

NGI and Internet2: Accelerating the Creation of Tomorrow's Internet

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Abstract

Internet2 is a consortium of leading U.S. universities working in partnership with industry and the U.S. government's Next Generation Internet (NGI) initiative to develop a faster, more reliable Internet for research and education including enhanced, high-performance networking services and the advanced applications that are enabled by those services [1]. By facilitating and coordinating the development, deployment, operation, and technology transfer of advanced, network-based applications and network services, Internet2 and NGI are working together to fundamentally change the way scientists, engineers, clinicians, and others work together. [<http://www.internet2.edu>]

The NGI Program has three tracks: research, network testbeds, and applications. The aim of the research track is to promote experimentation with the next generation of network technologies. The network testbed track aims to develop next generation network testbeds to connect universities and federal research institutions at speeds that are sufficient to demonstrate new technologies and support future research. The aim of the applications track is to demonstrate new applications, enabled by the NGI networks, to meet important national goals and missions [2]. [<http://www.ngi.gov/>]

The Internet2/NGI backbone networks, Abilene and vBNS (very high performance Backbone Network Service), provide the basis of collaboration and development for a new breed of advanced medical applications. Academic medical centers leverage the resources available throughout the Internet2 high-performance networking community for high-capacity broadband and selectable quality of service to make effective use of national

laboratories, computational facilities, and large data repositories.

The Internet2 Health Sciences Initiative enables a new generation of emerging medical applications whose architecture and development have been restricted by or are beyond the constraints of traditional Internet environments. These initiatives facilitate a variety of activities to foster the development and deployment of emerging applications that meet the requirements of clinical practice, medical and related biological research, education, and medical awareness throughout the public sector.

Medical applications that work with high performance networks and supercomputing capabilities offer exciting new solutions for the medical industry. Internet2 and NGI strive to combine the expertise of their constituents to establish a distributed knowledge system for achieving innovation in research, teaching, learning, and clinical care.

Keywords:

Internet, Digital Imaging, Information Networks, Digital Signal Processing

Introduction

Internet2 is a collaborative effort by over 180 United States universities to develop advanced Internet technology and applications vital to the research and educational missions of higher education. Internet2 is a project of the University Corporation for Advanced Internet Development (UCAID) [<http://www.ucaid.edu>]. UCAID is a nonprofit consortium, led by university members working in partnership with industry and government, to provide leadership and

direction for advanced Internet development. The “community” of Internet2 also includes international participation through agreements with similar groups worldwide.

University leadership drives Internet2 with the demand for advanced applications and valuable expertise to implement initiatives. The combination of requirements and resources provides a perfect setting for developing the next generation of Internet capabilities. By accelerating the technology transfer necessary to move the appropriate technologies into the commercial sector, Internet2 provides both a next generation network and the applications that run on high-performance networks.

Advanced application development has led to the introduction of various Internet2 initiatives. The Internet2 Health Sciences Initiative was created in January 2000 and allows members of Internet2 to find peers, work collaboratively, and share tools and other resources. Its goals include facilitating the creation and enhancement of health applications whose development and deployment have been hampered or prevented by traditional Internet technology. Through the U.S. National Library of Medicine, the U.S. government’s Next Generation Internet (NGI) initiative and the Internet2 Health Sciences Initiative work closely together to catalyze the development and deployment of advanced applications in the medical domain.

Background on Internet2-NGI Involvement

The research and education community required more functionality than existed in the Internet of the mid-90s. Responding to this need, in October 1996, thirty-four universities attended a meeting at which the Internet2 Steering Committee described the objectives of the project. Shortly thereafter, President Clinton and Vice President Gore announced the administration’s Next Generation Internet initiative.

Today, the university-led Internet2 effort and the federally led NGI initiative work together in many areas. For example, the Internet2 program works in partnership with the National Science Foundation’s (NSF) merit-based High Performance Connections program. Over 90 Internet2 institutions have received competitive grants, awarded to connect high-performance backbone networks.

Internet2 also functions in the larger context of federal research and development. Mission-oriented networks developed by federal agencies, such as NASA and the Department of Energy, are important elements of the NGI initiative and work in partnership with Internet2 [3]. For example, Internet2 participates in the NGI Joint Engineering Team (JET), which coordinates the development of federal agency advanced networks. [<http://www.slac.stanford.edu/comp/net/netorg.html>]

Network Engineering Activities

The Abilene network supports the Internet2 community by providing an effective interconnection among the regional networking aggregation points, or gigaPoPs, pioneered by Internet2 universities. Abilene was developed in partnership with Qwest Communications, Nortel (Northern Telecom), and Cisco Systems. Abilene uses high-speed Sonet facilities and IP-over-SONET routers, accessible to gigaPoPs in several dozen locations nationwide, to support the Internet2 infrastructure.

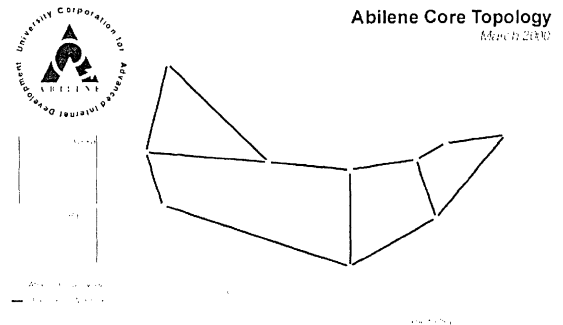


Figure 1— Internet2 High-Performance Network Backbone

Any higher education institution that is an Internet2 member is eligible to use the Abilene backbone network. Private and government organizations focused on research and education and collaborating with Internet2 universities also connect to Abilene with appropriate authorization. Each institution makes an individual decision about which network provides the necessary capabilities for advanced application development. [<http://www.ucaid.edu/abilene/>]

The Abilene network also provides a testbed for testing new networking technologies, such as quality of service (QoS) [4] and multicast [<http://www.internet2.edu/multicast/>] and IPv6. Abilene is operating initially at OC-48 (2.4 gigabits per second) backbone links. In parallel, Internet2 is working with partners to develop additional links running at OC-192 (9.6 gigabits per second) and beyond.

Middleware

Middleware is a layer of software between the network and the applications. This software provides services such as identification, authentication, authorization, directories, and security. In today’s Internet, applications usually have to provide these services themselves, which leads to competing and incompatible standards. By promoting standardization and interoperability, middleware makes advanced network applications much easier to use. The Internet2 Middleware Initiative is working toward the deployment of core middleware services at Internet2 universities. Authentication, authorization, and accounting capabilities allow advanced applications to operate

seamlessly among many organizations.
[<http://middleware.internet2.edu/>]

To create a national interoperable middleware infrastructure for the health industry, Internet2 has brought together a group of leading enterprise and medical campus IT architects to provide technical advice and direction. The Middleware Architecture Committee for Education in Medicine (MACEmed) fosters interoperability in areas such as security and directories, working in conjunction with the core middleware activities underway within the Internet2 project and industry.

Advanced Applications

Internet2 applications are those that make a difference in how we engage in teaching, learning, research, and clinical activities in higher education. Advanced applications do not operate across commercial Internet connections. These applications require enhanced functionality, such as high bandwidth, low latency (delay), low jitter, and security—characteristics not available on commercial Internet connections.

The higher education community drives Internet2 requirements. Therefore, application development encourages and supports all disciplines. Access to Internet2 applications should be ubiquitous, with connectivity available from the classroom to the laboratory, the library or the dormitory. NLANR (the National Laboratory for Applied Network Research) [<http://dast.nlanr.net/Clearinghouse/Query.htm>] provides a clearinghouse of advanced application examples from a variety of business domains.

Many universities provide local support for Internet2 applications development. The primary source of advanced applications funding, however, comes from the U. S. federal government. Federal agencies and departments, most notably NSF [<http://www.nsf.gov/>], NASA [<http://www.nasa.gov/>], the Department of Energy [<http://www.energy.gov/>], and the National Library of Medicine [<http://www.nlm.nih.gov/>], provide millions of dollars in research funding each year directly to Internet2 member universities [3]. These grants and contracts support technology research and the development of applications that take advantage of Internet2 networks.

There is no way to tell what the future “killer application” might be, but it is a question that is frequently asked of participants in the Internet2 community. It is clear that there are four critical attributes present in the most compelling applications. The first is advanced collaboration environments; that is, true interaction of users without the barriers of distance. The second is common access to remote resources, from telescopes to microscopes. The third is use of the network to build network-wide computation and data services, such as those under development in the Grid forum [<http://www.gridforum.org/>]. The fourth attribute is displaying information through virtual reality

environments, moving from static graphics and images to moving, three-dimensional animations.

The area that provides the widest benefit and largest aggregate use of the Internet2 network capacity is digital video. Video-based applications cover everything from Internet-based videoconferencing, to on-demand content, to remote control of microscopes and other instrumentation. Videoconferencing technologies used by Internet2 member institutions range from H.323, an international standard using connections typically at speeds of 384 to 768 kilobits per second, to advanced full broadcast quality video (full screen, 30 frames per second) at speeds up to 15 megabits per second.

Specific examples of advanced applications include:

Virtual Temporal Bone

University of Illinois at Chicago

<http://www.sbhhs.uic.edu/VRML/Research/TemporalBone/researchTB.htm>



Figure 2 – ImmersaDesk

A three-dimensional model of the human ear is explored by viewers using an electronic wand and a special pair of 3-D eyeglasses while facing a 20-square-foot projection screen. This configuration is called an ImmersaDesk [Figure 2]. The application and use of technology allow surgeons to familiarize themselves with the complex spatial relationships of the ear's anatomical structures. It offers students an unprecedented opportunity to “get inside” a hidden part of the body through visualizations never experienced before.

Space Physics and Aeronomy Research Collaboratory (SPARC)

The University of Michigan

<http://intel.si.umich.edu/sparc/>

SPARC brings together researchers in upper atmospheric and space physics from around the world, providing a set of online collaboration tools and workspaces that link together scientific instruments, data, and models. The collaboratory is itself a subject of study by computer and behavioral scientists who are developing and refining the tools and

organizational structures that will make such real-time, online collaborative research commonplace.

Internet2 and Next Generation Internet in the Health Sciences

A key objective of the Internet2 applications effort is to inform faculty and researchers about the opportunities presented by advanced network environments. The Internet2 Health Sciences Initiative was chosen as the first specialty area for Internet2 because of the variety of current Internet2 member activities underway that apply to the medical domain, and also the great potential yet untapped.

The Internet2 Health Sciences Initiative includes clinical practice, medical and related biological research, education, and medical awareness in the public. To this end, the following areas are emphasized:

- Facilitate and coordinate the creation and enhancement of health applications whose architecture and development have been restricted or prevented by the traditional Internet.
- Facilitate and coordinate the development of general application tools to take advantage of Internet2 advanced network services. These tools are most likely to arise in the process of developing specific applications across a range of application areas, but their ultimate value will be to seed the long-term distributed development of applications to support healthcare and the life sciences.
- Under the auspices of the Internet2 Applications Group, collaborate with other professional associations in the health sciences and Internet community to develop guidelines for safe and effective use of the Internet.
- Leverage and influence Internet2 resources to apply solutions to the medical domain.
- Inform the medical community of these developments through collaborative application demonstrations at the regional, national, and international levels.

The National Library of Medicine (NLM) is working to define capabilities of the Next Generation Internet (NGI) which will be required if the NGI is to be routinely used in health care, public health, health education, and biomedical, clinical, and health services research. These capabilities include: quality of service, medical data privacy and security, nomadic computing, network management and infrastructure technology as means for collaboration

NLM is funding testbed projects to demonstrate the use of these NGI capabilities by the health community. The demonstrations are designed to improve our understanding of the impact of NGI capabilities on the nation's healthcare, health education and/or research systems in such areas as cost, quality, usability, efficacy, and security.

The NLM NGI program serves as a research catalyst to enable the development of Internet technology in the medical domain. As these projects develop, an awareness of synergistic activities is emerging. The industry is currently experiencing a convergence as activities of government, academe, and industry work in partnership to accelerate the next stage of Internet development.

A good example of this construct is the Visible Human Project Advanced Concepts Technology Model for Collaboration under which scientists are utilizing NGI network capabilities to develop tools and applications for virtual anatomy education.

The NLM and Internet2 are working together to develop educational applications in a shared, networked environment. Stanford University, the University of Michigan, the University of Colorado, the University of California San Diego, and the Uniformed Services University of the Health Sciences form this consortium.

The purpose of this activity is to test the ability of each of the consortium partners to broadcast educational prototypes to the educational institutions of the other partners via the Abilene network. Complex virtual reality simulations of the structure and functions of the human body can be educationally shared between universities over high performance networks. It is proposed that this collaboration provides a model for other health collaborations. This collaboration model bridges between medical experts and engineering specialists.

Roadmap for the Future

The 1998 National Research Council (NRC) study commissioned by the National Library of Medicine, "Networking Health: Prescriptions for the Internet" serves as the roadmap for the Internet2 Health Sciences Initiative [5]. This study was designed to determine the technical capabilities that health applications require of the Internet and how these differ from other sectors (e.g., banking, defense, and entertainment). The study found that most currently visible applications are consumer-oriented websites; however, the potential of ubiquitous connectivity is great, including a more informed public, improved provider-to-provider and patient-to-provider communications, enhanced clinical decision support, and improved health outcomes and the ability to measure those outcomes.

Five important dimensions to healthcare network requirements are: bandwidth, quality of service guarantees, security, availability, and ubiquity. Current Internet technologies and functionality are insufficient for some health-related applications. The NRC report includes specific technical recommendations with respect to symmetric or dynamically reconfigurable 'last mile' bandwidth, quality of service guarantees, network security, as well as guidance for desirable characteristics of Next Generation Internet demonstration projects, healthcare

organizations, and public policy issues. This guidance is brought into action through Internet2, NLM, and NGI working in partnership with academe and industry.

The Internet2/NGI partnership is helping to ensure that the research, development, and deployment of necessary technical capabilities are available to support health applications. Testbeds that ensure suitable technical capabilities are currently using Internet2 infrastructure to facilitate experimentation with and evaluation of health and biomedical applications. The Internet2 network provides sufficient bandwidth to support a wide range of health applications.

However, additional issues need to be addressed. Security and quality of service are two primary issues to ensure that the Internet evolves in ways to support health needs over the long term. In addition, the health community needs to work with the networking community to develop improved technologies that are of particular importance to health applications.

The areas that need to be addressed include:

- Scalable techniques to provide bandwidth guarantees on demand
- Stronger forms of authentication
- Symmetric or dynamically reconfigurable broadband technologies for the 'last mile'
- Quality of service guarantees and quality of service "aware" applications
- Disaster operations
- Validation of online information
- Privacy tool to protect confidential information
- Access control mechanisms
- Controls on secondary distribution of patient health information
- Improved audit capabilities

Conclusion

The evolution to the next generation Internet will continue to lead to innovative new technologies and exciting new activities in the U.S. health arena. These changes also raise many questions. How does the industry utilize these new technical capabilities? What are the benefits to the industry at large? What are the issues associated with deploying these new technical capabilities?

Higher education was pervasively present at the birth of the current Internet and has contributed significantly to the infrastructure and application base at the heart of the Internet's present success. It would be ironic if higher education failed to be a proactive participant in the evolution of the next generation of network applications. These can be glimpsed on the Internet horizon today and promise to alter radically the prevailing methodologies of instruction, research, and public service. The Internet2 project is a clear signal that higher education intends to contribute to the advance of the network technologies and applications that will be the foundation for the knowledge

society envisioned by the U. S. government's Next Generation Internet initiative.

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