Internet: From the Beginning to the Big Bang

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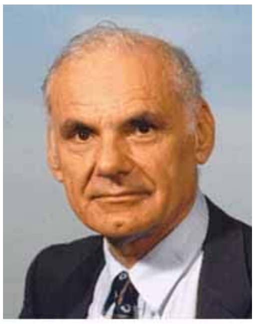
The Internet has revolutionized the computer and communications world like nothing before. The invention of the telegraph, telephone, radio, and computer set the stage for this unprecedented integration of capabilities. The Internet is at once a world-wide broadcasting capability, a mechanism for information dissemination, and a medium for collaboration and interaction between individuals and their computers without regard for geographic location.

The Internet represents one of the most successful examples of the benefits of sustained investment and commitment to research and development of information infrastructure. Beginning with the early research in packet switching, the government, industry and academia have been partners in evolving and deploying this exciting new technology. The Internet today is a widespread information infrastructure, the initial prototype of what is often called the National (or Global or Galactic) Information Infrastructure.

Its history is complex and involves many aspects - technological, organizational, and communal. And its influence reaches not only to the technical fields of computer communications but throughout society as we move toward increasing use of online tools to accomplish electronic commerce, information acquisition, and community operations. The Internet was conceived in the 1960s as a tool to link university and government research centers via a nationwide network that would allow a wide variety of computers to exchange information and share resources. The engineering challenges were manifold and complex, starting with the design of a packet switching network - a system that could make computers communicate with each other without the need for a traditional central system. Other challenges included the design of the machines, data exchange protocols, and software to run it.

On the heels of Sputnik and the onset of the Cold War, President Eisenhower thought it wise to create the Advanced Research Projects Agency (ARPA) in 1958, to keep the United States at the forefront of technology. However, before ARPA began supporting networking research seriously, Leonard Kleinrock had already invented the technology of the Internet in 1962 while an MIT graduate student.

Leonard Kleinrock is a computer scientist who made several extremely important contributions to the field of computer networking, in particular to the theoretical side of computer networking. His most well-known and significant work is his early study on queueing theory, which has applications in many fields, among them as a key mathematical background to packet switching, the basic technology behind the Internet. His initial contribution to this field was his doctoral thesis in 1962, published in book form in 1964; he later published several of the standard works on the subject.



Larry Roberts (Kleinrocks classmate at MIT) was brought to ARPA in 1966 to manage the program to create the packet-switched ARPAnet. This network was to form the foundation of the Internet. In 1967, Roberts convenes a conference in Ann Arbor, Michigan, to bring the ARPA researchers together. At the conclusion, Wesley Clark suggests that the network should be managed by interconnected 'Interface Message Processors' in front of the major computers. Called IMPs, they evolve into today's routers. Roberts and the ARPA team refine the overall structure and specifications for the ARPANET. They issue an RFQ for the development of the IMPs. Roberts works with Howard Frank and his team at Network Analysis Corporation designing the network topology and economics. Kleinrock's team prepare the network measurement system at UCLA, which is became the site of the first node.

At Bolt, Beranek and Newman (BBN), Frank Heart leads a team to bid on the project. Bob Kahn playes a major role in shaping the overall BBN designs. BBN wins the project in December 1968. Frank Heart puts a team together to write the software that will run the IMPs and to specify changes in the Honeywell DDP-516 they have chosen. The team includes Ben Barker, Bernie Cosell, Will Crowther, Bob Kahn, Severo Ornstein, and Dave Walden. Four sites are selected. At each, a team gets to work on producing the software to enable its computers and the IMP to communicate. At UCLA, the first site, Vint Cerf, Steve Crocker, and Jon Postel work with Kleinrock to get ready. On April 7, Crocker sends around a memo entitled 'Request for Comments.' This is the first of thousands of RFCs that document the design of the ARPANET and the Internet.

The team calls itself the Network Working Group (RFC 10), and comes to see its job as the development of a 'protocol,' the collection of programs that comes to be known as NCP (Network Control Protocol).

The second site is the Stanford Research Institute (SRI), where Doug Englebart saw the ARPA experiment as an opportunity to explore wide-area distributed collaboration, using his NLS system, a prototype 'digital library.' SRI supported the Network Information Center, led by Elizabeth (Jake) Feinler and Don Nielson. At the University of California, Santa Barbara (UCSB) Glen Culler and Burton Fried investigates methods for display of mathematical functions using storage displays to deal with the problem of screen refresh over the net. Their investigation of computer graphics supplies essential capabilities for the representation of scientific information.

After installation in September, handwritten logs from UCLA show the first host-to-host connection, from UCLA to SRI, is made on October 29, 1969.

The ARPANET begins the year 1971 with 14 nodes in operation. BBN modifies and streamlines the IMP design so it can be moved to a less cumbersome platform than the DDP-516. BBN also develops a new platform, called a Terminal Interface Processor (TIP) which is capable of supporting input from multiple hosts or terminals. The Network Working Group completes the Telnet protocol and makes progress on the file transfer protocol (FTP) standard. At the end of the year, the ARPANET contains 19 nodes as planned.

Many small projects are carried out across the new network still the overall traffic is far lighter than the network's capacity. Something needs to stimulate the kind of collaborative and interactive atmosphere consistent with the original vision. Larry Roberts and Bob Kahn decide that it is time for a public demonstration of the ARPANET. They choose to hold this demonstration at the International Conference on Computer Communication (ICCC) to be held in Washington, DC, in October 1972.

The ARPANET grows by ten more nodes in the first 10 months of 1972. The year is spent finishing, testing and releasing all the network protocols, and developing network demonstrations for the ICCC. In the same year, at BBN, Ray Tomlinson writes a program to enable electronic mail to be sent over the ARPANET. It is Tomlinson who develops the 'user@host' convention, choosing the @ sign arbitrarily from the non-alphabetic symbols on the keyboard.

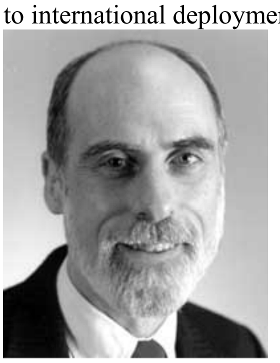
The ICCC demonstrations prove packet-switching a viable technology, and ARPA (now DARPA, where the 'D' stands for 'Defense') looks for ways to extend its reach. Two new programs begin: Packet Radio sites are modeled on the ALOHA experiment at the University of Hawaii designed by Norm Abramson, connecting seven computers on four islands; and a satellite connection enables linking to two foreign sites in Norway and the UK.

In 1973, Bob Kahn moves from BBN to DARPA to work for Larry Roberts, and his first self-assigned task is the interconnection of the ARPANET with other networks. He enlists Vint Cerf, who has been teaching at Stanford. The problem is that ARPANET, radio-based PRnet, and SATNET all have different interfaces, packet sizes, labeling, conventions and transmission rates. Linking them together is very difficult. Kahn and Cerf set about designing a net-to-net connection protocol. Cerf leads the newly formed International Network Working Group. In

September 1973, the two give their first paper on the new Transmission Control Protocol (TCP) at an INWG meeting at the University of Sussex in England. Meanwhile, at Xerox PARC, Bob Metcalfe is working on a wire-based system modeled on ALOHA protocols for Local Area Networks (LANs) what will become Ethernet.

DARPA supports computer scientists at UC Berkeley who are revising a UNIX system to incorporate TCP/IP protocols. Berkeley Unix also incorporates a second set of Bell Labs protocols, called UUCP, for systems to use dial-up connections in 1976. Also in this year Vint Cerf moves from Stanford to DARPA to work with Bob Kahn on networking and the TCP/IP protocols.

In 1977, Cerf and Kahn mount a major demonstration, 'internetting' among the Packet Radio net, SATNET, and the ARPANET. Messages go from a van in the Bay Area across the US on ARPANET, then to University College London and back via satellite to Virginia, and back through the ARPANET to the University of Southern California's Information Sciences Institute. This shows its applicability to international deployment.



Vint Cerf at DARPA continues the vision of the Internet, forming an International Cooperation Board chaired by Peter Kirstein of University College London, and an Internet Configuration Control Board, chaired by Dave Clark of MIT. In 1978, the ARPANET experiment formally is complete. This leaves an array of boards and task forces over the next few years trying to sustain the vision of a free and open Internet that can keep up with the growth of computing.

One year later, in 1979, Larry Landweber at Wisconsin holds a meeting with six other universities to discuss the possibility of building a Computer Science Research Network to be called CSNET. The idea evolves over the summer between Landweber, Peter Denning (Purdue), Dave Farber (Delaware), and Tony Hearn (Utah). In November, the group submits a proposal to NSF to fund a consortium of eleven universities at an estimated cost of $3 million over five years. This is viewed as too costly by the NSF. USENET starts a series of shell scripts written by Steve Bellovin at UNC to help communicate with Duke. Newsgroups start with a name that gives an idea of its content. USENET is an early example of a client server where users dial in to a server with requests to forward certain newsgroup postings. The server then 'serves' the request.

Landweber's proposal has many enthusiastic reviewers. At an NSF-sponsored workshop, the idea is revised in a way that both wins approval and opens up a new epoch for NSF itself. The revised proposal includes many more universities. It proposes a three-tiered structure involving ARPANET, a TELENET-based system, and an e-mail only service called PhoneNet. Gateways connect the tiers into a seamless whole. This brings the cost of a site within the reach of the smallest universities. Moreover, NSF agrees to manage CSNET for two years, after which it will turn it over to the University Corporation for Atmospheric Research (UCAR), which is made up of more than 50 academic institutions. In 1980, the National Science Board approves the new plan and funds it for five years at a cost of $5 million. Since the protocols for interconnecting the subnets of CSNET include TCP/IP, NSF becomes an early supporter of the Internet.

The period during which ad hoc networking systems have flourished has left TCP/IP as only one contender for the title of 'standard.' Indeed, the International Organization for Standards (ISO) has written and is pushing ahead with a 'reference' model of an interconnection standard called Open Systems Interconnection (OSI) — already adopted in preliminary form for interconnecting DEC equipment. But while OSI is a standard existing for the most part on paper, the combination of TCP/IP and the local area networks created with Ethernet technology are driving the expansion of the living Internet.

In January 1983, the ARPANET standardizes on the TCP/IP protocols adopted by the Department of Defense (DOD). The Defense Communications Agency decides to split the network into a public 'ARPANET' and a classified 'MILNET' with only 45 hosts remaining on the ARPANET. Jon Postel issues an RFC assigning numbers to the various interconnected nets. Barry Leiner takes Vint Cerf's place at DARPA, managing the Internet.

Numbering the Internet hosts and keeping tabs on the host names simply fail to scale with the growth of the Internet. In November, Jon Postel and Paul Mockapetris of USC/ISI and Craig Partridge of BBN develop the Domain Name System (DNS) and recommend the use of the now familiar user@host.domain addressing system.

Between the beginning of 1986 and the end of 1987 the number of networks grows from 2,000 to nearly 30,000. TCP/IP is available on workstations and PCs such as the newly introduced Compaq portable computer. Ethernet is becoming accepted for wiring inside buildings and across campuses. Each of these developments drives the introduction of terms such as bridging and routing and the need for readily available information on TCP/IP in workshops and manuals. Companies such as Proteon, Synoptics, Banyan, Cabletron, Wellfleet, and Cisco emerge with products to feed this explosion.

The upgrade of the NSFNET backbone to T1 completes and the Internet starts to become more international with the connection of Canada, Denmark, Finland, France, Iceland, Norway and Sweden in 1988. One year later, the number of hosts increases from 80,000 in January to 130,000 in July to over 160,000 in November! Australia, Germany, Israel, Italy, Japan, Mexico, Netherlands, New Zealand and the United Kingdom join the Internet.

In Switzerland at CERN Tim Berners-Lee addresses the issue of the constant change in the currency of information and the turn-over of people on projects. Instead of a hierarchical or keyword organization, Berners-Lee proposes a hypertext system that will run across the Internet on different operating systems. This was the World Wide Web.

The Internet has changed much in the two decades since it came into existence. It was conceived in the era of time-sharing, but has survived into the era of personal computers, client-server and peer-to-peer computing, and the network computer. It was designed before LANs existed, but has accommodated that new network technology, as well as the more recent ATM and frame switched services. It was envisioned as supporting a range of functions from file sharing and remote login to resource sharing and collaboration, and has spawned electronic mail and more recently the World Wide Web. But most important, it started as the creation of a small band of dedicated researchers, and has grown to be a commercial success with billions of dollars of annual investment.

This evolution will bring us new applications - Internet telephone and, slightly further out, Internet television. It is evolving to permit more sophisticated forms of pricing and cost recovery, a perhaps painful requirement in this commercial world. It is changing to accommodate yet another generation of underlying network technologies with different characteristics and requirements, from broadband residential access to satellites. New modes of access and new forms of service will spawn new applications, which in turn will drive further evolution of the net itself.

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