The Rocky Road to a Data Highway

NSFNET spawned a revolution in computer networking. Now it's giving way to the private sector, and the government's billion-dollar networking program is up in the air

Electronic networks, growing ever more powerful, are changing how scientists work. On this page and following ones we offer two stories that describe some of those changes. First, Christopher Anderson examines how networking, which began among scientists, is moving beyond their grasp. On page 1066, science writer Larry Krumenaker looks at x"virtual libraries" —projects that offer new ways to keep up with the scientific literature.

For computer networking, it is becoming the best of times. A quarter-century of government networking programs have paid off spectacularly with a fast-growing electronic web that today has 15 million users. Its biggest fan is Vice President Al Gore, who has spurred the Administration to propose a $2 billion, 5-year program to eventually take computer networks to schools, hospitals, and homes across the country. And the telecommunications industry, after decades of dismissing networking as a niche market, has suddenly embraced the concept of a networked nation with a $125 billion proposal to lay fiber optic cable and build routing stations.

But for users of the scientific computer network that brought all this about, times may be taking a turn for the worse. Last week, the National Science Foundation (NSF) quietly released a long-delayed set of guidelines for proposals to upgrade NSFNET, the computer network "backbone" it has run since 1986. This backbone connects some two dozen regional science and education networks—and hundreds of U.S. universities—which use NSFNET as a sort of interstate data highway to send messages and files across the country. These networks are in turn connected to hundreds of other networks, both commercial and public, to create a free-form and anarchic electronic web called the Internet. The Internet is the foundation of computer communications today, a vital link among collaborating scientists scattered across the country and around the globe, and the model for the data highway system of the future.

The gist of the new guidelines is this: After years of subsidizing network use for researchers, NSF will no longer offer a free ride to all. Pressured by computer and telecommunications companies to get out of day-to-day networking and let the free market take over, NSF will over the next few years force most researchers to start using commercial networks, on their own dime. Only the high-end users—scientists such as climate modelers whose appetites for data can't be served by commercial networks—will be able to use the high-speed NSFNET backbone of the future.

This leaves the government's networking efforts at an awkward transition. NSFNET is the core of a $120 million multi-agency effort known as the National Research and Education Network (NREN) program. NREN was once supposed to lead to a national billion-bit-per-second (gigabit) network, taking over from NSFNET in 1996. It still includes plans to develop a limited access version of such a network. But that limited access is leaving much of the research community up in the air.

NSF's decision on NSFNET "is going to play really badly" with the users, predicts Bruce Schatz, director of the University of Arizona's community systems laboratory and a member of a National Academy of Sciences panel that released a report last month on using networks for scientific collaborations. "People aren't likely to want to spend the extra money to hook up [to a commercial network] and pay time charges." That, he warns, could discourage scientists from using the networks for day-to-day communications—and stifle a spawning revolution in remote research collaborations.

But NSFNET director Stephen Wolff defends the new model, which he describes as a shift from "top down" to "bottom up" support for research networking. The government will continue to pay for researcher's cost of communications, he says, but now rather than paying up front for a big, widely used NSFNET, NSF will subsidize the use of commercial networks by allowing researchers to charge networking fees to their NSF grants, or perhaps by letting universities bill the charges to their indirect cost accounts.

The reason for this shift is that the networking world has changed. Working researchers may have started the whole phenomenon in the 1960s when they added e-mail as an afterthought to a system to access supercomputers remotely. But today, "science is no longer driving this," says David Lipman, director of the National Institutes of Health's National Center for Biotechnology Information. Today the Internet has more than 15 million users, and only one-third of them are scientists or engineers. "The changes are so profound that the science and technology community will be just a small [fraction] of the eventual users," Lipman says.

Those eventual users, at least in the world according to Gore, will be everyone. Superfast data lines will soon be as ubiquitous as cable TV connections, enthusiasts hope, giving universities, public schools, libraries, hospitals, and even private homes virtually instant access to everything from the holdings of the Library of Congress (video and sound included, of course) to real-time teleconferencing and movies on demand. Scientists and business people will be able to exchange images and graphic simulations as quickly as they now send e-mail notes and search remote, huge databases as if they were on their own hard disks. The whole country's going to be wired, and powerful economic forces, from the regional telephone companies to the cable TV industry, are fighting to build the next generation of networks to service it.

The NREN program might seem like a logical starting point for such a dream of national cyberspace. Back in 1991, NSF thought so too. But then it got its hands slapped. That year, when NSF first began preparing to solicit applications for the NSFNET upgrade, it was becoming clear just how big networking was going to be in this country. As a result, computer and communications companies objected to NSF's plans to pick a few firms to build it, arguing that such government support gave those companies a tremendous advantage when it came

1969: ARPANET, the first national computer network, is created by the Defense Department's Advanced Research Projects Agency (DARPA) so its researchers can share computer resources.

1972: DARPA demonstrates ARPANET to the public for the first time at the first International Conference on Computer Communications.

1980: Protocol developed to allow different networks to interconnect.

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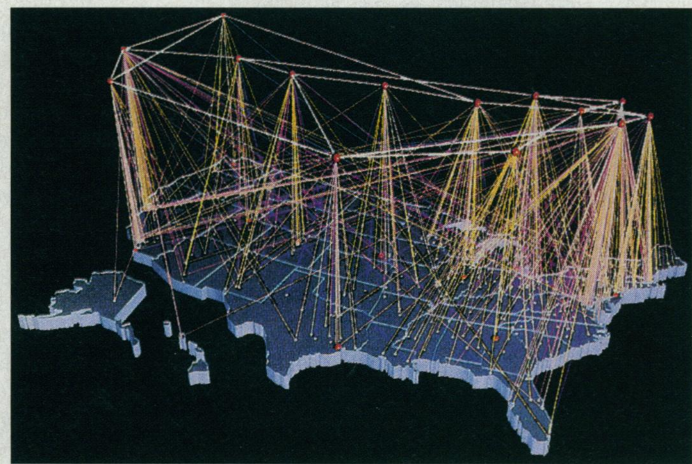
to networking the rest of the land. Strenuous objections to Congress followed, legislative intervention was threatened, and a chastened NSF went back to the drawing board.

And a much more modest drawing board it was. NSFNET will continue to exist, improving from today's 45 million bits per second to 155 million, and then, if all goes according to plan, gigabit speed. But the high-speed NSFNET backbone will be reserved for researchers who need to transmit vast amounts of data as quickly as possible. Although the commercial networks that other researchers are supposed to use are in short supply today, NSF anticipates that this new market of researchers needing network access would push the private sector to build more. NSF will use the usual peer-review process to decide who gets access to NSFNET. And a congressional bill introduced last month by Representative Rick Boucher (D–VA) would cement the NSF policy in legislation.

With NSF essentially dealing itself out of the larger game, where does that leave the grand plan for national webs of data flowing back and forth across the land? In other hands, mostly. Gore proposed what he called a National Information Infrastructure (NII) when he was a senator, but now that he's in the White House, other lawmakers have taken up the fight and their bill (first introduced this January in the Senate, where it bears the number S-4) is expected to come up for a vote this session.

The bill proposes $330 million over 5 years to develop such information resources as digital libraries, virtual reality technology, medical databases, and visualization techniques. It would also spend another $120 million on grants to help primary and secondary schools get access to the Internet. Clinton has proposed an even grander project: $1 billion over 5 years to develop network applications, and another $1 billion to help schools, libraries, and hospitals get on-line. Most of this funding would go to other agencies, from the National Institutes of Health to the Department of Commerce to the Rural Electrification Agency (which would give grants for "rural datafication").

As in any great social change, some people will fare better than others. The losers, at least for the moment, are those researchers (the majority, according to the congressional Office of Technology Assessment, which did a study in December on network use by scientists) who use the networks for nothing much more data intensive than e-mail. One way or another, they're going to have to start paying for networking, or go without. The winners are those who are pushing the envelope. That includes genome researchers who are developing ways to search DNA sequence databases in real time, and chemists who are designing molecules on remote supercomputers. Daniel Masys, director of the National Library of Medicine's Lister Hill Center for Biomedical Communications, is sponsoring the development of ways for radiologists to send x-ray pictures that can be assembled remotely into three-dimensional views of body interiors. He's also funding the Visible Human Project, which will eventually lead to a database of graphic images, position coordinates, and biological information that will allow network users essentially to take apart a person, examining any body part from virtually any angle or magnification.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The networked nation. NSF plans to reserve the NSFNET backbone *(heavy lines)* for the computing elite.

So far, such projects are more demonstrations of networking's power, rather than the sort of "killer application" that will prompt e-mail stalwarts to turn into high-end data crunchers. But those applications will come, Masys predicts, and the new NSF policy may even encourage researchers to find them. "I think scientists will be entrepreneurial in finding ways to stay on the backbone," he says.

Whatever happens to NSFNET and the rest of the federal networking programs, it's clear that the old days of scientists building networks for other scientists are fast departing. And a difficult transition period for research networks may simply be the price of success, says Vinton Cerf, vice president of the Virginia-based Corporation for National Research Initiatives. The 15 million people who now send e-mail, trade files, and search databases on the Internet work on a loose—and sometimes fragile—confederacy of smaller networks, tied together by a few communications and data transfer standards and the tireless enthusiasm of networking evangelists such as Cerf, who helped assemble it in the late 1960s. Part of the charm and vibrancy of the Internet, he says, comes from its anarchic roots. But with funding for networking technology and expansion estimated in the hundreds of billions of dollars over the next decade, the days when researchers could make network policy as they saw fit may be over.

For many of the pioneers, that's the not-unwelcome price of a research program becoming a national priority. Now that networking's future is in the hands of politicians and telecommunications giants, "I don't think any of us know where this thing is going anymore," says William Wulf, a University of Virginia computer scientist who ran the NSF program in the late 1980s, "but there's something exciting happening, and it's big."

–Christopher Anderson