

***Super-Size Bandwidth
and Two-Way Video
in the Classroom***

***Internet2 and its Impact
on Videoconferencing***

Super-Size Bandwidth and Two-Way Video in the Classroom

Internet2 and its Impact on Videoconferencing

Alan Greenberg

Wainhouse Research

June 2004



Contents

Executive Summary	5
Overview	7
Organization and Mission.....	7
Technology	7
Applications	9
Inter-Organizational Partnerships and Distance Education	9
The Video ‘Stuff’ of Internet2.....	11
Internet2 Commons	11
The Megaconference	12
ViDe and the Videoconferencing Cookbook	13
Beacon H.323 Test Software.....	14
IPv6	15
Applications.....	15
Two-Way Video.....	16
Streaming video.....	16
Tele-Immersion	17
Remote Instrumentation	17
Conclusion — Super-Size Bandwidth’s Impact on Video in the Classroom	18
About the Author.....	19
About Wainhouse Research.....	19
About Polycom, Inc.....	19
Appendix A – Acknowledgments.....	20

Figures

Figure 1 Abilene Network Design	8
Figure 2 Megaconference 2003 Global Map	13

Super-Size Bandwidth and Two-Way Video in the Classroom

Copyright © 2004 Wainhouse Research. All rights reserved.

Executive Summary

For a time after it was founded in 1996, Internet2 (Internet2) was perceived among many as “that other network,” an exotic luxury that was limited in value to all but a few research institutions.

This is evolving, however, and Internet2 is now rapidly becoming a “mover and shaker” that is changing how researchers collaborate and how educational institutions reach out to one another.

Internet2 is a consortium of over 206 universities (as of April 2004), as well as over 50 corporate members, 40 affiliate members, and 40 international ‘partners,’ many of which come from various consortia and governmental agencies. Its stated goals are threefold:

- To enable a new generation of applications
- To create leading edge research and educational network capabilities, and
- To transfer technology and experience to the “global production Internet”

The result is that Internet2 has become what it was intended to be: a test environment for pushing the envelope on networking and networked computing technologies, while also serving as a home for creating new applications for these technologies.

Internet2 backbones typically operate at 2.4 Gbps (OC-48) to 10 Gbps (OC-192) capacities today; its GigaPoPs (points of presence) provide regional high-performance aggregation points; and for member institutions, typically local campus networks provide no less than 100 Mbps to the desktop. At the backbone level, this is *minimally* more than 1,000 times the bandwidth of an E-1 line, and more than 19,000 times the bandwidth of a standard 128KB ISDN line. The technique being used to provide ample bandwidth is through over-provisioning, so that no one ever runs out of bandwidth.

This creates almost endless possibilities for what can be delivered over or achieved using this amount of bandwidth. Advanced applications include distributed computation, virtual laboratories, digital libraries, distributed learning, streaming video, remote instrumentation, and tele-immersion.

The focus of this white paper is on one specific application area, digital, two-way video in the classroom. Video is an ideal application for Internet2: it ‘likes’ bandwidth, and it does not perform well when carried over the lower-speed, ‘under-provisioned’ public Internet.

In addition, Internet2 already has begun to promote the increased use of videoconferencing in the classroom, specifically through initiatives and projects such as the K20 Initiative, Internet2 Commons, the Megaconference, the ViDe Cookbook, and early, test bed deployment of the ITU-T H.350 standard.

Through the Sponsored Educational Group Participant (SEGP) program, some 30,000 K-12 schools in 34 states in the U.S. alone already are connected to Internet2.

Through the Sponsored Educational Group Participant (SEGP) program, some 30,000 K-12 schools in 34 states in the U.S. alone already are connected to Internet2.

This will only increase in time, even as Internet2 also goes global through an increasing number of inter-networking agreements.

Wainhouse Research believes the massive capacity provided by Internet2 will have a domino effect on distance education, and in particular on the use of two-way, interactive video in the classroom. As educational organizations seek to increase their partnerships, improve learning in the classroom, and enhance ties between their own communities and communities elsewhere, there will be an exponential increase in use of two-way video. This trend mirrors the global economy in which we all live, and will help drive a greater ability for public and private institutions to *discover* applications together.

Overview

For a time after it was founded in 1996, Internet2 (Internet2) was perceived among many as “that other network,” an exotic luxury that was limited in value to all but a few research institutions. This is evolving, however, and Internet2 is now rapidly becoming a “mover and shaker” that is changing how researchers collaborate and how educational institutions reach out to one another. Contrary to popular opinion, Internet2 is funded primarily by universities and private enterprise, though some of its initiatives are government-funded and the organization is working in parallel to (and often in partnership with) the government-funded Next Generation Initiative (NGI).

Organization and Mission

In reality, Internet2 is a consortium of over 206 universities (as of April 2004), as well as over 50 corporate members, 40 affiliate members, and 40 international ‘partners,’ many of which come from various consortia and governmental agencies.¹ Its mission is no less lofty sounding than that of any other forward facing, futuristic group: *To develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow’s Internet.* Its stated goals are threefold:

- To enable a new generation of applications
- To re-create leading edge research and educational network capabilities, and
- To transfer technology and experience to the “global production Internet” (in other words, the Internet we all know and love so well).

The result is that Internet2 has become what it was intended to be: a test environment for pushing the envelope on networking and networked computing technologies, while also serving as a home for creating new applications for these technologies. In many respects it has been borne out of multiple forces which at times conflict and at times coalesce into shared, mutually beneficial goals. And emulating the creation of the original Internet, it is based on a unique partnership of governmental, educational, and corporate entities.

Technology

In practical reality, Internet2 is a collection of multiple groups of organizations and institutions and networks that meet certain minimum criteria for advanced network capabilities. Internet2 backbones typically operate at 2.4 Gbps (OC-48) to 10 Gbps (OC-192) capacities today; its GigaPoPs (points of presence) provide regional high-performance aggregation points; and for member institutions, typically local campus networks provide no less than 100 Mbps to the desktop. At the backbone level, this is *minimally* more than 1,000 times the bandwidth of an E-1 line, and more than 19,000 times the bandwidth of a standard 128KB ISDN line. The possibilities for what can be delivered over this amount of bandwidth are endless.

¹ The actual number of institutions which are benefiting from Internet2 through affiliate memberships, as discussed later in this white paper, is even larger.

To put the two Internets into perspective, the Internet, though powerful, could be described as the equivalent of a local dirt path in comparison to what is possible with Internet2 – the equivalent of a national highway system (Internet2). One way in which Internet2 offers such a rich network is by providing a “super-sized” Meta network. The super backbone in the U.S. is called the *Abilene* network: a collection of 101 participants that are connected at the full 10 Gbps. While those who connect to Internet2 may not all be directly connected to Abilene, they benefit from the bandwidth enabled by the network.

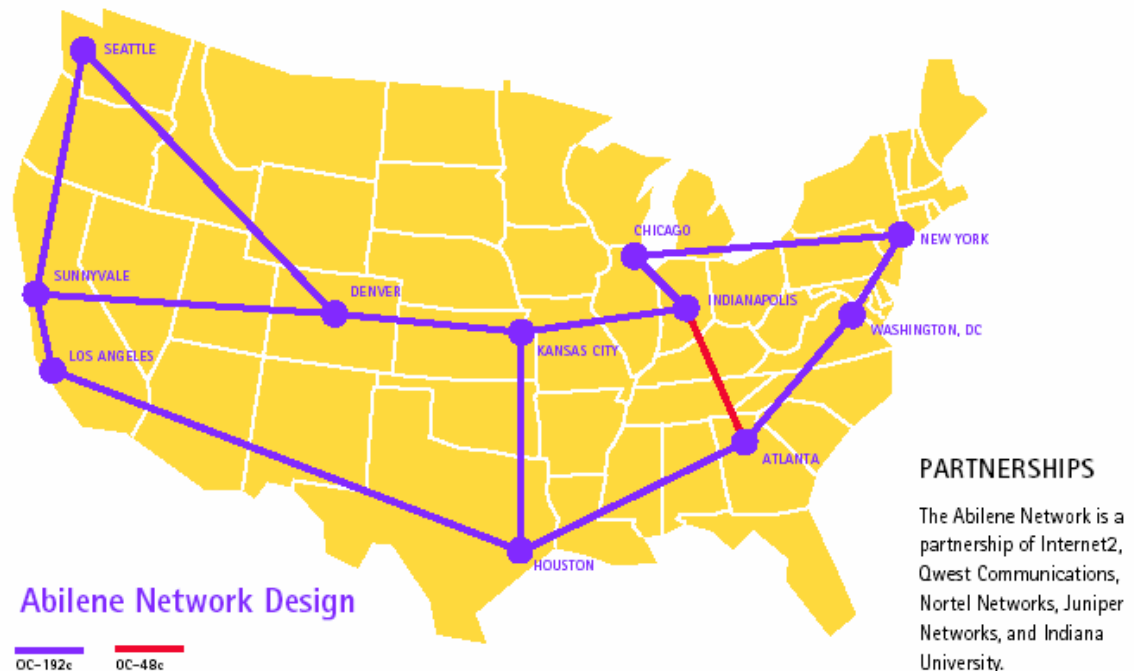


Figure 1 Abilene Network Design

Internet2 is a predecessor to an even more audacious effort, National LambdaRail (NLR). Like Internet2, NLR is not a single network, but a rich set of facilities, capabilities, and services that will support a set of multiple experimental and production networks for the U.S. research community. At this point in the early design phase, NLR has at its foundation a dense wave division multiplexing (DWDM)-based national optical footprint, being deployed on roughly 10,000 route-miles of fiber. Using Cisco Systems’ 15808 optical electronic system with a capacity of 40 channels (wavelengths) per fiber pair, each wavelength will be able to support transmission of 10 Gbps. With four wavelengths expected to be installed and available on the first day of operation, that will provide quadruple the network bandwidth of the Abilene network. Some aspects of NLR are complementary to Internet2 and it is worth mentioning primarily because it will function to Internet2 much as Internet2 functions to the production Internet: a harbinger of things to come. Details are at www.nationallambdarail.org.

Returning to the topic of Internet2, though super-sized bandwidth is important, it is far more valuable to think of Internet2 not only for its bandwidth, but also for the applications it is driving and the inter-organizational partnerships and change for which it is an agent.

Applications

What all this bandwidth makes possible are some very advanced applications that make Star Trek seem like yesterday's news. These include separately or in combination:

- Distributed computation
- Virtual laboratories
- Digital libraries (super-charged and made more broadly available)
- Distributed learning
- Streaming video
- Remote instrumentation
- Tele-immersion

Some of these applications are described in greater detail later in this document. Suffice to say, each of these could be subject of a white paper unto itself; in this case our focus is on digital, two-way video in the classroom.

Internet2 already has begun to promote the increased use of videoconferencing in the classroom, specifically through initiatives and projects such as the K20 Initiative, Internet2 Commons, the Megaconference, the ViDe Cookbook, and early, test bed deployment of the ITU-T H.350 standard.

Video is an ideal application for Internet2: it 'likes' bandwidth, and it does not perform well when carried over the lower-speed, non-Quality-of-Service enabled public Internet. In addition, Internet2 already has begun to promote the increased use of videoconferencing in the classroom, specifically through initiatives and projects such as the K20 Initiative, Internet2 Commons, the Megaconference, the ViDe cookbook, and early, test bed deployment of the ITU-T H.350 standard.

Inter-Organizational Partnerships and Distance Education

Wainhouse Research believes the massive capacity provided by Internet2 will have a domino effect on distance education, and in particular on the use of two-way, interactive video in the classroom. The process by which this will transpire is multi-faceted and complex, but put simply, as universities continue to create GigaPoPs, they will be looking for regional groups interested in connecting to those GigaPoPs.

In effect, the universities behind the GigaPoPs will act as Internet2 ISPs for smaller universities and colleges, as well as some of the larger primary and secondary school networks, such as various statewide networks or large metropolitan school networks.

Wainhouse Research believes the massive capacity provided by Internet2 will have a domino effect on distance education, and in particular on the use of two-way, interactive video in the classroom.

The interest on the part of many organizations will be to connect to universities and have access to the wealth of information, applications, and technologies available only through Internet2; on the part of others, the interest will be on two-way video and links with the broader world – as discussed later in this white paper.

Not so widely known is that Internet2 is already reaching many organizations not specifically described as one of its primary or affiliated members. This is partly the result of the K20 Initiative, meant to enlarge the reach of Internet2 through promotion to K-12, smaller colleges and universities, and not-for-profit organizations such as libraries and museums. In effect, the K20 Initiative enables smaller institutions to join as connected, secondary members at a fraction of the cost of full membership. According to Louis Fox, Director of Internet2 K20 Initiative, some 30,000 K-12 schools in 34 states in the U.S. alone already are connected to Internet2 via what is known as the Sponsored Educational Group Participant (SEGP) program.

The SEGP program supports the aggregation of educational organizations brought together in a statewide network or other wide-area network within a state. Examples of these aggregations are statewide K-12 networks, community college networks, and similar collectives of educational organizations. These networks are engaged in applications development and other projects designed to enhance their use of advanced networking infrastructure and services. Details about Internet2 K20 initiative and specifics about its participants are available at:

<http://k20.internet2.edu/segp/currentparticipants.html>

A state or regional education network interested in connecting to Abilene must find an Internet2 primary member to sponsor the connection. The entire state network will then be connected to the Abilene backbone via one of the 20 or so network GigaPoPs. Once connected, this state network will be known as an Internet2 SEGP. All network traffic destined for another SEGP or Internet2 member is routed over Abilene at little or no cost to the SEGP. The sponsoring Internet2 member generally covers the cost of the SEGP traffic.

Every state in the U.S. has one or more statewide networks that are a combination of higher education, governmental agencies, and primary and secondary school systems “riding” that network for video (and often data) services. We can only expect that the actual number of SEGP’s will continue to increase, providing educational opportunities domestically and internationally.

This is because the next wave of Internet2 growth will come from increasing connections for collaboration around the world. Many national (or regional) research network efforts similar to Internet2 exist around the world, and Internet2 has signed memoranda of understanding (MOUs) with over 40 such organizations with the objective of working together on both connectivity and applications. Internet2 does not specifically provide connectivity directly to those countries, but many of them do in fact connect to the United States (often with support from the U.S. National Science Foundation). Details on Internet2’s international activities can be found at www.internet2.edu/international/. For information about which networks connect to the United States, visit the StarTap Website at www.startap.net/.

Because Internet2 does not provide direct connectivity to international networks, it works hard (as if to compensate for this lack) by supporting *peering* between international networks and the Abilene network. Peering with Abilene is made possible via international connection points (also referred to as exchange points) which facilitate peering among US and international research and education networks. Peering can also be done via international links such as TransPAC or via other networks connected to Abilene, e.g., CALREN-2 or GEANT. The bottom line for organizations outside the U.S. is that it can cost surprisingly little to participate in a domestic or regional high-speed network, but the trick is to ensure that such a network is already involved in peering with Internet2. A visit to <http://international.internet2.edu/index.cfm> describes the essentials of how to harness the current international activity in this space.

The Video ‘Stuff’ of Internet2

Internet2 Commons

Internet2 Commons is a concept that arose out of one of Internet2’s many working groups, in this case the digital video working group. As an IP-centric network, the focus of Internet2 from the start (in terms of two-way video) has been on the ITU-T H.323 standard. As a result, the Commons has become a focal point for IP-based videoconferencing. The goal is to foster two-way video between anyone in the broader Internet2 membership, such as SEGP’s, as well as sub-groups within the larger member institutions. Thus Internet2 Commons provides multi-way videoconferencing services with capabilities such as simultaneous streaming, archiving, high-bandwidth support, continuous presence video layout options, and encryption. Hosted physically (as are many video-related projects and programs) by the Ohio Supercomputing Center and Ohio State University, the Commons is less an advanced network than a set of services meant to make two-way video (and other applications, such as web conferencing, streaming, and archiving) available to groups that otherwise would not have access to these capabilities. It is available in two flavors:

- The Prime Subscription, available for a \$2,000 annual fee that makes available 300 MCU port hours, with additional time available at affordable increments.
- The Alliance Subscription, available for a \$1,000 annual fee that provides the Commons MCU’s as a backup for a group’s own bridging service. It includes 100 MCU port hours and calls for a reciprocal MCU agreement.

The Commons has led to some unique educational initiatives that might not otherwise have taken place, including a distributed nursing informatics course that regularly brings together 11 sites with 6 instructors; the Network for Earthquake Engineering Simulation (NEES) that connects 15 to 20 sites some two to four times a month; and the teaching of lesser taught languages. When only one instructor of the Native American language Ojibway exists, as an example, Internet2 can foster cooperation between universities and lead to linguistics students keeping alive the language.

The Commons also serves as a way to deliver two-way video capabilities in alternate ways. As an example, it has implemented desktop collaboration technologies such as Polycom’s

WebOffice, the Virtual Rooms Videoconferencing Schemes (VRVS — a web- and reflector-based, software MCU that arose for videoconferencing and collaboration among the High Energy and Nuclear Physics communities), Wave Three Session Software, IMFirst, and other tools.

The Megaconference

The Megaconference events are the world's largest H.323 videoconferences, bringing together participants from locations literally all over the world. Held at various times after Fall Internet2 Member Meetings,

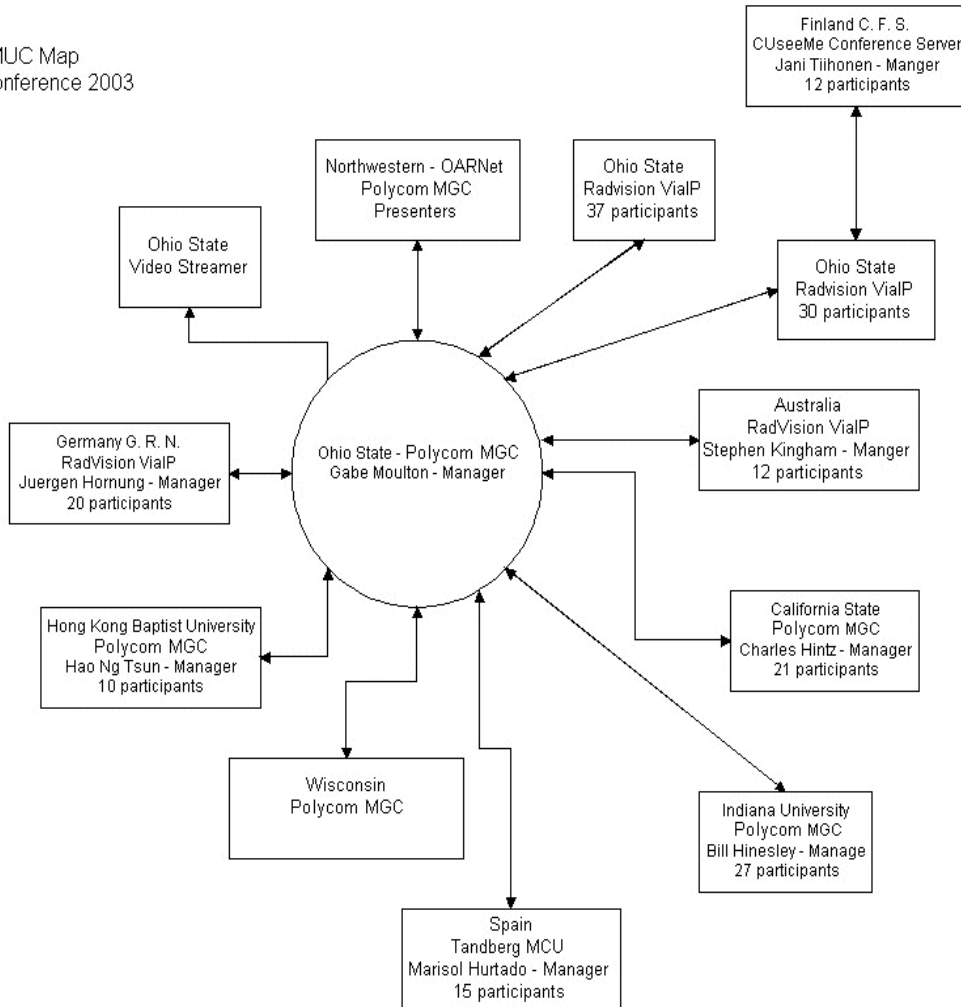
The Megaconference events are the world's largest H.323 videoconferences, bringing together participants from locations literally all over the world.

Megaconference participants discuss their programs from a content perspective and with an eye toward 'Best Practices.' *These are not technical presentations; only end users who actually use the technology in their own work are allowed to present.*

The brainchild of Dr. Bob Dixon of Ohio State University and OARNet, the Megaconference represents the 'democratization' of the videoconferencing community (somewhat in emulation of the traditional Internet — with an organized disorganization that lends itself to spontaneity, interactivity, and subsequent partnering). Each Megaconference — of which there had been five as of fall 2003 — has consisted of a series of presentations, chats, and group sessions meant to instruct, inform, and foster post-event contacts and partnerships. The most recent Megaconference included musical mini-concerts. Certain technical guidelines have been established, such as the use of H.263 video and 768 kbps connections, but these have not limited the *200 or so participants* who now take part in each event.

The following drawing demonstrates the complexity, sheer size, and global nature of the Megaconference. Listing the bridge locations does not tell the entire story, as some of the identified number of participants on each bridge may have been connecting other bridges as well.

MUC Map
Megaconference 2003



W J Hinesley 12/09/2003

Figure 2 Megaconference 2003 Global Map

Events like the Megaconference have put pressure on some of the traditional ‘closed off’ statewide networks that traditionally were ‘islands’ unto themselves (as a result of legacy technologies that lacked gateways or programmatic and funding decisions that limited openness to external networks). As Internet Protocol continues to grow, as an example, more and more legacy networks (such as fiber-optic and ATM networks) will find ways of connecting to the Megaconference and to Internet2. Events like the Megaconference Junior (designed for primary and secondary students around the world -- <http://megaconferencejr.cciu.org>) and the Keystone K-12 Conference (www.k12videoconf.org) will lead to increased exposure for Internet2 and video in the classroom. Megaconference details can be found at <http://www.megaconference.org>.

ViDe and the Videoconferencing Cookbook

ViDe (the Video Development Initiative) is a collaboration of 13 universities and other members of the international advanced networking community. Though not specifically an Internet2 program, its participants are members of Internet2 and have close ties with the organization. The ViDe participants are working together to advance the state of networked digital video and voice-

over-IP (VoIP), sponsoring working groups that are exploring such areas as video-on-demand, Quality of Service, Session Initiation Protocol (SIP), and the MPEG-4 video standard. Among other projects, ViDe provided an early test bed for H.350 directory services (see below), enabling vendors to see how their early implementations of H.350 deployed and enabled users to trial initial versions of this important directory standard. The ViDe.Net environment allows users to communicate with other ViDe.Net sites around the globe using any combination of IP telephone, wireless IP phone, desktop videoconferencing, or classroom technologies. Information about ViDe can be found at <http://www.vide.net>.

ViDe also provides a popular videoconferencing resource known as the “Cookbook.” Now on its Version 4.0, the Cookbook is an online tool for understanding the dynamics of H.323 videoconferencing, containing tips, networking fundamentals, best practices, and other valuable information. It can be found at <http://www.vide.net/cookbook>.

H.350 Directory Services

The H.350 story is an excellent example of the synergies that have developed between Internet2 members and video as an application (as represented by the Vide.Net). Ratified by the ITU in September 2003, H.350 resulted from an Internet2 video middleware working group (some of whose members were also members of ViDe). The H.350 standard provides a uniform way to store and locate information related to video and VoIP in directories that are linked seamlessly to enterprise directories. H.350 uses LDAP (Lightweight Directory Access Protocol) to store users’ voice, video and collaborative multimedia information in a way that integrates with directory and identity management systems already in place at large enterprises. Many of these enterprise systems also use LDAP; the new H.350 standard will enable enterprises to scale up video and VoIP operations to very large-scale deployments. Account configuration details, authentication and authorization are linked to the enterprise directory using LDAP. H.350 improves security by providing standardized management and storage of authentication credentials.

The practical impact of H.350 cannot be overstated when it comes to broadening the ability to find other organizations interested in videoconferencing. H.350 enables networks to register their video users with other networks – in effect creating super-directories of users. While we’re not likely to see one individual directory services provider anytime soon, we eventually will see numerous super-directories sprouting up which will enable communities of interest to find one another more easily. Vendors are already embedding H.350 support in their management and bridging software products; the IETF is likely to approve it as a standard in addition to the ITU; and it will play a role in further deployments of VoIP as well as video. All of this will go a long way to address the problem that was faced by adopters of videoconferencing in the past: whom are we going to call?

Beacon H.323 Test Software

Other tools also have arisen out of Internet2’s push into video. An example of one is the H.323 Beacon, a software tool that is the result of an Internet2 End-to-End Performance Project. The H.323 Beacon is a client that loads onto servers located on Internet2, as well as on PC’s. It allows users to create a kind of “fake” videoconference, in effect measuring, monitoring, and

troubleshooting possible performance of a call even before it is established. Our analogy at Wainhouse Research is that it is somewhat akin to a ‘ping’ or ‘TraceRoute’ command, only it provides significantly more diagnostic information and features a superior user interface. End users, network engineers, and conference operators can debug H.323 application performance problems from the network to the host (from end-to-end) using the Beacon software.

Developed by Internet2 and the Ohio Internet2 Technology Evaluation Center of the Ohio Supercomputer Center, the H.323 Beacon was introduced to the advanced networking community in fall of 2003. After a rigorous test period in conjunction with the Megaconference, the Beacon was selected for use by Internet2 Commons and was recommended for performance troubleshooting by various vendors. Additional information is available at www.itecoho.org/beacon.

The H.323 Beacon is one example of the End-to-End Performance Initiative (E2EPI). This is a specific Internet2 initiative designed to create a predictable and well-supported environment, making it possible for Internet2 campus network users to have routinely successful experiences in their development and use of advanced Internet applications. The E2EPI is focused on improving Quality of Service (QoS), understanding that ‘super-size’ bandwidth alone does not solve all problems. As of this writing, E2EPI is developing a distributed, scalable system to monitor, test, and report end-to-end performance. The system, called the E2EPI Performance Evaluation System (piPEs), will be able to indicate performance capabilities and locate problems along the path between two computers connected by a backbone network, participating campuses, regional networks, and GigaPoPs. When piPEs is completely deployed, it should significantly improve the opportunity for advanced Internet applications to operate at peak performance. More information about E2EPI can be found at <http://e2epi.internet2.edu>.

IPv6

As version 4 of the Internet Protocol (IPv4) ages, vendors, research consortia, and advanced users are preparing for the onset of the next version of the protocol: IPv6. With IPv4 addresses reaching their quantitative limits, and with the proliferation of wired and wireless devices, IPv6 will offer 128-bit Internet addresses (versus the 32-bit IPv4 addresses), which will dramatically increase the number of available IP addresses. There are many other enhancements to IPv6, including improved security and more efficient packet handling. Why is this important to videoconferencing? For several reasons: first, because improved data transmission efficiency will ultimately result in improved video transmission. Second, IPv6 will set the stage for many new applications, including areas like wireless videoconferencing. Many universities, businesses, and government research labs have taken leading roles in identifying and solving the challenges to improving IP. Internet2 is very active in this area. More details are available at <http://ipv6.internet2.edu>.

Applications

Thus far this document has described some of the initiatives and programs of Internet2, and

Internet2’s video applications encompass everything from Internet-based videoconferencing to on-demand content to remote control of microscopes and other instrumentation.

their potential impact on two-way videoconferencing.

The fact is, two-way video is only one of the areas in which Internet2 is ‘pushing the envelope’ on digital video. Internet2’s video applications encompass everything from IP videoconferencing to on-demand content to remote control of microscopes and other instrumentation.

Internet2 Digital Video Initiative (<http://dv.internet2.edu>) is one effort involved in developing a wide range of advanced digital video capabilities for the national research community. Over time, many of these applications will filter their way into other communities of interest which participate in or benefit peripherally from Internet2.

Two-Way Video

Already many K-12 practitioners throughout the world are beginning to seek to network more and more with one another or with institutions of higher education and research – whether through standard ISDN or Internet connections, or by taking advantage of access to Internet2. The examples are so numerous that those mentioned here could be considered the tip of the iceberg.

The examples (of practitioners throughout the world seeking to network) are so numerous that those mentioned here could be considered the tip of the iceberg.

California schools, as an example, connect over the state’s non-profit Corporation for Education Network Initiatives in California (CENIC)’s infrastructure and through initiatives such as the Digital California Project, a statewide initiative providing K-12 schools with access to the high-speed advanced services network, CalREN. This opens up both high-speed intra-state activities, as well as access through CENIC’s Internet2 connections to the any other institution on the globe. The Imperial County Office of Education, as an example, connects using Polycom ViaVideo, ViewStation, VSX 7000, and MGC-100 units for regular meetings, student activities, and even for international links, such as frequent connections to China. The State of Oklahoma’s OneNet reaches 80% of the state’s K-12 schools; these schools use Polycom ViaVideo, ViewStation, VS 4000, VSX 7000, and ClassStation packages to hold frequent links with others throughout the U.S., in Latin America, and Europe. While videoconferencing traditionally was found in rural locations, it increasingly is making its way into urban districts that are seeking to leverage investments in network and technology, as well as their own educational resources. Many large metropolitan districts are merging educational interests with other community and business interests to “go international” in search of partnerships for content, education, and business.

Streaming video

ResearchChannel is pioneering new methods of Internet-based distribution of HDTV and better-than-broadcast-quality video through ongoing collaborative technology experiments. This is a nonprofit consortium of leading research institutions focused on building high-quality Internet, cable, and satellite-based channels to facilitate the communication of research information.

<http://www.researchchannel.com>

Meanwhile, a *Public Television: Next Generation Interconnection Pilot*, run by the University of Wisconsin and Washington State University, is working on a thorny public television (PTV) challenge. Currently stations are connected by a one-way satellite system. The PBS stations at University of Wisconsin and Washington State University, along with a consortium of other university PTV stations, have been using Internet2 networks to begin developing new applications for the next-generation interconnection system. Using broadband IP video connections from their host universities, the PTV-Internet2 project members are testing station-to-station, broadcast-quality (MPEG-2) video streaming, server-based broadcast video-on-demand, video segment search and fulfillment at MPEG-2 levels, and collaborative program editing. Information on this initiative can be found at <http://ra.doit.wisc.edu:8888/vid.html>.

Tele-Immersion

The Tele-Immersion Project is exploring how to conduct realistic, life-sized, 3D tele-immersion to create what could be described as the most ‘complete’ interactive experience imaginable. It is a project of Advanced Network & Services, Brown University, the University of North Carolina, and the University of Pennsylvania. Project collaborators envision an *Office of the Future* where computer vision, networking, and computer graphics techniques are used to capture a dynamic 3D model of one office — including walls, furniture, objects, and people — and then re-create a virtual representation in a similarly equipped remote office. This concept is not new, with companies like Telesuite and others having attempted similar, though lower bandwidth, efforts at recreating the experience of being together. Internet2 networks offer a high performance test bed for this research, which demands high bandwidth and low latency to support real-time interaction between remote users and shared virtual objects. The work being done on projects like Tele-Immersion will likely have an impact on future applications for videoconferencing in many other environments as well.

Remote Instrumentation

While many have been expecting telemedicine to lead the way in remote operation of equipment, other interesting applications are under development using Internet2 as the test bed. North Carolina State University, for example, is running a project exploring real-time tele-operation of the Tele-vator. This is a computerized excavation backhoe that can be remotely operated over high-performance networks. Because of its size and potential criticality of operation (e.g., in hazardous rescue situations), the Tele-vator requires a high-level of sophisticated two-way feedback, including adequate depth of vision provided via high-definition stereovision. Guaranteed QoS -- such as network bandwidth, latency (delay) control, and jitter control -- are essential to ensure the quality of the 3D image, audio, and equipment control channels. Visit <http://CARL.ce.ncsu.edu> for more information.

Other video-related projects are underway by various members of Internet2, exploring areas like collaboration technologies, distributed learning, and digital libraries.

Conclusion — Super-Size Bandwidth’s Impact on Video in the Classroom

It should be clear by now that the sum of super-size bandwidth, a term which this analyst used somewhat indiscriminately to connote the idea of what Internet2 is all about, is going to be neither greater nor lesser than its parts. In other words, bandwidth itself is one great sum; but the parts themselves, the projects and programs underway to promote videoconferencing technologies, are also great sums that add up to something larger than what seem at first glance.

Every time a Megaconference occurs, it has a viral impact on the sensibilities and outreach behavior of current videoconferencing users. Every time a statewide network that is an SEGP enables some K-12 school to find and connect to another such organization across the country or across the oceans, it shows them that they can be connected to anyone on the globe in ways that far exceed text- or graphics-based, non-immediate mechanisms such as websites and e-mail. Projects like the Global Nomads links between students in the U.S. and Iraq, or Dr. Robert Ballard’s delivery of video directly from the Titanic over the public Internet and Internet2 in MPEG-2, are singular and unique today. These are likely to increase exponentially over time as greater bandwidth and a greater ability to *discover* applications together lead private and public organizations to interact more and more using video.

While eRate grants in the United States may be funding equipment purchases, it is Internet2 that is fostering a network sensibility that can be said to be 21st century. That sensibility will be like a steady drip that turns into a stream and then the equivalent of a fire hydrant.

While eRate grants in the United States may be funding equipment purchases, it is Internet2 that is fostering a network sensibility that can be said to be 21st century.

The flow will be less about the bandwidth, and more about what is riding that bandwidth: two-way interactive video and a host of other video-related technologies.

About the Author

Alan D. Greenberg is a Senior Analyst & Consultant at Wainhouse Research. As consultant, analyst, communicator, and strategist, Alan has worked in the telecommunications, videoconferencing, software and services, and multimedia arenas for 20 years, holding positions with VTEL, Texas Instruments, and several Austin, Texas-based startups, and consulting to many organizations. At VTEL he conducted research into dozens of distance learning networks, was product marketing manager for a set of turnkey classroom packages, and led a number of educational and training initiatives and research into healthcare networks. Most recently he was primary author on the segment report, *Video Communications Management Systems 2004*, was lead analyst on the Wainhouse Research WebMetrics research program, and authored the white papers *Navigating the Sea of Research on Videoconferencing-Based Distance Education* and *Best Practices in Live Content Acquisition for Distance Learning*. He also has authored reports on conferencing endpoints & bridges, streaming video, and voice/fax services. He specializes in primary end user research and is a trained focus group moderator and interviewer. Alan holds an M.A. from the University of Texas at Austin and a B.A. from Hampshire College, Amherst MA. He can be reached at agreenberg@wainhouse.com.

About Wainhouse Research

Wainhouse Research (www.wainhouse.com) is an independent market research firm that focuses on critical issues in rich media communications, videoconferencing, teleconferencing, and streaming media. The company conducts multi-client and custom research studies, consults with end users on key implementation issues, publishes white papers and market statistics, and delivers public and private seminars as well as speaker presentations at industry group meetings. Wainhouse Research publishes *Conferencing Markets & Strategies*, a three-volume study that details the current market trends and major vendor strategies in the multimedia networking markets, a variety of segment reports, and the free newsletter, *The Wainhouse Research Bulletin*. Its subscription content service can be found at www.wrplatinum.com.

About Polycom, Inc.

Polycom develops, manufactures and markets a full range of classroom, corporate training, and medical education solutions through its high-quality, affordable voice and video communication endpoints, video management software, web conferencing software, multi-network gateways, and multipoint conferencing and network access solutions. For additional information, visit www.polycom.com.

Appendix A – Acknowledgments

Super-Size Bandwidth and Two-Way Video in the Classroom is based on this analyst's opinions and the result of interviews with a handful of individuals involved with Internet2. Wainhouse Research wishes to thank the following individuals and their organizations, without whose support this document could not have been written. We also refer readers to the Internet2 website (www.internet2.org) for additional information.

Bob Dixon
(Robert S. Dixon, Ph D, PE)
Chief Research Engineer
Ohio State University, Office of the CIO
and Ohio Academic Resources Network (OARNet)
Bob_Dixon@osu.edu

Jill Gemmill
Assistant Director, IT Academic Computing
Internet2 Applications Lead
University of Alabama at Birmingham
JGemmill@uab.edu

Jonathan Tyman
Manager, Digital Video Initiatives
Internet2
tyman@internet2.edu

Greg Wood
Director of Communications
Internet2
ghwood@internet2.edu