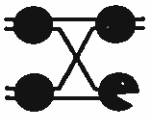

An Investment in Expanding Human Potential through High-Speed Communication: Application of a Broadband Network on a University Campus

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Abstract

This is a description of the final phase of Project Zeus in which we plan to make available to users at Washington University an advanced network serving thousands of high performance workstations supported by the necessary network hardware and software. At the same time Project Zeus will provide a realistic testbed for communications research on network congestion, routing, planning, interoperability, internetworking, remote visualization and techniques for operations and management. Project Zeus is poised to bring about the first community capable of broadband information sharing across cultures and thereby create a model for all information-rich communities of the next century. In addition, this experiment with an information-rich community consisting of variety of users unique to a university campus is expected to generate many innovative ideas and unanticipated demands for new applications of broadband technology. The description includes a brief review of our future technical plans.

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1. Motivation and Objectives

During the last several years there has been a growing recognition that *Asynchronous Transfer Mode* (ATM) cell-switching technology will form the basis of the next generation of communication networks. Attractive aspects of ATM technology are:

- scalability of the network, both in the total throughput and the port data rates;
- integration of diverse services such as multirate data, audio, video and high-resolution images; and
- compatible physical layers and signaling protocols applicable to both wide area and local area networks.

Washington University has been deeply involved in the development of ATM switching technology, a technology based on small, fixed-length packets called *cells* and the application of this technology to medical imaging. We have just completed a project sponsored by Southwestern Bell and NEC America aimed at demonstrating technical feasibility of the underlying technology and providing some initial applications. We have worked with commercial partners to create implementations of the technology. Now we plan to apply ATM technology throughout the university community for the benefit of users and to answer several pressing system questions that can only be addressed in an operational network environment running real applications. Thus, our objectives are twofold:

- make available to users an advanced network with thousands of high performance workstations supported by the necessary hardware and software; and
- provide a realistic testbed for communications research on network congestion, routing, planning, interoperability, interworking, remote visualization and techniques for operations and management.

Figure 1 illustrates the concept behind the proposed ATM network. The system would consist of several switches and a large number of concentrators located on each of the university's two campuses. The switches would be connected by transmission links operating at speeds of 155 Mb/s, 620 Mb/s and 2.48 Gb/s. Each switch would support potentially several hundred interfaces, with a variety of port speeds. We expect the majority of ports to be 155 Mb/s but will support higher speed ports as the need for them arises. These interfaces will be connected directly to multimedia workstations and central compute servers or

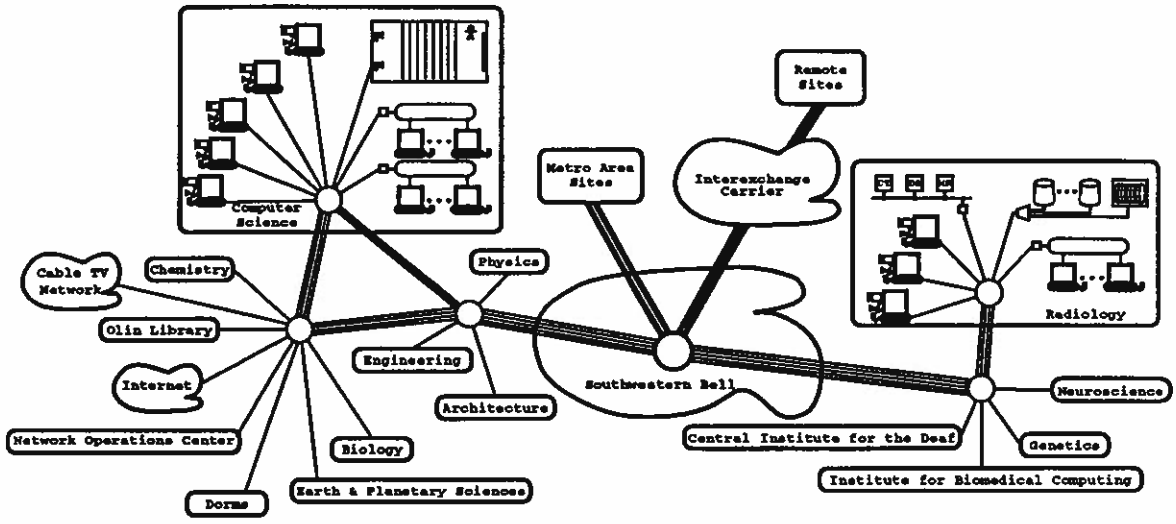

Figure 1. ATM Campus Network

alternatively connected indirectly through ATM concentrators or shared access LANs such as Ethernet or FDDI. Applications are planned throughout the campus involving scholars and students from many disciplines. Video will play a central role in the network, allowing access to centrally stored video information through the network, two-way or multipoint video conferencing and remote classroom instruction using video.

The network will include connections to remote sites using either dedicated or switched channels provided by the Internet, the local exchange carrier or interexchange carriers. In particular, connection to new broadband services planned by Southwestern Bell would make possible classrooms, medical offices and hospitals, all at locations more convenient to their clientele, and all linked to the university or the medical center by video, high resolution image transmission and shared databases. Connection to the Internet and interexchange carriers would allow scientists to interact with their colleagues at other institutions and with distant supercomputers via the emerging National Research and Education Network, a federally sponsored network which will support access speeds compatible with those of Project Zeus.

In summary, we propose to install and use new broadband network technology in a diverse academic community where experiments with electronic communication between different scholarly cultures can be examined and analyzed. We expect that our campus network will be the first to investigate the social effects of this new technology and consequently the first to discover new applications that can only be identified once the network is in place and then through the process of casual interaction and serendipity. There are many more reasons to cross a bridge from one culture to another than can be imagined by those for whom the only known way to reach the other side is by swimming.

2. Installing the Network

Project Zeus is organized in three phases. Phase 0, now complete, demonstrated feasibility of the core technology, provided a basis for a more complete design and a testbed for application development. The

network created in this phase is primarily an experimental vehicle, rather than an operational network and, therefore, does not support real users. This phase of the project began in 1988 and was completed in 1992. Support was provided by Southwestern Bell and NEC America.

Phase 1 began in January, 1992 and will run through 1994. It will create all the key components needed to establish an ATM campus network and provide extensive support for application development. When complete, the phase 1 network will be an operational system supporting a variety of users in key departments within the university. Support has been provided by SynOptics Communications, Inc., Timeplex, Southwestern Bell and Bell Communications Research.

During phase 2, which will run from 1994 through 1996, we plan to expand the range of interfaces that can be used to access the network, construct components for larger scale networks and reduce the cost of key network components. The phase 2 network will support users in all departments of the university and provide broadband connection to many collaborators outside the university.

Examples of applications that are now under consideration indicate the diverse nature of the community that we expect to make use of the Project Zeus technology in phase 2:

- interactive video discussions between students, faculty and teaching assistants at times and places of their choosing incorporating electronic whiteboards and relevant on-line databases.

- delivery of electronic medical images and other relevant patient information to primary care physicians, specialists and other health care professionals for medical decisions and treatment;

- archiving and analysis of images from planetary missions including delivery of these images on demand to space scientists throughout the nation;

- video capture of lectures, seminars and symposia for later recall at places and times convenient to the viewer.

- electronic communication for the hearing impaired that uses video to support lip reading and sign language;

- electronic cataloging and manipulation of images and three-dimensional scenes for students and faculty in art, architecture and urban design.

- interactive video instruction in a distributed classroom suitable for life-long learning.

This rich variety of users that the network is expected to serve in phase 2 will provide much needed information for the ATM industry. Such a testbed will provide:

- a reliable test of the bandwidth management algorithms designed to prevent network congestion;

- proof that network signaling software can function in a multivendor environment;

- a demonstration of the need for multipoint connections in network environments for group work, conferencing and instruction; and

- a means for the evaluation of various techniques for network planning, operations and management.

3. Future Plans

Phase 1 of Project Zeus began in January of 1992 and will run through 1994. Its primary objective is to create, with the help of our commercial partners, the key components needed to establish an operational ATM campus network, develop a set of exploratory applications that use the network and develop support tools to facilitate future application development. The specific technical goals for phase 1 are listed below.

- Develop an economical switch configuration supporting up to 128 ports at 155 Mb/s each, and an inexpensive concentrator that can be located in a wiring closet within close proximity of desktop workstations.

- Complete the multicast connection management software and add signaling interfaces to workstations. Design and implement basic network management software.

- Design and implement a workstation interface capable of using a full 155 Mb/s link and equipped with cell-pacing circuitry. Include support for JPEG coded video capable of operation at various compression ratios over a switched network.

During 1994 through 1996, in phase 2 of Project Zeus, we plan to expand the range of interfaces that can be used to access the network, construct components for larger scale and higher speed networks and reduce the cost of key network components. In addition, we plan to extend access to the network to others both inside and outside the university. The specific technical goals of phase 2 are listed below.

- Expansion of the network to departments and laboratories throughout Washington University.

- Develop a core switch supporting 256 ports at 620 Mb/s each, together with an inexpensive concentrator with 16-48 user ports. Improve the functionality and performance of the connection management software.

- Design and implement compatible ATM interfaces for multiple workstations, including support for HDTV video and multiple coded video channels.

- Establish interoperability between the campus network and a public network ATM switch in order to support connections to off-campus sites. This will require development of a 620 Mb/s ATM/SONET interface to the public network and extensions to the signaling software.

- Design and implement internet processors capable of processing fragmented packets without reassembly. These would support both IP datagrams and MCHIP packets.

- Design and implement a multiport ATM router that forwards IP datagrams across multiple fixed virtual channels and provides Ethernet and FDDI connectivity.

We have, and will continue to depend on government sponsors for the support of certain basic and applied research tasks. In addition, in both phases 1 and 2, we will depend upon our industry sponsors for financial support and for technical help with network components that they have licensed and developed from Project Zeus technology.

4. Conclusion

The phase 0 Project Zeus network is in operation, providing demonstration of all necessary components of a broadband campus network. The network contains four 16 port switches located in Washington University's computer science and radiology departments and in Southwestern Bell's headquarters and research organization. These four sites are linked by more than 180 miles of single mode fiber. A video conferencing application, an Ethernet interface and a physician's workstation have been developed to show the capability of the network.

During phase 1 several industry partners have been recruited and hardware and software technology licensed and transferred to them. During 1993 we expect a half dozen commercial 155 Mb/s switches to be installed at a handful of sites around our campus. Several application areas have been chosen for preliminary exploration. We hope to transform daily practice in these selected areas and, at the same time, carry out experiments that are useful in understanding future bandwidth requirements. Application development is already underway in electronic radiography, optical sectioning microscopy and preservation of images from planetary databases.

Phase 2 of Project Zeus provides an opportunity for a sponsor to bring about the new information age on a university campus, a vision made possible thorough broadband network technology. We believe that Project Zeus provides a unique combination of advanced communication technology and realistic broadband applications. This combination is important to the development of the ATM market because users and engineers must work together to understand the strengths, weaknesses and opportunities for this powerful new communications technology.

The stage is set through the accomplishments of the first two phases of Project Zeus, phases that provided both demonstration of the technology and its transfer to the commercial sector. A sponsor with vision and unconstrained by immediate product goals can bring about the first community capable of broadband information sharing and thereby create a model for all information-rich communities of the next century.