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Looking Backward and Forward at the Internet

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Re. April 1998.

This article reviews accounts of the origins and growth of the global Internet with an interest in their implications for the future. Many accounts take overly restricted views of technical development. For instance, the Internet is often seen as simply the outgrowth of US Defense Department work and popular enthusiasm. Recent interdisciplinary studies of technology present a more complex picture of how innovations are developed. They highlight technical alternatives, contributions of diverse groups, variety in meanings of technologies, and overall the surprising character of technology development. They suggest that the Internet has multiple origins and numerous particular reasons for its spread. Current discussions of the entry of Internet technologies into consumers' homes and the convergence among computing, media and telecommunications enterprises represent examples of more complex accounts of technology development. Such accounts will likely provide more powerful bases for policy, management and design.

Keywords history of technology, social studies of technology, communications infrastructure, computer networks, Internet, technology forecasting

In "Internet time", like "dog years", eons have passed since the first messages were sent between computers. The Internet now has its own history, though most of the events took place just years ago and portentous changes are taking place today. In this article, I want to suggest that the way we understand this history is important to our understanding of future social choices. Looking behind us more intelligently will make it easier to see paths ahead.

Today's Internet is often linked in a direct line of descent to plans among engineers and managers working in the 1960s and 1970s with the US Defense Department. The driving force behind the Internet's growth is supposed to be popular enthusiasm.

Recent interdisciplinary studies of technology present a more complex picture of how innovations are developed and distributed. They highlight the existence of technical alternatives, including less-than-optimal technical solutions; the contributions of many different (and often conflicting) groups; the possibility of a variety of meanings associated with technologies, and in general the contingent and often surprising character of technology development. The value of these perspectives is to more accurately portray the complexity of technical development. There may also be implications for policy debate, technology design and management strategy.

A case in point is the convergence of media, computers and telecom, of which the Internet is (and I would argue, always has been) an important aspect. This historical process, which is widely recognized as at once technical, industrial and political, has been and will continue to be fiercely multi-party and multi-faceted. There are a variety of technical alternatives being fought over. Different interests represent different meanings of communications technologies as well, including ideals of private profit and universal access. Will the future of the Internet be like its past, or like telephone or television, or something altogether different? Overall, it is generally understood, it is difficult to predict outcomes in the struggles in these industries because the interrelationships are too complex to be known deterministically.

I have divided the body of this article into two main sections. I begin with some of the most widely-circulating stories and points of view about the Internet. Then I describe contrasting perspectives taken by recent studies of technology, which I illustrate with a different set of examples.

Standard Perspectives

Many people have heard a little about the origins of the Internet. There are historical tales available on the Internet itself. There have been popular newspaper and magazine articles which feature retrospective accounts (e.g., Kantrowitz and Rogers, 1994; Kleiner, 1994), practical handbooks which include sections on the internet's history (e.g., Evanson, 1994; Krol, 1992), and technical reports which discuss aspects of the topic (e.g., Comer, 1991; FTP Software, 1991; Nicoll, 1994; Perry, Blumenthal, and Hinden, 1987; Roberts, 1971; Schultz, 1988; Siewiorek, Bell, and Newell, 1982). The general accounts usually run like this:

> The Internet had its origin in a U.S. Department of Defense program called ARPANET..., established in 1969 to provide a secure and survivable communications network for organizations engaged in defense-related research. Researchers and academics in other fields began to make use of the network, and at

> length the National Science Foundation (NSF), which had created a similar and parallel network called NSFNet, took over much of the TCP/IP technology from ARPANET and established a distributed network of networks capable of handling far greater traffic. (Brittanica Online, 1994)

This sort of overview assimilates arguments from two distinct bodies of earlier, more detailed historical accounts, each of which reflects different perspectives on the development of the Internet.

Architects

One point of view is that of engineering and managerial architects of the Internet. Their historical reflections are generally technical or governmental in focus, based on engineering documents, and sometimes include insider anecdotes. The architects' retrospectives can be characterized by two main features. These features are both insights and, as I will argue later, limitations.

First, today's global Internet is linked to a series of programs within the US government. As Vinton Cerf, a co-author of the Internet standard of data communications (TCP/IP) and recently known as a "father of the Internet", says, the Internet is "the direct descendant of strategically-motivated fundamental research begun in the 1960s with federal sponsorship...." (Cerf, 1995). The original effort was funded by the Defense Department's Advanced Research Projects Agency (ARPA). (Barber Associates, 1975; Bolt Beranek and Newman, 1981)

The roots of today's internetworking in a government program funded by ARPA is one of the best-known of the internet's origins. (Anthes, 1994; Salus, 1995) A recent journalistic knock-off, for instance, is described on the jacket cover as "...the story of the small group of researchers and engineers whose invention, daring in its day, became the foundation for the Internet. With ARPA's backing [they] began the quest for a way to connect computers across the country." (Hafner and Lyon, 1996)

The second main feature of the architects' accounts is that they point out and document key engineering decisions in the development of the technology. They identify technical accomplishments which appear significant in hindsight and describe how they were developed. Thus, for example, the immediate result of ARPA's funding, the ARPANET, has been described as one of the first and largest wide area networks (networks linking computers over long distances), the founding location of the TCP/IP protocol suite, and the first major network to use "packet switching". (van Atta, Reed, and Deitchman, 1990, 20-3, 20-4, 20-13) A similar approach is taken in a book entitled *Architects of the Web : 1,000 Days That Built the Future of Business* (Reid, 1997). But the greatest amount of technical detail is presented on the Internet itself, in various planning and discussion documents. Accounts such as these from the perspective of researchers, engineers and managers provide extensive detail on the technical aspects of innovations.

Users

Other stories about the history of the Internet take the point of view of users, by which is meant individuals who employ and adapt Internet services such as email or file transfer. These are accounts by and about enthusiasts. In these stories, it was the users who drove the development of the Internet, not only contributing traffic for the lines, but actually stimulating new applications and new directions of technical development for the engineers.

The common theme is that the Internet is a popular, liberal, democratic or even anarchistic medium. While having origins in the US Defense Department--a perennial irony for these stories--the Internet has grown to be an non-hierarchical arena for the free exchange of ideas and information. In accounting for its development, adjectives such as "informal", "accidental", and "lawless" abound (Rogers, 1995). From this perspective, the history of the

Internet is a story of expanding public access to Internet services and the flourishing of a culture of open discussion and technological enthusiasm.

One of the best-known and earliest narratives available on the Internet itself is entirely explicit about this notion. With an on-line collection of historical articles appearing since the late 1980s, Michael Hauben and Ronda Hauben say they intend to promote civic values which they regard as central to the formation of the Internet in its current form. They describe Usenet news, for example, as a "poor man's ARPANET" created by individuals who had experienced the benefits of flexible many-to-many communication in the military network (Hauben and Hauben, 1995; Hauben and Hauben, 1997). The ARPANET itself, in development and use, is interpreted as "democratic" in nature:

> ...the collaboration of the NWG [Networking Working Group] (mostly graduate students) and ARPA (a component of the military), seems to be contrary to the normal atmosphere of the times. Robert Braden of the Internet Activities Board reflects on this collaboration: "... One important reason it worked, I believe, is that there were a lot of very bright people all working more or less in the same direction, led by some very wise people in the funding agency. The result was to create a community of network researchers who believed strongly that collaboration is more powerful than competition among researchers...." (RFC 1336) These ideas point to a reason why the work of these computer scientists founded what has led to be one of the most amazing and democratic bodies (i.e.: The Net and the culture attached to it) to emerge in a long time. The community that has developed and the tools which accompany it form an important democratic force. (Hauben and Hauben, 1995, Chapter 6)

These themes have been reiterated in magazine articles, books, and other popular media. (Negroponte, 1995; Rheingold, 1993)

Such accounts sometimes dissolve into an exuberant welter of synonyms for "autarchic", such as the following:

> Still abiding by the Hacker Ethic, these tens of thousands of netheads have created myriad computer bulletin boards and a nonhierarchical linking system called Usenet. At the same time, they have transformed the Defense Department-sponsored ARPANET into what has become the global digital epidemic's resolutely grass-roots structure... The Internet... is open (nonproprietary) and rabidly democratic. It is run like a commune with 4.8 million fiercely independent members (called hosts). It crosses national boundaries and answers to no sovereign. It is literally lawless. (Brand in Rogers, 1995)

However, despite the rhetorical excesses, there are important insights bound up with accounts from the perspective of users. The key insights have been articulated by Hart, Reed and Bar in terms of two important facts about the history of the Internet: explosive growth, and widening access by a diversity of users. (Hart, Reed, and Bar, 1992)

There is no question that TCP/IP-based internetting has grown. Internet traffic, defined as data flow on the US national (NSFNET) backbone, grew explosively through 1988, when it began to roughly double in size each year. In 1983 the INTERNET had 200 computer nodes. In 1994 the global Internet, defined as access to email, comprised over 15,000 networks, 2.5 million permanently connected computers, and 25 million people in 125 countries, by one estimate. (Cerf, 1995) By the close of the next year, the number of networks, computers and people roughly doubled. Statistics such as these are controversial in their details but no one disputes the upward curve. Even the most conservative definitions yield results showing what any experienced Internet user can attest to: rapid growth.

There is also no question that access to Internet services has expanded to reach new populations. While once the province of the US Defense Department and its contractors, and it is still heavily concentrated in the United States, the Internet now reaches offices and some homes all over the industrialized world. Not only are there more users of TCP/IP protocols today than in 1970, but this population represents more walks of life. There has been a cornucopia of applications, including not only some of the original ARPANET services such as email and file transfer, but also bulletin boards, newsgroups, and, of course, the world wide web. As the burgeoning literature on "on-line interaction" and "computer-mediated communication" documents in detail, many users find new pleasures, new efficiencies and new possibilities in experimenting and communicating with Internet technologies.

What is more, the overall growth and greater access of Internet use has had important consequences for the expansion and diversification of Internet services and infrastructure. This is because users learn by doing. Once users have figured out what the Internet is good for--in their own terms--they quickly begin to develop new uses, and the volume and sophistication of traffic on the Internet is increased. Users are active participants in the development of a large technological system. (Hart, Reed, and Bar, 1992)

Timeline

By way of summary of the contributions and limitations of standard accounts, I present a table which combines some of the most salient themes. (See Table 1.) The table is modeled after a type of historical document now widely available on the Internet: a "timeline", which in its most basic form is a list of selected technical innovations in chronological order. The table illustrates two major lines of progress in three historical periods.

One line of progress, which reflects architects' perspectives, is a series from the ARPANET to today's global infrastructure which supposes particular continuities in technology and government support. Major government initiatives, usually identified with the titles of particular network systems, are important landmarks. Some of the most typical landmark systems are listed in the period headings of this table.

The other line of progress is a series of ever wider circles of user populations, beginning with the military and select computer researchers and expanding eventually to the computer-owning public at large. Such a series is also reflected in the headings of my table, since each includes a summary of new user populations involved during a period.

I have listed three periods as illustrative of a variety of periodizations which the literature offers. The first period is identified with the network-related research programs coordinated by ARPA. Through the 1970s, the ARPANET was elaborated and expanded, parallel and similar networks were set up among defense contractors and universities, and numerous regional networks, using various technical standards, took life. Access to the ARPANET was limited to the Department of Defense and its contractors, particularly in computer science and engineering.

A second period is defined by the establishment of NSFNET, bringing email and other internetworking services to supercomputing centers and an increasingly large number of university departments. The following boom in internetworking activity and demand sparked many new networks and service providers.

In the final period, recent events were initially identified with the 1991 US national announcement of a National Research and Engineering Network (NREN), which marked the movement of internetworking to a prominent position in national politics and contributed to further federal investments and massive expansion of users. The last several years have witnessed rapid spread of Internet access among businesses, university students and technical professionals, and even primary and secondary school students. Corporate advertising and efforts at electronic commerce grew substantially after the public was given access to the Internet in 1995. There has also been some political pressure toward the populist goal of approaching universal access. Groups in North America, Europe, and parts of Asia have been pushing to bring the Internet to public schools and libraries.

This table is not meant to be an authoritative source of validated information, but is meant to represent and synthesize other timelines and popular accounts of the history of the Internet. (E.g.: Baker, 1993; Corbin, 1991; Hart, Reed, and Bar, 1992; Zakon, 1996.)

Table 1. Timeline of the Internet

ARPANET: US DoD, contractors, computer researchers

1969: ARPANET on line, connecting UCLA and a few other university computer centers using NCP (Network Control Protocol).

1972: With 30 host computers in network, public demonstration at a computer conference in Washington, DC; InterNetworking Working Group (INWG) formed to establish standard protocols.

1977: THEORYNET on line, providing email to over 100 non-defense contracting computer researchers at University of Wisconsin.

1979: Unix User Network started, to send technical messages, and later adopted for other discussion groups as Usenet.

1981: IBM funds BITNET, providing email to some academics.

1982: INWG establishes TCP/IP as standard on ARPANET. CSNET on line, funded by National Science Foundation (NSF), for full range of network services between major US university computer science departments.

1983: MILNET on line, devoted to operational military nodes formerly on ARPANET.

1984: Over 1000 host computers connected to the Internet.

1985: Numerous regional networks set up.

NSFNET: Supercomputer centers, university faculty, staff and students

1986: NSFNET on line; management of regional nets by private firms begins; Usenet discussion groups reorganized to accommodate greater traffic.

1987: Contract to manage NSFNET awarded to Merit Network, Inc., which had managed a regional educational network with MCI and IBM.

1988: Private networks and for-profit service providers establish links to the Internet for commercial users.

1989: Over 100,000 host computers connected to the Internet.

1990: ARPANET decommissioned.

NREN: Large and small business, private citizens, schools, consumers

1991: NSF removes restrictions against commercial uses of the Internet; NREN legislation passed to provide for research on ultra-fast (gigabit) networks for commercial and supercomputing applications; World Wide Web (web) software distributed by the European Laboratory for Particle Physics (CERN).

1992: Faster backbone (T3 leased lines) added to NSFNET.

1993: Contract to manage various functions of NSFNET awarded to AT&T, General Atomics/CERFnet, and Network Solutions, Inc. A graphical browser for the web (Mosaic) distributed by the NSF-funded National Center for Supercomputing Applications.

1994: Widespread use of TCP/IP in corporate data communications.

1995: Popular Internet fad catches on, particularly email and web, extending to small businesses, homes and schools around the globe.

1996: Number of computer hosts exceeds 12 million. US President Clinton announces "Next Generation Internet" initiative.

Alternative Perspectives

Having reviewed some of the most influential perspectives on the nature and history of the Internet, I want to present an alternative set of perspectives based in recent interdisciplinary studies of technology. (Cf. (Bowker, 1995).) With roots in economics, sociology of science, and the history of technology, among other fields, recent technology studies have criticized restrictive models of technology development such as those embedded in what I have called architects accounts of the history of the Internet. They share many of the perspectives represented by user accounts of the Internet, but they take users' points of view even further, and take other points of view seriously as well.

Interdisciplinary technology studies now comprise a large body of comparative and case studies. The typical focus is often not particular objects but types of technologies, groups of technical approaches, and large technological systems. For example, in the economics of technical change, a key concept is the technological paradigm or regime, in which a family of technical approaches and practices, such as microelectronics, establish dominance in particular domains. (Dosi, 1982; Molina, 1993) Typically also, the focus is on new technology: its development, introduction, and adaptation. The goal they share is to consider an increasingly wide variety of factors and levels of analysis which contribute to technology development. (Basalla, 1988; Bijker and Law, 1992a; Bowker et al., 1997; Cowan, 1983; Elliot, 1988b; Foray and Freeman, 1993; Hard, 1994; Hughes, 1983; Kling & Iacono, 1988; MacKenzie, 1990; MacKenzie and Wajcman, 1985; Mowery and Rosenberg, 1989; Mukerji, 1994; Noble, 1986; Rosenberg, 1982; Thomas, 1994; Winner, 1986; Yearley, 1988)

The new studies arguably have valuable insights for corporate strategy, policy, design, and public debate. While not tightly coupled to practical outcomes, they are intended to more accurately portray the actual processes of technology development, and may provide general guidelines to help think through practical issues. (Rip, 1995) In other words, as in most social science, the new studies of technology sensitize readers to possible analytical approaches rather than generate exact or universal guidelines.

However, the new technology studies have immediate application in counteracting some of the inadequacies of the existing literature on internetworking. I will present this argument under the headings of four propositions. In each case, I will first explain the proposition in general terms. Then I will give empirical examples, in general technology studies and in particular instances from the development of the Internet.

There are few published accounts about the Internet which exemplify the perspectives taken by the new technology studies. For this reason, I will draw on examples described in popular media in order to suggest some of the depth and breadth of research that could be done in this vein.

It could be otherwise

First of all, the new technology studies come down strongly against any argument that a particular technical solution is the only possible or realistic one. When it is the nature of the technology that is used to justify such a position, it is called "technical determinism". But there are other forms of "determinism" as well, and the new technology studies are opposed to all of them in principle.

While the new studies acknowledge technical constraints, possibilities, contingencies and commitments, they assume that is no internal logic to technological development which merely unfolds in practice. Nor is there any other grand force which sweeps through history. Hindsight can make certain innovations seem like the only real contenders--especially since history is usually rewritten by the victors--but there were alternatives. (Bijker and Law, 1992a, 3)

Technology development also proceeds in a manner that is strongly dependent on existing practices, resources and abilities in a particular environment. It thus often proceeds in a way that will, from another point of view, appear less than optimal. One of the key concepts in the economic literature, for instance, is "path dependency", by which is meant that past actions and commitments to particular practices can restrict future choices, even though in principle other alternatives exist.

As I have shown above, standard accounts of the history of the Internet from the point of view of engineering architects tend to start from today's supposed successes and work backward, in a slim line of descent, from earlier ideas and programs to the next major breakthrough. User accounts start from a different inevitable point--namely, the need to communicate--but they take it as a given that people will use tools such as the Internet if they are available. From this point of view, the growth of the Internet is the result of people's desire for communication, full stop. (Schuster, 1994) This point of view glosses all of the details of why, how and which people are communicating.

Studies of the history of other technologies might help to provide some distance from the familiarity and apparent inevitability of today's Internet. For instance, it is often forgotten that domestic artificial lighting was preceded by large, public displays of electric lights. "That we no longer remember the excitement of electric light spectacles testifies both to the fact that [electrification since the late 19th... century has taken other turns] and to the tendency of every age to read history backward from the present." (Marvin in Rip, 1995, 418) Conversely, studies of electrical lighting have shown an enormous variety of materials and designs intended for use in similar settings. It is necessary to adopt the perspective of a particular time, place and set of concerns, with accompanying limitations in technical knowledge, in order to understand technological decisions at any one point.

With regard to the Internet, architects' retrospective accounts have tended to reduce the actual complexity facing researchers and managers at the time that they made particular decisions. For instance, while TCP/IP is now taken as the definition of the global internet, ARPANET ran using other protocols for about a decade before TCP/IP was established as a standard. Moreover, there have been various alternatives to TCP/IP at every time. For instance, OSI (Open-Systems Interconnection) was created by the International

Standardization Organization in the 1970s and by around 1990 was still held as the "European alternative" to TCP/IP and other protocols such as IBM's Systems Network Architecture. (Drake, 1993; Stix, 1989) A wider view suggests that the "milestones" identified in the technical histories are not points on a straight and narrow path, but islands of agreement, for certain groups with certain purposes at certain times, within an otherwise contentious field.

The 'communicational' determinism of users' accounts, is likewise belied by the details of communication on the Internet. Usenet, for example, is today a forum in which open and free-ranging discussion, including a wide range of political views, is the norm. (Benson, 1996) Was it inevitable that Usenet would evolve to support such norms and practices? In fact, as a recent study has shown, it evolved through the efforts of people and must be continually maintained by users as well. ..., "this consensus stems from a long and often painful struggle, as Usenet's designers, administrators, and users attempted to comprehend, define, and govern the communication system they had created." (Pfaffenberger, 1996, 365) In other words, the norms and actual practices of Usenet communication are the result of conscious efforts of participants. What is more, Usenet discussions are not completely open. Speech which is thought to restrict the ability of others from speaking is particularly loathsome to Usenet groups and is censured by participants.

Innovation requires many

The new technology studies also argue that technology development hinges on diverse groups of participants in two related senses. One is that a variety of individuals, groups, organizations and institutions are involved in technology development. Indeed, the more and more various groups are involved in a technology, the wider its support, and often the more deeply rooted and transformative the technology. The other is that conflict and competition are at least as important as cooperation. Conflict is not necessarily overt, but rather is often latent, reflected in the strategies that participants adopt to create advantage in their situation. (Bijker and Law, 1992b, 8-9; Cambrosio and Limoges, 1991) "Technology today provides an enormous and diverse range of resources in many social struggles. It is itself constructed and developed out of controversies and contests...." (Elliot, 1988a, 4)

From the point of view of recent studies, conflict is not necessarily bad for technology development. It is simply a fact of life that sometimes has useful outcomes. For instance, today the largest share of wind turbines is sold by Danish companies. However, studies have shown that Denmark's prowess in the field is the result of intense struggle among various groups since the oil crisis of the early 1970s, including large engineering firms, small craft shops, utilities, foreign and domestic buyers, and social movements. (Grin and Graaf, 1996; Karnøe, 1995)

Standard accounts of the development of the Internet tend to recognize a small set of groups and depict them as largely cooperative. In a new case study of work among Internet architects that acknowledges conflict among participants, Rogers (1998) argues that computer network architectures were designed in interaction with "the process of institutionalizing scientific disciplines and satisfying interorganizational constraints in the federal government."

Accounts stressing the autarchic character of the Internet tend to lose sight of numerous forms of control. For example, a recent paper argues that the Internet is coordinated behind the scenes of many casual users experience. They liken the Internet to an organization in which "99% of day-to-day functions to be handled by empowered employees, leaving the manger free to deal with the 1% of exceptional issues." (Gillett and Kapor, 1997)

Most importantly, standard accounts of the development of the Internet lose sight of stakeholders who are neither architects nor users, and influences that are not directly technical. Small groups of technicians are generally described as working in solitary splendor, rather than working, as Rogers study suggests, within conditions set by state agencies, corporations and other organizations, and in dialogue with larger organizational goals. While user accounts recognize a wider variety of individuals, they are typically conceived either strictly as individuals or as a mass. It should be possible to identify individuals, groups, organizations and institutions which have had galvanizing and organizing effects on both engineers and users.

One of the most immediate influences might be called "media organizers": people who promote resources on the Internet around particular user interests. Individuals who write about, construct and administer world wide web sites, emailing lists and bulletin boards are neither architects of the network services nor are they simply individual users. (See, e.g., (Donnelly and Ross, 1997; Patterson, 1996; Perry, 1996).)

Technologies have meanings

Another insight of the new technology studies is that there is no particular meaning inherent to a particular technology. Rather, technologies are associated with various ideas, intentions, purposes and contexts of use in different times and places, for different people and groups. Since it is often the case that people assume that their own preferred meaning for a technology is the only meaning, it is enough to say that technologies have more than one meaning. In the development of technologies, this implies that there is generally no direct path from research to full functionality because the meaning of technology takes twists and turns and unexpected routes.

The history of telephony is full of examples. At various times and places telephones have been considered worthless toys, a medium for musical concerts, and a kind of telegraph. "An understanding of what the telephone 'actually is' does not only affect... lexical definitions, it also has practical implications. The understanding of the telephone as a telegraph was significant when deciding which legal code would regulate the distribution and use of the telephone. The understanding of the telephone as a separate technology with special characteristics had implications for the research efforts to develop the basic elements of the telephone." (Bakke, 1994, 1) Viewing the history of telephony as a straight path toward the eventual outcome--hand-held devices for person-to-person voice communications, delivered by copper wire, to nearly every home and business in industrialized countries--skips over the long historical process of innovation, research, marketing and diffusion.

One issue of meaning in the standard history of the Internet is the contrast between its military origins and autarchic uses. What were the intended contexts of use and how do they relate to the actual technology designs? One way of resolving this question, for instance, is to argue that the ARPANET, while funded by an agency in the Pentagon, was not designed for directly martial use but to support military-related research. (O'Neill, 1995) Similarly, policy debates in Washington DC in the early 1990s featured two different visions of the meaning and purpose of public spending on information infrastructure: universal public access and grand scientific computing. (Hart, Reed, and Bar, 1992). More recently, and in countries all over the globe, another two competing visions have emerged in public debate: "the net as a pathway of commerce, dominated by large companies, vs. a series of places where citizens share information and build community." (Muller, 1996)

From a strictly technical viewpoint, however, there have been twists and turns in the Internet reconfiguring, for example, telephony. As has long been recognized, even the earliest networking of computers represents significant points of convergence between computing and telecommunications, and other points have been developing at an increasingly rapid pace. At the time of writing, one can hold a live audio conversation over the Internet. Telecom carriers are straining under the weight of new demands for data communications lines. One can send a fax from the Internet, send email from a fax, and have one's email read by machine over the phone. For reasons such as these, it is becoming increasingly anachronistic to refer to computing and telecommunications and other media by their conventional names. As one observer has argued, "as a result of the horizontal integration of all media (voice, audio, video, animation, data) in a common network and terminal infrastructure, telecommunications and networked-computing applications are no longer distinguishable." (Messerschmitt, 1996)

All technologies are network technologies

Overall, recent technology studies have built up a consensus that "...the success of technical innovations depends as much on a supportive social environment as on technical requirements. Typically, contributions by heterogeneous actors from different fields are needed for the validation, production and diffusion of new technologies." (Elliot, 1988a, 3) For this reason, recent technology studies have tended to reject simple models and embrace complex narrative. (Hughes, 1986; Kling, 1987; Kling, 1994)

A recurrent metaphor, in the work of an otherwise diverse group of writers, has been the network. Unlike a line, or even a tree, a network is taken as potentially limitless in its topology. Overall, the image of the network is used not as a 'model' but as a rhetorical tool to create a more open-ended conceptual space for investigation of technical change. It summarizes the notion that innovation results from complex, opportunistic interactions among a variety of different entities.

In economics, a related concept is what is generally called "network externalities", by which is meant the dependency that one group has on another in a particular technology. (Clark, 1985) But the most radical or fundamental network arguments are made by historians and sociologists. In the book punningly titled *Networks of Power*, a historian of electrification has argued that the establishment of power grids required a complicated set of social, organizational and political arrangements to be worked out. (Hughes, 1983)

Network metaphors contrast with the structure of architects accounts of the development of the Internet, which tend to describe well-defined lines. There is the line from conception to reality, such as the idea in the minds of ARPA managers to the building of a working ARPANET. There is the line from one government program to the next. There is the line from one key idea or invention to the next. The vagaries, false starts, different perspectives and competitive casualties of technical development are largely overlooked.

Users' perspectives on the development of the Internet illuminate one aspect of the networked character of technical development: how users have provided feedback in the form of changes in applications and demands to system developers. Users' perspectives on the Internet also implicitly show that the meanings of technologies have been different in various contexts.

A recent paper informed by technology studies makes a point of elaborating the metaphor of networks. In a revisionist account of the history of the ARPANET, Abbate argues that it "...comprised several different 'networks.' The system was built on a pre-existing social network of computer researchers. Superimposed on this was a funding network consisting of the individuals and sites that worked on ARPA contracts. Last in chronological order was the physical network, the ARPANET itself. All three types of networks crossed institutional and geographical boundaries that defined other environments in which the ARPANET builders participated." (Abbate, 1993)

For other examples of the suitability of network metaphors to the history of the Internet, one has to look no further than one's newspaper. Telecom, computing and other media have been coming together not only technologically but also as industries. As one journalist puts it, "The convergence of technologies is leading to a convergence of companies. They are merging and acquiring each other at the speed of their high-end products." (Government Executive, 1997)

Convergence, connection, and networking have all been the metaphors of choice in these developments, not only for discussing digital technologies, but also for understanding relations among major organizations, industries and sectors. The most significant trend has been the emergence of a "myriad of cross-investments and strategic alliances among and between all of the information industries". (Kavounas, 1996) Thus for example, "Microsoft, Disney, Time Warner, GE/NBC, TCI, and News Corp have together formed a web of joint partnerships...." (Auletta, 1997) It need hardly be mentioned, considering its prominence in the press, that the Internet plays many important roles in this competitive field.

What is more, it is widely held that the evolving network topology is too complicated to be known in advance. "Any long-term assumptions made now about the development of multimedia, networked multimedia, interactive, video dialtone, new media, and online information will be wrong because there will be a real difference in how these technologies are applied." (Communications International, 1995)

Although "convergence" has just recently emerged as a buzzword, and will soon be replaced by others, the dynamics that it speaks to--technical, industrial, social--have been taking place since the Internet began. Although government agencies took a leading role initially, this should not draw attention from the fact that corporations such as MCI, AT&T, and IBM have been involved with internetting since the start. There is a long, complicated and mostly unwritten history of corporate and other major organizations in a bewildering web of competitive and cooperative relationships linking computers.

Conclusion

According to widely-circulating accounts, the character and development of the Internet has consisted mainly of government programs, inventions, and demand from a wider and wider population. However, the standard accounts of the Internet's past are mistaken. Not because they have gotten their facts wrong, I have argued, but because they recognize a limited range of facts. A technological system that has not only covered the globe geographically, but has been shaped in many different ways by countless individuals, groups, organizations and institutions, requires a wide range analytically.

It is not that standard accounts are without value. Architects' accounts of the development of the Internet are far from simple in the detail they provide, particularly about technical decisions. Users' accounts offer important insights into processes of adaptation and adoption, the changing meaning of technologies, and the contestation of a variety of social issues in a technical arena.

Nonetheless, I have suggested, future scholarship about the Internet would benefit from extending the general findings of recent interdisciplinary studies of other technologies. These findings I summarized in terms of four aphorisms:

1. It could be otherwise.
2. Innovation requires many.
3. Technologies have meanings.
4. All technologies are network technologies.

For historians of the Internet to make use of the insights of recent technology studies, it will be necessary to expand the empirical basis of investigations. It is necessary to include at least the variety of actors, institutions and social processes that is already acknowledged by the press. Like users' stories about the Internet, new research should include contributions from non-engineers, but not only ones by individual users. Before the popular adoption and adaptation of Internet technologies, how were they designed in the first place? How have the interests and activities of various stakeholders affected the production of technologies and technical standards?

The most apparent omission in existing accounts is the role of large, powerful organizations. As well as showing the contributions of small groups of network engineers and enthusiasts, scholars should analyze contributions of well-organized and funded groups. (Roberts, 1992) In the discussion above, I mentioned a number of such organizations, any one of which would put the history of the Internet in a different light, including the following: national security and other state agencies; cross-agency and quasi-governmental bodies; telecommunications, computer, electronics and media companies; scientific organizations and groups; public policy lobby groups; university administrators and organizations (technical and non-technical). The task, though, is to explore relations and contexts among these and other actors. On this point the most apparent omissions are relations of power and conflict.

Existing accounts, as I have pointed out, have taken a rather harmonious and unbalanced view of their subject.

Having summarized the main arguments of the article, let me turn in closing to reflect on possible implications of a revised view of the Internet's development for an understanding of its future. Extrapolating from the standard observations, one would expect the future of the Internet to be more government programs, more inventions and more users.

Here again I would not take issue with the isolated facts, but with the overall picture that they build up. I do not disagree that the future of the Internet will see new government programs, new inventions and new enthusiastic users. However, if recent technology studies are a useful guide, the future of the Internet will consist of these things only in part.

As I suggested above, the approach of the new technology studies are in line with current discussions of "digital convergence". To put an even finer point on it, the four aphorisms with which I have summarized recent technology studies have direct counterparts in these discussions:

1. The future of the Internet is difficult to predict.

2. It will involve a wide variety of actors in a variety of relations, including conflict.

3. Meanings associated with the technologies will continue to be various and in flux.

4. Overall, the further development of the Internet is a highly ramified, complex historical process.

One point on which talk about convergence is probably misleading, however, is suggested by the key phrase, "digital convergence". The problem is that it puts the focus on technology as such, while the central finding of technology studies is that important innovations are never strictly technical in nature. What is more, if there is anything to extrapolate from current trends of the Internet, it is that the technology itself is increasingly less important as a driving force in its development, as it becomes both more commercial and more popular. At the same time, it is not generally recognized how much logistical and other maintenance work is required to use digital technologies. There are practical and cultural barriers to use of internetworking applications that will be increasingly salient as the cutting edge of Internet technologies becomes more sophisticated and groups with less technical support attempt to take part. (Kling, 1991; Kling, 1997)

Altogether, these points suggest a different scenario for the future of the Internet: The Internet continues to grow, in part fueled by extensions in infrastructure and populations which could be extrapolated from standard view, but also connecting to new infrastructures and populations. The Internet fad has little interest to main sources of growth: corporations, who want to get work done, especially coordinating far-flung and diverse information technology; and consumers, who don't care about being technically cool but who do care about the activities for which the Internet may be used as a tool. Technological enthusiasts of the 20th century who expected technically demanding new applications to take off, such as videoconferencing in offices, schools and homes, made overly aggressive predictions. Such applications develop over a longer time than expected by supporters, and unexpected other applications appear. There are extreme differences in the level of services between sectors (such as business and education) and between geographical areas and nations. The involvement of content providers and gatekeepers has an increasingly important role. Infrastructural crises, such as the Year 2000 problem and cyberterrorism, trigger shifts which were not widely anticipated even months before they happened.

Acknowledgments

A progenitor of this article was presented in a special session on the history of the Internet at the annual meeting of the Society for Social Studies of Science, October 1995. I thank all of the participants for their contributions and inspiration: Janet Abbate, Geoff Bowker, Judy O'Neill and Juan Rogers. I also thank Rob Kling, François Bar and an anonymous reviewer for their comments.

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