# Essays on the History and Politics of the Internet

# Essays on the History and Politics of the Internet:

*Cyberpolitics*

By

Jeffrey A. Hart

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# LIST OF ACRONYMS

| | |
|---|---|
| ACM | Association for Computing Machinery |
| AI | Artificial Intelligence |
| AICOA | American Innovation and Choice Online Act |
| AMD | Advanced Micro Devices |
| ANS | Advanced Network and Services, Inc. |
| AOL | America OnLine |
| ARPA | Advanced Research Projects Agency |
| AUMF | Authorization for the Use of Military Force |
| BBN | Bolt, Beranek, and Newman |
| BBS | Bulletin Board Services |
| BEREC | Body of European Regulators for Electronic Communications |
| CALEA | Communications Assistance for Law Enforcement Act |
| CAPPS | Computer-Assisted Passenger Prescreening System |
| CBUI | Coalition of Broadband Users and Innovators |
| CCTV | Closed-Circuit Television |
| CEA | Council of Economic Advisers |
| CER | Computing for Education and Research (NSF Program) |
| CERN | European Center for Nuclear Research |
| CIA | Central Intelligence Agency |
| CIX | Commercial Internet Exchange |
| CNRI | Corporation for National Research Initiatives |
| COICA | Combatting Online Infringement and Counterfeiting Act |
| DARPA | Defense Advanced Research Projects Agency |
| DDN | Defense Data Network |
| DDoS | Distributed Denial of Service |
| DMCA | Digital Millennium Copyright Act |
| DNS | Domain Name System |
| DoC | Department of Commerce |
| DoD | Department of Defense |
| DoE | Department of Energy |
| DPI | Deep Packet Inspection |
| DRM | Digital Rights Management |
| DSEA | Domestic Security Enforcement Act |
| DSL | Digital Subscriber Line |

| | |
|---|---|
| DVD | Digital Video Disc |
| EFF | Electronic Frontier Foundation |
| EU | European Union |
| FAA | Federal Aviation Administration |
| FACTS | Factual Analysis of Criminal Threat System |
| FBI | Federal Bureau of Investigation |
| FCC | Federal Communications Commission |
| FCCSET | Federal Coordinating Council for Science, Engineering, and Technology |
| FFKC | Financial Fraud Kill Chain |
| FISA | Foreign Intelligence Surveillance Act |
| FTP | File Transfer Protocol |
| FTTC | Fiber to the Curb |
| FTTH | Fiber to the Home |
| G7 | Group of Seven |
| G8 | Group of Eight |
| GAFAM | Google, Amazon, Facebook, Apple, and Microsoft |
| GDPR | General Data Protection Regulation |
| HDTV | High-Definition Television |
| HPC | High-Performance Computing |
| HTF | High-Terrorist Factor |
| HTML | Hypertext Markup Language |
| HTTP | Hypertext Transfer Protocol |
| IAB | Internet Activities Board |
| IAO | Information Awareness Office |
| IAP | Internet Access Provider |
| IBM | International Business Machines |
| IC3 | Internet Crime Complaint Center |
| ICANN | Internet Corporation for Assigned Names and Numbers |
| ICE | Immigration and Customs Enforcement |
| ICP | Internet Content Provider |
| ICT | Information and Communication Technology |
| IEEE | Institute for Electrical and Electronics Engineers |
| IETF | Internet Engineering Task Force |
| IGF | Internet Governance Forum |
| ILEC | Incumbent Local Exchange Carrier |
| IMP | Interface Message Process |
| ISP | Internet Service Provider |
| ITC | International Trade Commission |
| ITU | International Telegraphic Union |
| LAN | Local Area Network |

| | |
|---|---|
| MATRIX | Multistate Anti-Terrorism Information Exchange |
| Mbps | Megabits per Second |
| MIT | Massachusetts Institute of Technology |
| MP3 | MPEG Audio Layer 3 |
| MPAA | Motion Picture Association of America |
| MPEG | Motion Picture Experts Group |
| NAP | Network Access Point |
| NAS | National Academies of Science |
| NASA | National Aeronautics and Space Administration |
| NCSA | National Center for Supercomputing Applications |
| NCTA | National Cable Television Association |
| NGO | Non-Governmental Organization |
| NIST | National Institute of Standards and Technology |
| NREN | National Research and Education Network |
| NSF | National Science Foundation |
| NTIA | National Telecommunications Information Administration |
| OAMA | Open App Market Act |
| OECD | Organization for Economic Cooperation and Development |
| OMB | Office of Management and Budget |
| OSI | Open Systems Interconnection |
| OSTP | Office of Science and Technology Policy |
| PAA | Protect America Act |
| PARC | Palo Alto Research Center (Xerox) |
| PBS | Public Broadcasting System |
| PC | Personal Computer |
| PIPA | Protect Intellectual Property Act |
| PSN | Packet-Switched Network |
| R&D | Research and Development |
| RBDMS | Relational Database Management System |
| RBOC | Regional Bell Operating Company |
| RFP | Request for Proposals |
| RFQ | Request for Quotation |
| RIAA | Recording Industry Association of America |
| RISSNET | Regional Information Sharing System Network |
| SAG | Screen Actors Guild |
| SBC | Southern Bell Corporation |
| SEVIS | Student Exchange Visitor Information System |
| SGI | Silicon Graphics, Inc. |
| SOPA | Stop Online Piracy Act |

| | |
|---|---|
| SQL | Structured Query Language |
| SRI | Stanford Research Institute |
| SWIFT | Society for Worldwide Interbank Financial Telecommunications |
| SXSW | South by Southwest |
| TCP/IP | Transfer Control Protocol/Interconnection Protocol |
| TIA | Total Information Awareness |
| TSMC | Taiwan Semiconductor Manufacturing Company |
| UCLA | University of California at Los Angeles |
| UCSD | University of California at San Diego |
| UDP | User Datagram Protocol |
| URL | Uniform Resource Locator |
| USIIA | US Internet Industry Association |
| USSOCOM | United States Special Operations Command |
| VCR | Video Cassette Recorder |
| VHS | Video Home System |
| VoIP | Voice over Internet Protocol |
| VPN | Virtual Private Network |
| WAN | Wide Area Network |
| WELL | Whole Earth 'Lectronic Link |
| WSIS | World Summit on the Information Society |
| WWW | World Wide Web |

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# PREFACE

I started this work in 1982 while on sabbatical at the Berkeley Roundtable on the International Economy (BRIE) at the University of California, Berkeley. I am grateful for the support I received at BRIE, especially from John Zysman, Michael Borrus, Laura Tyson, and Stephen Cohen. I was fortunate to work with Francois Bar on a paper on the origins of the Internet as part of a BRIE contract with the European Commission. Robert Kahn made himself available for interviews during that time. A bit later, I worked with Robert Reed at Indiana University to complete the project. We received comments from Eric Aupperle and Vint Cerf on an early draft. An article based on the project was published by *Telecommunications Policy*.[1] Chapter One is a major revision and updating of that article.

At Indiana University, I participated regularly in meetings convened by the Rob Kling Center for Social Informatics. I received much needed comments and advice from Rob himself, but also from Barbara Cherry, Alice Robbin, Harmeet Sawhney, Noriko Hara, and Ron Day. Barbara Cherry provided extensive comments on what became Chapter Four.

I taught an undergraduate course on the politics of high technology for several years at Indiana University. In 2012, I benefited greatly from the help of four students -- Cody Foster, Alex Mirowski, Evan Latt, and Reed Taylor -- in writing a paper on file sharing that became Chapter Six of this book.

I participated in a series of meetings organized by J.P. Singh at various venues and that were attended by other scholars who influenced this work, including Sandra Braman, Ron Deibert, Daniel Drezner, and J.P. Singh himself.

I am hugely indebted to Vint Cerf and Joan Goldhammer Hart for reading a draft of this book and providing comments.

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[1] Jeffrey A. Hart, Robert R. Reed, and Francois Bar, "The Building of the Internet," *Telecommunications Policy*, 16 (November 1992), 666-689.

# INTRODUCTION

This is a book about the politics and history of the Internet. The Internet has been in existence for over forty years. The way we live our lives has changed considerably because of this new medium. As the Internet has become increasingly popular, it has been drawn into age-old struggles over censorship and freedom of expression. It plays an increasing role in commerce: controversies have erupted over privacy, security, consumer rights, intellectual property rights, taxation, and other matters. With the rise of Internet-connected smart phones, the Internet has become part of daily life for billions of people. When we need a bit of information about something, we "Google" it or we ask Siri. Soon smarter smartphones will be anticipating our needs even before we know we have them.

The Internet has become part of the larger struggle for power in both democratic and authoritarian societies. In democracies, we increasingly rely on the Internet for information about political actors and issues. Politicians, political parties, and organized interest groups use the Internet to communicate with their followers. But even in authoritarian systems, the Internet is playing an increasing role in politics. Attempts by authoritarians to control the flow of information can be temporarily disrupted by new technologies.[1] But those technologies are also used increasingly for surveillance and for ensuring that the government's views dominate public discourse.

One major theme explored in this book is the contrast between the dream and the reality of the Internet. Many of the creators of the Internet shared a vision of building systems that would empower individuals anywhere in the world to share their knowledge and creativity. This profoundly democratic dream came out of an age in which many pre-existing power structures were being questioned.

Before the Internet was invented, a number of people were beginning to think about how the introduction of new information technologies could create a better world. In his book on the cultural impact of Stewart Brand, publisher of the *Whole Earth Catalog*, Fred Turner argues that one consequence of the Cold War was the rise of a new

[1] For example, by virtual private networks (VPNs) or encrypted email services.

"cybernetic" vision of the world, "one in which material reality could be imagined as an information system."[2] Turner asserts that people like Stewart Brand thought that some of the ills created by technology (nuclear weapons, large mainframe computers, unsustainable agricultural technologies) could be solved by the introduction of new decentralizing technologies. Along with solar power and organic farming, Brand and his associates promoted the idea that personal computers and related technologies could empower individuals and small groups to get off the grid. Brand created the Whole Earth 'Lectronic Link (WELL) in 1985. "…[he] and other members of the network, including Kevin Kelly, Howard Rheingold, Esther Dyson and John Perry Barlow, became some of the most quoted spokespeople for a countercultural vision of the Internet."[3]

John Perry Barlow, former lyricist for the Grateful Dead, published "A Declaration of the Independence of Cyberspace" as a response to the signing of the Telecommunications Act in February 1996. In this document, Barlow argues that governments of nation-states do not have jurisdiction over cyberspace. Barlow conceives of cyberspace as more egalitarian than the public spaces that it coexists with; a world where people can express their views much more freely:

> Cyberspace consists of transactions, relationships, and thought itself, arrayed like a standing wave in the web of our communications. Ours is a world that is both everywhere and nowhere, but it is not where bodies live. We are creating a world that all may enter without privilege or prejudice accorded by race, economic power, military force, or station of birth. We are creating a world where anyone, anywhere may express his or her beliefs, no matter how singular, without fear of being coerced into silence or conformity.[4]

Barlow warns the governments of the world to keep their hands off cyberspace:

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[2] Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006), p. 5. See also John Markoff, *Whole Earth: The Many Lives of Stewart Brand* (New York: Penguin Press, 2022).

[3] Turner, p. 3.

[4] John Perry Barlow, "A Declaration of the Independence of Cyberspace," February 8, 1996, accessed at A Declaration of the Independence of Cyberspace | Electronic Frontier Foundation (eff.org).

> Cyberspace does not lie within your borders. Do not think that you can build it, as though it were a public construction project. It is an act of nature and it grows itself through our collective actions.[5]

Barlow's manifesto is an early statement of cyber-libertarian or cyber-anarchist views. By denying the right of governments to intervene in cyberspace, and by stressing the self-governing nature of the Internet, Barlow clearly associates himself with both anarchists and libertarians. More important than anarchism and libertarianism is the idealism that his manifesto expresses and the hopes it contains for a better future for mankind that the new technologies might make possible.

One of the founding fathers of the Internet, Vint Cerf, analyzes the success of the Internet as follows:

> The remarkable social impact and economic success of the Internet is in many ways directly attributable to the architectural characteristics that were part of its design. The Internet was designed with no gatekeepers over new content or services.[6]

Cerf also stresses the decentralizing and enabling impact of the Internet:

> The Internet is based on a layered, end-to-end model that allows people at each level of the network to innovate free of any central control. By placing intelligence at the edges rather than control in the middle of the network, the Internet has created a platform for innovation.[7]

The current reality is different, but precisely how and why is a matter of considerable debate. There are those who believe that the Internet simply preserves or even reinforces preexisting power structures. Others believe that it has the potential to increase inequality and to strengthen the hand of central governments and large corporations.

To summarize, this is a book about the history and politics of the Internet focusing on its implications for the distribution of power. Because I am a political scientist by profession, I will be focusing on power. By doing so, I hope to make political debates over Internet-related issues more understandable and perhaps more amenable to resolution by citizens engaging in the political process.

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[5] Ibid.

[6] Accessed at Vinton Cerf Quote: "The remarkable social impact and economic success of the Internet is in many ways directly attributable to the architect..." (quotefancy.com).

[7] Accessed at Rumored network neutrality approach might break the Internet instead of saving it | The Hill.

# CHAPTER 1

# THE ORIGINS OF THE INTERNET

## Introduction

The Internet is a family of technologies that allows people to communicate via computer networks. Communications engineers define it as a network of networks, but the underlying purpose is to enable people to communicate with one another. As a medium of communication, the Internet has much in common with other communications and transportation networks. Its value depends on how many people can reach one another at a reasonably low cost. The speed and the high degree of interactivity of many Internet-related applications, however, make the Internet qualitatively different from other media.

The Internet is available to users in many countries, but in some countries, only a small percentage of the population has full access. In others, access to certain types of content is strictly controlled by governments. Nevertheless, there are currently over 5.3 billion users worldwide (see Figure 2-1).[1] The growth in usage has been quite rapid and steady over time.

The Internet and its users constitute an interesting human community worthy of study in its own right. It is an arena for human interaction with its own culture and politics. It has elaborate rule-making and rule-enforcing mechanisms. It has security problems, just like other communities, and it is vulnerable to disruption by those who violate the codes necessary for maintaining any viable community. However, the Internet is embedded within a larger set of communities and in particular it is part of a system of nation-states that still holds great sway over what the Internet can offer. There is an important tension between the globalizing intent of the original Internet architecture and the jealous preservation of national jurisdictions on the part of governments that must be acknowledged in any serious attempt to analyze the impact of new technologies.

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[1] According to 2022 data as reported at http://www.statista.com/statistics/273018/number-of-internet-users-worldwide/.

The backbone of the Internet in the 1980s, the NSFNET, was built originally to connect major centers for research on supercomputing. The NSFNET took the place of an earlier national network created by the Defense Advanced Research Projects Agency (DARPA) called the ARPANET. I will focus in this chapter on the following questions: (1) how supportive political coalitions were assembled to permit the funding and building of the ARPANET, NSFNET, and finally the Internet; (2) how the usage of those networks changed as they became more capable; and (3) how that usage influenced the coalition-building for the evolution of the network.

## The Building of ARPANET

The ARPANET's origins can be traced to the appointment in 1961 of J.C.R. Licklider, at that time a professor of mathematics at MIT, as the first director of Information Processing Technologies Office of the Advanced Research Projects Agency (ARPA) at the Department of Defense. While Licklider was not a computer scientist, he was a visionary who believed in time-sharing and interactive computing.[2] One of Licklider's successors, Robert Taylor, also believed strongly in the idea of interactive computing. Licklider's and Taylor's efforts at ARPA helped to accelerate the development of time-sharing computers and computer networks.[3]

Even before Licklider and Taylor at ARPA were funding early work on time-sharing and networks, Paul Baran at the Rand Corporation was designing a digital voice network using what we now call "packet-switching" to create a robust communications system to survive a nuclear first strike. In reports in the late 1950s, Baran "proposed that messages be broken into units of equal size and that the network route these message units along a functioning path to their destination where they would be reassembled into coherent wholes."[4] Rand made public Baran's reports in

[2] M. Mitchell Waldrop, *The Dream Machine: J.C.R. Licklider and the Revolution that Made Computing Personal*, 4th Edition (San Francisco: Stripe Press, 2018).
[3] Interview with Robert Kahn, Corporation for National Research Initiatives, Washington, D.C., August 19, 1991. See also, Peter J. Denning, "The ARPANET after Twenty Years," Research Institute for Advanced Computer Science (RIACS) Technical Report TR-89.38, September 20, 1980, accessed at 19920002477.pdf (nasa.gov).
[4] Denning, "The ARPANET..," p. 12.

1964, and Baran later published some of the results in the *IEEE Transactions on Communications Systems.*[5]

In 1968, ARPA issued a request for quotation (RFQ) for a system to reliably link computers in academic, industrial, and government research laboratories on a network. ARPA's Taylor had hired Larry Roberts away from MIT's Lincoln Laboratory in 1967 to write the RFP and to decide on the sites. Roberts' reading of the works of Donald Davies of the National Physical Laboratory in England convinced him of the value of using higher capacity circuits for networks. According to Vint Cerf, he was already convinced of the desirability of using packet-switching.[6]

Robert Kahn, then a Professor of Mathematics at MIT, took a one-year leave in 1968 to work at a government-funded private Cambridge think tank called Bolt, Beranek, and Newman (BBN), so that he would have more in common with his colleagues at MIT. Many of his colleagues did applied work and Kahn felt that his own work was overly theoretical.[7] Kahn was assigned the problem of responding to ARPA's request for quotation for computer networks. Frank Heart at BBN had experience building computer hardware and knew how to take Kahn's architectural ideas and put them into practice. With the help of Heart and Severo Ornstein, Kahn wrote BBN's winning proposal for the ARPA contract. The contract was announced early in 1969.[8]

The first node was delivered to UCLA nine months later. The head of the UCLA group was Len Kleinrock. Kahn and another BBN employee, Dave Walden, went to UCLA to test and debug the first node. BBN built an interface message processor (IMP) for ARPA, a computer which translated between messages and packets. An IMP is now called a router. In December 1969, the network was expanded to four nodes.[9]

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[5] Paul Baran, 'On Distributed Communications', Vols I-XI, Rand Memoranda, Rand Corporation, Santa Monica, CA, August 1964: and Paul Baran, "On Communications Networks," *IEEE Transactions on Communications Systems*, Volume CS-12 (1964), pp. l-9.

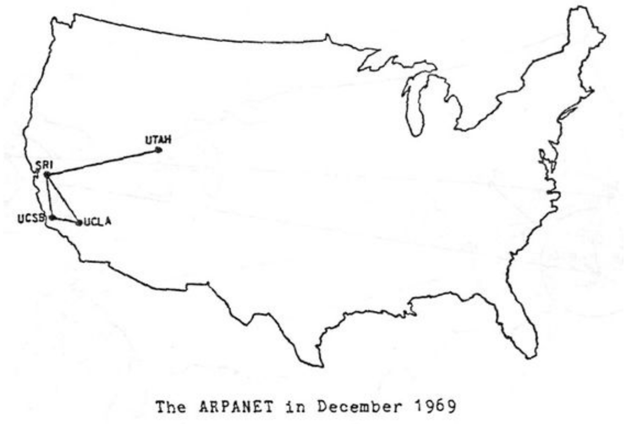
[6] Personal communication from Vint Cerf, April 2023. Roberts read Baran's work only after he had already done some testing of packet switching in 1966.

[7] John Markoff, "Robert Kahn's Vision of a National Network of Information Begins to Take Hold," *New York Times*, September 2, 1990, p. F1.

[8] Interview with Robert Kahn. See also Katie Hafner and Matthew Lyon, *Where Wizards Stay Up Late: The Origins of the Internet* (New York: Simon and Schuster, 1996); Janet Abbate, *Inventing the Internet* (Cambridge, Mass.: MIT Press, 1999).

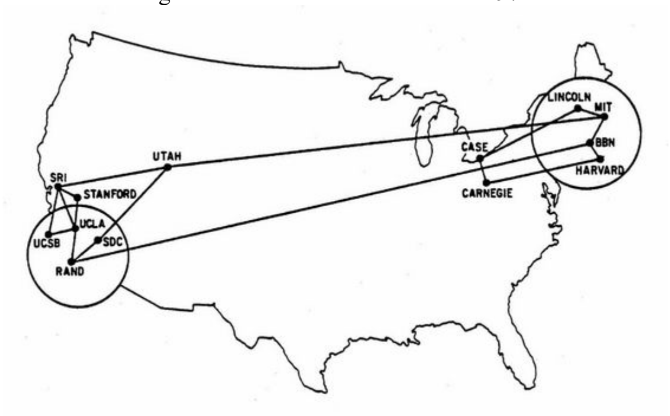
[9] Interview with Robert Kahn. The four nodes were UCLA, Stanford Research Institute, University of California, Santa Barbara, and the University of Utah.

Figure 1-1. ARPANET in December 1969




In 1970, two additional nodes were installed at Harvard and MIT. By mid-1971, over 30 computers were linked to the ARPANET.[10]

Figure 1-2. The ARPANET in Mid-1971

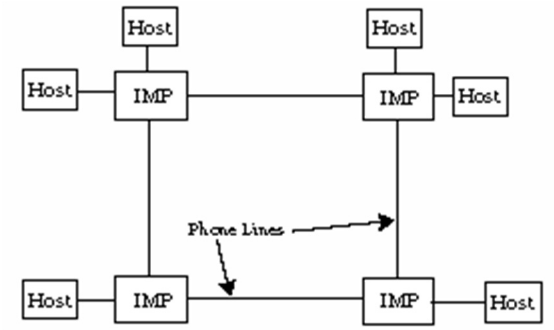



In 1972, Kahn joined DARPA eventually to become Director of the Information Processing Techniques Office where he started the Strategic Computing Program. At this point, the ARPANET was built

[10] John Markoff, "Robert Kahn's vision of a national network of information begins to take hold," *New York Times,* September 2, 1990, p. F1.

around IMPs.[11] The network itself consisted of host computers connected to IMPs which were linked together by means of leased phone lines.

Figure 1-3. Basic Structure of the ARPANET




## The Origins of TCP/IP and its Role in the ARPANET and the Internet

In October 1972, Kahn used the ARPANET for the first public demonstration of digital packet switching at the International Conference on Computer Communications in Washington, D.C. A packetized signal is broken into components called "packets." Packet switching is different from the earlier switching technology, circuit switching, in the following manner. First, in a packet-switched network, packets have no previously determined routes or paths. Each packet travels separately by the best route possible at any given time. The separate packets do not have to take the same route. Once the packets arrive at their destination, they are reassembled into the proper sequence.[12]

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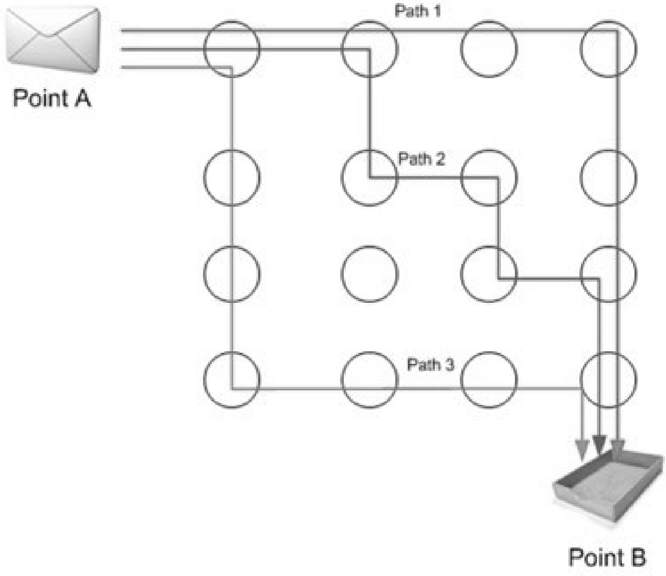
[11] IMPs are now called Packet Switch Nodes (PSNs). The original IMPs were Honeywell DDP-516 minicomputers. See Andrew S. Tannenbaum, *Computer Networks*, 2nd Edition (Englewood Cliffs, N.J.: Prentice Hall, 1989), p. 35.
[12] Defense Data Network, *DDN New User's Guide*, February 1991, p. 5.

Figure 1-4. A Packet-Switched Network




The ARPANET started as a packet switching network. Packet switching made the ARPANET more useful to the computer science and military community.[13] Now it was possible to link up many different kinds of computers at slow but acceptable data transfer rates and data could be transferred reliably. Access to the ARPANET was limited to defense agencies, defense contractors, and computer scientists conducting research on artificial intelligence and computer science in general. As of 1971, the most widely used application on the ARPANET was electronic mail. Computer scientists were the heaviest users.[14]

Its users came to see the ARPANET as an invaluable tool, and later put pressure on the Department of Defense to provide broader access to realize its full potential for the scientific community. By 1983, the ARPANET had expanded to around 100 nodes (from 4 in 1969), but access was still limited to defense agencies and defense contractors. Two new special purpose networks were built by the National Science Foundation and IBM in the early 1980s on the model of ARPANET -- CSNET and BITNET -- to give access to electronic mail capabilities to the

[13] Robert E. Kahn, "A National Network: Today's Reality, Tomorrow's Vision, Part 2," *Educom Bulletin*, Summer/Fall 1988, pp. 73-74.
[14] Personal communication from Vint Cerf, April 2023.

non-defense-contracting computer science and academic communities respectively. Access to the CSNET gave computer scientists access to all the nodes on the ARPANET.[15] BITNET connected only those local networks that were connected to an IBM mainframe.[16]

Vint Cerf joined DARPA in 1976.[17] Cerf first met Walden and Kahn in 1969 when they went to UCLA to test the four-node node network (see Figure 1-1 above). Kahn wanted Cerf at DARPA because Cerf knew a lot about network protocols and operating systems. The Department of Defense wanted to interconnect computers with satellites and packet radio systems[18] for the military, and Kahn needed someone who could help him integrate the operating system with the packet protocols. In the process, Cerf and Kahn invented the "gateway" concept, which allowed very different types of networks to be connected, even though they used different sized data packets and worked at different clock speeds.

The IEEE published a paper by Cerf and Kahn in May 1974 which outlined a set of network interconnection protocols designed to do this that is now known as TCP/IP.[19] Thanks to its robustness, adaptability, and relative simplicity, TCP/IP has become a world standard for interconnecting computers. Since TCP/IP was distributed at virtually no cost to the computing community as part of the earlier versions of the kernel of the Berkeley UNIX operating system called Berkeley Software

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15 CSNET, initially funded by NSF, was developed around 1980. At one time, CSNET had almost 200 participating sites and connections to almost fifteen countries. CSNET still serves a number of industrial and collegiate sites. See Karen Armstrong McKelvey, Michelle Margolis, and Susan Estrada, *CERFNET User's Guide*, July 1991, Section 6.1.

16 See John S. Quarterman and Josiah C. Hoskins, "Notable Computer Networks," in Peter J. Denning (ed.), *Computers Under Attack: Intruders, Worms, and Viruses* (New York: Addison-Wesley, 1990). BITNET and CSNET were merged in 1987 to form the Corporation for Research and Educational Networking (CREN).

17 He was supported by DARPA at Stanford from 1972 and 1976.

18 In particular, the ALOHA system pioneered at the University of Hawaii, and first deployed in 1971. See Tannenbaum, *Computer Networks*, p. 182.

19 TCP stands for Transmission Control Protocol and IP for Interconnection Protocol. See Tannenbaum, *Computer Networks*, pp. 36-40; John Davidson, *An Introduction to TCP/IP* (New York: Springer Verlag, 1988; and Douglas E. Comer, *Internetworking with TCP/IP: Principles, Protocols, and Architecture* (Englewood Cliffs, N.J.: Prentice Hall, 1988). Cerf was later to play a key role, along with Kahn, in building a political coalition to support the construction of a national data network to replace the ARPANET when it was decommissioned in 1990.

Distribution (BSD),[20] it rapidly became the most widely used interconnection protocol. All UNIX-based systems still contain TCP/IP in the kernel, and many other mainframes and large minicomputers also support TCP/IP interconnection services as supplements to their proprietary network architectures. Eventually, operating systems for personal computers also came to include TCP/IP support. TCP/IP remains a major reason for the rapidly expanding traffic on the Internet.

To summarize, developments in packet switching and network protocol standardization greatly expanded the possibilities for the ARPANET. However, the ARPANET had to face a number of other challenges and opportunities during its lifetime to maintain its viability and utility for the user community. One of these was to incorporate local area networks (LANs), starting from the development of Ethernet at Xerox Corporation's Palo Alto Research Center (PARC).[21] Luckily, Ethernet was designed from the start to be compatible with TCP/IP protocols. Thanks to the gateway concept pioneered by Kahn and Cerf, ARPANET access could expand rapidly via connection with regional and special-purpose computer networks.[22] The challenge which ARPANET could not handle, and which led to its demise, was the unwillingness of the Department of Defense to spend money to upgrade the backbone.

## The Building of the NSFNET

A national program for supporting research in supercomputing got underway in the late 1970s and early 1980s which put very strong

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[20] It should be noted that funding for early UNIX research came mainly from AT&T Bell Labs, MIT, and General Electric. It is interesting to note that Berkeley UNIX research led not only to the proliferation of TCP/IP systems but also to the formation of Sun Microsystems under the leadership of researchers like Bill Joy. See Wikipedia, "Sun Microsystems," accessed at Sun Microsystems - Wikipedia.

[21] ARPANET's solution to the LAN problem was to develop a gateway system that became the basis for a service called Telenet. Invented at BBN in 1972, Telenet went on to become a privately owned available data network available to users nationally by dialing local telephone numbers. See Chapter 2 for more about the development of Ethernet.

[22] In the 1970s, a variety of regional and limited-purpose national networks joined the ARPANET to offer broad connectivity. Merit, Inc., which operated a wide-area network for the state of Michigan, joined the ARPANET early on. BARRNET, linking government and academia in the San Francisco Bay Area, also joined the ARPANET. These were all part of the NSFNET regional network system and sponsored in part by NSF. See Joseph Polka, "Getting Together Bit by Bit," *Science*, Vol. 248, April 13, 1990, p. 160.

pressures on the federal government to build a public network accessible to all major research facilities, public and private. The Computing for Education and Research Program (CER) was established at the National Science Foundation (NSF). This program did not include supercomputing initially, but early in 1980 the NSF got Congressional approval for the construction of five supercomputing centers. The selection of sites was made in 1983-84 and new supercomputing centers were built in 1985-1986 at Cornell University (the Cornell National Supercomputer Facility), Princeton (the John Von Neumann Center), Pittsburgh (the Pittsburgh Supercomputing Center), the University of Illinois at Urbana/Champaign (the National Center for Supercomputing Applications), and the University of California at San Diego (the San Diego Supercomputer Center).[23] Four additional supercomputing sites (at the University of Delaware, Purdue University, the University of Washington at Seattle, and the University of Minnesota) were included in the NSFNET networking plans in 1986-87.[24]

There were so few supercomputer centers because of the great expense of building the new machines. Because scientists who were not based at universities near the centers wanted access to them, the NSF decided to provide access via networks. At a meeting in 1979 at the University of Wisconsin, Kent Curtis of NSF approached Robert Kahn of DARPA to ask whether the ARPANET would be capable of linking the separate supercomputing facilities. Kahn was enthusiastic about the idea, but it was not to be.

The Department of Defense had decided to expand the original ARPANET in the early 1980s. In October 1983, the ARPANET was officially split into two networks: the MILNET and the “residual” ARPANET. Prior to the split, ARPANET had 100 nodes and combined R&D activities with more strictly military ones. The new MILNET with 60 nodes, was to be a strictly military network, but there were gateways to connect the MILNET to the “residual” ARPANET. That left 40 nodes for

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[23] Sidney Karin and Norris Parker Smith, *The Supercomputer Era* (New York: Harcourt Brace Jovanovich, 1987), pp. 105-111. The Princeton center was closed after an NSF review in 1989-90. See *High Performance Computing and Networking for Science Advisory Panel: A Background Paper* (Washington, D.C.: Office of Technology Assessment, 1991).

[24] Interview with Dr. Robert Kahn, Corporation for National Research Initiatives, August 29, 1991. Purdue, Minnesota and Colorado State had supercomputing facilities prior to the NSF initiative in 1984. See *High Performance Computing and Networking*, pp. 33-36, for a complete list of supercomputing centers in the United States.

the "residual" ARPANET which Kahn hoped would become the backbone for the new network linking the NSF supercomputing centers.[25]

The Pentagon asked Congress for an expansion of the MILNET to 3600 nodes and was authorized to do so, but there were not enough people in the Defense Communications Agency to perform the work necessary for the requested expansion.[26] So Kahn had the idea that he could create a super coalition of supporters of both the NSFNET and the MILNET to build the new supercomputer network and the new MILNET simultaneously by adding nodes to both the MILNET and the residual ARPANET.

For a while, it looked like this plan would work. However, the labyrinthine acquisition procedures of the Department of Defense and delays in the delivery of switches from the phone companies created long lags in the addition of new nodes, so the NSF decided instead to bypass DARPA and to build the new supercomputing network on its own. After a brief and unsuccessful attempt to link the supercomputing centers with a "do-it-yourself" network, the NSF issued a Request for Proposals (RFP). The contract was won in 1987 by a team led by Merit, Inc., which included IBM and MCI.[27]

The NSF awarded $14 million to the Merit-led team to put the NSFNET backbone in place. Merit was responsible for the management and administration of the NSFNET. MCI was responsible for maintaining the leased lines for five years. IBM provided its NetView network management software and switches based on IBM computers. By July 1988, the T1 backbone was in place.[28]

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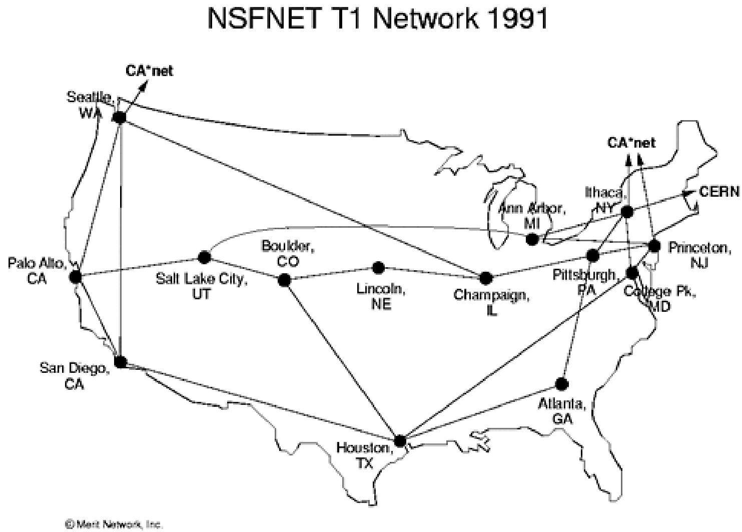
[25] Defense Data Network, *DDN New User's Guide*, February 1991, p. 8.
[26] Interview with Robert Kahn, Corporation for National Research Initiatives, August 29, 1991.
[27] Eric Aupperle, "Building Merit," *Information Technology Quarterly* (Summer-Fall 1989), pp. 7-9; and interview with Robert Kahn.
[28] Willie Schatz and Mary Jo Foley, "Users Welcome New NSF Network with Glee and Caution," *Datamation*, September 1, 1988.

Figure 1-5.

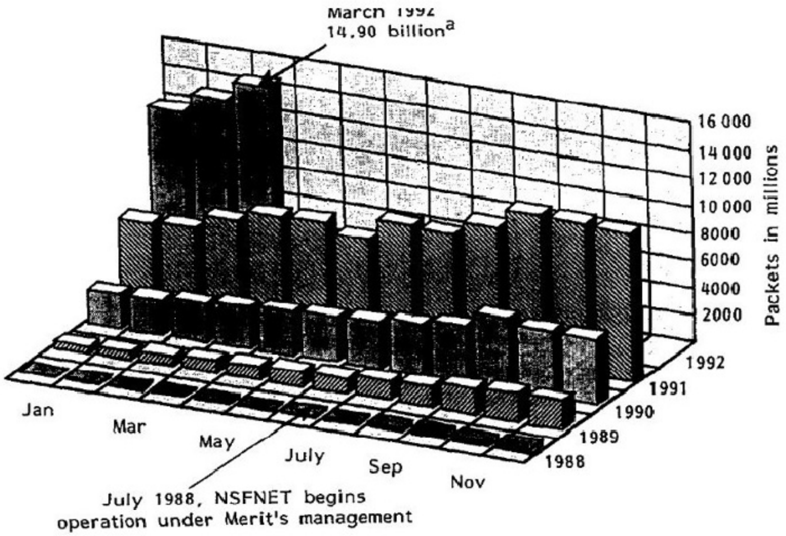



There were twelve to thirteen nodes on the NSFNET backbone with the capability of transferring data at 590 kilobits per second, a rate considerably higher than the speed of the ARPANET (56 kilobits per second in the early 1980s). Despite NSF's decision not to build the NSFNET on the foundation of the ARPANET, the NSFNET shared ARPANET's decision to use the TCP/IP family of protocols for interconnection. The builders of the NSFNET considered Open Systems Interconnection (OSI) protocols but opted for TCP/IP because they believed the OSI interconnection protocols were not ready.

## Rapid Growth of Traffic on the NSFNET

Traffic on the NSFNET grew very rapidly. In May 1989, traffic was approximately one billion packets per month. By May 1991, traffic had increased to 7.56 billion packets per month, a 140 percent increase over the 3.15 billion packets transmitted in May 1990 (see Figure 1-6).

Figure 1-6. NSFNET Packet Traffic History, 1998-1992




In 1989, around 200 universities had access to the NSFNET through the Internet.[29] The total number of networks on the system in May 1989 was 516. Of those, 95 were foreign. By May 1991, there were 2,763 networks on the system, including the MILNET networks configured for the NSFNET backbone (added in the summer of 1990). The number of foreign networks on the NSFNET was 882 in May 1991.

The residual ARPANET was decommissioned in 1990 and all the old civilian ARPANET nodes were taken off the network. Most of the civilian users of the ARPANET had made the transition to the Internet by then, often through regional or mid-level networks. The ARPANET had served its purpose well but was not able to become the backbone for the new NSFNET because it was too slow. The visions behind the NSFNET and the Internet were more expansive and inclusive. Virtually all academics, most employees of the U.S. government, and some employees of private businesses now would have access to the Internet. The next step

[29] Ivars Peterson, "Highways for Information," *Science News*, Vol. 133, June 18, 1988, pp. 394-395.

would be to expand access to all employees of commercial businesses able to pay an interconnection fee.

## The Mid-Level Networks

To arrange the interconnection of universities to the NSFNET, a system of NSF mid-level networks was established around a number of existing regional networks and some new ones.[30] The following is a list of all the NSFNET mid-level networks:

| | |
|---|---|
| BARRNET | Northern California |
| CERFNET | Southern California |
| CICNET | Illinois, Iowa, Michigan, Minnesota, Ohio, Wisconsin |
| CSNet/CREN IP&X25 | International and National |
| JVNCNET | Eastern US and International |
| LOS NETTOS | Los Angeles |
| MichNet/Merit | Michigan |
| MIDNET | Arkansas, Iowa, Kansas, Missouri, Nebraska, Oklahoma |
| MRNET | Minnesota |
| NCSANET | Illinois, Indiana, Wisconsin |
| NEARNET | New England |
| NEVADANET | Nevada |
| NORTHWESTNET | Northwestern US |
| NYSERNET | New York |
| OARNET | Ohio |
| PREPNET | Eastern US |
| PSCNET | Eastern US |
| SDSCNET | San Diego Supercomputer Network |
| SESQUINET | Texas |
| SURANET | Southeastern United States |
| THENET | Texas |
| USAN | National |
| VERNET | Virginia |
| WESTNET | Western United States[31] |

[30] The establishment of the regional networks was to some extent a reaction to the decommissioning of the ARPANET.
[31] This list was published in the *CERFNET User's Guide*, July 1991, p. 17.

Some of these mid-level networks, like CERFNET, provided interconnection services for private businesses for a fee consistent with the NSFNET Acceptable Use Policy.[32] Acceptable use involved "research and instruction at not-for-profit institutions in the United States..." Commercial (for-profit) uses were permissible only if they were consistent with the overall purposes of the NSFNET. Exceptions had to be approved at the NSF Project Office on a case-by-case basis.[33] This seems not to have placed too many limitations on the information technology firms of California, many of whom had access to the Internet through CERFNET.

There were enough commercial users of the Internet who did not want to be bound by the NSFNET Acceptable Use Policy that there was considerable demand for purely private Internet interconnection services. For example, Hewlett-Packard set up its own proprietary internet for the purpose of linking its geographically-dispersed research operations. National Semiconductor Corporation used its private internet to network advanced workstations to conduct simulations of new circuit designs.[34]

In addition, some of the burden of managing the existing networks was shifted to private sector firms, through service contracts with the mid-level networks. For example, PSInet (run by Performance Systems International of Reston, Virginia) provided network management services to NYSERNET, that used to be performed by NYSERNET itself. PSInet also provided access to the Internet via NYSERNET for commercial firms in the New York area. Another private firm, UUNET Technologies of Falls Church, Virginia, provided Internet connection through its AlterNet. General Atomics of San Diego did the same through its CERFNET operations.[35]

The NSFNET added T3 leased lines to its existing T1 leased lines (bringing trunk transmission speeds up to 45 Mbps) in 1991-92 through a contract with a firm called ANS (Advanced Network and Services, Inc.), which was a nonprofit joint venture formed by MERIT, IBM and MCI in 1990. MERIT no longer managed the NSFNET as it did originally, but only collected statistics on network usage. IBM and MCI formed another joint venture called ANS CO+RE (pronounced core, short for "commercial"

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[32] ATT acquired CERFNET in 2000. See https://www.cybertelecom.org/industry/att.htm.
[33] Ibid, pp. 19-20.
[34] Interview with Robert Kahn and personal communication with Vint Cerf; John Markoff, "A Network of Networks That Keeps Scientists Plugged In," *New York Times*, January 1, 1992, p. 21.
[35] See Sharon Fisher, "Whither NREN?" *Byte*, July 1991, pp. 181-190.