

Chapter 11

Evolution of the Internet

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Most people around the world who encounter the Internet consider it to be a vibrant medium of exchange that supports a wide variety of uses, most of them commercial. Many also know that, having been created with support from the United States Government, Defense Advanced Research Project Agency (DARPA) initially, and later the National Science Foundation (NSF), the Department of Education (DOE) and other agencies and departments, the Internet has its roots in the research and development community. In recent years, the private sector has made extensive investments in building Internet capabilities, and its recent growth has been almost entirely fueled by such private sector initiatives. However, as recently as a decade ago, the Internet was still the private enclave of the research and education community. At that time, few in the telecommunications business believed that the private sector would come to play such a critical role in leading its continued development and that the Internet would come to play such a central role in the United States (and indeed the world's) economy in the short span of ten years.

This article begins with a brief summary of the developments that led to the widespread availability of the Internet. Consideration will then be given to some of the key transition issues in moving the Internet from the province of United States Government control to the private sector. The need for effective management structures and standards will be highlighted, together with the need for continued awareness on the part of governments concerning the Internet and its operation. Finally, some of the longer-term needs of the user community, as well as those of Internet service and equipment providers, in addressing the possibilities for the future, are discussed.

BACKGROUND

The Internet is a collection of networks around the world that inter-operate seamlessly via an open

architecture and its associated protocols. The first three networks in the Internet were the Advanced Research Project Agency Network (ARPANET), packet radio network, and packet satellite network, all sponsored by DARPA several decades ago. Each of these three networks was individually designed and implemented, but most importantly, the Internet architecture was created to be independent of the detailed design or implementation of any of its constituent networks. As a result, the technology for networking could evolve and change, and the latest technology could be integrated with the prior technology simply by adding new networks.

The success of the Internet was therefore heavily dependent on the underlying computer communications technology that had been pioneered in the ARPANET. The basic notions of packet switching were already well known by the late 1960s and had been successfully demonstrated in the ARPANET project by the early 1970s. In addition, the notion of layered host protocols, also demonstrated in the ARPANET project, allowed for building new applications and services on top of existing ones, and has been carried forward to the present as a basic paradigm for protocol implementation.

To get to the Internet architecture was not a completely straightforward path, however, from the early network developments. In fact, the original implementation of the packet satellite network equipment assumed it would be integrated into upper memory of an ARPANET IMP (Interface Message Processors), and not be a separate, externally accessible network. This was perhaps the first of many cases where the network management required close co-ordination with network architecture and raised the basic issue of overall governance of the 'network of networks'. As is now known, there is no single entity responsible for the overall performance of the Internet, as there is no entity responsible for the performance of the world economy. Some perceive this as a fatal weakness; others, as a principal strength. Whatever

their views, all the participants have a fundamental interest in the success of the system and will generally do their part to contribute to it, while recognizing that they may need to work together on certain problems and issues that cannot be resolved in isolation.

Networking development over the past four decades may generally be categorized as follows:

- The period of the 1960s, in which basic ideas emerged for computer networking, particularly those of packet switching and the possibilities for sharing resources over computer networks.
- The period of the 1970s, when packet switching technology was developed and demonstrated in several experimental and commercial networks, beginning with the ARPANET at speeds of 50 Kbps. This was mainly a period of technological development, including the development of local area networks like the Ethernet and small computers such as the Xerox Alto for individual users that presaged the personal computer as we now know it.
- In the 1980s, widespread deployment and commercialization of the technology began. Networking was extended to the entire research and higher-education communities. Industry took to manufacturing and selling personal computers and workstations, local-area networks, and related software. Transmission Control Protocol/Internet Protocol (TCP/IP) became the standard protocol for computer communications. The National Science Foundation Network (NSFNET) replaced the ARPANET as the backbone of the Internet at speeds of 1.5 Mbps. By the late 1980s, there were thousands of networks and tens of thousands of hosts on the then emerging Internet. Most of these were local and regional networks that had been formed during the decade.
- The 1990s has been the decade of commercialization of the Internet. Beginning with the first experiments to link commercial e-mail

systems to the government-supported (and, at the time, still-dominant) portion of the Internet, the desirability of allowing commercial interactions on the NSFNET grew. The ARPANET was decommissioned. The Boucher Bill, passed by United States House of Representatives in early 1993, opened up the National Science Foundation Network (NSFNET) to commercial use. A few years later, sufficient private sector networking capability was deemed to exist, and US Federal government support for the NSFNET ceased. Although the Internet was growing at 100% per year prior to 1993, the introduction of the Mosaic browser for the World Wide Web caused usage of the Internet to accelerate dramatically (see Statistical Annex, Section 3). It is now widely assumed that, by the end of this decade, approximately 100 million users will have access to the Internet. A decade later the number might easily be a factor of ten larger, representing perhaps 10% of the world's population.

TRANSITION TO THE PRIVATE SECTOR

While the decision by the United States Government to privatize key parts of the Internet, such as the Domain Name System (DNS), became embroiled in debate across many continents, this is not a new phenomenon. Indeed, the move to privatization has been taking place steadily over many decades. In the late 1970s, DARPA began to involve the research community in the decision-making process for ARPANET standards, and by the mid-1980s, this basic responsibility had been assumed by the research community. As part of its strategy from the beginning, NSF encouraged and, in several cases, funded the development of local and regional research networks by the private sector. With support for the Internet Engineering Task Force (IETF) and the Internet Assigned Numbers Authority (IANA, www.iana.org/

[faqs.html](#)), NSF empowered these groups to take responsibility for leading the effort to establish standards. In working with the Internet Society and various diverse groups from many quarters, it recognized the role that private-sector bodies had to play in the overall organization and governance of the Internet.

At this point, with respect to the evolution of the Internet, the essential function of the United States Government, in co-operation with other governments, should be:

- to ensure that a fair process is set up for the evolution of the Internet at the local, national, regional and global level;
- to provide supervisory capability in the event that private-sector efforts fail to ensure fairness or guarantee the effective working of the Internet;
- to remove any bottlenecks, barriers and other obstacles to progress;
- to support advanced research, as appropriate; and
- to address policy issues concerning the Internet, and to encourage or otherwise stimulate progress in the Internet towards the general well being of society.

With the possible exception of the last two, these functions can be quite difficult for governments to carry out effectively. The notion of fairness is likely to be elusive among competing parties, and, left to their own devices, private sector organizations will be more inclined to tilt the process in their own favour whenever possible. The private sector may provide supervisory functions, but these too must be watched closely, if only in the public interest. Finally, it may be difficult to identify many of the barriers and bottlenecks, let alone to find effective ways to overcome them. It is important that the harbingers of change not be hindered by established ways of doing business.

Governments cannot effectively solve these problems unilaterally, but they can and should draw upon input from the private sector. Research is the key to

unlocking new capabilities. While industry has the incentive to carry out short-term research, often in the process of product development, with few exceptions, it will not invest for the long-term. Since the break-up of the Bell System in 1984, the amount of long-term industrial research has remained low. Only states seem able to make the commitment to long-term research funding (see UNESCO's Draft World Declaration on Science and the use of Scientific Knowledge, www.unesco.org/science/wcs/eng/declaration_e.htm). The US President's Information Technology Advisory Committee (PITAC) recently recommended that funding for long-term information technology research be significantly increased. This advice is likely to be acted upon positively in the US Congress, although the exact amount of the increase over time will not be known for some time.

At a time when the role of government appears to be diminishing, the issue of Internet governance is also being discussed with some fervour. The notion of a single organization or party being responsible for the overall operation of the Internet seems as unusual as that of a similar body for governance of the world's economy. Each network operator will be subject to one or more governmental regimes and legal systems, and standards that enable interoperability must be maintained and allowed to evolve. This requires collaboration and interchange. While groups such as the Internet Society and IETF, and more recently the World Wide Web Consortium (W3C) and the Internet Corporation for Assigned Names and Numbers (ICANN) (www.icann.org/faq.html) represent efforts among many interested parties to work together, the first steps toward collaboration among the Internet Service Providers were taken during the past decade. Specific examples are the formation of the Commercial Internet Exchange (CIX) in the late 1980s to facilitate the exchange of traffic among commercial internet service providers, and more recently the formation of the Internet Operators Group known as IOPS.ORG to work on problems and issues concerning performance

of the Internet. The formation of ICANN to co-ordinate issues of naming and addressing is merely the most recent development for keeping watch over a portion of the Internet governance problem in a private-sector organization.

TRENDS, NEEDS AND REQUIREMENTS

In this section, some of the trends, needs and requirements for the Internet in the coming years are briefly discussed. This discussion is necessarily incomplete as the Internet offers opportunities in virtually every direction and dimension. Nevertheless, the following are likely to be central to any such developments.

Higher Bandwidth. In the span of three decades, the speed of network lines has increased from 50 Kb/s to 10 Gb/s. Today, the typical user can access the Internet by dial-up connections at 56 Kb/s or with special local access provisions such as Integrated Services Digital Networks (ISDN) at 128 Kb/s, Cable modems at 10 Mb/s (shared with other cable users on his part of the system), or via various levels of Digital Subscriber Lines (DSL) from the telephone companies at dedicated speeds up to about 6 Mb/s. The cost of such local connections in the United States ranges from about several dozen dollars per month up to a few hundred, for the most advanced DSL services. At these access speeds, the long-haul portion of the Internet typically costs from a few dozen dollars to a few thousand dollars per month. Yet very few users, if any, have access to the gigabit-per-second throughput capabilities available from some carriers. There are simply no provisions to supply them to individual users unless they spend considerable sums to commission such services to be provided on an individual case basis (at a cost that can easily run into the hundreds of thousands of dollars or more). So gigabit speeds are economically impractical for most users at present. For businesses, where the investments can be shared among many users and

considered as a business expense, the situation is more manageable, but there is little incentive to make these investments unless the traffic or the applications demand it. If inexpensive local access with consumption-based pricing of long-haul services can be provided, then high-speed capabilities may become affordable for businesses. Computer and software companies will then have an incentive to produce the needed hardware and software for gigabit applications.

Wireless Connectivity. The rapid growth of paging, cellular telephony and other wireless applications (including wireless Local Area Networks, or LANs, and Internet access) have caused the prices for wireless devices to drop almost to the level of commodities. Palm-sized devices with computing capabilities approaching those of full desktop PCs (but with limited display, storage and battery life) have recently emerged and will eventually dominate the market. It is not unlikely that most of these devices will have wireless connections and still remain commodity priced.

The ability to stay connected, if one chooses, wherever one goes, is likely to be the norm. However, small size will ultimately dictate the refinement of speech input technology as a means of controlling computer interactions. Innovative means of display are likely to emerge, as are methods for pointing and selecting within these new contexts. Wireless access at speeds up to 1.5 Mb/s in the next decade seems destined for those who can afford the high cost, but much higher-speed wireless access in the local environment is also possible. Economics, among other things, will determine if it is practical to provide this capability using wireless technology in place of fibre or to replace copper. Finally, satellite access will continue to be attractive for certain applications, including access into the fixed telecommunications plant at nearby points, or for world-wide communications that do not depend upon the terrestrial communications plant at all (see, for instance, Chapter 13).

Ubiquitous IP. The current Internet Protocol provides a 32-bit field for addresses. This field, which was once considered by its inventors as overkill, since it could designate several trillion machines or end devices, is now close to saturation from the widespread proliferation of personal computers. Efforts to accommodate this growth have focused around the development and deployment of IPv6, a 128-bit version of the protocol that augments the original version in several important ways. Although it may seem hard to believe now, we may ultimately find that even such huge numbers as 10^{40} (which is about how many devices can be addressed with 128 bits), are not large enough. This size will enable every device known to have a network address. With ubiquitous chip-sized computation available for pennies or less, every refrigerator, toaster, oven, furnace, light switch and doorknob can, in principle, be monitored and/or controlled by the authorized parties on the Internet.

Proliferation of Digital Information. E-mail has been a fixture on the network since the earliest days of the ARPANET, as have computer files and the ability to move them between machines on the network. The World Wide Web has greatly simplified the mechanics of specifying files as a single string (known as a Uniform Resource Locator, or URL) consisting of the machine name followed by the file name. Furthermore, the Web design took some of the best features of Standard General Markup Language (SGML), a graphics markup language pioneered by the publishing community, and produced a simplified version called HTML that was easier to learn. Files written in HTML could be more easily manipulated by computer for presentation on many screens than could files formatted in many different, perhaps even arbitrary ways. Many users connect to the Internet simply to send and receive e-mail and to access the Web. These two functions are a first important step in making digital information available on the Internet. Recent efforts to create repositories of digital objects that can persist over long periods of time and

that can be accessed with precision through sophisticated search mechanisms are almost within reach. These systems, part of an open-architecture approach known generally as 'digital object infrastructure', have the ability to encompass the Web as well as most other information systems.

E-commerce. The ingenuity of entrepreneurs is nowhere more likely to be exploited than on the Internet. Almost every day, there are new and innovative approaches to the use of the Internet in ways that astonish even the most experienced observers. Business on the Internet currently amounts to several thousand million dollars per year and is anticipated to grow to over a trillion dollars early in the next century. Recent estimates are that the Internet phenomenon was responsible for approximately one-third of the economic growth in the United States during 1998. Concern about security of credit card numbers has been greatly alleviated by the scarcity of serious problems, and by the credit card companies taking the major part of the responsibility for fraud, thus protecting the end-user to a great extent. The main concerns are now focused on matters such as authenticating parties to any given transaction, resolving privacy and security issues, and finding the means to resolve general classes of disputes. There is currently no more debate on Internet-based taxation. Over the long-term, as the Internet economy continues to grow, the need to have a solid means of administering taxes to supplant lost local taxes, or to displace them in some effective way, will loom as large issues that may require international co-operation. Essential to this area of discussion will be the need for better information about the Internet, its operation and its use, much of which is simply unavailable at present. Analysis and interpretation of the data will probably be subject to many interpretations by different groups over time.

Current needs and requirements for further progress will be focused on the following issues.

→ A widely-available and internationally-accepted

means of certification. This may involve governments at some level, including the certification of government information. For non-governmental certification, this service can be provided by the private sector.

→ A means of **managing intellectual property** in the network environment (see also Chapter 8). First, it is essential to be able to identify intellectual property consistently and coherently. The technology for incorporating independently-developed identification systems is basically available, but the ability to mark digital information to render it tamper-proof, or for which certain information is hidden, is still being explored by researchers. Rights and interests in intellectual property are primarily those covered by patent, copyright and trademark. Nevertheless, it remains difficult to identify those rights and interests, or to know what, in general, can be done with digital information obtained over the Net. A method based on stated operations for digital objects was described in a report by the Cross-Industry Working Team. Languages have been developed for automating the negotiation of certain uses. However, for the most part, rights holders are still reluctant to make their valuable resources available on the Internet for fear that the information will be widely disseminated free of charge, and will thus adversely affect their revenue.

→ **Security technology** is becoming fairly widespread on the Internet today, especially with the use of powerful encryption for handling credit cards and for interchanges between authorized parties, such as banking and other financial institutions. Further, restrictions that had been placed on the general use of encryption technology using 56-bit keys are no longer in effect, but do remain in effect for stronger modes of encryption. While such technology offers great power to protect information, it may also

introduce serious impediments to usage of information even by authorized users, and introduces significant overheads in the secure management of keys as well as of overall systems. Laws vary widely from country to country on this subject.

- **Fighting viruses (worldwide).** The spread of viruses can occur with great speed; steps to detect and fight them will require the co-operation of many parties. In some cases, there may not be time to establish working relationships with other countries to deal with such attacks, and prior plans for co-operation will be essential. In the United States, the Computer Emergency Response Team (CERT) at Carnegie Mellon University tracks most known security threats and alerts responsible bodies, as it finds appropriate. This kind of information exchange has been extremely effective to date, and will become increasingly important to maintain over time.
- **Execution of contracts.** Unless well-known means are available for two or more parties on the Internet to enter into contracts, the ability of the Internet to support the growth of electronic commerce will be greatly impeded. Legal documents in most countries still requires ink signatures, or facsimile backed up by ink signatures. Digital signature technology has progressed to the point where it can replace ink signatures, provided the administrative means of managing it is deployed and maintained. Failure to adjudicate disputes cannot be allowed to depend on lack of ink signatures or the ability to verify digital signatures. Simply stated, there must be confidence that courts in the various countries will recognize the legitimacy of such contracts and treat them accordingly.
- **Building digital libraries and means of dissemination.** Significant progress has been made in the digitization of material and in making it available via the Web. Yet most of the collection

of the world's information is still inaccessible by computer. Further, the large body of information which is available on line is not accessible except by browsing or through some other trial-and-error search fashion. It is becoming a critical requirement to rectify this problem, most likely through innovative cataloguing and indexing techniques still in the early research stage, so that access to information on the Internet will become relatively straightforward (see box 7.1).

FOR THE FUTURE

The future rarely plays out the way we imagine it will, and in the full knowledge that any such predictions are likely to be disproved by practice, the following possibilities may nonetheless be proposed.

E-commerce will continue to flourish, with a move away from prepackaged buying options prepared by sellers, to more opportunities for customization and other user-defined products and services. Intermediate organizations on the Internet will find better ways to match the needs of potential customers and suppliers of goods and services.

Better means for locating all kinds of items will be developed, including the ability to locate individuals (primarily those who wish to be found, but possibly some who do not), to locate sources of goods of all kinds including new and used components, and even to trace the history and performance of selected goods and services (and/or their providers).

Building worldwide markets is largely a non-technical problem, but technology can greatly assist in this domain. The organization of marketing forces on the Internet is still in its infancy and will probably only increase in sophistication over time.

Collaboration is one of the largely untapped gold mines on the Internet. The applications in which groups or individuals at different locations, and even at different times, work together on missions of common purpose, are potentially enormous, and difficult to carry out effectively via other means.

From applications such as IP video and teleconferencing, which have early prototypes on the low bandwidth of today's Internet, to joint manufacturing design and development, to strategic planning by teams of experts, the field of possibilities is large. Furthermore, applications that involve or even stimulate the development of information as malleable content, to be further worked on by others, while respecting the rights of the original creators, could open up new modes of creativity.

Finally, the potential for the use of sensors, activators and control mechanisms of all kinds on the Internet has remained largely unexplored. Improvements in weather prediction resulted directly from the use of global satellite monitoring systems. It is possible to imagine weather instrumentation deployed on virtually every building, vehicle and individual which is able to report local conditions. The utility of a three-dimensional fine-grained grid of such weather information, combined with mathematical prediction models could improve our long-range prediction abilities by days, or even weeks. The ability to use the Internet for facilities and operations of all kinds could become routine. The remote operation of manufacturing plants is one example; the possibility of collaborative telemedicine is another. Distributed simulation experiments used in connection with real systems offers further possibilities here.

CONCLUSIONS

The Internet is creating a revolution in society just as significant as the Industrial Revolution. It may be suggested that the technology resulted from far-sighted investment by the United States government and the active involvement of the research community, later amplified by contributions from industry and a supportive government policy. Since current applications on the Internet have focused increasingly on electronic commerce, the need for careful consideration of the many public-policy issues has grown. Many of these will not be amenable to

rapid solutions and will require continued involvement of governments around the world in co-operation with the private sector. Basic operation of the Internet has long since moved to the private sector, but its continued evolution will depend on providing the kind of universal connectivity for data exchange with generally accepted open standards that the current users have come to cherish. Issues of sovereignty and conflicting legal systems will continue to define the limits of what is and what is not possible, but increased co-operation and collaboration over the Internet may have the effect of bringing our various systems closer together. The rights of all parties making use of the Internet will ultimately require careful consideration in the world's deliberative and law-making bodies. While the Internet will surely continue to contribute to economic growth, it will take both strong resolve and commitment to avoid the inequities which would result from having technologically created a world of haves and have-nots.

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