The *Next* INTERNET

John Yue

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THE INTERNET2 AND THE NEXT GENERATION INTERNET OFFER THE FUTURE FOR HIGH-SPEED, HIGH-PERFORMANCE GLOBAL NETWORKING.

DENNIS FOWLER

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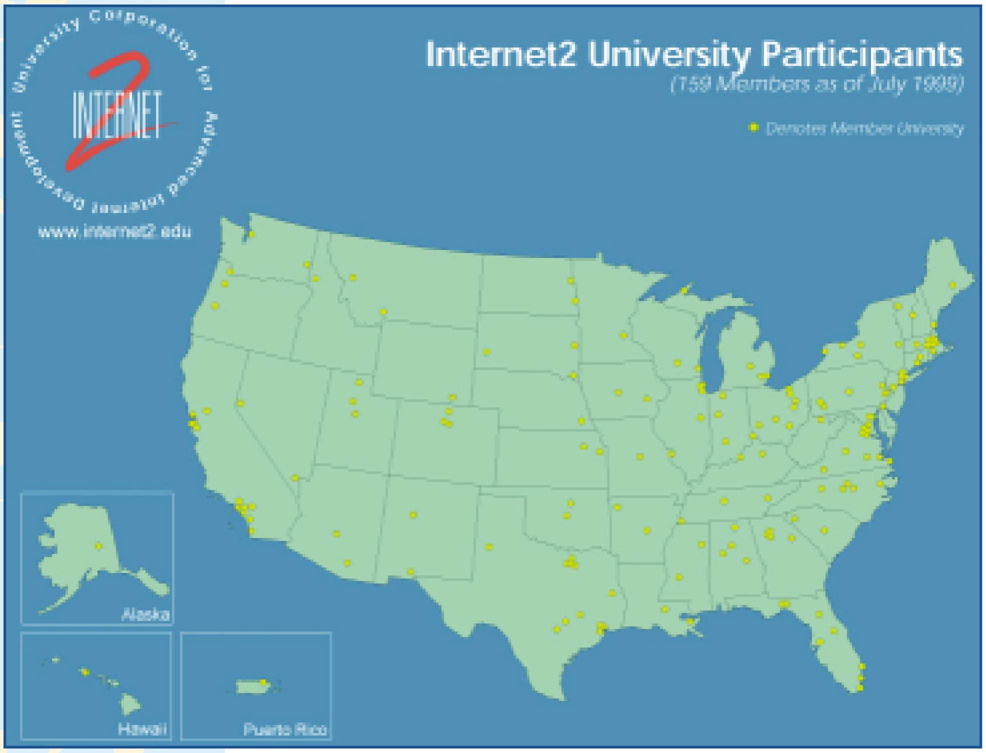
Back in the late 1960s, a collaborative effort by the Department of Defense's Advanced Research Projects Agency (DARPA) and some private academic and commercial institutions resulted in a small, experimental network called ARPANET. Thirty years later, we know it as the Internet. In less than five years of commercialization, the Internet itself has given birth to an entire new industry, and it is generating an economic and social revolution, to say nothing of a few new millionaires every time a Net startup issues an IPO.

Unfortunately, the Internet today is also showing strains from the load it carries. Industry wants wider bandwidth. E-commerce demands greater reliability. Applications such as real-time video need not only bandwidth but priority over less time-critical traffic such as e-mail. There are even those who predict the Internet itself is in danger of collapsing under the load. There's a real need for some serious upgrading.



UCAID's I2 map shows more than 150 affiliated universities coast-to-coast, including Arizona State, Columbia, Tulane and Stanford.

Unfortunately, the researchers and innovators who gave birth to this technology have lost the incubator that nurtured it. The Internet has grown so public and so congested that it is difficult, bordering on impossible, for researchers to develop on it the next generation of Internet technologies. A recent study by Steve Lawrence and G. Lee Giles of NEC Research Institute revealed that 83% of Web sites contain commercial information, while only about 6% contain scientific and educational information.

As a result, a new academic/corporate collaboration called the University Corporation for Advanced Internet Development (UCAID) has established a program, Internet2 (I2), for developing the technologies and tools needed to generate the next evolutionary step in global networking. The intent is to use I2 to develop a network with bandwidth 100 to 1,000 times greater than today's Internet, with the tools and capabilities to apply and manage that bandwidth intelligently. At the same time, a federally funded effort called the Next Generation Internet, or NGI, also promises a new Net that is capable of truly reliable high performance.

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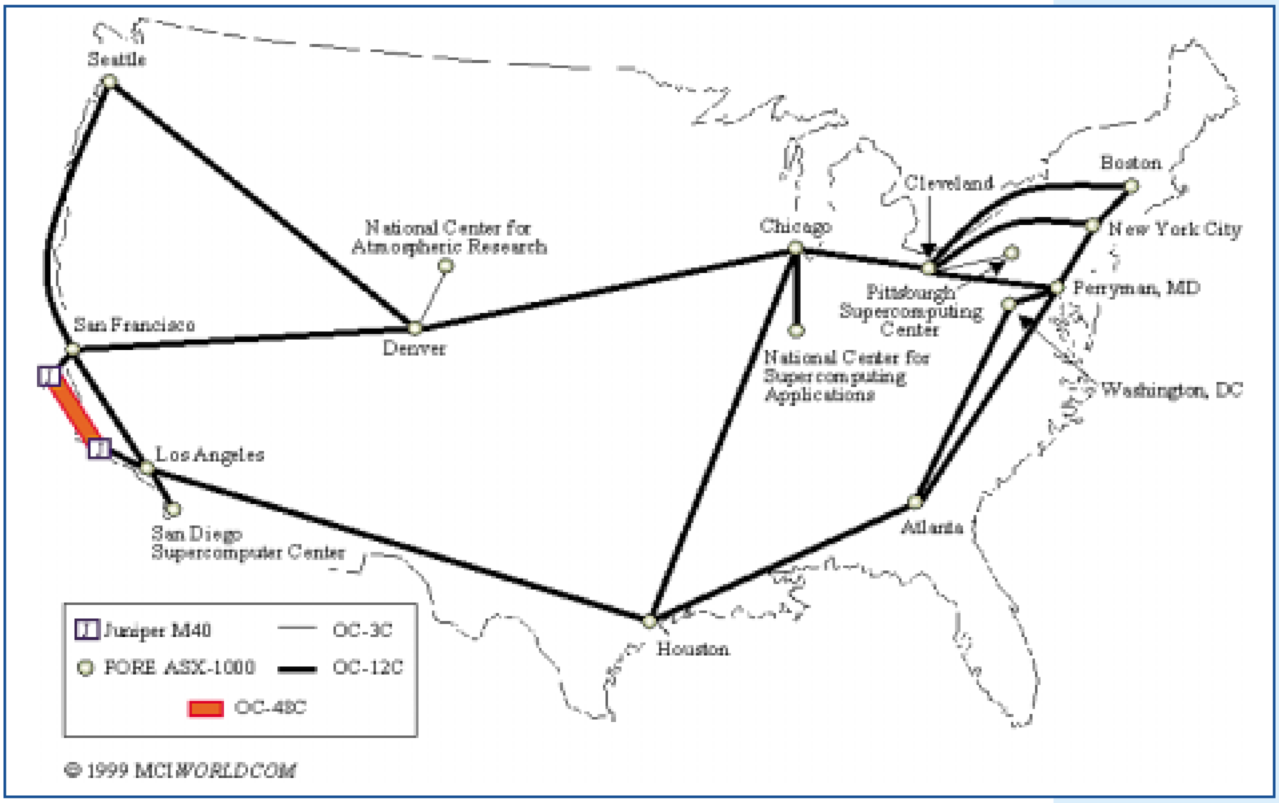
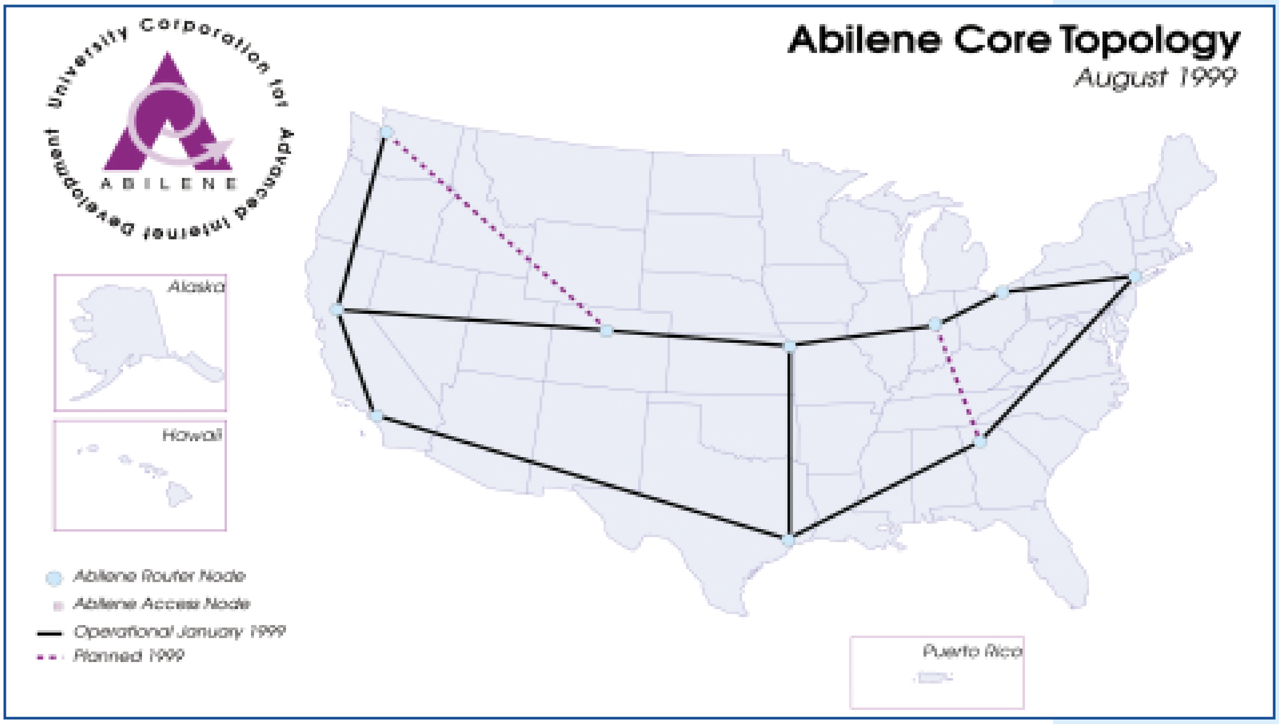


The I2 uses two interconnected backbones: vBNS (top), maintained by MCI WorldCom, features high-speed service between Los Angeles and San Francisco that will be expanded nationwide by year-end; Abilene (bottom), built by UCAID solely for the I2 project, boasts high-performance fiber and SONET technology.



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THE I2 MISSION STATEMENT

As put forth in its Mission Statement, the I2 project is to "facilitate and coordinate the development, deployment, operation and technology transfer of advanced, network-based applications and network services to further U.S. leadership in research and higher education and accelerate the availability of new services and applications on the Internet."

Note that there is nothing in the Mission Statement that says that Internet2 will replace the existing Internet. Rather it says that I2 will be used to develop future network applications and services. I2 actually replaces the network lost by the research community, the community that originally had a monopoly on the use of the Internet. One of I2's goals is to "re-create a leading-edge research and education network capability," not become another commercial medium.

I2 gives researchers and educators a quiet Ivory Tower, if you will, where they hope to create and demonstrate new networking applications. It gives them a place that will allow them enhanced collaboration, as well as the ability to conduct experiments that can benefit from an advanced network that is not overrun by the merchants. It will also allow the coordinated development and adoption of standards and practices among the participating institutions to ensure quality of service and interoperability on such a network.

I2 PARTICIPANTS

More than 150 universities are members of the Internet2 project. (For the latest information on Internet2, go to *http://www.internet2.edu/.)* These run, alphabetically, from Arizona State University through Columbia, Cornell, Princeton, Stanford, Tufts and Tulane to the University of Arkansas. I2 affiliates include research operations such as the National Center for Supercomputing Applications, the Army Systems Engineering Office, Jet Propulsion Laboratories, National Institutes of Health, and the Survivors of the Shoah Visual History Foundation.

While it is a non-commercial venture, I2 would be impossible without corporate assistance. The infrastructure itself requires cables and switches that the academic members would be hard pressed to provide.

The list of corporate partners includes 3Com Corp., Advanced Network & Services, Ameritech, AT&T, Cabletron Systems, Cisco Systems, Fore Systems, IBM, ITC^DeltaCom, Lucent Technologies, MCI WorldCom, Microsoft, Newbridge Networks, Nortel Networks, Packet Engines, Qwest Communications, StarBurst Communications, WCI Cable and Xylan.

As you can see, some of the very companies that were born out of ARPANET and that built the Internet are participating in I2.

I2 TECHNOLOGY — PIPELINES AND GIGAPOPS

When the engineering of I2 began about 1997, certain requirements were established for it. One was making sure it was affordable for the institutions that would be using it. This, of course, was in addition to the basic technical requirements of high speed and reliability. At its most basic level, what was needed was one or more backbones (pipelines) and ways for the users to connect to them (Points of Presence, or PoPs).

PIPELINES

Probably the easier-to-implement aspect of I2 was the backbones. In 1993, the National Science Foundation, recognizing the need for advances in high-speed/high-performance networking, solicited proposals for the very high-performance Backbone Network Service (vBNS).

In 1995, MCI was named vBNS provider, and under the agreement began work to provide IP and connectionless networking protocol (CLNP) services, beginning at 622 megabits per second (OC-12) using ATM switching and SONET fiber optic transmission technologies. An OC-12 backbone spanning the country was quickly inaugurated. In January 1999, the first OC-48c (2.5 gigabits per second) link began carrying production traffic between Los Angeles and San Francisco using Juniper M40 routers. Coast-to-coast OC-48 service is scheduled to be completed by the end of the year. Actual performance measures for the vBNS links can be seen at *http://www.vbns.net/OC48/oc48map.htm*.

Today, vBNS serves five supercomputing centers and more than 70 universities nationwide, including Georgetown, University of Kentucky, Vanderbilt, University of Maryland, Penn, Johns Hopkins, Princeton, Syracuse, MIT, Harvard, Michigan, Iowa, Idaho, Notre Dame, Washington State, Stanford, UCLA and USC. Access to vBNS is controlled by the NSF through grants given to qualifying institutions.

With vBNS already available, it was logical that I2 would utilize it as a backbone. But more than one backbone was wanted. Interconnected with vBNS is Abilene, built by I2's own sponsoring agency, UCAID. Announced in April 1998 by Vice President Al Gore, this high-performance network was developed in partnership with Qwest Communications, Nortel and Cisco Systems specifically for the I2 project. It began operation in early 1999, with full deployment set for the end of the year.

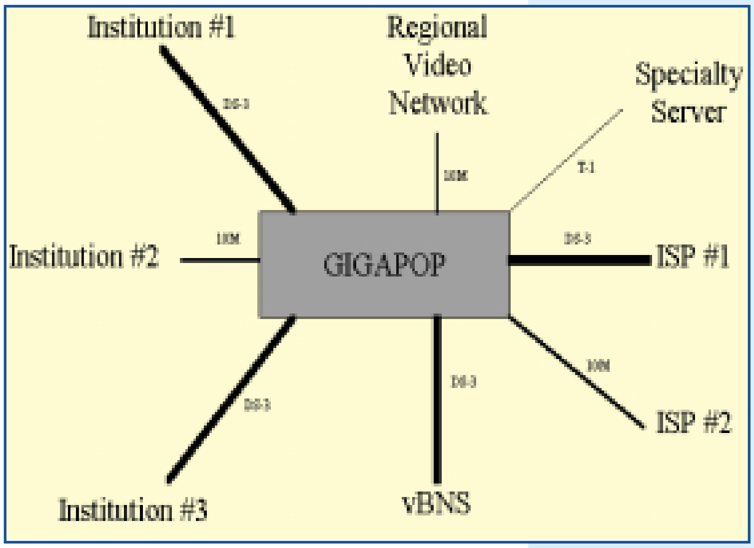
Abilene uses Qwest's fiber with high-speed SONET equipment from Nortel and IP-over-SONET routers from Cisco Systems. The Network Operations Center is located at Indiana University.

In addition to the connection with vBNS, Abilene also has peering arrangements with the NASA Research and Education Network (NREN), Defense Research & Engineering Network (DREN), the Department of Energy's ESnet, Canada's CA*net2, Scandinavia's NORDUnet, and the Netherlands' SURFnet.

Any higher-education institution participating in the I2 project through membership in UCAID is eligible to use the Abilene backbone network.

GIGAPOPS: MAKING THE CONNECTION TO I2

The greater challenge of the I2 project's infrastructure was providing the required access, or Points of Presence (PoPs), to the backbones. These PoPs had to offer capabilities not generally available on a typical Internet PoP. One of these requirements was support of both the



GigaPoPs provide multi-point access to the I2 as well as improved QoS.

current Internet Protocol (IP) version 4 and its successor, IP v6.

An I2 PoP must also be capable of allowing network applications to specify and receive a certain level of performance, a "quality of service" that includes not only transmission speed but latency, throughput and scheduling. QoS includes the ability to prioritize traffic, so time-critical packets get preferential routing over packets for applications where delays are acceptable. To save the I2 members money, it was specified that institutions should also be able to access the regular Internet through the same connection they use to attach to I2.

The solution to these requirements is what are called gigaPoPs. A gigaPoP is a regional network interconnect point that provides access to I2 for one or more I2 members.

GigaPoPs are distributed geographically for effective sharing, and accept a number of different types of connections.

Beyond the simple routing functions you'd expect, one of I2's goals is "bandwidth on demand." If Princeton suddenly needs more bandwidth to send live video to Stanford, the gigaPoPs must be capable of allocating it and providing the quality of service demanded.

GigaPoPs come in one of two types. Type I gigaPoPs serve only I2 traffic, routing that traffic through one or two connections to other gigaPoPs. Since they are essentially isolated on I2, Type I gigaPoPs have little need for complex internal routing and firewalling.

Type II gigaPoPs provide access to both I2 and other networks to which I2 members need access, including the current Internet. Again, one of the requirements in place for I2 is to provide both I2 and regular Internet service through a single connection, thus saving the cost of additional network connections; Type II gigaPoPs meet this need.

Type II gigaPoPs have a rich set of connections to other gigaPoPs, so they require more complex routing capabilities. Since they are connected to other networks, they also require greater security capabilities to protect I2 and its participants from unauthorized access.

One important aspect of this architecture is that members' networks that are connected to the gigaPoPs are assumed to be non-transit networks. All of their I2 traffic is routed through the gigaPoP, and their networks do not carry traffic between an I2 gigaPoP and the general Internet.

While connections to both vBNS and Abilene employ gigaPoPs, since vBNS carries traffic other than I2's as well as non-IP traffic, a vBNS PoP is not necessarily an I2 gigaPoP. Rather, I2 gigaPoPs connect to MCI's vBNS PoPs. Abilene's gigaPoPs, on the other hand, are I2 gigaPoPs, since Abilene was built specifically to serve I2.

WHERE I2 IS TODAY

I2 is up and running, with backbones in place. As noted previously, MCI began the vBNS project in 1995, and today it serves I2, supercomputing centers and universities with coast-to-coast OC-12 service, plus OC-48c service between Los Angeles and San Francisco. The plan is to offer OC-48 service over the entire vBNS backbone by the end of the year.

Some of I2's work deals with nuts-and-bolts programming; the IPv6 working group, for example, is helping to develop and implement the next version of the Internet Protocol.

Abilene, which will also offer speeds up to 2.4 gigabits per second (OC-48), gave its first public demonstration at a meeting of I2 members on Sept. 29, 1998. It began nationwide operation on Feb. 24, 1999, providing high-performance network services to 37 universities. By the end of the year, that number is expected to top 70 universities and research facilities. Nortel Networks is providing network planning and engineering services, network management and optical networking, while Cisco Systems provides high-speed communications equipment and ongoing engineering support. Qwest Communications provides 10,000 miles of fiber optic network and engineering support.

The work of I2 actually began with the engineering of the gigaPoPs. On the operational level now underway, some of I2's work deals with the very basic nuts and bolts of networking. I2's IPv6 working group, for example, is occupied with the development and implementation of the next version of the Internet Protocol. The Multicast Working Group is dealing with the challenge of sending the same information simultaneously to multiple network addresses.

One of the more vital efforts is the I2-QoS Working Group's QBone, which is a testbed for differentiated network services. The goal is to develop a method of providing different levels of service over high-performance networks by prioritizing traffic. Giving real-time video a higher priority than e-mail is one example. A delayed e-mail packet is rarely an inconvenience, but a dropped packet of video information could mean a dropped frame, and a noticeable and perhaps critical interruption. The success of many other I2 projects, such as I2-Digital Video, is contingent upon the success of the QoS Working Group.

The I2-Distributed Storage Infrastructure group has the goal of demonstrating a way to distribute information across the network in storage facilities. Doing this speeds access to information by reducing delays imposed by distance. Internet Content Channels would allow replication of files that could then be transparently delivered through a single URL to end-user communities from the nearest warehouse.

I2-Digital Video is developing a wide range of advanced digital video capabilities for the national research community. Included in this group's work is development of not only the architecture to be used, but both the core and edge technologies, the technologies that will operate over the network as well as the technologies needed by the end users.

I2 LIVES

One demonstration of I2 took place in Washington, D.C., back in February at a ceremony unveiling Abilene, and it illustrates how the new technologies being developed are themselves applied in non-computer fields. At the ceremony, Dr. W. Scott Melvin at Ohio State University in Columbus was shown on the screen during a two-hour procedure to open a 39-year-old man's esophagus. Another doctor, Dr. Jerry Johnson, standing by at Washington's Union Station, collaborated with Dr. Melvin during the procedure.

While it wasn't perfect (there was some delay in the audio packet transfer), Dr. Melvin observed that the video "was high enough in quality that colleagues can see enough detail to comment on the surgery in real time."

THE NEXT GENERATION INTERNET (NGI)

NGI, the hot topic in Washington these days, is not the same thing as I2. NGI is about networking technology; I2 focuses on applications. The intent of the NGI program is to combine four existing networks — NREN, DREN, ESnet and the National Science Foundation Network (NSFNET), all of which peer with Abilene — into two high-performance testbeds that will connect colleges and universities.

I2 is complementary to the NGI initiative, and I2 and NGI are already working together in many areas. For example, I2 is participating in the NGI Joint Engineering Task Force (JET) to ensure the interoperability of the technologies being developed.

NSF has committed to NGI by connecting 150 sites to a testbed providing a hundredfold increase in performance. Meanwhile, as its part of NGI, DARPA is deploying a testbed with a thousandfold increase in performance at more than 20 sites.

Obviously, there is a great deal of overlap between the two projects. Combine I2 with NGI, add in vBNS and Abilene, and you have an alphabet soup of networks and partners, all addressing the many different issues involved from different angles. While the fiber is in place to move the data, the routers and switches are undergoing continuing refinement on the various backbones, while I2 addresses core issues such as QoS, management and administration of high-speed networks.

THE TRICKLE-DOWN EFFECT

As spelled out in the I2 Mission Statement, one goal of I2 is to "transfer new capabilities to the

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global production Internet." The intention is that as I2 matures, its technology will be adopted by the public Internet.

The list of collaborators on the Internet2 project would seem to ensure that what the researchers develop will not be "bottled up" and stuck away on a shelf in some musty laboratory. I2's corporate partners can hardly ignore the commercial possibilities of what is born on I2. The symbiotic relationship between business and academia should be a virtual guarantee that what is developed on I2 will become available on the commercial Internet, probably sooner rather than later.

THE STATE OF THE ART

But is it soup yet, and what flavor soup will it be?

Some very tough issues remain that leave us far short of having an I2 (or NGI) that can enjoy widespread use. Among the most crucial is the already-mentioned quality-of-service dilemma. Applications that require tight QoS — real-time video being one of the best examples — are still best handled on private ATM networks.

Prioritizing traffic is perhaps the biggest challenge in the QoS issue. Multi-Protocol Label Switching (MPLS) is one way being offered to address the problem. However, the Internet Engineering Task Force (IETF's) MPLS Working Group has been entangled in a debate involving competing implementations in the MPLS protocol; this has resulted in a draft standard that includes both methods. Not all the parties interested in MPLS are pleased with this approach, arguing that it will make implementation complex and interoperability problematic.

NGI, the hot topic in Washington these days, is not the same thing as I2; but there is a great deal of overlap between the two projects.

The heart of much of the Internet2 project's work is making it possible for distant people to work together effectively. Besides this year's demonstration of online collaboration during surgery, back in March 1998 Dr. Tom Ferrin, director of the Computer Graphics Laboratory at the University of California at San Francisco, demonstrated a "collaboratory" that allows scientists from around the country to share and interactively manipulate three-dimensional molecular models. This technique is extremely useful in drug and biomaterials design.

Just because there have been some demonstrations of what can be done, however, does not mean that I2's payoff is right around the corner. It's unlikely any of it will appear on the Internet in the next six months. Michael Rabin, who manages AT&T's involvement with I2, estimates that I2 advances will be making their way into the commercial Internet within three years.

Multicasting is another technology facing complex issues, with some debate taking place as to how best to implement it. Some propose that it should be implemented at the lower layers of a multivendor switch/router network in the NGI. Others propose that it can be better handled using a mesh of Web-caching proxy servers running over a less intelligent network.

For the I2/NGI to meet real-world needs, even the issue of Service Level Agreements (SLAs) must be addressed. It is no longer enough that these contracts simply specify some average level of performance, as it is measured today. They must become more tightly aligned with customers' applications if they are to offer the assurances needed in real life.

Bandwidth, ironically, is not the issue here. "We can put out tons of data," says David

Jahn, a meteorology researcher at the University of Oklahoma. “The problem is we can’t deal with it.”

He compares the problem to trying to drink from a fire hose, but it might better be compared to trying to pick the olives out of a flood of martinis being pumped through a fire hose. It’s all there, but the important stuff is still in danger of getting lost amidst the spam and joke lists.

Even the quality of the edge systems is an issue. The final stretch of pipe — the “last mile” — has to be able to handle the flow, and then the end system — the computer on your desktop or the set-top box on your TV — has to be capable of dealing with it as well. While today’s desktop systems can more than handle a dial-up or even ISDN connection, that’s not enough to cope with what is coming on the Internet of the future.

CONCLUSION

One certainty of I2/NGI is that businesses are eager to implement whatever emerges from it. Federal Express, for example, is already building a global purchasing system to take advantage of the new network. Due to launch this summer, the system will eventually allow more than 100,000 employees in 90 countries to purchase everything from pens to truck parts. Initially operating over the Internet, the system will migrate to I2 technologies as they become available, replacing a current mélange of private networks and paper-based processes. It will allow simultaneous review of purchasing plans by financial, legal, technical and business managers, replacing the slower, more expensive sequential review used today.

What we are not likely to see are sudden, revolutionary changes. The Internet has already revolutionized everything from telecommunications to commerce itself. Streaming video exists, but it’s just not very reliable, as almost anyone who has tried to teleconference over the Internet can tell you.

I2 and NGI now address the evolutionary steps needed to maximize the potential of the network; they promise a faster, more mature, more reliable medium, one that is capable of making real the dreams of the entrepreneurs. This is the incubator for the technologies of the future Internet. ~

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