Internet History

From ARPANET to Broadband

When the Department of Defense (DOD) issued a $19,800 contract on December 6, 1967, for the purpose of studying the "design and specification of a computer network," the world didn't take notice. But it should have. For, from that small, four-month study grew the ARPANET (Advanced Research Projects Agency Network). And, from ARPANET emerged the Internet.

Like many information and communications technologies, the Internet we know today grew from seeds planted by the U.S. Government. Specifically, the Advanced Research Projects Agency (ARPA) was established in 1957 to respond to the perceived scientific and technological advantage the then-Soviet Union displayed in launching the Sputnik satellite. ARPA was charged to "direct or perform such advanced projects in the field of research and development as the Secretary of Defense shall, from time to time, designate by individual project or by category." In plain language this meant that ARPA, along with the newly created National Aeronautics and Space Administration, was to regain technical superiority for the United States.

Some of those employed by ARPA realized the only way this goal could be achieved was to bring together the brainpower resident in discrete pockets at universities and research institutions spread across the United States. To maximize this sharing of brain-power, it quickly became clear that significant advances in computing technology were required. These computing advances had to provide avenues for both the sharing of ideas and the sharing of computing power and programs. So, an Information Process Techniques Office (IPTO) was created within ARPA in 1962 to achieve this purpose.

The first head of that office was J.C.R. Licklider. He envisioned an "intergalactic" community that could emerge from a single computer time-sharing system. He thought such a community possible because he held a different view of computers. Instead of thinking of computers as giant calculators, Licklider laid out a vision in which computers would fulfill their greatest promise as a "communication medium between people."

From The Internet: A Short History of Getting Connected, *prepared by the Federal Communications Commission.*

About this same time, a RAND researcher by the name of Paul Baran was working on a classified U.S. Air Force contract whose purpose was to identify ways to strengthen the Nation's telecommunication infrastructure so that it could survive a nuclear strike. Part of his solution was to develop distributed telecommunication networks. If information was truly distributed, instead of everything flowing into and out of central points, then a network could still work effectively even if some legs of the network were damaged or removed. Implementing such a distributed network involved a technique called packet switching.

While this classified early-1960s work was not directly known to ARPA staff, its ideas of a distributed network using packet switching were key concepts for the ARPANET. Thankfully for the development of the ARPANET, unclassified work on these concepts was also being done independently by other researchers, such as Donald Davies and Leonard Kleinrock.

Packet switching is an approach that breaks a message down into separate, discrete pieces or packets. Each packet then moves from its point of origin to its destination over any open route, regardless of which path the other packets take. When all the packets arrive at the destination they are reassembled — and the message is delivered intact.

With these ideas — packet switching and computers as galactic communication devices — in place, what was needed were technologies that allowed different computers, from different manufacturers, with different operating systems to communicate with each other. To meet this technological need ARPA decided to "contract out," using a competitive bidding process among 140 potential bidders.

In 1968, $563,000 was committed to a contract with the purpose of designing, constructing, installing, testing, and maintaining four interface message processors (IMPS) that would link computers at the Stanford Research Institute, the University of California-Santa Barbara, the University of California-Los Angeles (UCLA), and the University of Utah. The contract promised that these IMPS would: "Provide the communications capability required for the ARPA computer research facilities but ... also be a unique prototype of future communications systems."

Thus, from these beginnings the ARPANET was born. On October 15, 1969, on the second try, the IMPS installed at UCLA and the Stanford Research Institute connected and began a communication revolution with the words "log in."

■ Common Standards

In 1969, when the ARPANET eventually connected computers at Stanford, UCLA, UC-Santa Barbara, and the University of Utah, it was a significant step toward realizing the vision of the computer as an extender of human capabilities. But four connected computers did not constitute a "galactic" network. How ARPANET created the foundation upon which today's true "galactic" network, the Internet, is built is a story about using common standards and protocols to implement vision.

One historian of the Internet says, "In the beginning was — chaos." And so it often is when people are trying something so new that many can't even find words to describe it. But while chaos can bring great energy and excitement, differing techniques, media, and protocols have to give way to common approaches if a build-up of chaotic energy is to result in something other than an explosion.

Excerpts from *Request for Comments* (RFC) 100 (August 1987) give a peek into how the original ARPANET team harnessed the energy of their new creation. These insights also show that, from its very beginning, today's Internet was conceived and established as a peer-to-peer network:

> At this point we knew only that the network was coming, but the precise details weren't known. That first meeting was seminal. We had lots of questions. ... No one had any answers. We did come to one conclusion: We ought to meet again. The first few meetings were quite tenuous. We had no official charter. Most of us were graduate students and we expected that a professional crew would show up eventually to take over the problems we were dealing with. ... Later ... it became clear to us that we had better start writing down our discussions. ... I remember having great fear that we would offend whomever the official protocol designers were ... [so we labeled our decisions] "Request for Comments" or RFCs.
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> Over the spring and summer of 1969 we grappled with the detailed problems of protocol design. Although we had a vision of the vast potential for intercomputer communication, designing usable protocols was another matter. ... It was clear we needed to support remote login for interactive use — later known as Telnet — and we needed to move files from machine to machine. We also knew that we needed a more fundamental point of view for building a larger array of protocols.
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> With the pressure to get something working and the general confusion as to how to achieve the high generality we all aspired to, we punted and defined the first set of protocols to include only Telnet and FTP [file transfer protocol] functions. In December 1969, we met with Larry Roberts in Utah, and suffered our first direct experience with "redirection." Larry made it abundantly clear that our first step was not big enough, and we went back to the drawing board.
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> Over the next few months we designed a symmetric host-host protocol, and we defined an abstract implementation of the protocol known as the Network Control Program. ("NCP" later came to be used as the name for the protocol, but it originally meant the program within the operating system that managed connections. The protocol itself was known blandly only as the host-host protocol.) Along with the basic host-host protocol, we also envisioned a hierarchy of protocols, with Telnet, FTP, and some splinter protocols as the first examples.
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> The initial experiment had been declared an immediate success and the network continued to grow. More and more people started coming to meetings, and the Network Working Group began to take shape. Working Group meetings started to have 50 and 100 people in attendance instead of the half dozen we had had in 1968 and early 1969.... In October 1971 we all convened at MIT for a major protocol "fly-off." Where will it end? The network has exceeded all estimates of its growth. It has been transformed, extended, cloned, renamed, and reimplemented. But the RFCs march on.

Indeed they do. Today there are nearly 4,000 RFCs and they are just one of several mechanisms used to propose and decide on standards for the Internet — a network of networks that learned from the ARPANET but had to be created and developed on its own terms. Because of the increasing complexity the Internet's TCP/IP protocols represented when compared to ARPANET's NCP protocol — simply put, the difference between creating one national network versus linking multiple, worldwide networks — several additional methods and organizations were established in the 1980s and 1990s to deal with protocol and standards.

First among these was the 1986 establishment of the Internet Engineering Task Force (IETF). The IETF took over responsibility for short- to medium-term Internet engineering issues, which had previously been handled by the Internet Activities Board. The Internet Society (ISOC), begun in 1992, provides an organizational home for the IETF and the Internet Architecture Board (IAB) (previously IAB stood for the Internet Activities Board).

Another organization, the ICANN (Internet Corporation for Assigned Names and Numbers), established in 1998, is a public-private partnership that is "responsible for managing and coordinating the Domain Name System (DNS) to ensure that every address is unique and that all users of the Internet can find all valid addresses. It does this by overseeing the distribution of unique IP addresses and domain names. It also ensures that each domain name maps to the correct IP address."

These and other organizations employ a variety of working groups, task forces, and committees to work through a multistage process of suggesting, reviewing, accepting, and issuing standards for the Internet. When a specification reaches the point that it "is characterized by a high degree of technical maturity and by a generally held belief that the specified protocol or service provides significant benefit to the Internet community," it is released as an Internet Standard. Today there are 63 Internet Standards.

By making common standards a routine practice from the beginning, ARPANET began pouring a strong foundation. In fact, ARPANET was so dedicated to common standards that RFC 1 was issued on April 7, 1969, six months before the first network connection was made. By 1982, when ARPANET transitioned to the use of the TCP/IP working protocols, the foundational footings had fully settled and the way was open for broader public involvement.

■ Making the Connections

The ARPANET, predecessor to the Internet, started with an inspiring vision of a "galactic" network, practical theory about packet switching, and a suite of standardized protocols. But none of this would have mattered if there hadn't also been a way to make and maintain connections.

Author Ronda Hauben described some of the early concerns about network transmission quality this way:

> In 1966–67 Lincoln Labs in Lexington, Massachusetts, and SDR in Santa Monica, California, got a grant from the DOD [U.S. Department of Defense to begin research on linking computers across the continent. Larry Roberts, describing this work, explains,
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> "Convinced that it was a worthwhile goal, we set up a test network to see where the problems would be. Since computer time-sharing experiments at MIT (CTSS) and Dartmouth (DTSS) had demonstrated that it was possible to link different computer users to a single computer, the cross-country experiment built on this advance." (Once timesharing was possible, the linking of remote computers was also possible.) Roberts reports that there was no trouble linking dissimilar computers. The problems, he claims, were with the telephone lines across the continent, i.e., that the throughput was inadequate to accomplish their goals.

Packet switching resolved many of the issues identified during the pre-ARPANET, time-sharing experiments. But higher-speed phone circuits also helped. The first wide area network demonstrated in 1965 between computers at MIT's Lincoln Lab, ARPA's facilities, and the System Development Corporation in California utilized dedicated 1,200 bps (bits per second) circuits. Four years later, when the ARPANET began operating, 50 Kbps (kilobits per second) circuits were used. But it wasn't until 1984 that ARPANET traffic levels were such that it became more cost-effective to lease T1 lines — 1.5 Mbps (megabits per second) than to continue using multiple 50 Kbps lines.

The increasing connection speed of T1 lines brought with it increasing demand, particularly from private sector businesses. By 1991, when all restrictions on commercial use of the Internet were lifted, the National Science Foundation (NSF) — which from 1987 to 1995 helped the United States make the transition from the ARPANET to today's Internet — had its entire network backbone connected to 45 Mbps T3 lines. In 1994, a year before the private sector assumed responsibility for the maintenance of the Internet backbone, the NSF upgraded the Internet backbone to Asynchronous Transmission Mode, 145 Mbps.

While large institutions, governments, and businesses have found it economically worthwhile to pay for high-speed connections for most of the past 40 years, in most American homes — where the Internet became of interest after the introduction of the graphically oriented World Wide Web in 1993 — affordable Internet access has been limited to 56 kbps modems operating over public phone lines. However, recently introduced broadband products and services offer North American households the possibility of getting access to a bit more of the bandwidth and connection speed actually available on the Internet.

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Glossary

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Telephony — The technology that makes it possible to transmit sound between two distant points — traditionally, the conventional telephone system, but now covering communication involving modems, sound cards, speakerphones, voicemail, and other systems involving computing and the Internet.

Voice over Internet Protocol (VoIP) — A telephone connection over the Internet. The data are sent digitally, using the Internet Protocol instead of analog telephone lines. This allows people to talk to one another long-distance and around the world without having to pay long-distance or international phone charges.

World Wide Web (WWW) — Created in Switzerland, WWW is client/server software. It uses the HTTP (Hypertext Transfer Protocol) to exchange documents and images. ■

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North American households' access to broadband began in 1996, when Rogers Communications introduced the first cable modem service in Canada.

Broadband encompasses several digital technologies (cable, satellite, DSL [digital subscriber line], powerline, and wireless) that provide consumers with integrated access to voice, high-speed data, video-on-demand, and interactive delivery services. The Congressional Research Service says that:

> Broadband access, along with the content and services it might enable, has the potential to transform the Internet. ... For example, a two-way, high-speed connection could be used for interactive applications such as online classrooms, showrooms, or health clinics, where teacher and student (or customer and salesperson, doctor and patient) can see and hear each other through their computers. An "always on" connection could be used to monitor home security, home automation, or even patient health remotely through the web. The high-speed and high-volume that broadband offers could also be used for bundled service where, for example, cable television, video-on-demand, voice, data, and other services are all offered over a single line.

A growing percentage of U.S. households seem to agree that broadband connections have many advantages. Between 2000 and 2001, broadband subscriptions rose over 50 percent, with an additional 48 percent growth in 2003. ■

Net Neutrality Overview

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further authority and has successfully used its existing authority, in a March 3, 2005, action. In that case, the FCC intervened and resolved, through a consent decree, an alleged case of port blocking by Madison River Communications, a local exchange (telephone) company. The full force of antitrust law is also available, they claim, in cases of discriminatory behavior.

Proponents of net neutrality legislation, however, feel that absent some regulation, Internet access providers will become gatekeepers and use their market power to the disadvantage of Internet users and competing content and application providers. They cite concerns that the Internet could develop into a two-tiered system favoring large, established businesses or those with ties to broadband network providers.

While market forces should be a deterrent to such anticompetitive behavior, they point out that today's market for broadband delivery is largely dominated by only two providers, the telephone and cable television companies, and that, at a minimum, a strong third player is needed to ensure that the benefits of competition will prevail. The need to formulate a national policy to clarify expectations and ensure the "openness" of the Internet is important to protect the benefits and promote the further expansion of broadband, they claim.

The adoption of a single, coherent, regulatory framework to prevent discrimination, supporters claim, would be a positive step for further development of the Internet by providing the marketplace stability needed to encourage investment and foster the growth of new services and applications.

Furthermore, relying on current laws and case-by-case antitrust-like enforcement, they claim, is too cumbersome, slow, and expensive, particularly for small start-up enterprises. ■