networks from the Internet using Web browsers.[15] In 1997, a videotex Uniform Resource Locator scheme emerged which took the following form:

videotex://<host>:<port>/<videotexservice>;<attribute>=<value>

Unlike the Hypertext Transfer Protocol, the videotex URL would not specify an object, such as videotex page, but would stipulate a videotex service that was accessible from the Internet. A hypothetical example might be as follows:

videotex://acres.mctel.fr/demo

where ‘acres.mctel.fr’ refers to the host and ‘demo’ to the videotex service. If a user entered this videotex URL into their Web browser, the ‘demo’ videotex service would start immediately, and the user could then navigate through an inverted tree hierarchy of pages. As demand for accessing videotex networks from the Internet did not become significant, the videotex URL did not become widely adopted. If people wanted to access videotex networks from the Internet, such as Télétel, they would therefore usually do so using a videotex emulator instead of a Web browser.

[15] Mavrakis, et al., *Videotex URL Specification*.

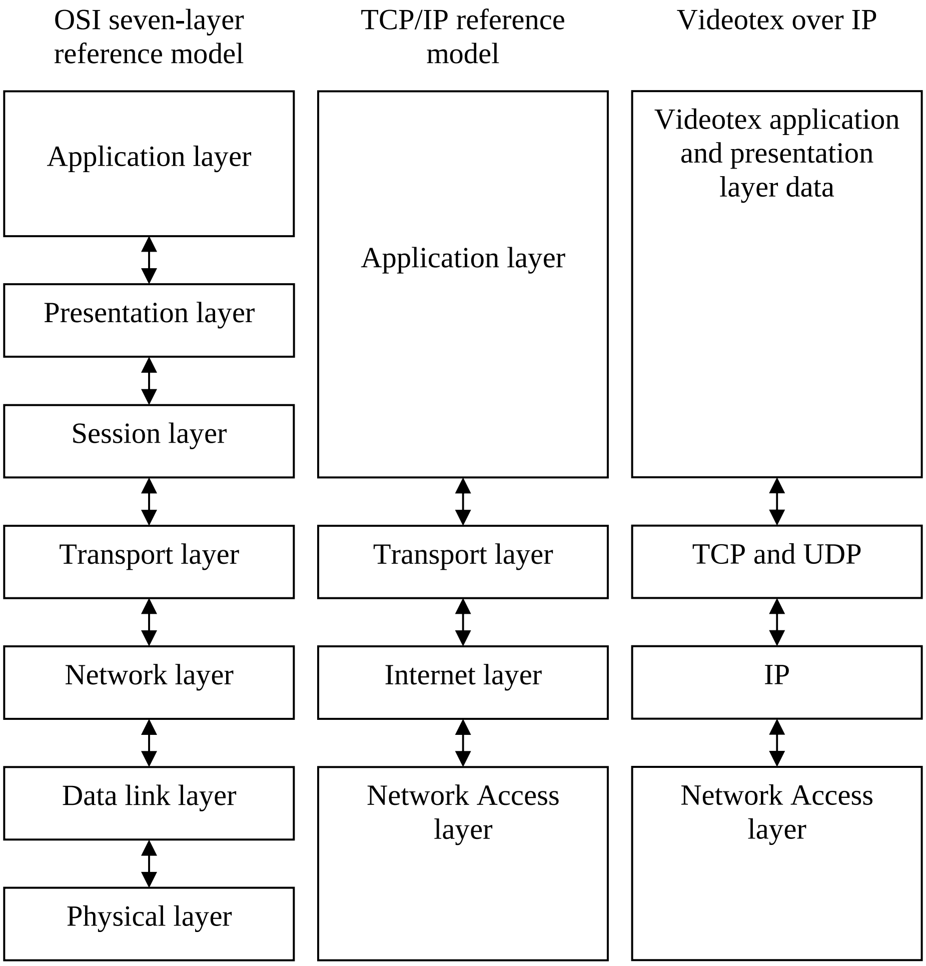

Figure H.8. OSI, TCP/IP, and videotex over IP.

Appendix I. CompuServe and Bulletin Board Systems

I.1 OSI, X.25, and CompuServe

CompuServe used the X.25 lower layer protocols to transmit packets of data created by the higher layers, in particular the application layer (see Figure I.1). CompuServe located its proprietary protocols in this layer.

I.2 Bulletin Board Systems

Although CompuServe provided over 3,000 services by the mid 1990s, the main facility which attracted the most use, apart from e-mail, were CompuServe's forums. These Special Interest Groups (SIGs) were a form of Bulletin Board System (BBS) which subscribers used to communicate with other people. However, CompuServe did not invent Bulletin Board Systems. During 1978, Ward Christensen and Randy Suess, two friends in Chicago, discussed the idea of providing electronic access to the newsletter of a club, the Chicago Area Computer Hobbyist's Exchange, via computers and modems. Both considered the possibility of providing the electronic equivalent of the club's cork noticeboard which members used to leave messages for one another. Christensen and Suess decided to set up an electronic noticeboard, using the XModem file transfer protocol, which Christensen had developed during 1977. Within one month, both had created the first BBS, known as the Computerized Hobbyist Bulletin Board System. Users could connect to the BBS, later known as the Computerized Bulletin Board System (CBBS), which Suess, as the system operator (Sysop), hosted on his personal computer at home.[1] People could leave messages for each other and this facility soon attracted hundreds of users, many of whom asked Suess for the BBS software, which he supplied.[2] In addition, both he and Christensen wrote an article for the November 1978 issue of the Byte magazine, explaining what the CBBS was and how the software worked, in an attempt to encourage other people to set up BBSs.[3]

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[1] D. Rapp, "From Bulletin Boards to Blogs," *Technology Review*, September 2003, p. 88.

[2] Like electronic mail, Bulletin Board Systems were an asynchronous technology, which meant that the person that read a message did not have to be online at the same time as the person who had created the message. See T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 436-437.

[3] W. Christensen and R. Suess, "Hobbyist Computerized Bulletin Board," *Byte*, November 1978, pp. 150-157. The CBBS closed during the early 1990s. By then, people had connected to the BBS more than a quarter of a million times. See Rapp, "From Bulletin Boards to Blogs," p. 88.

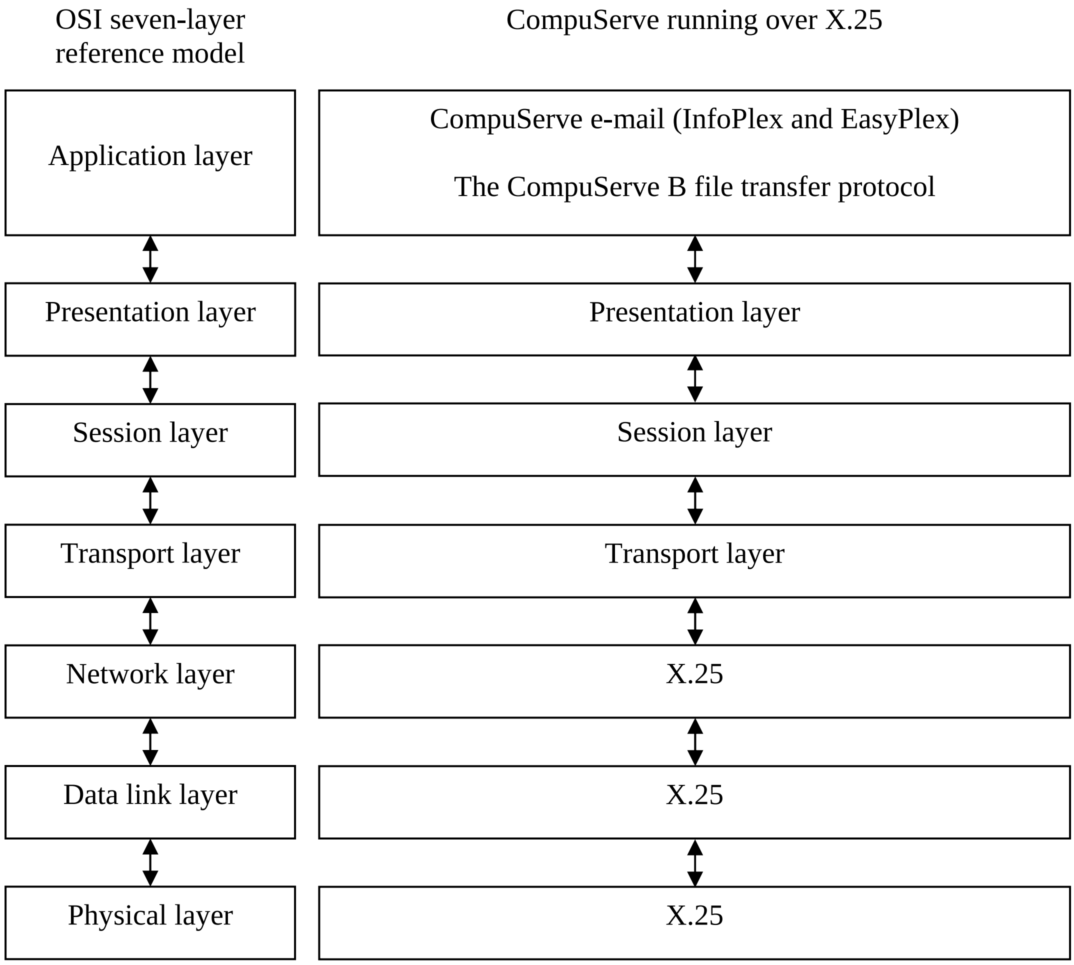

Figure I.1. CompuServe's protocols running over X.25.

Their efforts worked. Bulletin Board Systems started to emerge throughout the US during the early 1980s (see Figure I.2).[4] Privately run by hobbyist computer users, people used these systems to download software and communicate on many different subjects, including computers, the news, and science.

In addition to the Bulletin Board Systems run by individuals, larger BBSs emerged during the late 1970s and early to mid 1980s. The three most prominent were Usenet, FidoNet, and The WELL. In 1979, Tom Truscott and Jim Ellis, two graduates at Duke University in the US, decided that they wanted to create a computer network which would link UNIX machines together.

[4] It was not cheap to establish and then run a private BBS during the early to mid 1980s in the US. For instance, sysops would have to pay approximately $3,000 in start-up costs, followed by about $50 a month for expenses such as telephone bills and electricity. See P. Tootill, "Up and Running," *Personal Computer World*, April 1985, pp. 198-200.

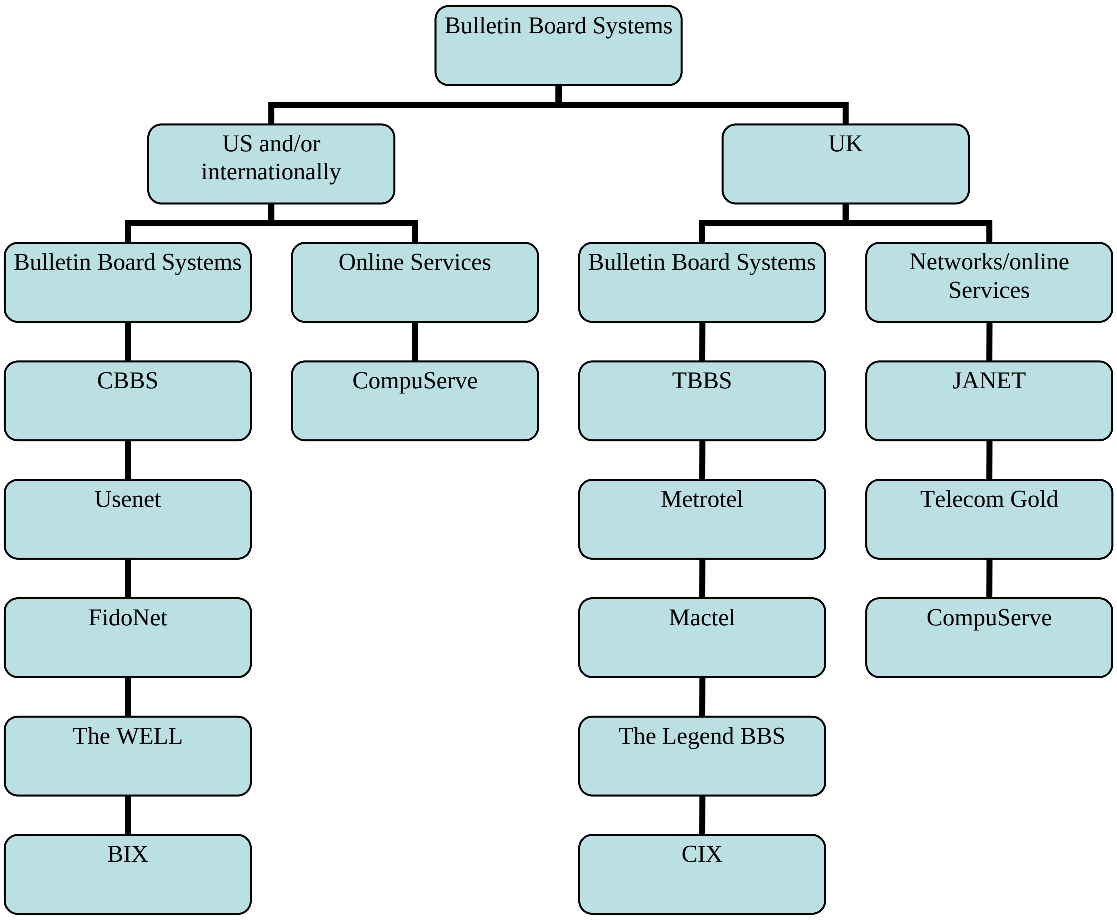

Figure I.2. Bulletin Board Systems.[5]

Using the UNIX-to-UNIX CoPy (UUCP) program and several other UNIX-related utilities, such as the find command, Truscott and Ellis created scripts which established connections between machines, determined the date of files, and updated older copies with newer versions.[6] This system became the basis for Usenet. A form of bulletin boards, known as newsgroups, started to appear which people could access from any UNIX machine that had access to a telecommunications circuit such as the PSTN or a leased line. The idea behind Usenet was to create a computer network for UNIX users, who could not access the ARPANET. People therefore referred to Usenet as the 'poor man's ARPANET'. Usenet originally used two hosts at Duke

[5] The figure shows Bulletin Board Systems, which existed in the US and/or internationally, as well as in the UK. BBSs either existed as part of a network or service, which also provided many other facilities, or on their own.

[6] M. Hauben and R. Hauben, *Netizens: On the History and Impact of Usenet and the Internet* (Los Alamitos, CA: IEEE Computer Society Press, 1997), pp. 39-41.

University.[7] Within a year, 100 sites transmitted 25 news articles between the computers everyday.

By the mid 1980s, there were Usenet hosts in several countries including the UK, France, Norway, and Australia. In 1988, 11,000 hosts throughout the world were transmitting 1,800 news articles a day. Thousands of people used programs, called newsreaders, to download lists of newsgroups to their computer. They then decided which newsgroup to subscribe to, and their newsreader downloaded the news articles for this group. People could then follow news threads of interest and contribute to these topics. Two other bulletin board networks followed Usenet. Tom Jennings and a friend John Madill established FidoNet during 1984 as a way of transmitting files from Jennings' Bulletin Board System to Madill's PC. FidoNet evolved during the 1980s, with nodes emerging throughout the US which people could use to access the BBS for discussion purposes and send and receive e-mails. From 100 nodes in 1984, this grew to 1,400 by 1986. Seven years later, there were 20,000 nodes throughout the world which approximately 2 million people accessed. Of these about 200,000 used FidoNet to send and receive e-mails.[8] The other BBS, which became prominent during the 1980s, was The WELL. In 1985, Larry Brilliant, owner of the computer conferencing firm Network Technologies International, decided that he wanted to set up a Bulletin Board System which people could use to communicate on many different topics. He approached Stewart Brand, founder of The Whole Earth Catalog magazine, and together they set up The Whole Earth 'Lectronic Link (WELL) during 1985.[9] Whereas Usenet adopted the moniker of newsgroups for Bulletin Board Systems, The WELL referred to BBSs as conferences. At this time, many people who used Bulletin Board Systems remained anonymous, using pseudonyms when posting messages to newsgroups or conferences. However, The WELL did not allow people to remain anonymous, as it wanted people to act responsibility, and saw the requirement to specify names as a way of achieving this aim.[10]

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[7] P.H. Salus, *Casting the Net: From ARPANET to Internet and Beyond* (Reading, MA: Addison-Wesley, 1995), p. 135.

[8] R. Busy, "FidoNet: Technology, Tools, and History," *Communications of the ACM,* vol. 36, no. 8, 1993, pp. 31-35.

[9] The Whole Earth Catalog targeted people who wanted to influence and improve subjects such as politics, the environment, and education. See *About the WELL*, The WELL, 2002, Available from: http://www.well.com/background.html, Accessed on: 11 September 2004.

[10] C.J.P. Moschovitis, et al., *History of the Internet: A Chronology, 1843 to the Present* (Oxford: ABC-Clio, 1999), pp. 127-129.

The US was not the only country where Bulletin Board Systems emerged. Throughout the 1980s, BBSs appeared on many computer networks such as Télétel. In the UK, they arrived on existing networks, such as JANET and Telecom Gold, and on new services. There were two main types of BBS in the UK during the 1980s: private Bulletin Board Systems and commercial services, most notably the Compulink Information eXchange (CIX). Private BBSs started to emerge during the late 1970s. Computer hobbyists acquired the necessary hardware and software and then magazines, such as Personal Computer World, started to provide listings of the BBSs people could access, together with brief details of the systems. As individuals ran these private bulletin boards, several of the systems were only accessible during certain hours and every one required users to establish dial-up connections to the host computer, no matter where this machine was in the UK. Once connected, BBSs usually presented a log on screen, followed by the main menu. For example, if a user wanted to access the privately run Typical Bulletin Board System (TBBS) in Liverpool, they would encounter the log on screen followed by a menu that contained a list of commands which people could use to access the facilities provided by the Liverpool Mailbox TBBS (see Figure I.3 and Figure I.4).

Although most privately run BBSs only provided basic facilities, such as the ability to view and contribute posts to different topics, some, including the Liverpool Mailbox TBBS, provided additional features. For example, people could use this system to send and receive e-mails to other compatible BBSs and upload and download software. In addition, it overcame the limitation of restricted access hours, by enabling people to connect to the TBBS 24 hours a day. Like most privately run systems, users could access the Liverpool Mailbox for free, excluding the cost of the telephone call.

Many people established Bulletin Board Systems in the UK during the 1980s. To help promote compatibility between the disparate BBSs, several sysops decided to establish the Association of Free Public Access Systems, during the early 1980s. In 1983, this Association decided to adopt the 300 bps CCITT V.21 modem standard for all BBSs that were part of this group.

```
Welcome to TBBS European Headquarters

* * *  LIVERPOOL MAILBOX  * * *

Britain's first 24 hour microcomputer bulletin board!

Member of the Association of
    Free Public Access Systems.

Liverpool mailbox needs sponsors
See news section for details

First Name? joe
Last Name?
```

Figure I.3. Log on screen for the Liverpool Mailbox TBBS circa 1985.[11]

By 1986, 98% of the 33 systems used this standard.[12] The number of systems continued to increase throughout the late 1980s and early 1990s. By 1987, there were over 100 private BBSs in the UK, with names such as Metrotel and Mactel.[13] In addition, some BBSs were nodes in the international FidoNet, with names including Dataflex Fido and Access Fido. By 1991, the number of BBSs had increased to over 255 in England, 14 in Scotland, 8 in Wales, and 1 in Northern Ireland.[14] However, when the Web became popular from the mid 1990s onwards, most of these systems disappeared.

In addition to private BBSs, several commercial companies established systems during the 1980s and early 1990s. Some, such as the Legend Bulletin Board, offered users access to more than 2 gigabytes of files for the cost of a telephone call and an additional charge of 39 or 49 pence a minute, depending on the time of day a user accessed the service.[15] Others, such as the Compulink Information eXchange, offered subscribers many facilities.

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[11] P. Tootill, "Bulletin Boards: Get on the Phone to Your Micro," *Personal Computer World*, November 1983, pp. 148-149.
[12] See P. Tootill, "Over and Out!" *Personal Computer World*, October 1986, pp. 212-213 and *The Newsletter of the National Dragon Users Group*, The National Dragon User Group, 1986, Available from: http://members.aol.com/kjnash/update/DRGUP020.HTM, Accessed on: 12 June 2005.
[13] P. Tootill, "UK Bulletin Boards," *Personal Computer World*, April 1987, pp. 214-215.
[14] G. James, "Bulletin Boards," *Personal Computer World*, August 1991, pp. 275-276.
[15] "The Legend Bulletin Board," *Personal Computer World*, November 1995, p. 311.

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<R>ead Messages on main board
<S>can Messages on Main Board
<E>nter Messages on Main Board
<K>ill messages on main board
<M>ail ... Electronic mail section
<G>roups ... Special Interest Groups
<H>ow-Long ... Elapsed Time on System
<T>erminate Session
<I>nfo ... System Information
<N>ews Bulletins
<D>ownload Programs
<£>Upload ... Submit programs
<U>serlog ... List of callers
<C>hat ... Talk to SYSOP
<A>gain ... Re-logon to system
<P>roducts ... List of Merchandise
<O>rder ... Place Merchandise Order
<L>ocal features and utilities
```

Figure I.4. The main menu of the TBBS in Liverpool.[16]

CIX began like most BBSs. Frank and Silvia Thorney obtained shareware from the US and then set up their system, Compulink, using a computer in their home. In addition to acting as sysops, the Thornleys' also started to offer a shareware distribution service, enabling people to obtain software from Compulink which would acquire the shareware from the US and then post it to users. This service became popular and they used the funds from this venture to invest in Compulink. They then decided to purchase a licence for a conferencing system, called CoSy, which the University of Guelph in Ontario had developed during the early 1980s.[17] Several companies used this software including the magazine Byte, with its Byte Information eXchange (BIX) service, the Open University, and other institutions such as the University of Arizona.[18] Launched in 1987, the Compulink Information eXchange offered users the ability to read and contribute to newsgroups and access other facilities such as downloading software. As well as offering conferencing facilities, CIX also enabled people to send and receive e-mails. Unlike private BBSs, which

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[16] Ibid.
[17] D. Winder, "Just for Cix," *PC Pro*, October 2002, pp. 201-203.
[18] On BIX see S. Gold, "BIX Clever," *The Guardian*, 5 December 1985, p. 16. On the CoSy conferencing system and the Open University's adoption of this software see R. Thomas, "Talking to More Purpose," *The Guardian*, 14 January 1988, p. 17. On the University of Arizona's use of CoSy see B.H. Maginnis, "Computer Conferencing at the University of Arizona," *Proceedings of the 17th Annual ACM SIGUCCS Conference on User Services, Bethesda, Maryland, 1989* (New York: ACM Press, 1989), pp. 263-267.

usually only had one telephone line that connected users to the system, CIX was a multi-user BBS. Within one year, there were more than 200 conferences on the service. Users paid a registration fee of £13.80 followed by £2.53 an hour during the day and £1.38 an hour during off-peak periods.[19] Although people could use standard communications software, such as Procomm Plus, to access CIX, many preferred to use an Offline Reader (OLR), as these saved money by automating the task of downloading new messages from conferences and new e-mails.[20] Many people used an OLR, known as A Most Excellent Offline Reader (AMEOL), to connect to the service (see Figure I.5).[21]

Using software such as AMEOL, CIX subscribers communicated with other users and downloaded the latest drivers for their hardware or updates for programs. Before CompuServe set up its service in the UK during 1990, CIX was the main online service which people used to obtain software updates for their PCs. In addition to PC users, who were the principal type of user, journalists were also attracted to CIX. Initially this meant magazines, such as Personal Computer World and PC Magazine, establishing conferences, but soon many journalists were using the service to file copy to publishers, communicate with readers and other journalists, as well as keeping up to date with news, and downloading software.[22] By 1995, the Compulink Information eXchange, had become the largest Bulletin Board System in the UK with 15,000 users. However, by then, its subscribers wanted to access the Internet. CIX therefore planned to launch itself as an ISP during 1995 which would enable people to access facilities such as telnet, FTP, and the World Wide Web.[23]

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[19] P. Tootill, "Talking Big," *Personal Computer World*, September 1988, pp. 188-189.
[20] S. Rodda, "For External Use Only," *Personal Computer World*, June 1995, pp. 554-556.
[21] B. Ure and S. Palmer, *AMEOL: The Off-line Reader for CIX* (Surbiton, Surrey: CIX Ltd, 1994).
[22] For instance, during the mid 1980s, Personal Computer World established the pcw/news conference on CIX for computer news. PC Magazine followed this with a conference, which enabled people to communicate with the readers of the magazine in different newsgroups, download software, and contact the editor. See "CIX 'n' BIX Online," *Personal Computer World*, December 1987, pp. 78 and 83 and "PC Magazine Goes for CIX," *PC Magazine*, May 1990, p. 17. Some journalists therefore used CIX in a similar way to which other journalists used Newslink. However, CIX never dedicated its service to the needs of publishers as Newslink did. It was a BBS, which also offered e-mail facilities, which journalists used to file copy for stories. See J. Schofield, "Diary," *Personal Computer World*, June 1991, p. 7.
[23] D. Brake, "CiX Takes its First Steps into the Graphical Web," *Personal Computer World*, April 1995, p. 302. Other BBSs, such as the Legend BBS, also offered Internet access services from the mid 1990s onwards. See "The Legend Internet BBS," *Personal Computer World*, May 1996, p. 216.

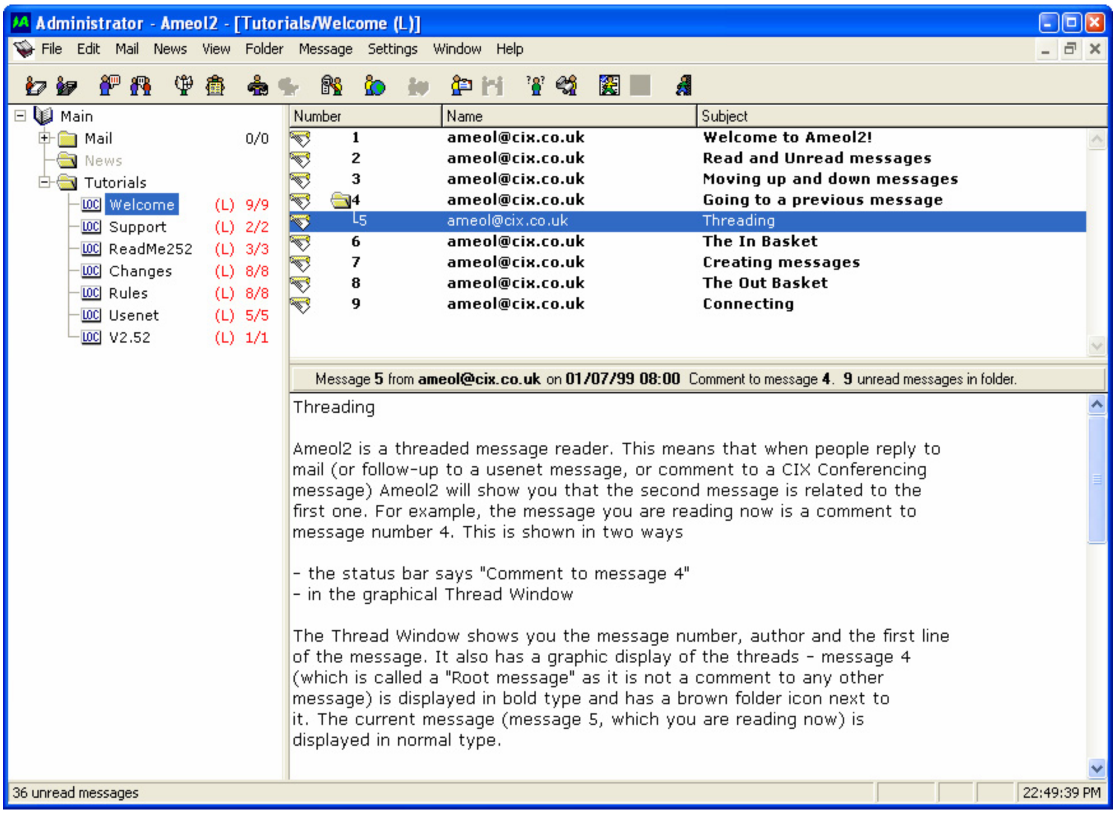

Figure I.5. The AMEOL Offline Reader.

By the time that CIX had launched itself as an ISP, people could use Web browsers to access Bulletin Board Systems such as Usenet, The WELL, CIX, and other BBSs.[24] In 1995, The WELL launched a new service, The WELL Engaged, which enabled people to access the BBS using a Web browser. By then, 10,000 people used The WELL. During the same year, the Deja News company launched a Web site that provided access to Usenet. In 2001, Google acquired Deja News, and integrated access to Usenet via its Web site.[25] In 2005, there were over 54,000 newsgroups on Usenet, accessible from both newsreaders and Web sites such as Google's Groups (see Figure I.6).[26] By then, Usenet had become the largest Bulletin Board System in the world.

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[24] *The WELL Debuts WELL Engaged, its New Graphical Interface*, The WELL, 1996, Available from: http://www.well.com/p-release/release02.html, Accessed on: 11 September 2004.
[25] *Groups Help*, Google, 2005, Available from: http://groups.google.co.uk/support/bin/static.py?page=basics.html, Accessed on: 12 June 2005.
[26] *Group Directory*, Google, 2005, Available from: http://groups.google.co.uk/groups/dir?hl=en&sel=33554433, Accessed on: 12 June 2005. As there are many Usenet servers throughout the Internet, Google Groups is not the only service to provide access to Usenet. Other examples include ISPs, such as Blueyonder, which supply access to Usenet for their customers.

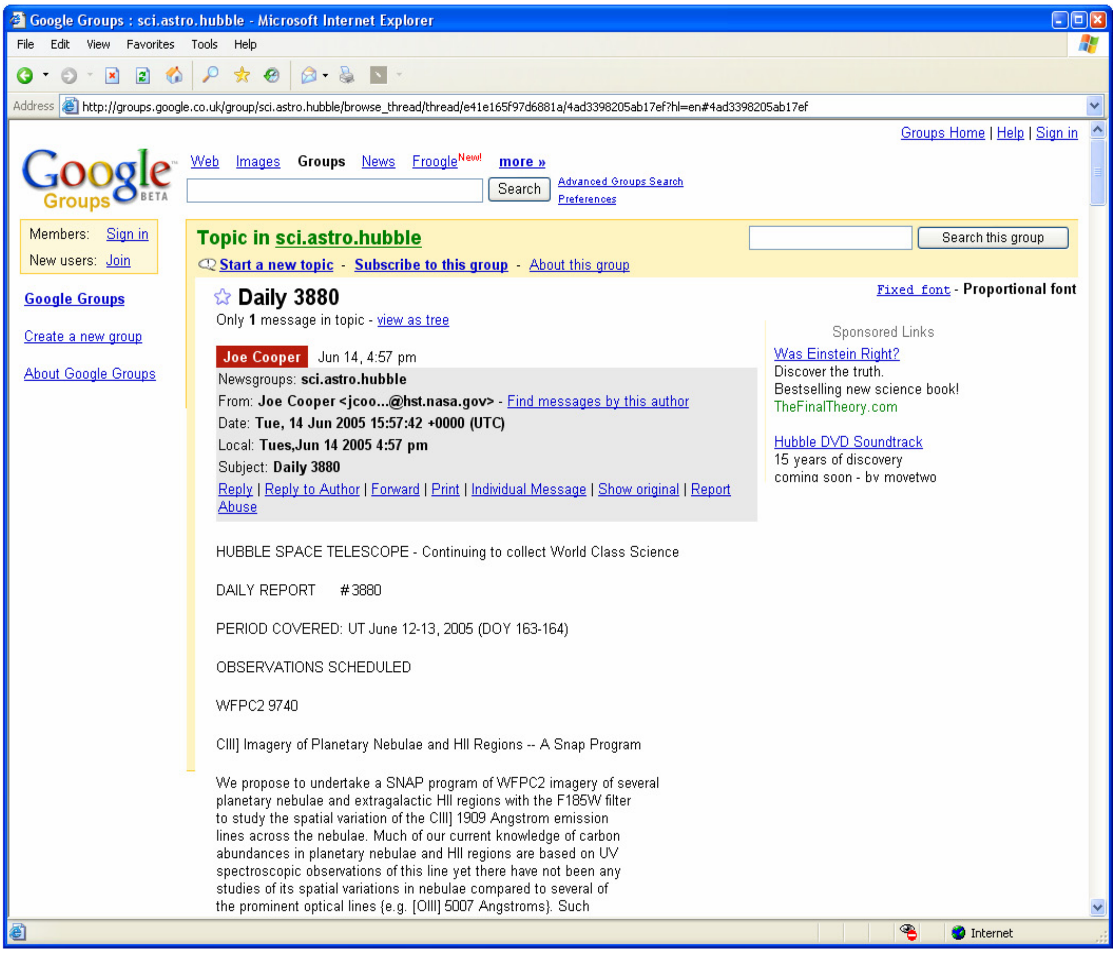

Figure I.6. Accessing a Usenet newsgroup using Google Groups.

Appendix J. The DNS and the NRS

J.1 The Domain Name System

Every computer on a network must have a unique address which identifies that computer on the network. On networks that use the Internet Protocol suite, computers use Internet Protocol numbers for this task. These numbers are quite long and can therefore be difficult to remember.[1] An example is the IP address for the 'One NASA' Web site: 204.200.223.156. To make things easier, the Domain Name System (DNS) translates names into addresses. It arranges the Internet into a logical hierarchy, with the root domain at the top, followed by country and generic domains (see Figure J.1). Country domains include .uk and .fr, and generic domains include .com and .org. Second-Level Domains (SLDs) follow these Top-Level Domains (TLDs), and in the UK these include .co.uk and .ac.uk. Beneath these are organisation specific domains such as .warwick.ac.uk and .ucl.ac.uk. Lower down the hierarchy, departments within institutions and organisations can have their own domains, such as .cs.ucl.ac.uk. Therefore, if a person using a computer in the Computer Science department of University College London wanted to visit the 'One NASA' Web site, they would type http://www.onenasa.nasa.gov into their Web browser. The browser would then ask a local DNS server if it knew the address for this site. If not, this process of querying DNS servers up the hierarchy would continue until a server returned the correct address which the browser would then use to download the appropriate Web page.[2]

J.2 The Name Registration Scheme

JANET's Name Registration Scheme (NRS) worked in a similar way to the DNS. It stored 12-bit addresses for host computer systems and then translated names into the appropriate addresses. The Network Executive controlled the range of addresses available this process.

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[1] This problem is not new. For example, new telephone numbers can be hard to remember. To help people to remember a telephone number and the name of a business, many companies in the US use the letters written onto the keys of a telephone's keypad to create words. Examples include Expedia's 1-800-EXPEDIA, Apple Computer's 1-800-MY-APPLE, and AT&T's 1-800-CALL-ATT. Written as numbers these are 1-800-397-3342, 1-800-692-7753, and 1-800-225-5288 respectively.

[2] K. Siyan and T. Parker, *TCP/IP Unleashed*, 3rd ed. (Indianapolis, IN: Sams, 2002), pp. 120-122.

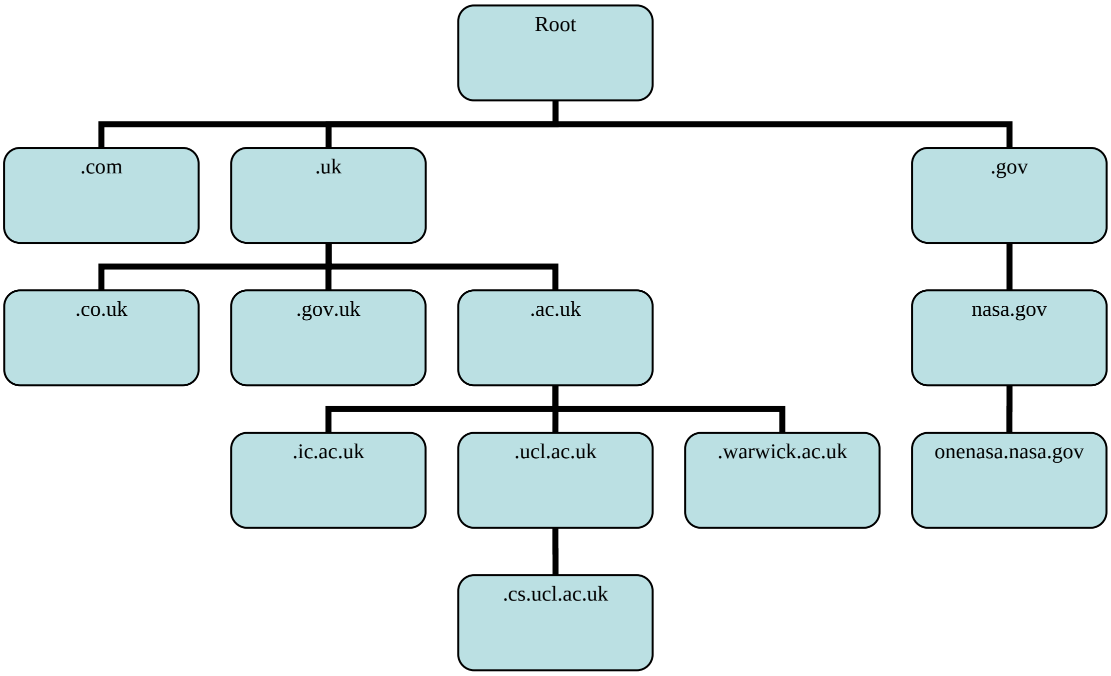

Figure J.1. The Domain Name System.

Operators at JANET's Network Operations Centres (NOCs) then assigned addresses from their range of numbers to machines within their local domain. One of the differences between the NRS and the DNS was that while the Internet's system listed the Top-Level Domain at the end, the NRS listed this information first. People referred to these systems respectively as the "little endian" and "big endian" order for domain names.[3] The Computer Science department at University College London was therefore uk.ac.ucl.cs using the "big endian" order, compared to its "little endian" equivalent on the Internet, .cs.ucl.ac.uk.[4]

[3] J. Sharp, *Name Ordering*, UKERNA, 1994, Available from: http://www.ja.net/services/publications/archive/newsletters/network-news/issue42/name.html, Accessed on: 11 October 2005.
[4] M. Patel, *The Joint Academic Network JANET* (Manchester: University of Manchester, 1988), pp. 20-21.

Appendix K. Protocol Migrations

K.1 JANET IP Service

The JANET IP Service worked by tunnelling TCP/IP packets over the X.25 JANET network. Tunnelling enables a network that uses one type of protocol, such as X.25, to transmit packets created by a different type of protocol, such as TCP/IP. This process is similar to how TCP/IP encapsulates data. In the example shown in Figure K.1, User A wants to transmit information to User B. JIPS encapsulates the TCP/IP packets, which make up the information, within X.25 packets and then transmits the packets across JANET. When the packets reach their destination, the JANET IP Service reverses the process. An analogy is to think of a Eurostar train transporting cars through the Channel Tunnel. The train, cars, and protocols are transportation mechanisms for different types of entities. When a Eurostar transports a car through the tunnel, it is moving another type of transportation vehicle from one place to another.[1] The same process was also true of the JANET IP Service. X.25 transported TCP/IP packets throughout the network.[2]

K.2 The Transition to TCP/IP

The first stage in the transition from X.25, the Coloured Books, and OSI to the Internet Protocol suite, involved the X.25 over TCP/IP (XoT) service. XoT worked by tunnelling X.25 packets over the TCP/IP JANET network. In the example shown in Figure K.2, User A wants to transmit information to User B. XoT encapsulates the X.25 packets, which make up the information, within TCP/IP packets and then transmits the packets across JANET. When the packets reach their destination, the XoT service reverses the process.

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[1] On tunnelling, including the Channel Tunnel analogy, see A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 425-426.

[2] Several technologies replaced JIPS. One of the first technologies used by UKERNA was native TCP/IP which involved JANET transmitting TCP/IP packets over leased lines that UKERNA dedicated to TCP/IP traffic. Other alternatives included transmitting TCP/IP over SMDS, PDH, ATM, SDH, and DWDM.

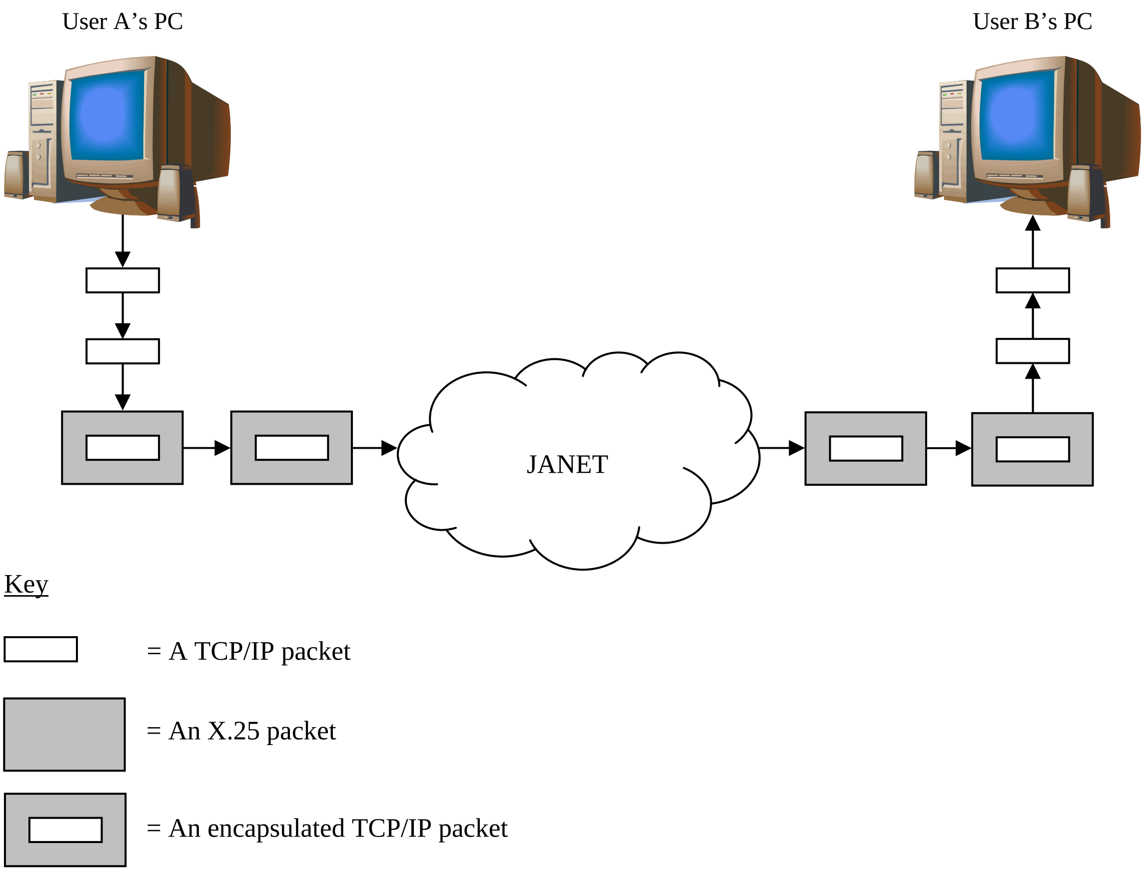

Figure K.1. The JANET IP Service.

UKERNA also launched the Terminal Access Conversion Service (TACS), the FT-relay service, and the Mail Conversion Service (MCS) to assist with the transition to the Internet Protocol suite. One of the first services that people developed on the early computer networks was the ability to use a computer to control a remote host. Several standards emerged to control this communication, including X.25's X.29 standard, and the Internet's telnet protocol. As the academic community used both X.29 and telnet, TACS provided a conversion service which enabled people to access facilities provided by incompatible remote hosts. A person using X.29 could therefore login to a remote host that used the Internet telnet protocol.[3]

[3] *The JANET Terminal Access Conversion Service Guide*, UKERNA, 2001, Available from: http://www.ja.net/documents/TACS/tacs5.html, Accessed on: 31 July 2004.

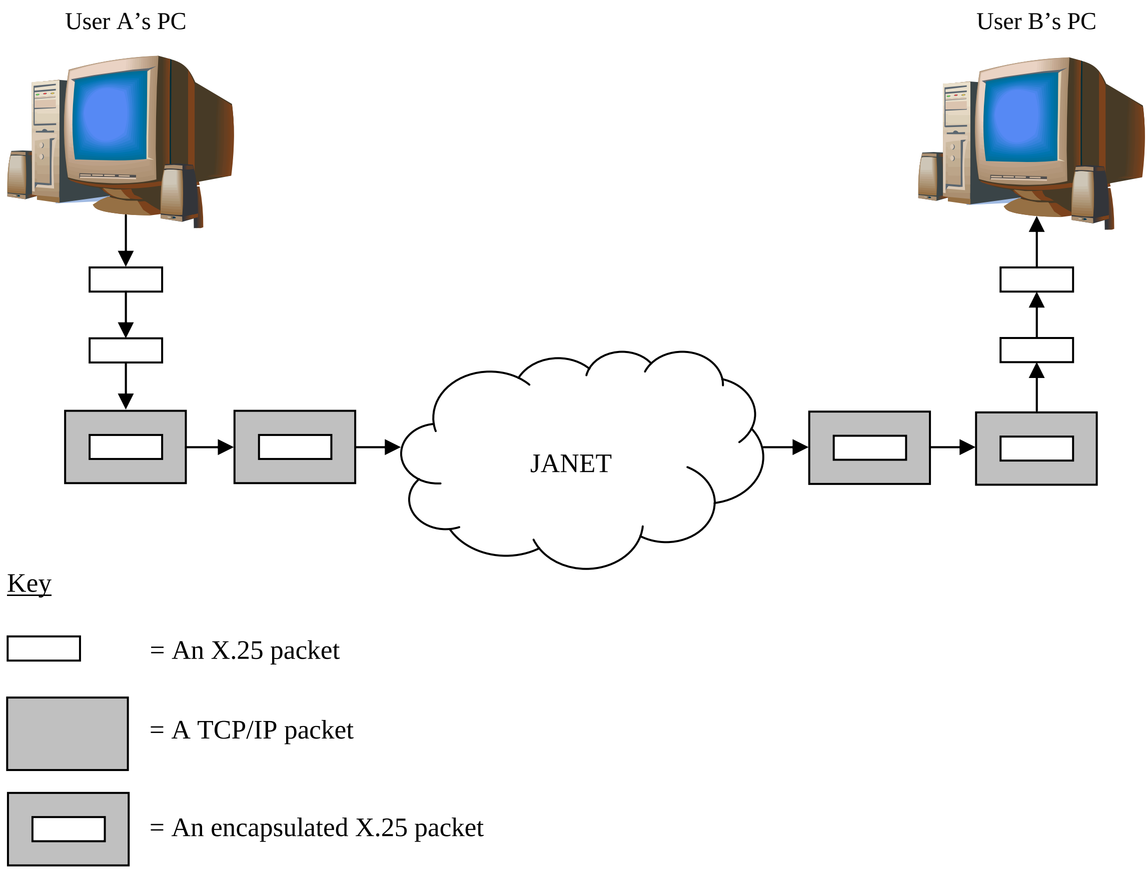

Figure K.2. The X.25 over TCP/IP service.

Another service to emerge on the early computer networks was the ability to transmit files from one computer to another. People developed several standards for the file transfer process, including the academic community's Blue Book standard, the OSI File Transfer Access and Management standard, and the Internet's File Transfer Protocol. UKERNA's FT-relay service provided a conversion service between the three protocols. A gateway existed between users and remote hosts, and this enabled, for example, a person who used the Blue Book file transfer protocol, to download a file from the Internet.[4]

During the 1980s and 1990s, incompatibilities between different e-mail protocols meant, for example, that a person who used the Grey Book protocol could not communicate with someone that used SMTP.[5] To solve this problem UKERNA

[4] K. Lewis, *File Transfer to the Internet*, UKERNA, 1991, Available from: http://www.ja.net/documents/NetworkNews/Issue34/news34.txt, Accessed on: 31 July 2004.
[5] Although both the Internet and JANET used the same e-mail header format, they used different protocols to transmit e-mails: the Internet used SMTP while JANET used the Blue Book file transfer

provided the Mail Conversion Service. The MCS provided a central mail relaying service which received e-mails, translated them between the source and destination protocols, and then relayed them towards their destination. A person who used the Grey Book protocol could therefore send and receive e-mails to people who used SMTP on JANET or on the Internet.[6]

Figure K.3 provides an overview of the protocols involved in the migration process.

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protocol as part of the Grey Book interim standard. Both SMTP and the Blue Book were incompatible with each other.

[6] T. Clark, *Mail Conversion Service*, UKERNA, 1995, Available from: http://www.ja.net/documents/Mailguide/mailguide-8.html#8, Accessed on: 31 July 2004.

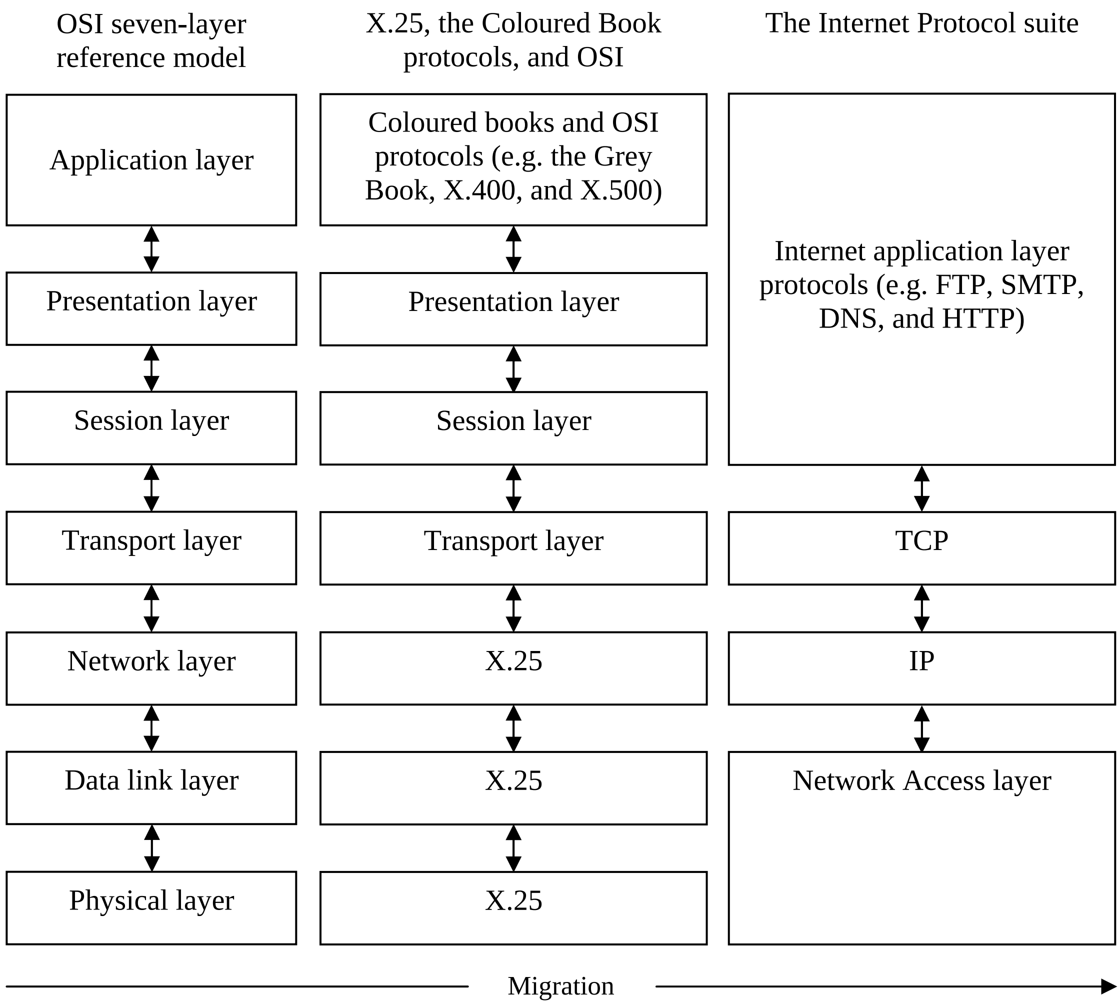

Figure K.3. OSI, X.25, the Coloured Book protocols, and the Internet Protocol suite.

Appendix L. Electronic Mail, X.400, and X.500

L.1 OSI, X.25, and Public E-mail Networks

Public electronic mail networks, such as Telecom Gold, used the X.25 lower layer protocols to transmit packets of data created by the higher layers, in particular the application layer, which is where companies located the proprietary e-mail protocols (see Figure L.1). Protocols for accessing third party databases were also located in this layer of the OSI reference model.

L.2 Gateways Between Telecom Gold and Online Databases

When a user logged onto Telecom Gold in order to access an online database provided by a third party provider, they first connected to one of Telecom Gold's computers via the Telecom public network and the Goldnet LAN (see Figure L.2). This computer then established a connection with the external database using PSS. Once connected, Telecom Gold together with the provider converted the data supplied from the database into a format that the e-mail service could display on-screen in a format that a user was already familiar with which made accessing these external sources of information as easy to use as possible. Both Telecom Gold and the third party databases used American Standard Code for Information Interchange (ASCII) text format which made communication between the e-mail service and the external online sources of information relatively easy, especially when compared with BT's other network Prestel.

L.3 X.400

X.400 operated at the presentation and application layers of the OSI seven-layer reference model. The X.400 (1984) Red Book and X.400 (1988) Blue Book standards contained several protocols, as shown in Figure L.3.[1]

[1] One of the differences between the X.400 (1984) and X.400 (1988) standards was that the former standard could not transfer files between computers, a fact that limited its appeal for anyone that wanted to transmit files such as spreadsheets. Although the 1988 and 1992 revisions of X.400 added file attachment capabilities and other solutions to this problem appeared, most organisations never adopted them. See K. Scott, "X.400 Gateways Exchange Graphics, Spreadsheets," *Data Communications*, May 1990, pp. 153-154.

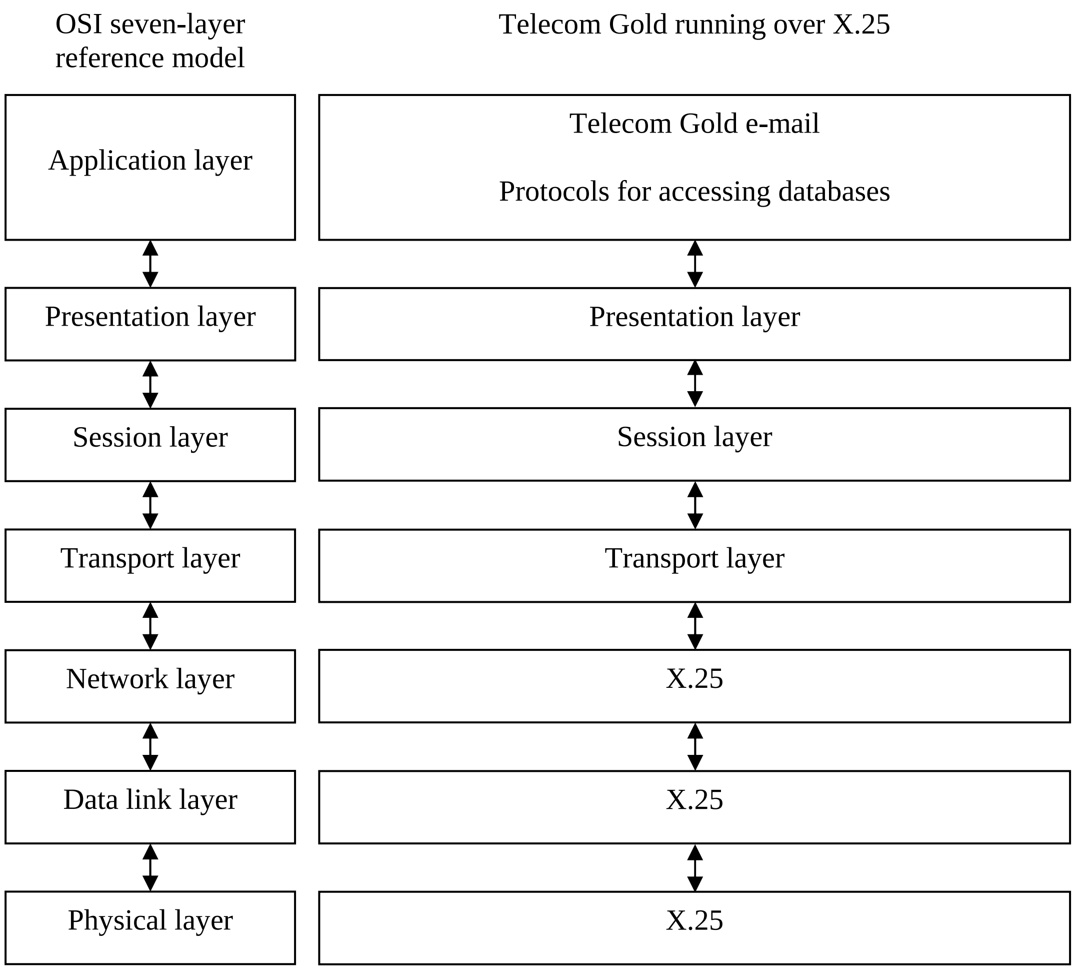

Figure L.1. Telecom Gold running over X.25.

These protocols used the services provided by the OSI compatible session and transport layers, the X.2 series of recommendations, which in turn used the facilities supplied by X.25.[2]

X.400 worked in a similar way to how SMTP e-mail works on the Internet, but with some important differences. X.400 was a Message Handling System (MHS) which enabled incompatible e-mail systems to exchange messages. If a company wanted to create a private network, it would establish a Private Management Domain (PRMD), whereas if a company wanted to provide a public service it would establish an Administrative Management Domain (ADMD). In the example shown in Figure L.4, X.400 connects several incompatible e-mail systems. Although some companies did use X.400, no single system existed to interconnect every system shown below.

[2] See C. Betanov, *Introduction to X.400* (Boston: Artech House, 1993), pp. 1-77 and 195-243 and J. Cashin, "E-mail Standard Marks Progression toward OSI," *Software Magazine*, December 1990, pp. 91-95.

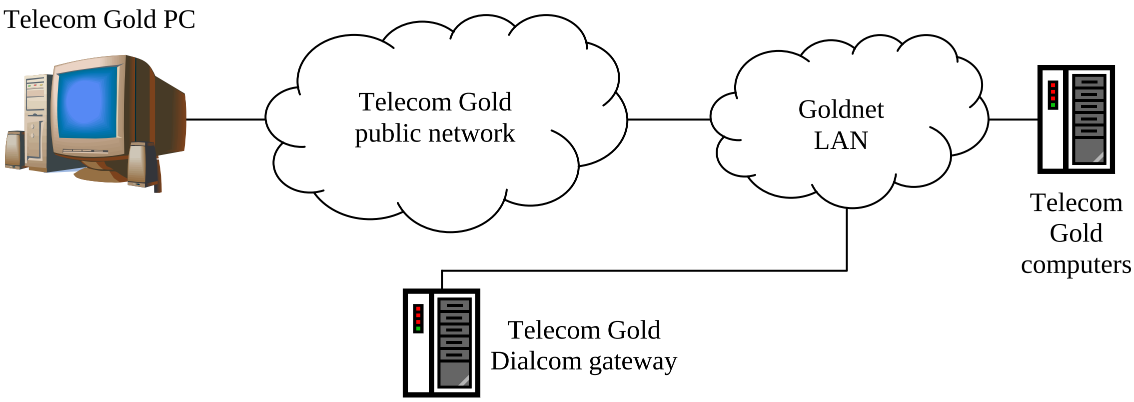

Figure L.2. A Telecom Gold gateway to an online database.

Companies could run X.400 over X.25 and TCP/IP networks. Message Transfer Agents (MTAs) interconnect every ADMD which also contain several User Agents (UAs) that provide the interface between a user's e-mail client and an MTA.[3] Originally, the UAs resided on the computer where a user received their e-mails but with the emergence of PCs, this changed so that a user could use an UA, which was part of an e-mail client, to connect to a remote server to collect their messages. This is the reason why computer scientists developed POP3 and IMAP4.

An alternative to a global e-mail network that contained an interconnected network of X.400 MTAs, was the use of X.400 gateways at the edge of networks. These gateways would provide the necessary translation facilities needed to convert messages and addresses between proprietary formats and the formats used by X.400 (see Figure L.5).

X.400 electronic mail addresses could contain a lot of information and it is for this reason that they were more complicated than the addresses used on networks such as Telecom Gold, JANET, or the Internet.[4] Even shorthand versions of an X.400 address could be hard to understand and remember.[5]

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[3] People use the terms User Agent and Mail User Agent (MUA) interchangeably.
[4] On X.400 O/R addresses see Betanov, *Introduction to X.400*, pp. 30-45.
[5] X.400 addresses could contain nine or more attributes, although people usually preferred to use a shortened 6-attribute version. During the late 1980s and early 1990s, people recognised that the X.400 addressing structure was too complicated, especially when compared to the format used on the Internet, which was simple. If X.400 was to compete with the Internet, then they would need to simply the X.400 addressing structure. Several potential solutions emerged including reducing the number of attributes from nine or more down to six, and from six to a more manageable two. People also suggested that people use address books to hide the complexity of addresses. None of these options became widely adopted. See P. Merenbloom, "X.400 Headache No. 1: Simplify the Addressing Scheme," *InfoWorld*, p. 47, R. Grimm and D. Heagerty, "Recommendation for a Shorthand X.400

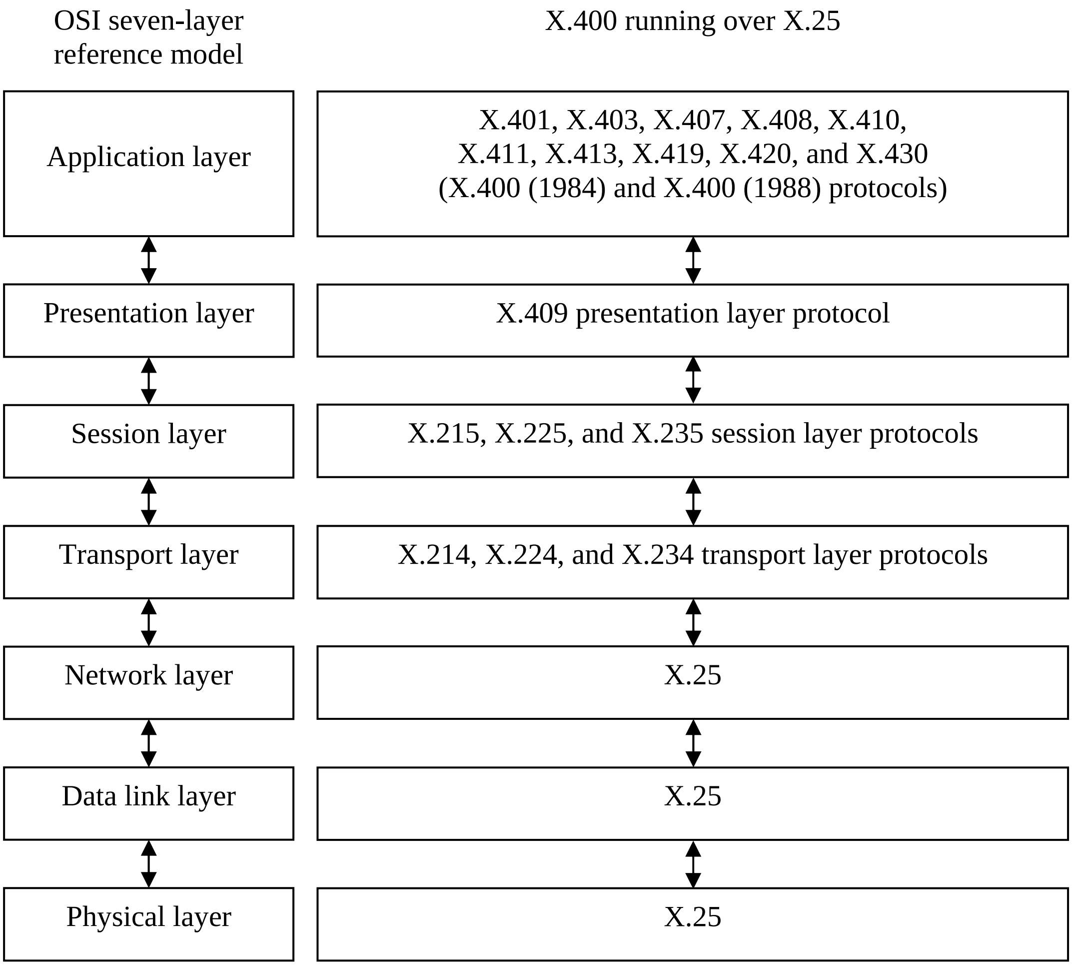

Figure L.3. X.400 running over X.25.

X.400 Originator/Recipient (O/R) addresses contained several attributes, including country, organisation, and personal names. Table L.1 provides a list of some of the attributes.

The following example is a simplified 6-attribute X.400 O/R address:

G=Rebecca; S=Clark; O=UCL; OU=CS; P=uk.ac.; C=GB.

where G = Given name, S = Surname, O = Organisation, OU = Organisation Unit, P = Private Management Domain, and C = Country.

The equivalent Internet e-mail address would be r.clark@cs.ucl.ac.uk.

Address Notation," *Computer Networks and ISDN Systems*, vol. 17, no. 4-5, 1989, pp. 263-267, and B. Brown, "E-mail Community Pushes to Simplify X.400 Addresses," *Network World*, 24 May 1993, pp. 2 and 6.

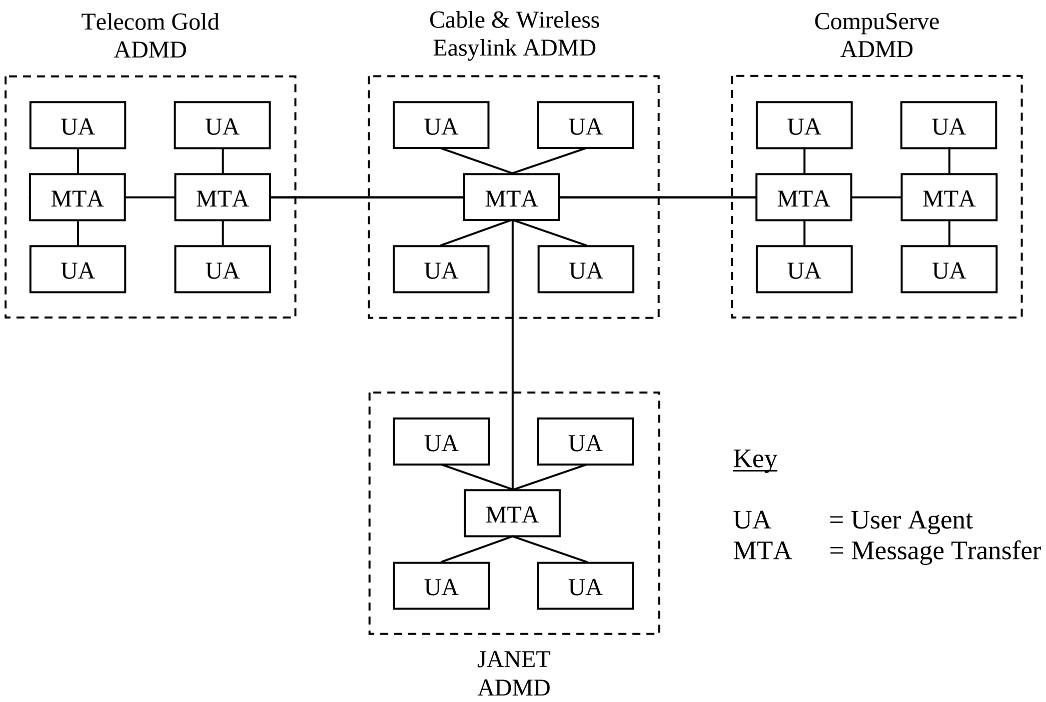

Figure L.4. The X.400 Message Handling System.[6]

BT's Gold 400 gateway was an example of an X.400 gateway that provided the necessary translation facilities needed to convert messages and addresses between proprietary formats and the formats used by X.400 (see Figure L.6).

L.4 X.500

X.400 worked in conjunction with another technology, known as X.500, which was a directory standard which operated at the application layer of the OSI seven-layer reference model. While JANET's Name Registration Scheme stored the names and addresses of host computers within the network, X.500 stored information relating to people. In 1988, the CCITT ratified X.500 and it revised the standard during 1992. These standards contained several protocols, as shown in Figure L.7. These protocols used the services provided by the OSI compatible session and transport layers, the X.2 series of recommendations, which in turn used the facilities supplied by X.25.[7]

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[6] In practice, networks contained several private and administrative management domains. The figure illustrates how X.400 could interconnect several incompatible networks: the Grey Book e-mail protocol on JANET, SMTP on the ARPANET, and a proprietary protocol on the commercial e-mail service Telecom Gold.

[7] B. Sheresh and D. Sheresh, *Understanding Directory Services*, 2nd ed. (Indianapolis, IN: SAMS, 2002), pp. 111-162. On the Internet, the Internet Engineering Task Force published a similar distributed directory standard to X.500 in 1993. Known as the Lightweight Directory Access Protocol (LDAP), its designers originally intended the protocol to be an inexpensive way of accessing information stored in

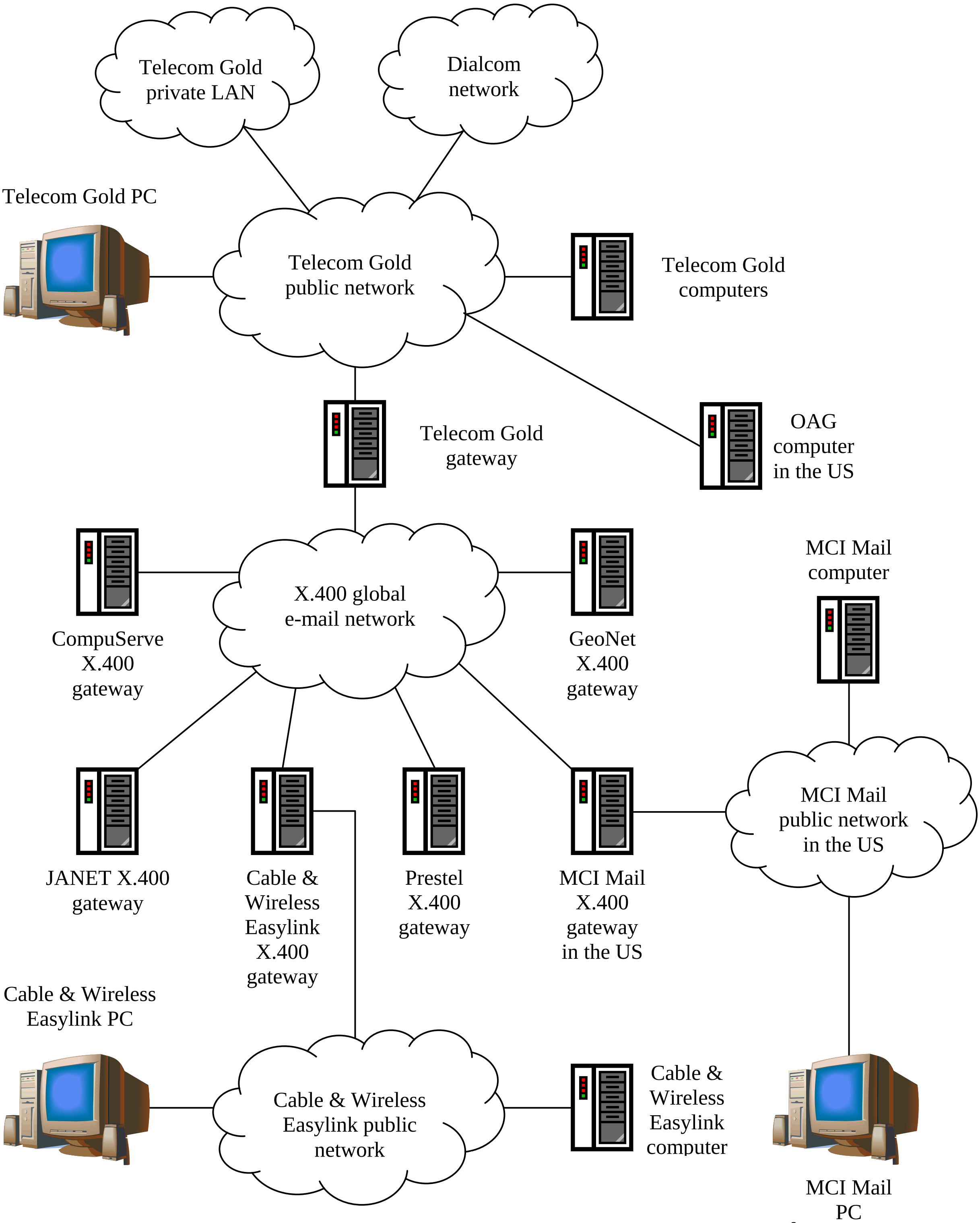


Figure L.5. The X.400 global e-mail network showing gateways between the networks.[8]

X.500 directories using PCs. It later developed into an independent directory standard, which, while less sophisticated than X.500, was easier to implement and inherently compatible with TCP/IP. See T. Howes, "LDAP: Use as Directed," *Data Communications*, February 1999, pp. 95-96, 98, 100, and 102-103 and K. Siyan and T. Parker, *TCP/IP Unleashed*, 3rd ed. (Indianapolis, IN: Sams, 2002), pp. 441-475.

[8] In the figure above, the X.400 gateways indicate that the networks attached to these computers are not running the X.400 standard as their native protocol. The gateways are therefore converting between the proprietary protocols and X.400.

Table L.1. Example of X.400 O/R Address attributes.

Attribute
Country name
Administrative Management Domain (ADMD)
Private Management Domain (PRMD)
Organisation name
Organisational unit name
Personal name
Common name
Distribution list name
Network user identifier
Network address
Terminal identifier
Terminal type
Numeric O/R address
Telex O/R address
Postal O/R address

X.500 was similar to the Domain Name System as it proposed a hierarchy of information, with the root of this information tree at the top. Below this came countries, organisations, units within organisations, and finally individuals (see Figure L.8). Using X.500, people could find information about individuals such as their e-mail addresses. People would use Directory User Agents (DUAs) to query Directory System Agents (DSAs). Multiple DSAs contained the directory information, stored as a distributed database in a similar way in which domain information was stored in the Name Registration Scheme and in the Domain Name System (see Figure L.9). If a person used a Directory User Agent to find Rebecca Clark's e-mail address in the above example and the DUA found this information, it would return the address in the X.400 e-mail format: G=Rebecca; S=Clark; O=UCL; OU=CS; P=uk.ac.; C=GB.[9]

[9] While the Top-Level Domains .US and .GB exist, most people choose not to use them, preferring .com and .uk. See C.J.P. Moschovitis, et al., *History of the Internet: A Chronology, 1843 to the Present* (Oxford: ABC-Clio, 1999), pp. 173 and 175.

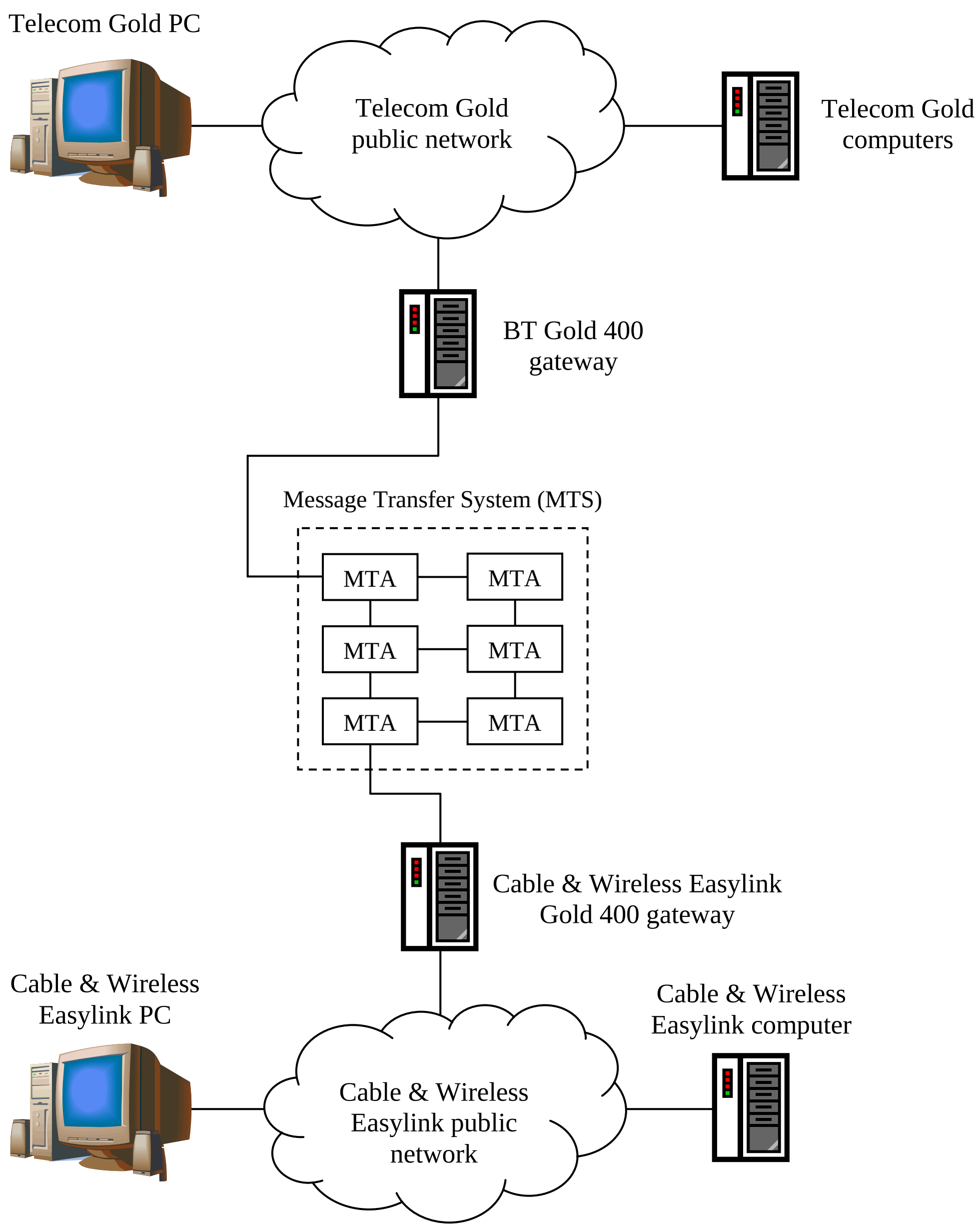


Figure L.6. The Gold 400 gateway.[10]

[10] In the figure above, the Gold 400 gateways indicate that Telecom Gold and Cable & Wireless Easylink are not running the X.400 standard as their native protocol. The Gold 400 gateways are therefore converting between the proprietary protocols and X.400. The MTS shown in the centre of the figure would exist between BT's Gold 400 gateway and Cable & Wireless' Gold 400 gateway. For the system to work, each MTA would have to be X.400 compatible.

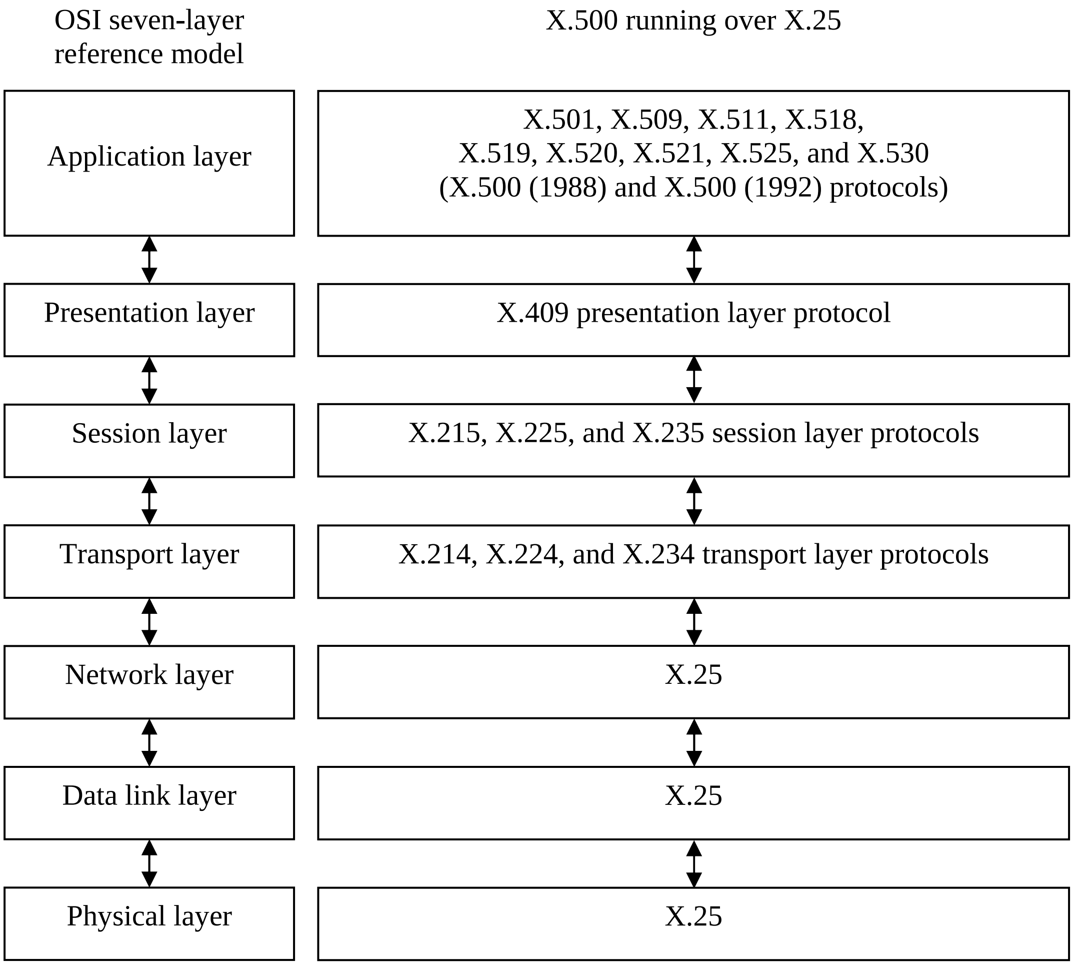


Figure L.7. X.500 running over X.25.

L.5 SMTP, POP3, and IMAP4

Computers store and transmit electronic mail in several formats including plain text, Hypertext Markup Language, and rich text.[11] The Multipurpose Internet Mail Extensions enable people to send files as well as messages.

[11] One of the earliest standards for the format of electronic mail on the ARPANET, the 1973 standard RFC 561, specified the format for e-mail headers containing information such as author, title, and date. During the 1970s and early 1980s, people developed this standard and ratified two main revisions: RFC 733, in 1977, and RFC 822, in 1982. See K. Johnson, *Internet Email Protocols: A Developer's Guide* (Harlow: Addison-Wesley, 2000), pp. 15-70, A. Bhushan, et al., *Standardizing Network Mail Headers*, IETF, 1973, Available from: http://www.ietf.org/rfc/rfc561.txt, Accessed on: 15 October 2005, D.H. Crocker, et al., *Standard for the Format of ARPA Network Text Messages*, IETF, 1977, Available from: http://www.ietf.org/rfc/rfc0733.txt?number=733, Accessed on: 15 October 2005, and D.H. Crocker, *Standard for the Format of ARPA Internet Text Messages*, IETF, 1982, Available from: http://www.ietf.org/rfc/rfc0822.txt?number=822, Accessed on: 15 October 2005.

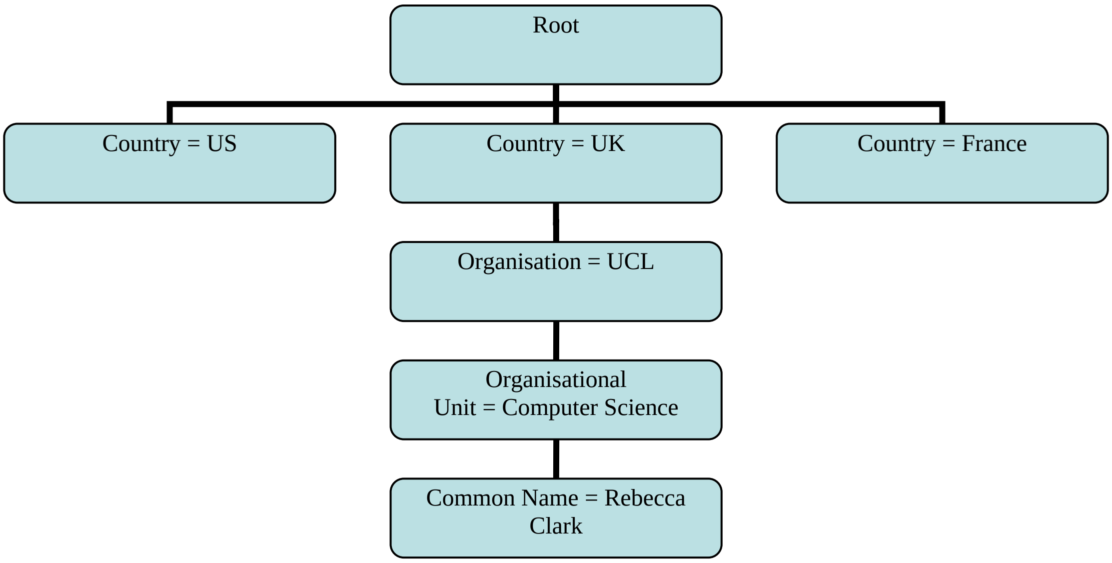
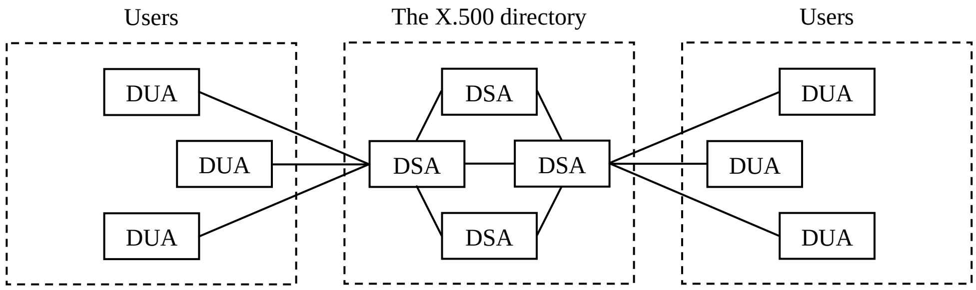


Figure L.8. An example X.500 hierarchy.

The Internet uses e-mail servers and a protocol known as the Simple Mail Transfer Protocol (SMTP) to transmit e-mails across the Internet. In the example shown in Figure L.10, User A wants to send an e-mail to User B. They compose the e-mail using an e-mail client, such as Microsoft Outlook or Mozilla Thunderbird, and send the message. The UA then transmits the e-mail to its local MTA. The MTA inspects the address of the e-mail and, assuming that the address does not correspond to an e-mail account stored on its server, forwards it, using SMTP, to another MTA. The e-mail servers then transmit the e-mail through the Internet. It is important to realise that there is no predefined route that the e-mail takes. Figure L.10 illustrates this using the dotted lines between the simplified e-mail servers. When the e-mail reaches the destination e-mail server, the Message Delivery Agent (MDA) transfers the e-mail to the addressee's mailbox. These mailboxes usually store e-mails in the Post Office Protocol version 3 (POP3) format or the more sophisticated Internet Message Access Protocol version 4 (IMAP4) format. User B's e-mail client then downloads the message from the server to their computer using either POP3 or IMAP4. An analogy is to think of SMTP as a mail carrier, with POP3 and IMAP4 corresponding to post offices.[12]

[12] See Johnson, *Internet Email Protocols*, pp. 71-135 and 205-318. On e-mail, SMTP, POP3, and IMAP4, including the postal system analogy, see T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 436-444, 612-614, 995-996, and 1155-1158.



Key

DUA = Directory User Agent
DSA = Directory System Agent

Figure L.9. An X.500 directory and interactions between agents.

In addition to using an e-mail client, such as Microsoft Outlook, to send and receive e-mails, people can use Webmail services to achieve the same objective. Example Webmail services include MSN Hotmail, Yahoo! Mail, and Google's Gmail. MSN Hotmail works by dynamically rendering the headers of e-mails and then creating the HTML code needed to generate the user interface that a person sees when he or she views their inbox. MSN Hotmail uses a similar process to generate the other Web pages that users access within the service. MSN Hotmail's e-mail system interfaces with the Internet using, for example, SMTP servers to send e-mails.[13]

L.6 Running SMTP Over TCP/IP and Grey Book Over X.25

While the Internet community originally designed SMTP to run over TCP/IP, SMTP can also operate over X.25. Jonathan Postel, who was the author of SMTP, suggested that anyone wishing to use the e-mail standard over X.25 should use TCP/IP over X.25.[14] However, the UK academic community chose not to do this. During the early 1980s, the Joint Network Team (JNT) adopted the ARPANET header format and used the Blue Book file transfer protocol, instead of SMTP, to transfer e-mails formatted using the ARPANET header standard. The JNT ratified the resulting standard for e-mail on JANET as the Grey Book protocol which ran over X.25 (see Figure L.11).[15]

[13] On Hotmail's Front Door Architecture see O. Shahine, *Inside Hotmail*, Microsoft Corporation, 2005, Available from: http://download.microsoft.com/download/1/4/e/14e92bc9-066a-4e70-8e72-b5095147c6fe/omar_shahine_2005_inside_hotmail.wmv, Accessed on: 19 October 2005.
[14] J.B. Postel, *Simple Mail Transfer Protocol*, IETF, 1982, Available from: http://www.ietf.org/rfc/rfc0821.txt?number=821, Accessed on: 13 May 2004.
[15] R. Braden, et al., "The JNT Interim Mail Protocol," *Proceedings of Networkshop 10, University of Nottingham, 14-16 April 1982* (Nottingham: University of Nottingham, 1982), pp. 1-5.

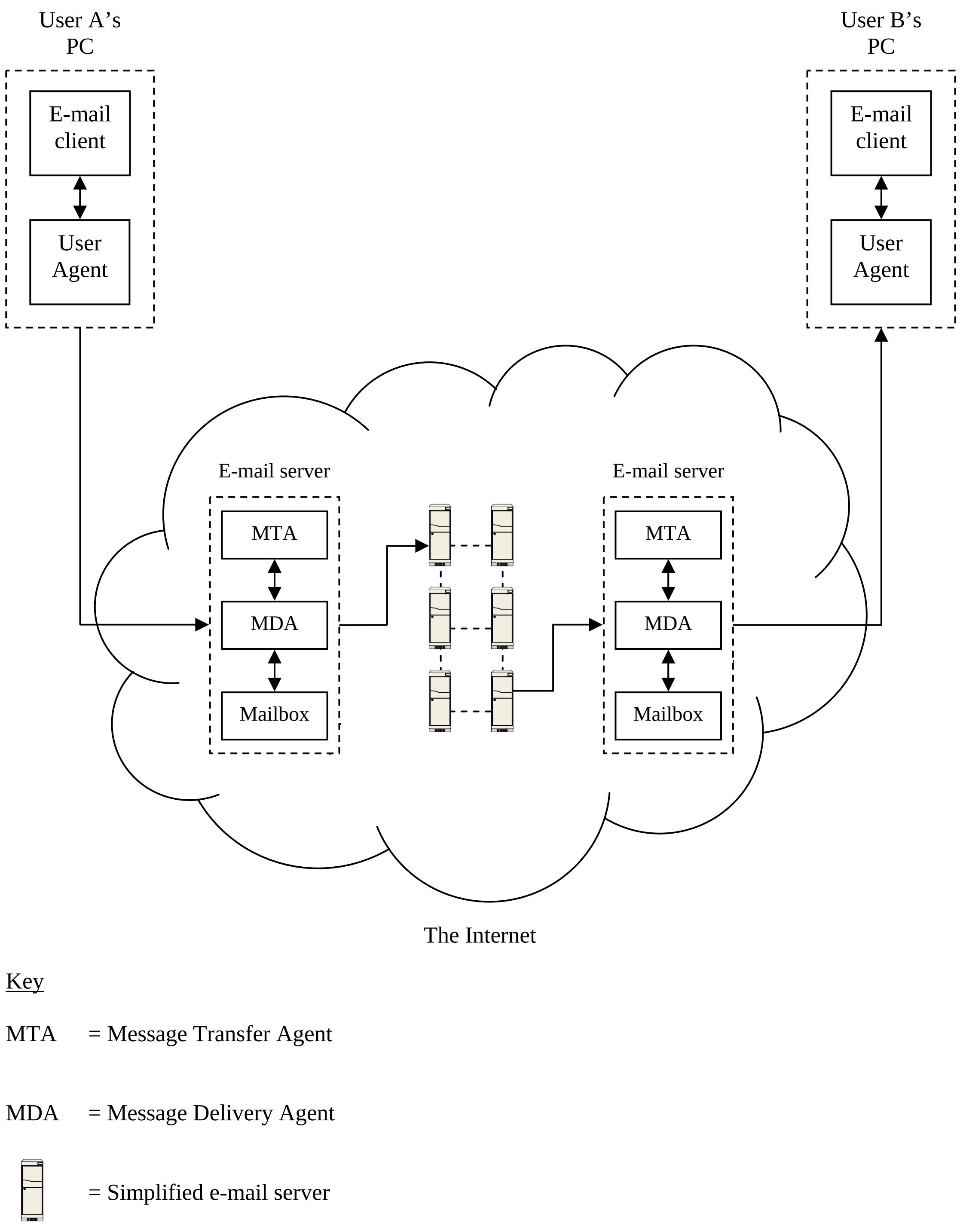


Figure L.10. How the Internet transmits e-mails.[16]

[16] For simplicity, the figure only presents three example servers. The Internet does of course contain thousands of e-mail servers. The figure shows an example route that an e-mail might take through the Internet. The MTAs would determine the chosen route, based on the address contained within the e-mail.

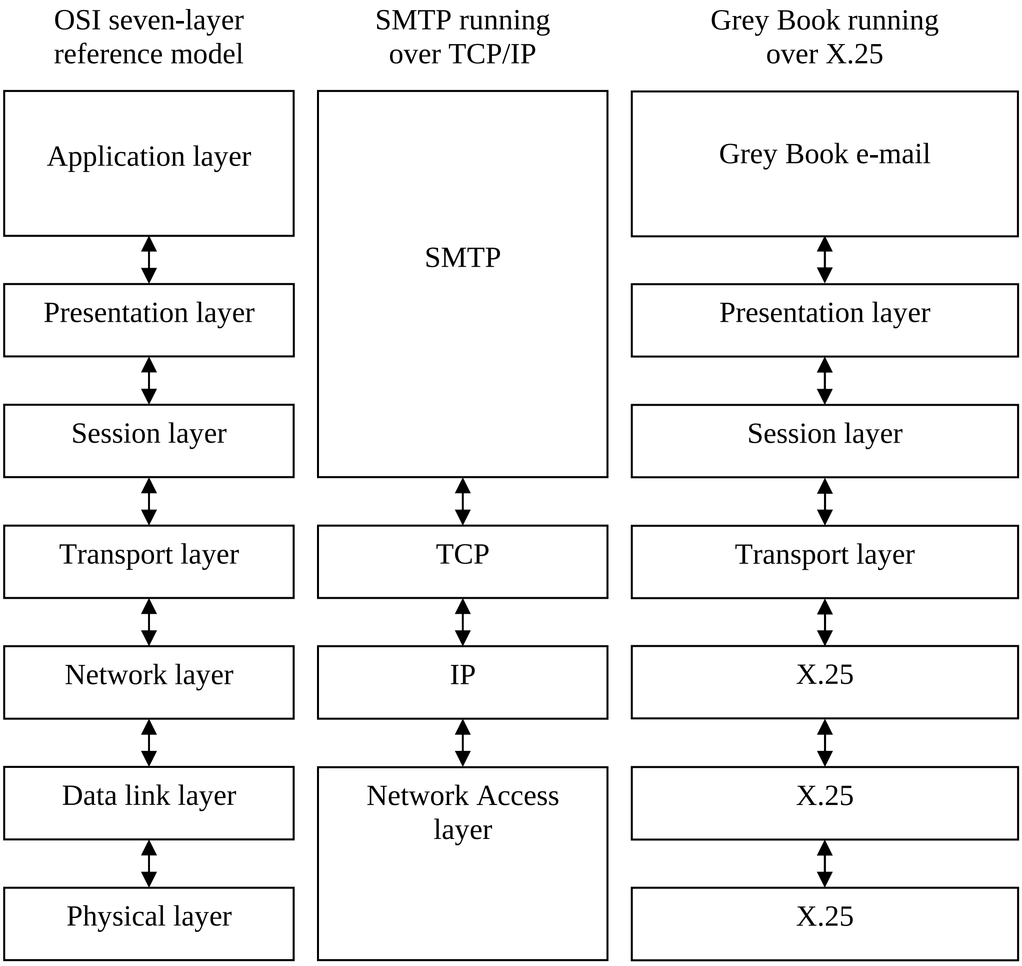


Figure L.11. SMTP running over TCP/IP and the Grey Book running over X.25.

Appendix M. Archie, Gopher, Veronica, and WAIS

M.1 Introduction

During the early 1990s, developers created several new Internet applications, including Archie, Gopher, Veronica, and WAIS. These tools improved the way in which users found information on the Internet. Before these applications became available, it was difficult for users to find information on the global network. An analogy is to think of the early the ARPANET and Internet as a set of libraries which did not contain library catalogues or librarians.[1] Finding information on these networks was therefore difficult and time consuming, unless you knew exactly where to find something that interested you. For example, if a user knew that a file existed on the Internet but did not know where it was stored, they would have to search through lists of files on servers using telnet. If they found the file, they would use an FTP program to download it. Without an easy and efficient way of finding files and other information, the Internet's value would be limited. The developers of tools, such as Archie, Gopher, Veronica, and WAIS, intended to help rectify this problem. Because of this, the tools became popular with Internet users.

As well as improving the ability to find information on the Internet, some of the new tools also began to improve the usability of the Internet. Since the emergence of the ARPANET in 1969, many people had developed Internet applications and had mainly done so at universities. The reason was that only universities and other DARPA-funded sites could connect to the ARPANET. The trend of developing applications at universities continued with tools such as Archie, Gopher, and Veronica. As mainly computer scientists developed Internet tools, they used the UNIX operating system which was popular within computer science departments.[2] Ken Thompson, Dennis Ritchie, and other researchers developed UNIX at Bell Labs during 1969. UNIX is a powerful operating system which can run on many different types of computer. However, the original Command Line Interface (CLI) of UNIX was not user friendly. UNIX presents users with a shell which is the interface between the operating system and the user. A prompt on screen indicates that the computer is waiting for a user to

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[1] On the early ARPANET and Internet, including the library analogy, see E. Krol, *The Whole Internet: User's Guide and Catalog*, 2nd ed. (Sebastopol, California: O'Reilly, 1994), pp. 234-235.
[2] M. Joy, et al., *Introducing UNIX and Linux* (Basingstoke: Palgrave Macmillan, 2002).

type a command, such as the 'ls' command, which displays a list of the files that are stored in the current directory. As UNIX used a Command Line Interface, this meant that users needed to interact with the operating system using commands. This type of interface could therefore create problems for new users. For example, new users were often unsure of what action they needed to perform to achieve a specific goal. They were also often unable to determine if the system had successfully achieved the goal, based on the feedback received.[3] As UNIX came with TCP/IP and as developers used UNIX to develop Internet applications, the tools that emerged were usually command-based. For example, to use an FTP program, the user needed to know the command to start the program as well as the commands used to connect to an FTP server, find a file, and then download it to their computer. If a person wanted to use the Internet during the 1980s and early 1990s, they therefore needed to know how to use the Command Line Interfaces of operating systems, such as UNIX and MS-DOS, and the commands used by the Internet applications.[4] The interface of the Internet was therefore not user friendly.[5] However, with the introduction of tools such as Gopher, Veronica, and WAIS, the interface of the Internet improved. For example, Gopher used menus which meant that users could access information without having to memorise commands.

M.2 Archie

Alan Emtage, Peter Deutsch, and Bill Heelan invented Archie at McGill University during the early 1990s. To help McGill University save money, Emtage and his colleagues searched for public domain software on the Internet which the School of Computer Science could use. This process involved finding servers on the Internet that would allow them to download files without first needing user accounts on the servers. Emtage, Deutsch, and Heelan searched these anonymous FTP sites which was a laborious process. They therefore developed a program to automate the task of searching for files on the Internet. The result was Archie, a program that searched

[3] On the gulfs of execution and evaluation see J. Preece, et al., *Human-Computer Interaction* (Wokingham: Addison-Wesley, 1994), pp. 273-274.
[4] During the 1980s, developers ported applications such as FTP from UNIX to other operating systems such as MS-DOS. However, as MS-DOS also used a Command Line Interface and as the applications still used commands, this created the same problems for MS-DOS users as for new users of UNIX.
[5] J. Romkey, "What the Internet Needs: Soothing the Savage Interface (s) of the Internet," *Internet World*, November/December 1993, pp. 78-82.

anonymous FTP archives, hence the name. In the example shown in Figure M.1, Archie compiles a list of files and their associated servers and then stores this information in a database on an Archie server. In the example shown below, the user wants to find a file which is stored on the anonymous FTP Server A, although they are not aware of this fact. The person uses a telnet program, an Archie client, or commands within e-mails, to query the database stored on an Archie server to find the location of a file that interests them. Once the server has told the user where the file is located, the user can then use an FTP client program to download the file from Server A.[6] After inventing Archie, Emtage and Deutsch founded Bunyip Information Systems and commercialised the search tool. However, people could still use programs in the public domain to access Archie servers, and the service became popular and therefore diffused throughout the Internet.[7]

M.3 Gopher

Mark P. McCahill and other programmers invented Gopher at the University of Minnesota in 1991. Two factors influenced the name 'Gopher': the 'Golden Gophers' university mascot and the purpose of the tool, namely to 'go fer' information on the Internet. Gopher provided a hierarchical set of menus which people navigated using a client program to find the information that they wanted. Gopher was therefore an Internet browser which people used to browse through menus stored on Gopher servers. These servers diffused throughout the Internet and enabled people to search for information on many topics. Gopher provided links between menus and services and these links were seamless, meaning that people could navigate through the entire system of servers, known as Gopherspace, with ease. People referred to the main Gopher server at the University of Minnesota as the 'mother Gopher'. This server was typical of the Gopher servers around the world. It presented a menu containing categories of information such as computer information, discussion groups, fun and games, libraries, and news. By navigating through the menus, people could perform several tasks including finding text, images, and files. Gopher was an application that provided a single user interface to several Internet tools.

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[6] Krol, *The Whole Internet*, pp. 188-189.
[7] P. Gilster, *Finding It on the Internet: The Essential Guide to Archie, Veronica, Gopher, WAIS, WWW (Including Mosaic), and Other Search and Browsing Tools* (New York: Wiley, 1994), pp. 9-35.

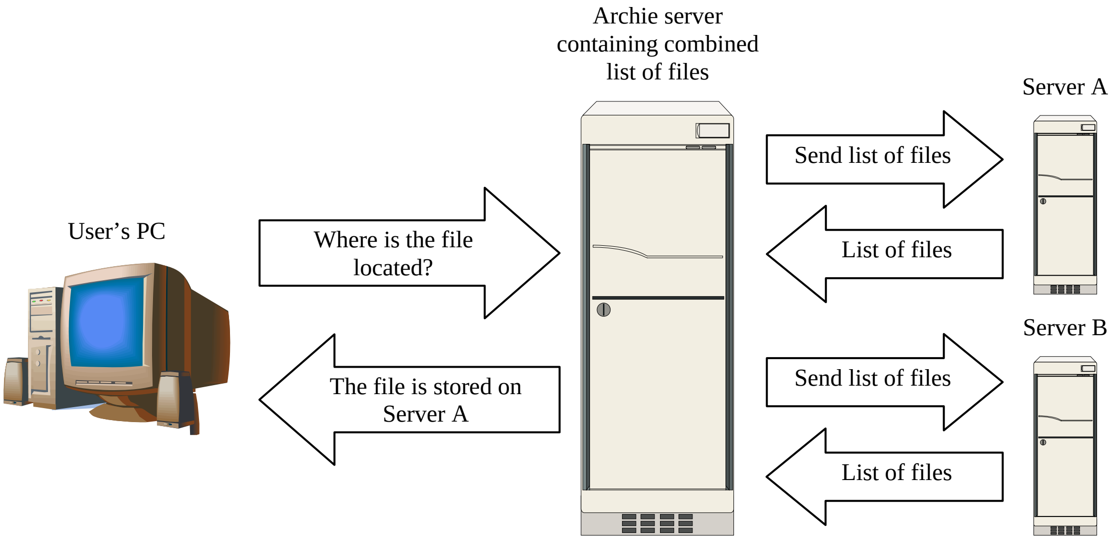

Figure M.1. Archie.

These included telnet, FTP, Archie, and WAIS. For example, people could use Gopher to access Archie, search for a file, and then download it using FTP. Gopher therefore helped to integrate numerous Internet applications and helped to improve the usability of the Internet for Gopher's users. To help address the time-consuming process of navigating up and down the menu hierarchy, Gopher provided a bookmark facility. Using bookmarks, a user could store the location of a favourite menu, news item, or other information, and then return to the bookmarked item later. The ability to browse information on the Internet using menus, as well as Gopher's other features, made the browser very popular during the early 1990s. However, in 1993 the University of Minnesota decided to charge royalties to companies that used Gopher. This decision concerned many people that used the system, and therefore affected the diffusion of Gopher throughout the Internet.

In the example shown in Figure M.2, a user in New York wants to browse through Gopherspace to see what files they can download. They start their Gopher client, connect to a Gopher server, which in this case is the University of Minnesota server, and then examine the on-screen menu. The user wants to see what files are stored on a server in another country. They therefore type 3 and press the enter key on their keyboard. The Gopher client then displays a new menu which lists continents. The user decides to browse countries in Europe and therefore types 3 and presses enter. Another menu appears which displays European countries.

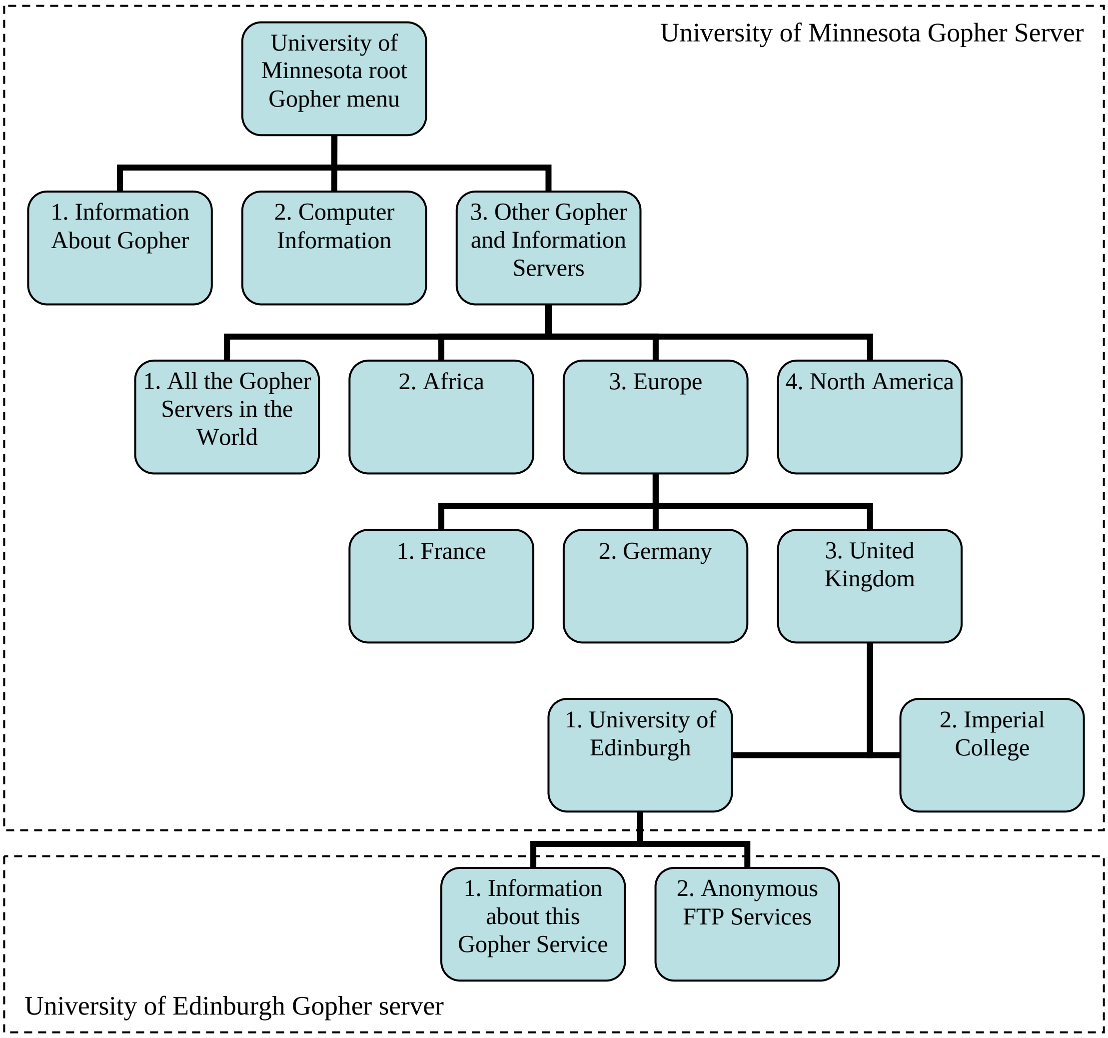

Figure M.2. An example of Gopher's hierarchical menus.

The user wants to see what files are stored on servers in the United Kingdom and therefore selects this option. The next menu displays several Gopher servers in the UK. The user decides to look at what the University of Edinburgh's server contains and therefore presses 3 followed by enter. When the user presses the enter key, the Gopher client contacts the University of Edinburgh's server and requests the server's root menu. The Gopher client then displays this menu. From the user's perspective, this is just another menu. However, the menu is from another server which in this case is located in Edinburgh. The user is not necessarily aware of this fact, as Gopher made the process of navigating through Gopherspace seamless. When the user reaches the root menu on the Edinburgh Gopher server, they type 3 and press enter to display the menu containing information about anonymous FTP services. They then browse through this menu to find a file that they want. The user can then use their Gopher client to download the file from the Edinburgh server to their computer.[8] Figure M.3 illustrates an example path through Gopherspace.

M.4 Veronica

Steve Foster and Fred Barrie at the University of Nevada invented the Very Easy Rodent-Oriented Net-wide Index to Computerised Archives (Veronica) tool during 1992.[9] One of the problems with Gopher was the laborious process of navigating through a hierarchy of menus which, depending on the search, could contain thousands of menu items. To help solve this problem, Foster and Barrie developed Veronica. Every two weeks, this service use to search the menus provided by the servers within Gopherspace and then stored the menu items in a database. It would then create keywords for the menu items (see Figure M.4). Veronica then enabled people to search this index using keywords.[10] In the example shown in Figure M.5, a user wants to search Gopherspace for information relating to the Internet. They therefore use their Gopher client to connect to a Gopher server, select the menu item to search Gopherspace using Veronica, and then enter the keyword 'Internet'. The Veronica server then searches its database which contains the indexed menu items from all Gopher servers. When Veronica has completed the search, it generates a customised set of Gopher menus which the user can then navigate in the same way in which they usually navigated Gopherspace. Veronica was therefore an Internet search tool. People used their Gopher client programs to access Veronica, by following a link to the search tool on Gopher's menus. Veronica servers diffused throughout the Internet and the service became popular.[11]

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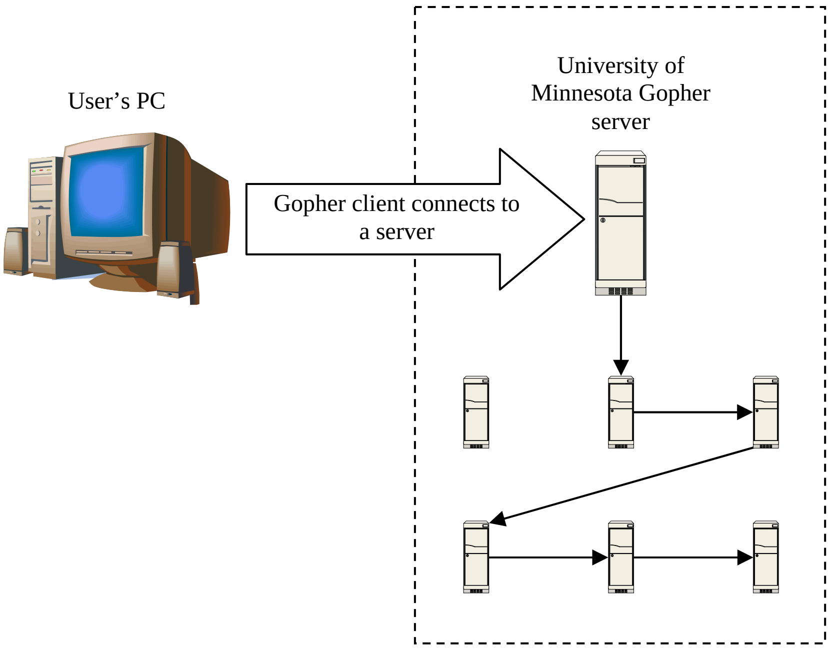
[8] Instead of navigating through Gopherspace, the user could have used their Gopher client to search for files using Archie, which would have been more efficient. See Gilster, *Finding It on the Internet*, pp. 37-75.

[9] J. Mardikian, "How to Use VERONICA to Find Information on the Internet," in *Librarians on the Internet: Impact on Reference Services*, R. Kinder ed. (New York: Haworth Press, 1994), pp. 37-45.

[10] *The Internet Unleashed* (Indianapolis: Sams, 1994), pp. 599-603.

[11] Gilster, *Finding It on the Internet*, pp. 77-98.



A subset of Gopherspace

Figure M.3. An example path through Gopherspace

M.5 WAIS

Brewster Kahle invented the Wide Area Information Server tool at the Thinking Machines Corporation during the early 1990s. Four companies were involved in the development of WAIS: the Thinking Machines Corporation, Apple Computer, Dow Jones & Company, and KPMG. Each company contributed different elements to the project. For example, the Thinking Machines Corporation provided expertise in information retrieval engines, while Apple supplied knowledge of user interface design. WAIS differed from previous Internet tools, such as Gopher and Veronica, as it enabled a user to search for information within documents. This full-text search facility therefore provided a powerful addition to Gopher and Veronica's ability to browse and search for information based on filenames and other objects. In the example shown in Figure M.6, a user wants to search for documents that relate to computers. Using a WAIS client, the user selects the database (s) that they want to search, for example the Wall Street Journal. The user then enters their query in English into a text box and then clicks the 'Run' command.

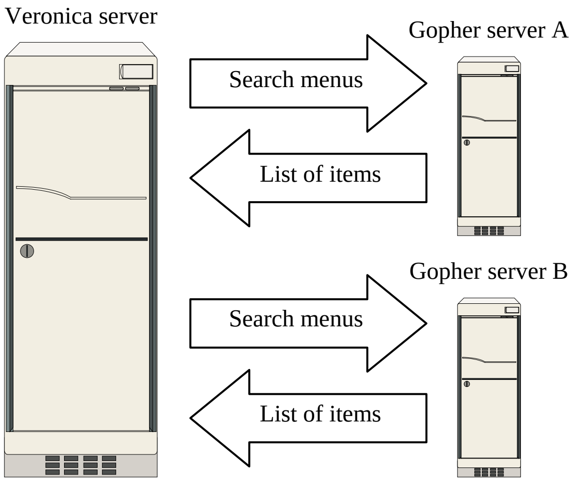


Figure M.4. A Veronica server searching the menus of Gopher servers.

The client then transmits the query to a WAIS server which translates the English query into the WAIS language and executes the query.[12] The server transmits the list of relevant documents back to the client which displays them on-screen. The user can then browse through the results and if they find a document that interests them, they can download it. WAIS could search for information in databases stored on servers throughout the world. WAIS could access several different types of information including text, images, audio, and video.[13]

[12] WAIS used the Z39.50 standard, which defined the query language, which was similar to the Structured Query Language (SQL), as well as the protocol used by clients and servers for information retrieval. See *The Internet Unleashed*, pp. 606-607.
[13] B. Kahle and A. Medlar, “An Information System for Corporate Users: Wide Area Information Servers,” *Online*, September 1991, pp. 56-60.

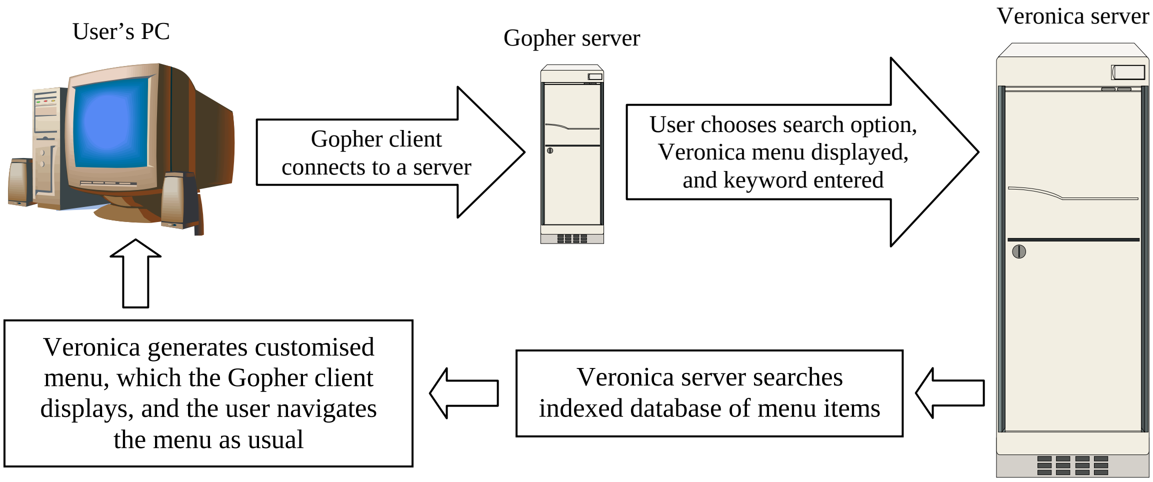


Figure M.5. Searching a Veronica database.

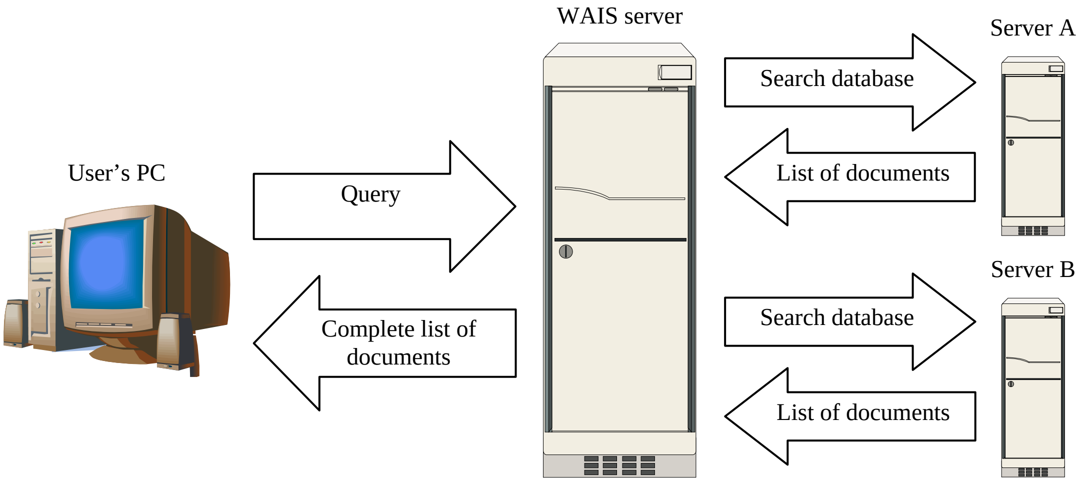


Figure M.6. Using WAIS to search for information in databases.

Appendix N. The World Wide Web

N.1 The Evolution of the Web

Tim Berners-Lee invented the World Wide Web at CERN in 1989. The purpose of Berners-Lee's invention was to create a "global information universe", using several concepts and technologies, the most fundamental of which was the connections that existed between information.[1] These connections had interested Berners-Lee since his childhood.[2] While at school, he had been interested in how the brain can link two seemingly random pieces of information and how computers could potentially emulate this process. During this period, Berners-Lee had also consulted a book that his parents owned called "Enquire Within Upon Everything". This book contained advice on many different topics, including marriage and etiquette, with numbered paragraphs for each topic.[3] By 1891, there were 85 editions of Enquire and over 1.1 million people had purchased a copy of the book. Berners-Lee perceived the book as a "portal to a world of information" and this idea, together with the idea of creating connections between information, has stayed with Berners-Lee throughout his life.

In 1980, CERN awarded a contract to Berners-Lee and a friend to help replace the software associated with two particle accelerators. As part of his job, Berners-Lee needed to remember the names of many people with whom he interacted. He also needed to remember details relating to projects and computers.[4] As he did not trust his ability to remember this information, he therefore developed a program called ENQUIRE-WITHIN which he created during his spare time.[5] Enquire enabled a person to document the modules or nodes of a system and then establish links between different nodes.[6] For example, Berners-Lee used Enquire to record pages of information about people, projects, and computers. Using the system, he could establish links between the nodes within a file and between nodes in different files. Berners-Lee stored Enquire on a Norsk Data minicomputer and wrote a manual for

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[1] T. Berners-Lee, et al., "World-Wide Web: The Information Universe," *Electronic Networking*, vol. 2, no. 1, 1992, pp. 52-58.
[2] T. Berners-Lee, *Weaving the Web: The Past, Present and Future of the World Wide Web by its Inventor* (London: Texere, 2000).
[3] *Enquire Within Upon Everything*, 85th ed. (London: Houlston and Sons, 1891), p. III.
[4] R. Wright, "The Man Who Invented the Web," *Time*, 19 May 1997, pp. 64-67.
[5] T.J. Berners-Lee, *The ENQUIRE System Short Description*, W3C, 1980, Available from: http://www.w3.org/History/1980/Enquire/scaled, Accessed on: 16 August 2004.
[6] A node was a single page of text, similar to a card in a card index file.

anyone that wanted to use the program. However, despite some interest from colleagues, no one used the program after Berners-Lee had left CERN.

Berners-Lee returned to CERN during 1984 to begin another contract. He created a new program called Tangle which encoded phrases using complex data structures, and recreated the phrases when asked to do so. However, the program encountered problems with reconstruction and Berners-Lee therefore decided not to continue with its development. While experimenting with Tangle, Berners-Lee developed a Remote Procedure Call (RPC) program. RPC enabled two computers, which used incompatible operating systems, to communicate across a network such as the CERN network (CERNET).[7] As well as creating the RPC program, Berners-Lee also began to re-create the ENQUIRE-WITHIN program on his portable computer. However, the second version of the program did not allow him to establish links between files. It was therefore a functionally reduced version of Enquire and Berners-Lee did not pursue its development. However, he believed that CERN needed a program, such as Enquire, which would enable researchers to organise information. Physicists within the High-Energy Physics community at CERN were required to remember many types of information. For example, CERN contained thousands of researchers who were involved in many projects and experiments. These scientists also used many different types of computer from manufacturers such as IBM, DEC, and Apple. It was important that researchers master this information as quickly as possible, so that they could contribute to CERN's projects.[8] To help researchers manage this information, Berners-Lee knew that CERN needed a flexible documentation system. By combining the ideas embodied in Enquire with his RPC program, he could create such a system.

What Berners-Lee was proposing was a hypertext system. Hypertext stores and presents information in a non-linear format, using hyperlinks to establish connections between information. The development of hypertext began with the ideas developed by Vannevar Bush, who was the Director of the Office of Scientific Research and Development (OSRD) in the US. In 1945, Atlantic Monthly published an article by

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[7] J. Gillies and R. Cailliau, *How the Web was Born: The Story of the World Wide Web* (Oxford: Oxford University Press, 2000), pp. 70-74.
[8] T.J. Berners-Lee, et al., *World-Wide Web: An Information Infrastructure for High-Energy Physics*, CiteSeer, 1992, Available from: http://citeseer.ist.psu.edu/12816.html, Accessed on: 19 August 2004.

Bush which embodied many of the ideas associated with hypertext.[9] Bush was concerned with the increasing volume of scientific information and he therefore proposed a technological device that could help resolve this problem. As human beings' brains store and recall information by association, Bush envisaged a device that could support these processes. Called the Memex, it would store information on microfilm and enable people to create trails (links) between information. While no one developed the memex, Bush's ideas influenced many people who subsequently explored the proposed concepts. Two of the most influential people to develop hypertext systems were Douglas Engelbart and Ted Nelson. While working for the Stanford Research Institute (SRI) during 1962, Engelbart published a report which looked at a variety of topics including how people could use technology to manage the increasing complexities of society.[10] Engelbart was particularly interested in how machines could augment human intelligence and how both could form a symbiotic relationship which could co-evolve. In the report, Engelbart examined Bush's ideas and explored the idea of associative trails using a series of linked cards. In 1968, Engelbart presented his ideas at the AFIPS Fall Joint Computer Conference.[11] This presentation included a demonstration of the oNline-Line System (OLS) which included hypertext concepts such as links.[12] While Engelbart described a system that involved hypertext, he did not use the word hypertext. Nelson invented this term during 1962 and publicised the concept in a conference during 1965.[13] During the 1960s, he started to work on an ambitious hypertext-based system called Project

[9] V. Bush, "As We May Think," *Atlantic Monthly*, July 1945, pp. 101-108. Other publications subsequently reprinted Bush's article. For example, in 1945 Life reprinted it and in 1996 interactions published the article together with images from the Computer Museum. In addition, during 1995 Brown University and MIT held a symposium to celebrate Bush's seminal paper. See V. Bush, "As We May Think: A Top U.S. Scientist Foresees a Possible Future World in Which Man-made Machines will Start to Think," *Life*, November 1945, pp. 112-114, 116, 118, 121, and 123-124, V. Bush, "As We May Think," *Interactions*, March 1996, pp. 35-46, and R. Simpson, et al., "50 Years After "As We May Think": The Brown/MIT Vannevar Bush Symposium," *Interactions*, March 1996, pp. 47-67.

[10] D.C. Engelbart, *Augmenting Human Intellect: A Conceptual Framework*, Bootstrap Institute, 1962, Available from: http://www.bootstrap.org/augdocs/friedewald030402/augmentinghumanintellect/AHI62.pdf, Accessed on: 20 August 2004.

[11] D.C. Engelbart and W.K. English, *A Research Center for Augmenting Human Intellect*, Bootstrap Institute, 1968, Available from: http://www.bootstrap.org/augdocs/friedewald030402/researchcenter1968/ResearchCenter1968.html, Accessed on: 20 August 2004.

[12] T. Bardini, *Bootstrapping: Douglas Engelbart, Coevolution, and the Origins of Personal Computing* (Stanford: Stanford University Press, 2000).

[13] T.H. Nelson, "A File Structure for The Complex, The Changing and the Indeterminate," *Proceedings of the 1965 20th National Conference, Cleveland, Ohio, August 24-26* (New York: ACM Press, 1965), pp. 84-100.

Xanudu. Although the system did not become a success, work continues on refining the concepts proposed by the project.[14]

When Berners-Lee developed his Enquire hypertext system during 1980, the ideas explored by Bush, Engelbart, and Nelson did not influence his work, as he was not aware of them. However, as Berners-Lee began to refine his ideas, the work of these predecessors would later confirm the legitimacy of his system. Berners-Lee began to work towards his system during 1988. He approached his boss, Mike Sendall, with the idea and Sendall asked him to write a proposal. Berners-Lee knew that his system would have to accommodate the way in which researchers worked, instead of forcing them to adapt to the way the system worked. The reason for this was that other people had developed documentation systems at CERN which tried to change the way people worked. These systems had failed. Berners-Lee also knew that for his system to become a success, it would need to communicate with machines that ran different operating systems. Berners-Lee believed that TCP/IP would solve this problem and therefore modified RPC so that it could communicate using these protocols. During March 1989, Berners-Lee submitted his proposal which provided an overview of the proposed system.[15] The proposal highlighted the utility of hyperlinks, the concept of a browser running on a client's machine, and the need for a hypertext server. Berners-Lee gave his proposal to Sendall and others at CERN but nothing happened. He subsequently approached his boss with the suggestion that CERN purchase a NeXT computer which Berners-Lee could explore.[16] Sendall agreed and added that as part of this exploration, Berners-Lee could develop his hypertext system on the machine. Berners-Lee then reformatted his proposal and submitted it again during May 1990. However, nothing happened again. Berners-Lee found it hard to convince people of

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[14] T.H. Nelson, "Xanalogical Structure, Needed Now More than Ever: Parallel Documents, Deep Links to Content, Deep Versioning, and Deep Re-Use," *ACM Computing Surveys*, vol. 31, no. 4es, 1999, pp. 1-32.

[15] T. Berners-Lee, *Information Management: A Proposal*, W3C, 1989, Available from: http://www.w3.org/History/1989/proposal.rtf, Accessed on: 19 August 2004.

[16] During 1985, the founder of Apple, Steve Jobs, left the company to found a new company called NeXT Inc. In 1988, NeXT released its first computer, the NeXT Cube workstation. Based on the Motorola 68030 processor, it had a high-quality black and white display, a sophisticated Graphical User Interface, and a powerful Object Oriented Programming (OOP) language. NeXT priced the workstation at $6,500 and marketed it for use in universities. However, the computers and the software did not become a success. See B. Brown, "NeXT PC Touts High Features, Low Price," *Network World*, 24 October 1988, pp. 11-12, D. Crabb, "Your Next Step Should be to this Integrated OOP," *InfoWorld*, 12 August 1991, pp. 71 and 73, and C.J.P. Moschovitis, et al., *History of the Internet: A Chronology, 1843 to the Present* (Oxford: ABC-Clio, 1999), pp. 130-133.

the potential of his system. The people he talked to at CERN as well as people involved with hypertext outside the laboratory could not comprehend the concept that he was proposing. However, Robert Cailliau offered his moral support. Cailliau had joined CERN in 1974 and had worked on several projects including a HyperCard hypertext project for the laboratory's administrators. Cailliau could see the utility of Berners-Lee's ideas and therefore re-wrote the May 1990 proposal and began to promote the proposed system throughout CERN.[17] While Cailliau tried to obtain support for the project, Berners-Lee invented a name for the system. After dismissing names such as Information Mesh, Mine of Information, and The Information Mine, he chose the World-Wide Web, as it reflected the global nature of the proposed system and contained a mathematical term relating to nodes and links. Having decided on a name, Berners-Lee began to develop the Web. The first task was to create a Web browser which he completed during October 1990 (see Figure N.1). He used the NeXTStep's tools to create the hypertext system, and this saved him time compared to developing the browser on another platform. Berners-Lee called the browser WorldWideWeb, although he later changed it to Nexus to distinguish it from the global information system. WorldWideWeb was an editor as well as a browser, and Berners-Lee used it to create the first Web pages.

After developing the browser, Berners-Lee created the protocol that clients and servers would use to communicate. Known as the Hypertext Transfer Protocol (HTTP), this was similar to FTP and NNTP. However, it was more efficient than these older protocols as it only required a client to establish one TCP/IP connection for each Web page request.[18] Computers could use HTTP to transmit pages containing text, hypertext, and images. As well as creating the Web browser and HTTP, Berners-Lee also developed the addressing system for the Web. Universal Resource Identifiers (URIs) identified the name of a resource as well as its location. Hypertext documents used URIs within hyperlinks to find documents.

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[17] T. Berners-Lee and R. Cailliau, *WorldWideWeb: Proposal for a HyperText Project*, CERN, 1990, Available from: http://www.w3.org/Proposal.html, Accessed on: 15 September 2004.

[18] Computer scientists refer to this as a stateless connection, which means that a client and a server only maintain a TCP connection during an operation such as a request for a Web page. Stateful connections sometimes maintain a communication channel even though the client and server are not transmitting data. They are therefore not as efficient as stateless connections. See T. Sheldon, *McGraw-Hill Encyclopedia of Networking & Telecommunications*, 3rd ed. (New York: Osborne/McGraw-Hill, 2001), pp. 1186-1187 and T. Berners-Lee, et al., "The World-Wide Web," *Communications of the ACM*, vol. 37, no. 8, 1994, pp. 76-82.

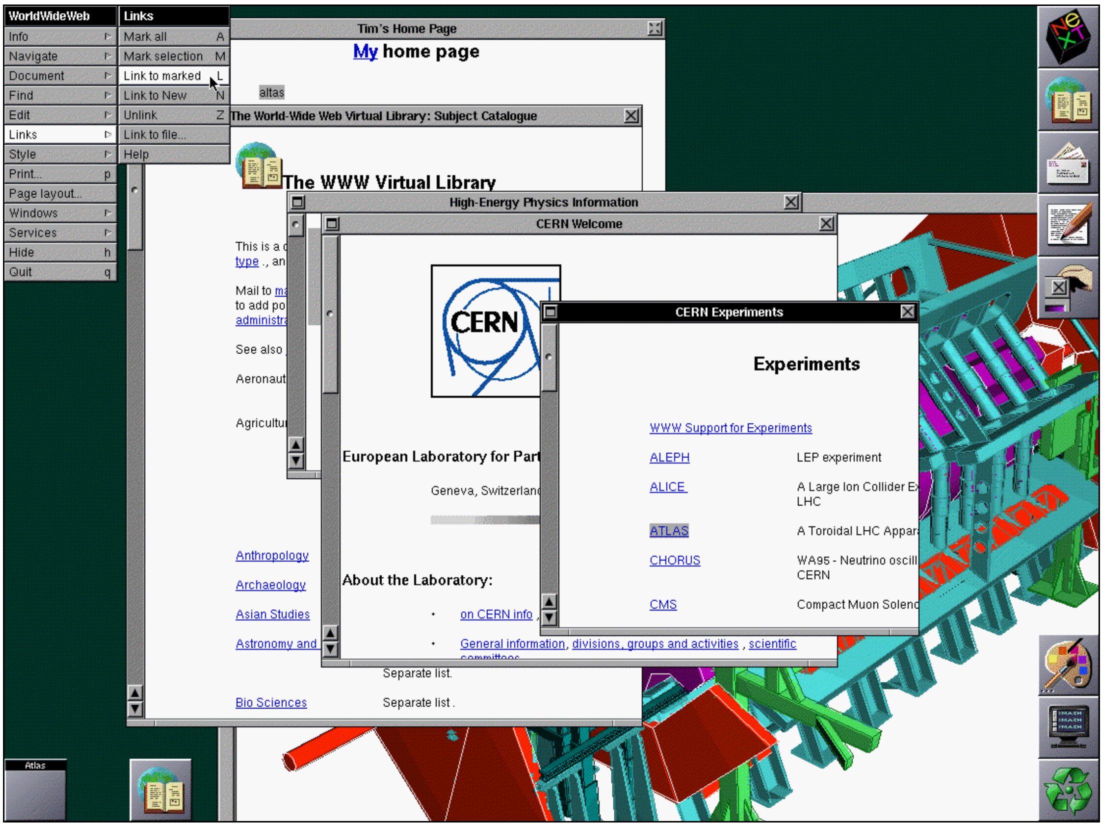

Figure N.1. The WorldWideWeb browser in 1993.[19]

To define how the Web should format pages, Berners-Lee also developed the Hypertext Markup Language (HTML) which was similar to another page description language known as the Standard Generalised Markup Language (SGML) with the addition of hyperlinks.[20]

By December 1990, Berners-Lee had developed a working version of the Web on his NeXT computer. He then developed a Web server which also ran on his workstation. The new server had an Internet address, nxoc1.cern.ch, and an alias, info.cern.ch, which would enable the server to move to another computer, while retaining the same address. Berners-Lee also created a Web page that described how the Web worked, with specifications for HTML, HTTP, and URIs. With the addition of another NeXT workstation, which Cailliau used, both Berners-Lee and Cailliau were able to communicate via the info.cern.ch server. At this point, Berners-Lee modified the

[19] The first version of the browser did not display text and images within the same window. In addition, the screen would be in black and white, as Berners-Lee's NeXT workstation had a monochrome monitor. See T. Berners-Lee, *The WorldWideWeb browser*, W3C, 2004, Available from: http://www.w3.org/People/Berners-Lee/WorldWideWeb.html, Accessed on: 15 June 2003.

[20] R. Cailliau and H. Ashman, "Hypertext in the Web - A History," *ACM Computing Surveys*, vol. 31, no. 4es, 1999, pp. 1-6.

WorldWideWeb browser so that it could access Usenet's newsgroups on the Internet. The browser could therefore access thousands of pages of information, in addition to the Web pages at CERN. However, by the beginning of 1991, there was only one Web browser running on a single platform: the NeXTStep operating system. Berners-Lee and Cailliau needed browsers on other platforms, such as the PC, for the Web to become accessible to users on the Internet. Berners-Lee therefore asked Nicola Pellow, a work placement student, to develop a Web browser. Berners-Lee and Pellow referred to this browser as a line mode browser, as it could run on any type of computer including teletypewriters. The rationale for the browser was to enable anyone to access the Web even if users did not have a browser on their computer. People could use telnet to connect to the info.cern.ch server and then use the line mode browser to explore the Web.[21] The line mode browser used a Command Line Interface to display information. Users could chose options by pressing numbers, and in this respect, it was similar to Gopher.

By 1991, the Web had one server and two browsers. However, it only contained a few Web pages. To help solve this problem, Berners-Lee enlisted the support of a colleague called Bernd Pollermann. Pollermann maintained CERN's phonebook on an IBM mainframe and once he learnt about Berners-Lee's project, he agreed to work with Berners-Lee to provide this information to users through the Web. Up until then, people had to log onto the mainframe to view names and telephone numbers. By developing a gateway, Berners-Lee and Pollermann provided access to the phonebook, other databases, catalogues, and search engines through the Web. This gateway therefore increased the amount of information available on the Web. Having achieved this, Berners-Lee, Pellow, and Cailliau began to port the line mode browser to other platforms such as mainframes, UNIX workstations, and personal computers. Berners-Lee also wanted the Web browser to become the main user interface through which people accessed information from different sources.[22] He therefore adapted the Web so that it could access information in Gopherspace and on Wide Area Information Servers. These facilities continued to increase the amount of information that was accessible through a Web browser. While Berners-Lee, Pellow, and Cailliau

[21] Gillies and Cailliau, *How the Web was Born*, pp. 203-204.
[22] T.J. Berners-Lee, et al., "The World-wide Web," *Computer Networks and ISDN Systems*, vol. 25, no. 4-5, 1992, pp. 454-459.

worked on the Web, they also promoted their system within CERN. However, no one seemed to understand what the Web could do and everyone therefore dismissed it. Undeterred, Berners-Lee released the code for the WorldWideWeb browser, the line mode browser, and the Web server on to the Internet. To increase awareness of the Web, Berners-Lee posted messages to newsgroups. People on the Internet started to e-mail him to say that they had successfully set up a Web server. Berners-Lee provided links to these servers from the main Web page stored on the info.cern.ch server. As the number of servers increased, Berners-Lee and Arthur Secret, a student, developed a catalogue of Web sites. Known as the Virtual Library, this divided sites into categories and therefore helped people to find information on the Web.[23] Creating links to other sites also became popular with the users that ran the Web servers on the Internet. They created links to other sites and by 1992 many links existed between servers throughout the Web.

As the Web started to grow, it was clear that unless people owned a NeXT workstation, they would not be able to view the Web as a graphical information space which had been Berners-Lee intention when he had developed it on his NeXT machine. There was therefore a need for browsers on other platforms that were more sophisticated than the line mode browser. However, CERN had limited resources and Berners-Lee therefore encouraged others outside of the laboratory to develop Web browsers.[24] During 1992, three new browsers emerged. Masters' students at the Helsinki University of Technology developed the first browser, called Erwise, which was a sophisticated X-Windows browser. However, its developers were not interested in continuing with its development after they graduated. Another student, Pei Mei, developed a browser called ViolaWWW while at University of California at Berkeley. ViolaWWW could display graphics as well as enabling users to download files. Cailliau and Pellow developed the third browser. Known as Samba, this browser ran on the Apple Macintosh. These browsers helped to increase the number of people who could access the Web. However, a new browser eclipsed these early developments in 1993. Known as Mosaic, it could display plain text, hypertext, images, and audio and

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[23] G. Manning, *About the Virtual Library*, WWW Virtual Library, 2002, Available from: http://vlib.org/AboutVL.html, Accessed on: 19 August 2004.
[24] T. Berners-Lee, *The World Wide Web: Past, Present and Future*, W3C, 1996, Available from: http://www.w3.org/People/Berners-Lee/1996/ppf.html, Accessed on: 19 June 2004.

video clips.[25] It could also access information using a variety of protocols including HTTP, Gopher, FTP, WAIS, Archie, and NNTP. Marc Andreessen and Eric Bina had developed Mosaic at the National Center for Supercomputer Applications (NCSA) during the end of 1992.[26] Both Andreessen and Bina were familiar with the Web and could see the potential of a graphical browser. They therefore spent months developing Mosaic for X-Windows. While it was not the first graphical browser, it did incorporate images and text within a single window. It was more sophisticated than previous browsers and because of its ability to display graphics instead of just text, it more closely approximated to Berners-Lee's original vision for the Web. Once Andreessen and Bina had developed Mosaic, others at NCSA became very enthusiastic about the potential of the software. While computer scientists had written earlier browsers for other computer scientists, Mosaic was a more professional product. For example, it had used an installation program to install the browser. Andreessen, Bina, and others at NCSA knew that for Mosaic to become a success outside of the UNIX community, they had to transfer it to other platforms. Work therefore began on porting the code to Microsoft Windows on the PC and the Apple Macintosh. Towards the end of 1993, Andreessen and Bina posted Mosaic for UNIX on the servers at NCSA. Within weeks, tens of thousands of people had downloaded the program. The exponential growth of the Web had therefore begun. However, this growth could not have occurred if CERN had not released the code for the Web into the public domain during 1993.[27] Berners-Lee recognised that this was, of course, a crucial decision that helped the Web to diffuse throughout the Internet.[28]

As the Web entered the public domain during 1993, Berners-Lee approached the Internet Engineering Task Force (IETF) with the specification for URIs, so that the

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[25] M. Andreessen and E. Bina, "NCSA Mosaic: A Global Hypermedia System," *Internet Research: Electronic Networking Applications and Policy*, vol. 4, no. 1, 1994, pp. 7-17.
[26] R.H. Reid, *Architects of the Web: 1,000 Days that Built the Future of Business* (Chichester: Wiley, 1997), pp. 1-68.
[27] W. Hoogland and H. Weber, *Statement Concerning CERN W3 Software Release into Public Domain*, CERN, 1993, Available from: http://intranet.cern.ch/Chronological/Announcements/CERNAnnouncements/2003/04-30TenYearsWWW/Declaration/Page1.html, Accessed on: 10 June 2004 and W. Hoogland and H. Weber, *Statement Concerning CERN W3 Software Release into Public Domain*, CERN, 1993, Available from: http://intranet.cern.ch/Chronological/Announcements/CERNAnnouncements/2003/04-30TenYearsWWW/Declaration/Page2.html, Accessed on: 10 June 2004.
[28] T. Berners-Lee, *Message from Tim Berners-Lee*, 2003, Available from: http://intranet.cern.ch/Chronological/Announcements/CERNAnnouncements/2003/04-30TenYearsWWW/TimsMessage/WelcomeTimsVideo.html, Accessed on: 21 August 2004.

IETF could ratify this as a standard. Problems occurred, such as objections to the name Universal Resource Identifier. These objections resulted in a new name: the Uniform Resource Locator (URL). The IETF later published the specification as a Request for Comments (RFCs) document.[29] However, Berners-Lee felt that a new organisation would be more appropriate to standardise the Web. He was concerned that as the Web diffused throughout the Internet, it could divide into several isolated groups of users such as academics and companies. In addition, some information might remain free for everyone to access, while other information may become restricted. A consortium could help to retain the open nature of the Web and allow developers to agree on the standards that they would use. Berners-Lee raised the idea of a consortium with Michael Dertouzos, who worked at the Laboratory for Computer Science at the Massachusetts Institute of Technology (MIT). Dertouzos was enthusiastic about the idea and they agreed that the consortium should have two main offices: one at CERN and the other at MIT. After a lot of work by Berners-Lee, Dertouzos, and others, CERN and MIT established the World Wide Web Consortium (W3C) during 1994, with support from DARPA and the European Commission. MIT appointed Berners-Lee as the first director of W3C, an organisation that would develop specifications for the Web that were open to everyone on the Internet. During December 1994, CERN withdrew from the consortium to concentrate on a new particle accelerator, which left the W3C at MIT to focus solely on the development of the Web.[30]

N.2 How the Web Works

Web browsers are applications that operate above the application layer of the TCP/IP reference model. Browsers can use the services provided by many of the application

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[29] T. Berners-Lee, *Universal Resource Identifiers in WWW: A Unifying Syntax for the Expression of Names and Addresses of Objects on the Network as used in the World-Wide Web*, IETF, 1994, Available from: http://www.ietf.org/rfc/rfc1630.txt?number=1630, Accessed on: 21 August 2004.

[30] By 1997, there were over 230 members of the W3C and this had increased to 363 members by 2004. Members include companies such as IBM, Microsoft, and AT&T, as well as institutions such as Stanford University. Three organisations host the W3C: the Laboratory for Computer Science at MIT, the European Research Consortium for Informatics and Mathematics, and the Keio University of Japan. The hosts undertake a variety of activities including organising tutorials about Web technologies, establishing relationships with companies and user groups, and issuing newsletters. See T. Berners-Lee, *Realising the Full Potential of the Web*, W3C, 1997, Available from: http://www.w3.org/1998/02/Potential.html, Accessed on: 20 August 2004, I. Herman, et al., *About the World Wide Web Consortium (W3C)*, W3C, 2004, Available from: http://www.w3.org/Consortium, Accessed on: 22 August 2004, and I. Herman, *Role of a W3C Office*, W3C, 2003, Available from: http://www.w3.org/Consortium/Offices/role.html, Accessed on: 22 August 2004.

layer protocols, including HTTP, FTP, SMTP, Gopher, and WAIS, which means that people can use their Web browser as a unified user interface for multiple Internet protocols and services (see Figure N.2).[31] Uniform Resource Locators are central to the operation of the Web. A URL is composed of three sections, separated by a colon and forward slashes: first section://second section/third section. The first section specifies the protocol a browser needs to use to communicate with a server, which is usually the Hypertext Transfer Protocol, although it can also be FTP and other examples shown in Figure N.2. An example of the first section of a URL is http://. The next section of a URL specifies the domain name of a machine on the Internet. An example of a domain name is www.onenasa.nasa.gov. The final section of a URL is the file name of either the main Web page stored on the server, known as the homepage, or a file that is stored in a directory or subdirectory. An example of a homepage is Onehome.htm. The full URL for this Web site is therefore http://www.onenasa.nasa.gov/Onehome.htm. If a Web page is stored in a directory or subdirectory, forward slashes separate the different parts of the address. In the following example, the 'astropix.html' file is stored in the 'apod' directory on the National Aeronautics and Space Administration (NASA) Web server: http://antwrp.gsfc.nasa.gov/apod/astropix.html.[32]

The next component of the Web is the Hypertext Transfer Protocol.[33] HTTP is a request and response protocol. A client requests a Web page from a server, and the server responds by transmitting the page to the browser. For example, in Figure N.3 a user wants to display the homepage of the 'One NASA' Web site. They type the address (www.onenasa.nasa.gov) into their browser's address bar and press the enter key on their keyboard. The browser then asks a Domain Name System server for the IP address of the URL (204.200.223.156) and the DNS returns this information to the browser. The browser uses this information to establish a connection with the NASA's Web server and then asks the server to send the homepage (Onehome.htm) to the client.

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[31] D. De Maeyer, "Internet's Information Highway Potential," *Internet Research: Electronic Networking Applications and Policy*, vol. 7, no. 4, 1997, pp. 287-300.
[32] A.S. Tanenbaum, *Computer Networks*, 4th ed. (Upper Saddle River, NJ: Prentice Hall PTR, 2003), pp. 612-615 and 622-625.
[33] D. Gourley, et al., *HTTP: The Definitive Guide* (Beijing: O'Reilly, 2002).

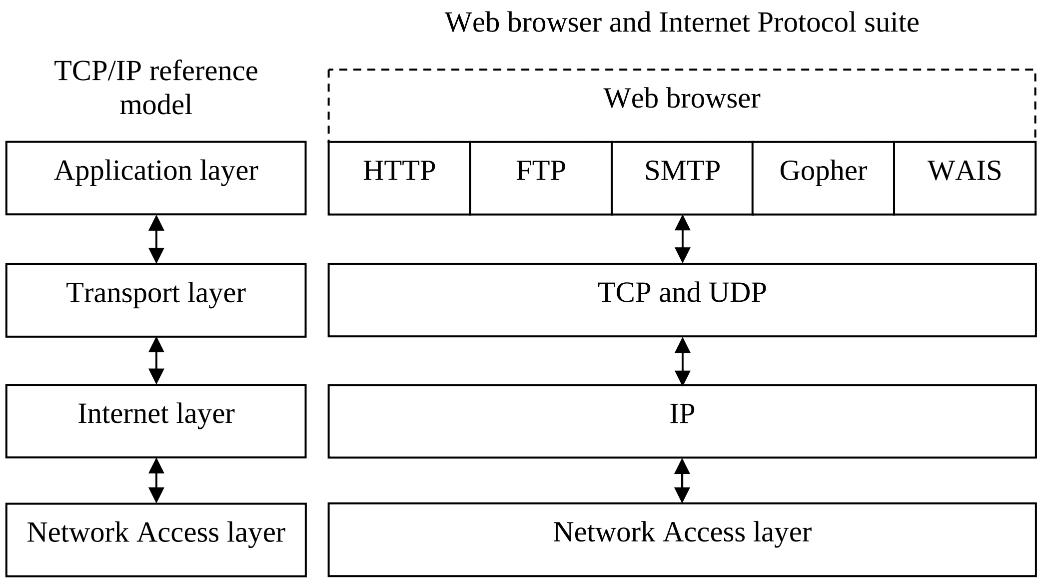

Figure N.2. The relationship between a Web browser and the Internet Protocol suite.

The server responds by transmitting the Onehome.htm file and then terminates the connection between the client and the server. A similar process occurs when the browser requests images from a server.

The process of requesting an IP address for a domain name occurs every time a browser needs an address. Therefore, when a user clicks on a hyperlink, the browser requests the IP address associated with the hyperlink. Hyperlinks contain URLs which identify the location of a resource on the Internet as well as the resource itself. In the example shown in Figure N.4, a browser establishes a connection to the CNN.com Web site, and the user then browses the site's Science & Space section looking for information about astronomy. While browsing the site they find a hyperlink to NASA's main site which they click. The browser then contacts a DNS server to obtain the IP address of NASA's server, and uses this information to contact the server and request the site's homepage. The browser displays this homepage and the user starts to browse through the site. While looking at images of space in the Images section of the site, they find a link to NASA's Astronomy Picture of the Day (APOD) site. They click on the link and the browser repeats the process of contacting the DNS server, followed by the APOD server, and then displays the web page. Figure N.5 illustrates what the user would see during this navigation process.

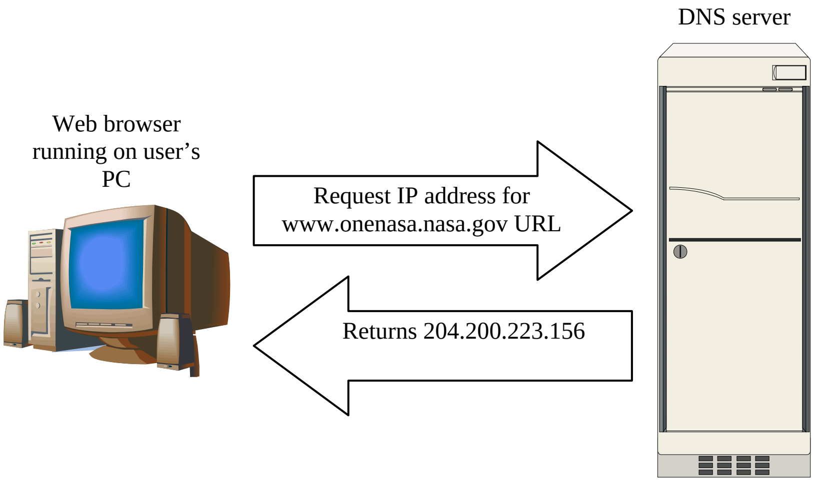

Figure N.3. The DNS lookup process.

The final component of the Web is the Hypertext Markup Language.[34] Developers create Web pages using HTML or the eXtensible Hypertext Markup Language (XHTML).[35] HTML files are stored as text files and contain the tags used to define the formatting of a page. Most tags are composed of a beginning tag and an end tag. For example, to make the words 'Science links' appear bold on a Web page, a Web developer would use the HTML tags and . HTML contains many tags, including a tag for hyperlinks. For example, to create a hyperlink to NASA's homepage, a developer would use the <a href > tags. To insert an image into a Web page, a developer creates a link to the image file using the <img> tag. People can create Web pages manually using HTML code, or they can use a Web page editor, such as Macromedia's Dreamweaver or Microsoft's FrontPage, which automatically creates HTML code. Figure N.6 shows the HTML code used to create the Web page shown in Figure N.7.[36]

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[34] Ever since Berners-Lee invented HTML during the early 1990s, the language has continued to evolve. The World Wide Web Consortium has ratified each version of HTML. Examples include versions 2.0, 3.2, 4.0, and 4.1.

[35] HTML is a subset of the Standard Generalized Markup Language (SGML). SGML is a comprehensive markup language but people need to use complicated tools when creating documents. As SGML is too complex for the needs of most people, the World Wide Web Consortium developed the eXtensible Markup Language (XML). XML enables programmers to develop Web-based solutions for different types of users including physicists, mathematicians, and physicians, all of whom need to present several different types of information. XML is a metalanguage, which developers can use to define other languages. An example of such a language is the eXtensible Hypertext Markup Language. XHTML is the successor to HTML. Since its introduction in the early 1990s, HTML has acquired features, which make it incompatible with SGML. XHTML is the solution to this problem. It will also enable developers to display information, such as chemical formulas, which HTML is not able to do. The W3C has ratified two versions of XHTML: 1.0 and 1.1. See C. Musciano and B. Kennedy, *HTML & XHTML: The Definitive Guide*, 4th ed. (Beijing: O'Reilly, 2000), pp. 8, 479, and 500-501.

[36] D. Comer, *Computer Networks and Internets: With Internet Applications*, 4th ed. (Upper Saddle River, NJ: Pearson Prentice Hall, 2004), pp. 530-534.

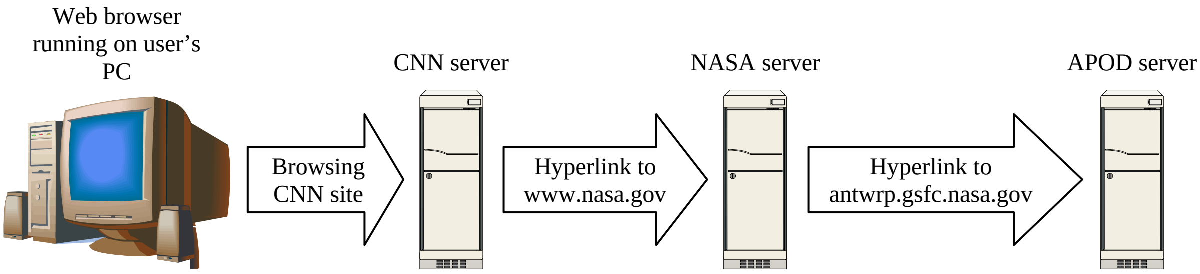

Figure N.4. Browsing the Web using hyperlinks.

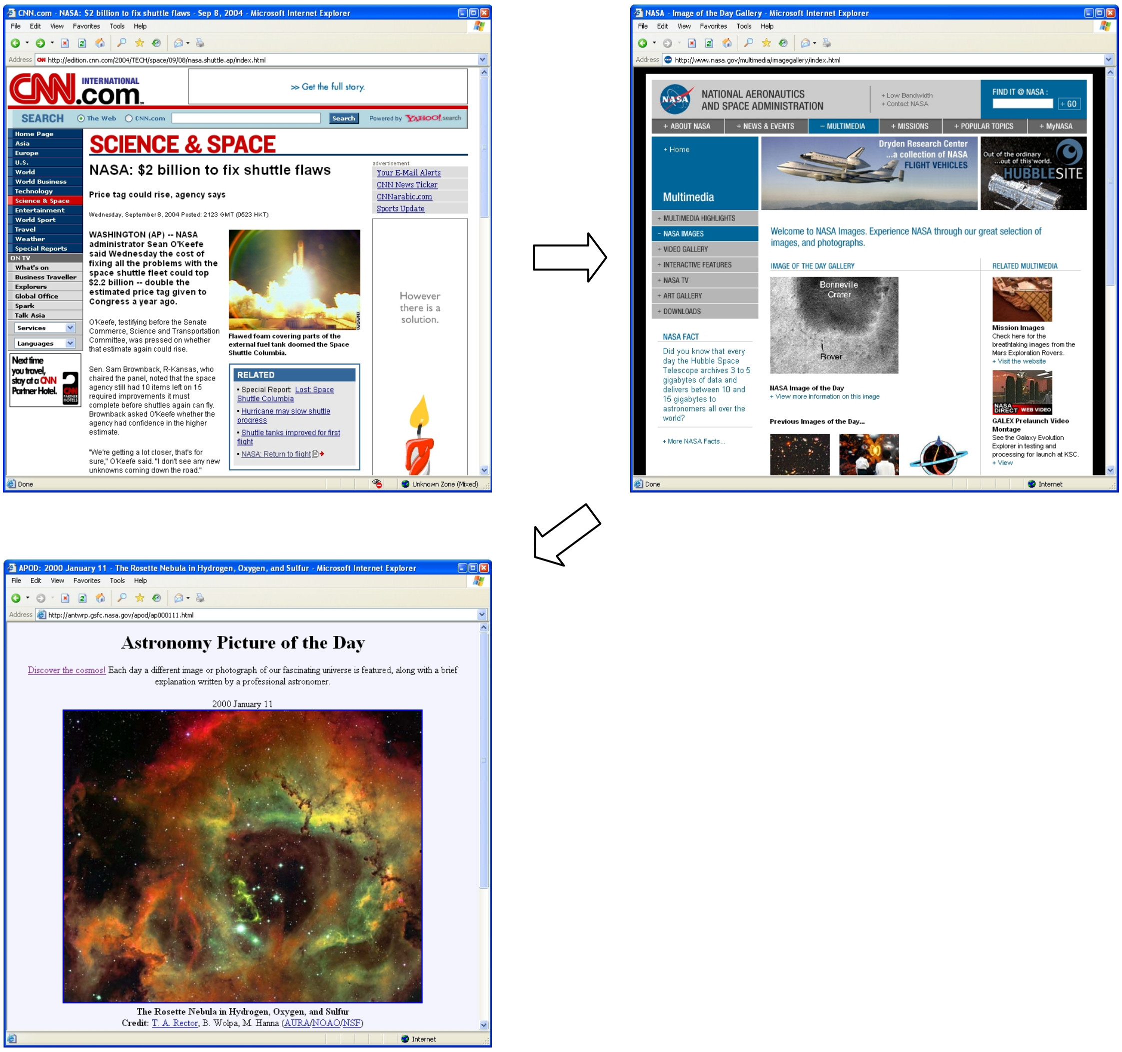

Figure N.5. Browsing the Web from a user's perspective.

```
<html>
<head>
<meta http-equiv="Content-Type" content="text/html; charset=windows-1252">
<title>Web page title</title>
</head>
<body>
<b>Science links:</b>
<p>
<a href="http://www.nasa.gov"> NASA's homepage</a></p>
<p>
<img border="0" src="logo_nasa.gif" width="288" height="51"></p>
</body>
</html>
```

Figure N.6. The HTML code used to create the Web page shown in Figure N.7.

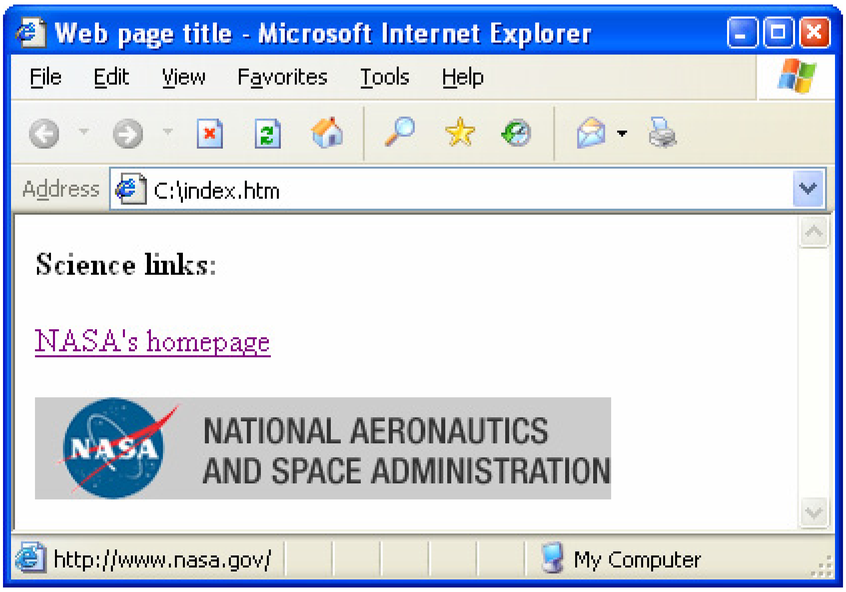

Figure N.7. The Web page created by the HTML code shown in Figure N.6.

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This bibliography includes the primary and secondary sources that I used during my research. Although I consulted over 2,500 resources, I have only included materials that are relevant to the thesis.

I have donated certain materials to two institutions. The UK National Archive for the History of Computing (http://www.manchester.ac.uk/nahc) has received original documentation, such as manuals relating to Poptel, GeoNet, and the Manchester Host. The Science Museum, London (http://www.sciencemuseum.org.uk) has received original Telecom Gold and CompuServe manuals. In addition, I will donate my interviews and the e-mails that I received from my correspondents to both institutions, subject to the interviewees and correspondents granting permission for these depositions.

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