

Computer networks and the Internet: A brief history of predicting their future

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The computer era began almost 70 years ago, in 1943, with the creation of ENIAC. The Internet itself is almost 40 years old, and the packet technology that underlies it goes back about another 10 years to the early 1960s. The relatively rapid emergence of this technology provides a very nice case study of how, over the years, visionaries, technologists, story-tellers and others have tried to look into the future and understand how computer networks would evolve, and what they would imply for the computer and for society. We do not attempt to retell here the complete history of the Internet; that story is told in a number of places, including (Abbate 1999) and (Hafner and Lyon 1996). We have explored the stages of the Internet's emergence from a particular perspective—how people have attempted, with variable success, to foresee the future trajectory of the Internet.

The early days—first there was the computer

The story of computing usually begins with Charles Babbage, Ada Lovelace and John von Neumann. However, most of their contributions relate to the mathematical, organizational and mechanical principles that would enable a computing machine. Vannevar Bush provided one of the earliest visions about the power of computers to transform the way we work and think. In his paper titled “As we may think” (Bush 1945), Bush proposed the concept of a Memex, a device that could store all the documents used by a researcher, allow inter-document links and annotations to be added to these documents as they are studied and considered, and save all these associations so they could be retrieved later. This system anticipates the graphical tools used today for knowledge organization, and to some extent anticipated the links found in the World Wide Web. The vision is positive in outlook and brilliant in its anticipation. At the same time, it is worth noting what is missing: any idea that different people could link what is stored in their Memex systems. His vision of the Memex is a physical device, perhaps the shape of a desk, and the only way to share one's stored information would be to invite another researcher to come sit at it. Each person would have his own Memex, and the exploration and structuring of knowledge is essentially an individual activity in his conception.

One can speculate that the reason for this limitation in his vision is that while there were hints in 1945 as to how computing and storage might be realized, there were no such hints about communication. The technologies of the telephone and radio were very specialized, and dedicated to communication among people, not machines. Looking at the phone system, it may just have been too much of a jump to envision linking all the Memex together.

Over the next 20 years, richer visions emerge of how computers and humans could interact. But as late as the early 1960s they seem to have the same bias: more of an emphasis on the individual interacting with the computer, and less on how the computer might be a tool to link the efforts of many humans and augment their ability to communicate. In 1962, Doug Engelbart¹ of SRI wrote a long report for the Air Force Office of Scientific Research titled “Augmenting Human Intellect: A conceptual framework” (Engelbart 1962). This report directly builds on the earlier paper of Vannevar Bush, and presents a rich discussion of cognitive processing enhanced by computing, but only near the end of the 132 page report is there a mention of collaboration. On page 105 of the report, a section titled “Team Cooperation” begins with the following suggestive text: “Let me mention another bonus feature that wasn’t easily foreseen. We have experimented with having several people work together from working stations that can provide intercommunication via their computer or computers. ... This proves to be a really phenomenal boost in group effectiveness over any previous form of cooperation we have experienced.”²

Engelbart, like Bush, presented a vision of man-computer interaction in an entirely positive way. They see the outcome as improved intellectual effectiveness, an unambiguous good that should be pursued with the same vigor (according to Engelbart) as harnessing nuclear power.

The concept of the network

In the mid-1960s, there was a shift in thinking and the concept of communication among computers rapidly emerges. In particular, the idea of packet switching (the basis for the ARPAnet and then the Internet), arose independently from the research of Paul Baran and Donald Davies. Their work had a similar technical approach, but has very different roots and motivations.

Paul Baran’s work, done at Rand, arose from the question of how one could build a command and control system that could survive a nuclear attack. Unless one has a first-strike doctrine, one must ensure that military command and control must be able to function after a nuclear attack. At the time of his work, networks were being built to hook electronic systems together, but they were highly specialized (e.g. the wide-area SAGE radar defense system, on which Baran had worked), and usually were very hierarchical and centralized in design. Baran saw the benefit of a highly distributed mesh network of control points (unmanned computers that forward messages) as the key to a network that could not be destroyed by attack. He believed that such a network should be built, and the nature of the network should be revealed to the Soviets, both so that they could understand our second-strike capability, and also so that they could replicate the concept.

¹ Engelbart, an early leader in man-machine interaction, is known, among other things, for the invention of the computer mouse.

² It should be noted that when Engelbart was writing, the concept of time-sharing had emerged, a scheme which allowed a number of users at terminals to interact simultaneously with a single computer, so it was possible to perform experiments where several users interact and collaborate without having to envision the possibility of networks.

Baran believed that their command and control systems were so abysmal that accident launch was of more concern than intentional attack. His proposal is described in an 11 volume report titled “On Distributed Computing”, in 1964, building on a series of reports written for Rand between 1960 and 1962 (Baran 1960).

While this work, positioned in the mindset of the cold war, was entirely focused on mitigating the risk of war by making available a resilient second-strike capability, Baran did speculate on broader-long term implications of his ideas. In an interview in 2001 (Brand 2001), Baran recollects a talk that he gave in the mid-60s:

Around December '66, I presented a paper at the American Marketing Association called "Marketing in the Year 2000." I didn't talk about packet switching, but I described push-and-pull communications and how we're going to do our shopping via a television set and a virtual department store. If you want to buy a drill, you click on Hardware and that shows Tools and you click on that and go deeper. In the end, if you have two drills you're interested in, then you hit your Consumers Union button, and their evaluation goes up on the screen. Pretty much what WebTV is.

Donald Davies conceived his version of packet switching in a very different context. He worked for the National Physical Laboratory in England. In 1963, he was appointed to manage government support for the British computer industry, at a time when there was widespread UK government fear of US displacing UK's computer industry. He set out to promote fast message switching as a means for communication between computers, in order to develop a framework for innovation and UK commercialization. His vision of the applications that might come to pass included (as of 1965), remote data processing, point-of-sale transactions, database queries, remote control of machines, and online betting (Abbate 1999). His networking approach exploited the computing paradigm of the day (time-sharing), and used his packet switching concept to allow users at a distance to gain access to the processing power of a central time-sharing system.

Davies's vision had commercial motivations—the preservation of the British computer industry, and his viewpoint seems to be a totally positive one with respect to the benefits and risks of computer networking. His ideas were being discussed by 1965, and the formal publication occurred in 1967.

Even before these two proposals were published, there was other work on new approaches to networking. Len Kleinrock, in his PhD thesis at MIT (Kleinrock 1962), and in the following book (Kleinrock 1964), described and analyzed a system for message switching, where a message has much in common with a packet. Kleinrock offers no visions of the impact of networks. His work is very mathematical in nature, applying queuing theory to message queues, and in the process laying the groundwork for a large body of network queuing theory. None the less, this work is part of a movement that brings into focus the potential for computer networking.

With the work of Kleinrock, Baran, Davies and others, there was a sudden shift in perception. The idea of hooking computers together using some sort of network was in the air, and future predictions changed rapidly. One of the first to articulate the power of hooking people together using networked computers was J.C.R Licklider.

A comparison of some of Licklider's papers illustrates the shift in thinking. In 1960, Licklider published a paper titled "Man-Machine Symbiosis" (Licklider 1960), in which he discussed the potential power of the computer to facilitate and transform the process of thinking and problem solving in the scientific and technical sphere. In this paper, he discussed the computer itself, including specialized memory structures for information storage and retrieval, and various possibilities for a more powerful human interface, including flat panels integrated into desks, large displays on walls, and natural language interaction. But there is no mention of networking.

Shortly thereafter, Licklider was asked to go to ARPA³ and establish a program in interactive programming, which he did for several years. In this period, he supported the funding that demonstrated time-sharing; later that office funded the ARPAnet. The role of the network to connect computers together came quickly into focus. In 1968 Licklider published his article "The Computer as a Communication Device" with Robert Taylor (Licklider and Taylor 1968).

In this article, they assert that the eventual range of application for human interaction will be very broad. They wrote:

What will go on inside? Eventually, every informational transaction of sufficient consequence to warrant the cost. Each secretary's typewriter, each data-gathering instrument, conceivably each dictation microphone, will feed into the network.

You will not send a letter or a telegram; you will simply identify the people whose files should be linked to yours and the parts to which they should be linked-and perhaps specify a coefficient of urgency. You will seldom make a telephone call; you will ask the network to link your consoles together.

You will seldom make a purely business trip, because linking consoles will be so much more efficient. When you do visit another person with the object of intellectual communication, you and he will sit at a two-place console and interact as much through it as face to face.

They also saw the network as a basis for widespread access to information. They wrote:

³ ARPA, the Advance Research Projects Agency, was established within the U.S. Department of Defense in 1958 in response to the Russian launch of Sputnik. It was responsible for leading edge research to preserve the technology edge of the DoD, and funded many of the important early breakthroughs in computing and communications.

Available within the network will be functions and services to which you subscribe on a regular basis and others that you call for when you need them. In the former group will be investment guidance, tax counseling, selective dissemination of information in your field of specialization, announcement of cultural, sport, and entertainment events that fit your interests, etc. In the latter group will be dictionaries, encyclopedias, indexes, catalogues, editing programs, teaching programs, testing programs, programming systems, data bases, and—most important—communication, display, and modeling programs.

Overall, their assessment of the impact of networked computers is an optimistic one. In their conclusion, they wrote:

When people do their informational work “at the console” and “through the network,” telecommunication will be as natural an extension of individual work as face-to-face communication is now. The impact of that fact, and of the marked facilitation of the communicative process, will be very great—both on the individual and on society.

First, life will be happier for the on-line individual because the people with whom one interacts most strongly will be selected more by commonality of interests and goals than by accidents of proximity. Second, communication will be more effective and productive, and therefore more enjoyable. Third, much communication and interaction will be with programs and programmed models, which will be (a) highly responsive, (b) supplementary to one’s own capabilities, rather than competitive, and (c) capable of representing progressively more complex ideas without necessarily displaying all the levels of their structure at the same time—and which will therefore be both challenging and rewarding. And, fourth, there will be plenty of opportunity for everyone (who can afford a console) to find his calling, for the whole world of information, with all its fields and disciplines, will be open to him—with programs ready to guide him or to help him explore.

For the society, the impact will be good or bad, depending mainly on the question: Will “to be on line” be a privilege or a right? If only a favored segment of the population gets a chance to enjoy the advantage of “intelligence amplification,” the network may exaggerate the discontinuity in the spectrum of intellectual opportunity.

On the other hand, if the network idea should prove to do for education what a few have envisioned in hope, if not in concrete detailed plan, and if all minds should prove to be responsive, surely the boon to humankind would be beyond measure.

Unemployment would disappear from the face of the earth forever, for consider the magnitude of the task of adapting the network's software to all the new generations of computer, coming closer and closer upon the heels of their predecessors until the entire population of the world is caught up in an infinite crescendo of on-line interactive debugging.

While their last paragraph might reflect a wry understanding of the reality of dealing with computers, the overall vision is positive and forward looking. They anticipated the possibility of a “digital divide”, and the movement of work to the place where it could best be done, which might foreshadow off-shoring. The article does note that issues of security and privacy are of active concern and that they are beginning to get the attention they deserve.

In 1969, the year after that report, the first nodes of the ARPAnet became operational, linking UCLA (Kleinrock's lab) to SRI (Engelbart's laboratory). Packet switching was demonstrated, and a generation of technical folks got on with the task of making it practical. For a moment, the visionaries had done their job and the engineers were given their marching orders.

Doubt and skepticism

Not all the assessments of packet switching were optimistic. One recurring theme in the early days of packet switching is the skepticism voiced about the concept by the traditional telecommunications providers, in particular AT&T. Baran recollected (Brand 2001) that when he tried to interest AT&T in the idea, he was told: "It's not going to work. And furthermore, we're not going into competition with ourselves." Larry Roberts recollected (Roberts 1986): “In some of the initial technical speeches I gave, communications professionals reacted with considerable anger and hostility, usually saying I did not know what I was talking about since I did not know all their jargon vocabulary.” From one perspective, this response is a classic illustration of what Christensen called the “innovator's dilemma” (Christensen 1997), in which an incumbent industry rejects a new idea which then matures and overtakes it. In fact, this early rejection may have been very liberating for the designers of packets switching, and may have materially contributed to the success of the concept. While this is pure speculation, it is possible that if AT&T research had fully participated in the evolution of packet switching, they might have imposed a bias on the idea in order to fit in with their conception of voice services that could have limited its general utility. When AT&T research did get involved with the packet switching concept, they put forward an alternative to the Internet design called Asynchronous Transfer Mode, or ATM, based on switching small, fixed size data cells rather than larger, variable size packets as the Internet does. This design was considered more suitable for voice, and was not, as initially standardized, the commercial success that the Internet was.

This resistance to the idea that the Internet might be successful persisted for some time. In 1994, the Computer Science and Telecommunications Board of the National Academies released a report about the future of networking (Computer Science and

Telecommunications Board 1994). While the report discusses the Internet at length, some of the committee members insisted that the report not identify the Internet by name as the future trajectory of computer networks. Rather, they insisted that the report talk about the concept in the abstract as an Open Data Network, or ODN. The title of the report does contain the word “Internet”, but in the phrase “The Internet and Beyond”. These committee members had the view that while the Internet might have proved its point about the value of packet switching, the eventual commercialization would be based on a successor design that the commercial world (in particular the telecommunications industry) would put forward.

What is the network for: the designers vs. the users

The original vision of Licklider, described above, saw the network as a tool for collaboration among workers on scientific and intellectual problems. In the early stages of the design of the ARPAnet, the expectation of the designers was more focused on resource sharing. Larry Roberts identified five possible uses for the emerging ARPAnet in (Roberts 1967): these were load-sharing (balancing load between a number of computers), message service (e.g. email), data sharing, program sharing, and remote service (when the computer, the program and the data are all remote). While message service shows up in the list, it is not considered very important. Roberts asserted at the time that: “[message service] is not an important motivation for a network of scientific computers”.

The users proved him wrong, and flocked to email as soon as it was available. Both the users at the research sites and the managers at ARPA were quick to figure this out. (Abbate 1999) has a rich discussion of the rapid emergence of email as the dominant application on the ARPAnet.

The users, first of the ARPAnet, and then of the Internet, continue to be an active force in defining what the network is, both by choice of application, and by the creation of unexpected applications never anticipated by the network creators. This trend continues to today, with the success of user-created programs for peer-to-peer music sharing.

The vision of the network as a tool for collaborative scholarly activity continues as a powerful idea through the 1980s. In 1989, Bill Wulf proposed the idea of a *collaboratory* (Wulf 1989), which again argues for the creation of tools to allow linked computers to be used as a rich environment for computer-based collaboration. This term was often used through the 1990s to refer to this conception. At the same time, it seems that advanced tools for collaboration, such as teleconferencing, have been very slow to mature and prove their worth in the market. Simple tools such as email continue to dominate the space of human interaction well into the 1990s.

The engineering decade

In the 1970’s, the concept of packet switching was reduced to practice, and the concepts of the Internet were proposed. In 1974, Cerf and Kahn wrote their seminal paper that laid

out the vision for the Internet (Cerf and Kahn 1974). The set of issues raised by the paper are essentially all technical: most centrally how to hook dissimilar networks together to achieve overall end-to-end communication. They do identify the issue that different networks will have different owners, which will require some sort of accounting, an idea that was then immediately (and successfully) ignored for perhaps the next 20 years of Internet development.

Industry structure and network architecture

In 2010, the structure and role of the Internet Service Provider is a topic of considerable debate, on topics such as network neutrality, rural access, competition, vertical integration and the like. However, there is little evidence that the early designers of the Internet were concerned with the eventual shape of the industry that would emerge to provide commercial Internet service. The rejection of packet switching (and the more general idea of computer networking) by the telephone providers may have liberated the architects to view the design as a purely technical problem. But at least some of the early designers of networks were very sensitive to the powerful actors that would sooner or later come to shape the global network as they tussled for power.

In the 1970's, there was a substantial debate between advocates of two sorts of network, called "datagram" and "virtual circuit". Datagram networks have a simpler core, with more functions shifted to the hosts at the edge. Virtual circuit network have more function in the core of the net, and thus more power and control shifted to the network operator. The Internet is a datagram network; the ARPAnet was more a virtual circuit network, and the data network standard developed by the telephone industry, Asynchronous Transfer Mode, or ATM, is a virtual circuit network.

One of the vocal advocates of the datagram approach was Louis Pouzin, who was building a datagram network called Cyclades in France at the same time that the Internet was being first built. In 1976, he published a paper with the following conclusion(Pouzin 1976):

The controversy DG vs. VC in public packet networks should be placed in its proper context.

First, it is a technical issue, where each side has arguments. It is hard to tell objectively what a balanced opinion should be, since there is no unbiased expert. This paper argues in favor of DG's, but the author does not pretend being unbiased. Even if no compromise could be found, the implications would be limited to some additional cost in hardware and software at the network interface. So much resources are already wasted in computing and communications that the end result may not be affected dramatically.

Second, the political significance of the controversy is much more fundamental, as it signals ambushes in a power struggle between carriers

and computer industry. Everyone knows that in the end, it means IBM vs. Telecommunications, through mercenaries. It may be tempting for some governments to let their carrier monopolize the data processing market, as a way to control IBM. What may happen, is that they fail in checking IBM but succeed in destroying smaller industries. Another possible outcome is underdevelopment, as for the telephone. It looks as if we may need some sort of peacemaker to draw up boundary lines before we all get it trouble.

In contrast to the Internet, Pouzin's Cyclades network was not ultimately successful. Its failure is often (if speculatively) attributed to the hostility and resistance of the French PTT.

The emergence of the PC

The early Internet designers did have aspirations to hook all the general-purpose computers in the world together. What was missing from this vision was just how many of those computers there might be. The vision for the Internet was limited by the vision of computing. During the 1970s, local area networks (LANs) were trialed, and there were early experiments (e.g. at Xerox PARC) on personal computing with advanced displays. However, the potential impact of personal computers really came into focus with the emergence of the IBM PC, which was launched in 1981. While IBM had a somewhat narrow view of how the PC would be networked (in particular as a peripheral to an IBM mainframe using the IBM network protocols called SNA), the Internet research group at MIT (including one of us, Clark) was quick to implement a version of the Internet protocols for the PC and attach it to the Internet. In 1985, we published a paper titled "The Desktop Computer as a Network Participant" (Saltzer, Clark et al. 1985), but we did not avail ourselves of the opportunity to comment on the larger implications, and concentrated on the technical issues of implementing network protocols in very small and underpowered systems. To us at that time, this was still the decade of engineering. None the less, this period marks the point where the Internet architects can see that they may be connecting millions of computers, not thousands.

The stages of expansion

In the mid-1980s, the NSF took over the operation of the physical network that provided university connectivity, the ARPAnet technology was decommissioned, and the first NSF backbone was created. In 1988, the CSTB was asked to review the plans for the next stages of the NSFnet, which it endorsed enthusiastically (Computer Science and Telecommunications Board 1988). Again, one finds little commentary of a cautionary nature—the focus is on scholarly and scientific activity, the motivation is increased productivity, the benefits (following the pattern of Engelbart and Licklider) are positive, and the only concern is not to build a network that is hard to use, so that it frustrates its user constituency. The reports also mentions the objective of national advantage and competition with other parts of the globe (mostly Europe) for leadership in computing and communications.

Emerging public perception

By the late 80's, a significant number of people were using email, and business cards with email addresses were becoming common. Indeed, to those who had heard of the Internet, it was synonymous with email. But in fact, the Internet was little in the public eye in the 1980s. A search of Lexis/Nexis turns up very few articles in newspapers and magazines about the Internet in that decade. As Figure 1 shows, this level of visibility changes suddenly in November 1988, when Robert Morris released the so-called "Morris Worm", which turned out to be the first major denial of service attack across the Internet. The event was reported on the Today show the next morning, and both the Internet and its security vulnerabilities gained wide visibility.

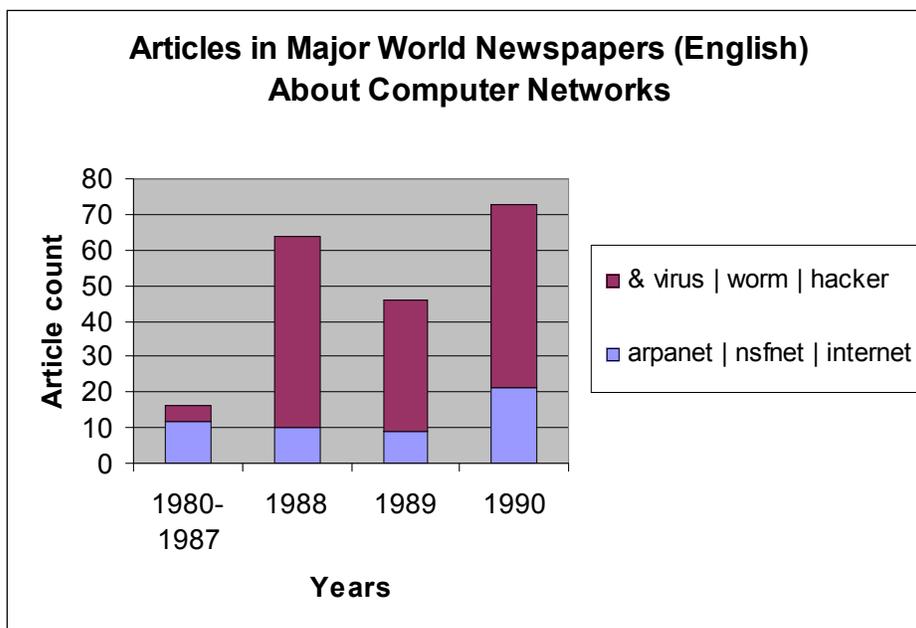


Figure 1: Frequency of articles in major newspapers that discuss Internet

It is interesting to note when public interest and advocacy groups come into existence, since it might be that such groups might have seen further into the future than the public at large. However, in the 1980s there were few events that brought to the forefront the issues that might motivate such groups. In fact, most of the groups that we associate with public advocacy with respect to the Internet did not even exist in the 1980s. The group Computer Professionals for Social Responsibility (CPSR)⁴ was founded in 1983. Its initial concern had nothing to do with networking, but with opposition to President Regan's Strategic Defense Initiative, followed by concerns about electronic voting. A subgroup interested in privacy, the Electronic Privacy Information Center (EPIC)⁵, was

⁴ See <http://www.cpsr.org/>

⁵ See <http://www.epic.org/>

spun out of CPSR, but this did not occur until 1994. The Electronic Frontier Foundation⁶ was founded in 1990, motivated by a case involving free speech, civil liberties and privacy, but not directly associated with the Internet. Their interest in the Internet grew rapidly, of course, as the 1990s brought more Internet-centric issues to the front. The Center for Democracy and Technology⁷, a group with interests centered on the Internet from its beginning, was founded in December, 1994. So once the Internet emerges into the public view, there is a rapid development of public advocacy groups, but there is little evidence that these groups manage to take a long view into the future and identify issues of concern before there is a public manifestation of the problem. This pattern may have to do with fund-raising, priorities and a rich space of immediate concerns, or some other reason.

The 1990s: the business of making predictions comes of age

At about the time that the Internet attracts a wider public visibility, we can finally observe the emergence of futurists predicting how it will all turn out. The following quotes were gathered by the Elon University/Pew Internet project *Imagining the Internet*, and are copied from their web site⁸. They provide a diverse set of viewpoints about the future of the Internet from the early 1990s. It is interesting to note that this site has no predictions from earlier than 1990, however. Before that time (or perhaps prior to 1988) the Internet appears to be the invisible revolution.

Mondo 2000 editor R.U. Sirius (real name, Ken Goffman), as quoted in a 1992 article in the Bergen (N.J.) Record headlined "Unfolding the Future":

"Who's going to control all this technology? The corporations, of course. And will that mean your brain implant is going to come complete with a corporate logo, and 20 percent of the time you're going to be hearing commercials?"

Peter Huber, a senior fellow at the Manhattan Institute, quoted in a 1992 Forbes article titled "An Ultimate Zip Code":

"Combine GPS with a simple transmitter and computer ... If you want to track migratory birds, prisoners on parole or – what amounts to much the same thing – a teenage daughter in possession of your car keys, you are going to be a customer sooner or later."

David Porush, a professor at the Rensselaer Polytechnic Institute, in a 1992 speech for the Library and Information Technology Association:

"If cyberspace is utopian it is because it opens the possibility of using the deterministic platform for unpredictable ends ... We might even grow a

⁶ See <http://www.eff.org/about>

⁷ See <http://www.cdt.org/>

⁸ See <http://www.elon.edu/e-web/predictions/150/1960.xhtml>

system large and complex and unstable enough to leap across that last possible bifurcation - autopoetically - into that strangest of all possible attractors, the godmind."

Futurist Alvin Toffler, in a 1993 Wired article titled "Shock Wave (Anti) Warrior":

"If we are now in the process of transforming the way we create wealth, from the industrial to the informational ... the more knowledge-intensive military action becomes, the more nonlinear it becomes; the more a small input someplace can neutralize an enormous investment. And having the right bit or byte of information at the right place at the right time, in India or in Turkistan or in God knows where, could neutralize an enormous amount of military power somewhere else ... Think in terms of families. Think in terms of narco-traffickers. And think in terms of the very, very smart hacker sitting in Tehran."

John Perry Barlow, internet activist and co-founder of the Electronic Frontier Foundation, in a 1994 essay for Wired magazine titled "The Economy of Ideas":

"We're going to have to look at information as though we'd never seen the stuff before ... The economy of the future will be based on relationship rather than possession. It will be continuous rather than sequential. And finally, in the years to come, most human exchange will be virtual rather than physical, consisting not of stuff but the stuff of which dreams are made. Our future business will be conducted in a world made more of verbs than nouns."

Tom Maddox, in a 1994 article for Wilson Quarterly titled "The Cultural Consequences of the Information Superhighway":

"The sharp-edged technology of the NII can cut a number of ways: It can enlarge the domain of the commodifiers and controllers; it can serve the resistance to these forces; it can saturate us all, controlled and controllers alike, in a virtual alternative to the real world. Meanwhile, most of humanity will live and die deprived of the wonders of the NII, or indeed the joys of adequate nutrition, medical care, and housing. We would do well to regulate our enthusiasms accordingly - that is, to remember where love and mercy have their natural homes, in that same material world. Otherwise we will have built yet another pharaonic monument to wealth, avarice, and indifference. We will have proved the technophobes right. More to the point, we will have collaborated to neglect the suffering of the damned of the earth - our other selves - in order to entertain ourselves."

A snapshot of 1994

1994 is a reasonable stopping point for this review of the past. In that year, the Computer Science and Telecommunications Board released a study of the future of networking (Computer Science and Telecommunications Board 1994). That report is a useful time capsule of the state of thinking as of the early 1990s. That report identifies the importance of an open platform for innovation, along the lines of the Internet, and it identifies issues of citizen access to the network, access to information, privacy, freedom of speech, intellectual property, economic issues of investment, and the role of government in shaping the future.

Summary

Some parts of the story told here are very typical: for example the rejection of the novel idea by the incumbent industries. Other parts are perhaps less so. One interesting aspect of the story is the long period of gestation before the technology really enters the public awareness, almost 30 years from 1960 to 1990. The story presented here illustrates the stages in which emerging technologies, both computational and communications, shift the framework for envisioning the future: the emergence of computer networks themselves in the mid '60s, the emergence of LANs and PCs around 1980, and the popular visibility of the Internet in the 1990s.

Overall, the tone of the early observers and advocates is very positive, and perhaps narrow. In the beginning, and up through the 1988 CSTB report, most of the advocacy for widespread networking of computers is in support of a rather narrow range of applications—essentially the facilitation and enhancement of scientific, technical and scholarly activities. This focus, while quite compelling as a motivation for funding, did not lead the writers to explore the broader range of possible activities, and the implications, both positive and negative, that might emerge when society as a whole entered into the Internet. Another motivation for a positive tone is the anticipated opportunities for commercialization and national industrial advantage. This is not a context in which one would tend to dwell on potential downsides.

The narrow nature of the early visions is in strong contrast to the reality of the forces that define the future. Since the Internet is intended as a general platform for a wide set of unanticipated uses, a great number of futures are possible. Since the users of the technology play an especially important role here is picking the actual outcome, the future is not under the control of the network designers, the policy makers, or any other organized set of actors. This reality makes predicting the future, no less trying to control it, especially difficult.

Citations

- Abbate, J. (1999). Inventing the Internet. Cambridge, MIT Press.
- Baran, P. (1960). Introduction to Distributed Communications Networks. On Distributed Communications, Rand Corporation. 1.
- Brand, S. (2001). Wired Legends. Wired.
- Bush, V. (1945). As we may think. Atlantic Monthly.

- Cerf, V. and R. Kahn (1974). "A Protocol for Packet Network Intercommunication." Communications, IEEE Transactions on [legacy, pre - 1988] **22**(5): 637-648.
- Christensen, C. M. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Cambridge, Harvard University Press.
- Computer Science and Telecommunications Board, N. R. C. (1988). Toward a National Research Network. Washington, D.C., National Academy Press.
- Computer Science and Telecommunications Board, N. R. C. (1994). Realizing the Information Future: The Internet and Beyond. Washington, D.C., National Academy Press.
- Engelbart, D. (1962). Augmenting Human Intellect: A conceptual framework, Stanford Research Institute.
- Hafner, K. and M. Lyon (1996). Where Wizards Stay Up Late: The Origins of the Internet. New York, Simon & Schuster.
- Kleinrock, L. (1962). Message Delay in Computer Networks with Storage. Electrical Engineering. Cambridge, MIT. **PhD**.
- Kleinrock, L. (1964). Communication Nets: Stochastic Message Flow and Delay. New York, McGraw-Hill Book Company.
- Licklider, J. C. R. (1960). "Man-Computer Symbiosis." IRE Transactions on Human Factors in Electronics **HFE-1**: 4-11.
- Licklider, J. C. R. and R. Taylor (1968). "The Computer as a Communication Device." Science and Technology.
- Pouzin, L. (1976). Virtual circuits vs. datagrams: technical and political problems. Proceedings of the June 7-10, 1976, national computer conference and exposition. New York, New York, ACM: 483-494.
- Roberts, L. (1967). Multiple Computer Networks and Intercomputer Communication. ACM Symposium on Operating Systems Principles, Gatlinburg, TN.
- Roberts, L. (1986). The Arpanet and computer networks ACM Conference on the History of Personal Workstations, Palo Alto, ACM Press.
- Saltzer, J., D. Clark, et al. (1985). "The Desktop Computer as a Network Participant." IEEE Journal on Selected Areas in Communications **3**(3): 468-478.
- Wulf, W. (1989). Towards a national laboratory.