Luker envisions the Internet of the future as a communications system of truly staggering proportions that will energize and transform learning and scholarship, as well as many other activities. The primary academic applications of an advanced Internet will likely be collaborative research and distance learning, although key improvements in the networking performance and capacity of today's machines are essential to furthering current efforts. Luker outlines higher education's role in achieving an advanced Internet, and emphasizes the need for colleges and universities to transform their services.

Over the last two years, much discussion has taken place about an advanced Internet that will somehow replace or supersede the Internet of today. What is this future Internet? Where will it come from? Why do we need it? How might it impact higher education? How should we be involved? While this article may not provide definitive answers to each of these questions, it does explore the key issues of the advanced Internet and its implications for both higher education and society at large.

What Is the Advanced Internet?

The concept of this future Internet, which is sometimes mislabeled “Internet2” or the “Next Generation Internet,” lives today in a loose collection of projects that share a common vision. The vision describes a world in which each person and each source of information and many other objects of interest are interconnected by a communications system of truly galactic proportions that makes it almost transparently easy and affordable to share information and communicate. Such a system, many claim, will energize and transform learning, commerce, scholarship, design, entertainment, and many other human activities. This vision is not especially new—it has been a core theme in science fiction—but has only recently achieved widespread recognition and support, most likely through a combination of staged, futuristic demonstrations and the explosive growth of today's Internet.
Capabilities

How do we define an advanced Internet? Although a qualitative leap in capabilities can be described in many technical ways, these approaches have not proved to be very useful. This is because what may seem like hard requirements at one time (e.g., 40 megabits/second and transmission capacity per quality video stream) are often overtaken by clever inventions (e.g., quality compressed video streams at 2 megabits/second) that better exploit the underlying resources. Technical definitions also fail because they speak only to technicians, yet can take on a political life of their own. (Do you remember the sometimes emotional battles between proponents of “full-motion analog” and “compressed digital” video systems in our educational television networks?) Though not as simple, a far better approach is to speak of desired services and capabilities from the user’s point of view.

This approach was taken in a 1995 conference in Monterey, California, sponsored by the National Science Foundation and ten associations representing diverse activities of research, libraries, teaching and learning, and networking in higher education. Conference participants explored the promise of advanced networking in parallel tracks called “Scholarly Communications and Publishing” and “Networked Applications.” Network engineers discussed technical performance requirements in a third track. Base-level services in an advanced Internet were estimated to include the support of simultaneous “high quality” audio/video communications between all parties of a conversation. (The actual network performance this entails has gone down since that time.) This base capacity must be scaled up for the community of users, requiring much greater capabilities near large sources and sinks such as digital libraries and campuses. Although capacity demands can grow much larger for individual applications, this seems to be truly essential only in special cases.

After adequate performance, the chief interest of most individual users is convenient and affordable access. It is important that all members of the collaborating community have high quality, standardized access to the necessary information and communications tools. For higher education, this requirement would normally include many locations in surrounding communities (i.e., from the home and desk of each student) as well as additional specific locations throughout the world (from every colleague.) Lack of high quality access outside the campus LAN is perhaps the greatest deficiency in today’s academic Internet.

Applications

Research Collaborations. Two generic, academic applications arise in nearly every discussion of an advanced Internet. Perhaps the easiest to understand is “collaboration for research.” Network designers take this simple phrase as a code for a complex system of communication and information tools that make it appear, in so far as is possible, that the collaborators are all in the same room along with their instruments, libraries, technical assistants, and other requirements, with full support for their creative activities. At one extreme, this might take
the form of a CAVE (cave-like automatic virtual environment) with video walls, floor, and ceiling in which participants explore their data by literally walking through them in a three-dimensional virtual world. Such designs stress the network by requiring several channels of high quality video per person. They place much stronger demands, however, on the design of the underlying information systems that integrate and support collaborative activities. These are likely to depend on the particular discipline or task at hand. A key challenge is to find an underlying framework on which to build such collaboration systems.

Of course, collaboration for research has been noted widely as one of the great success stories of the present Internet, even without such fancy new developments. The basic tools of e-mail and the Web have made it possible for investigators to consult and share information with their teams on a minute-by-minute basis, instead of at the leisurely-to-glacial pace of paper mail and national conferences. More recent is the trend of placing complex instruments such as telescopes directly on the network, effectively moving them into the investigator’s own lab or office. Such efforts often make a compelling case for an advanced Internet in that they are often severely limited by present network performance and security, but would otherwise represent a great advance.

There are at least two distinct avenues for progress in networking for research. In the first, generic collaboration tools will be found to work much better (or even work for the first time) given a significant general improvement in the network. Remote control of an electron microscope will suddenly succeed once the remote image approaches the speed and clarity of that on the console, assuming that ancillary problems of convenience, security, privacy, cost, and reliability can also be brought under control. When this happens, however, a dramatic and qualitative shift to remote operations can occur in real time, instead of as a cumbersome series of batch transactions. Just as when interactive computing replaced punched cards, this transformation can multiply the productivity of the investigator.

Similarly, remote discussions of astronomy can be greatly improved with high quality videoconferencing and shared whiteboards, but these tools will not be used for “real” work until they are affordable, convenient, and secure. Of course none of these problems are specific to astronomy. All must be solved to achieve success in learning systems, electronic commerce, and entertainment as well, and all can be solved by the same general improvements.

The second avenue for improvement in remote collaboration is much more problematical. Network access to the catalog of a research library can be quite useful, but access to the contents of the library is what is really needed. But this, of course, demands the introduction and regular operations of production digital libraries. And exactly what specialized tools would be best for astronomers? How far can they go with the basic Internet collaboration services provided, for example, by Microsoft NetMeeting? Customized facilities could provide much greater power, but with the usual tradeoffs of
standardization, cost, distribution, access, training, support, and obsolescence.

Many network scientists get excited only when humans (i.e., the carbon units) are removed from the loop, since it is machine-to-machine communications that can truly challenge a network. It is possible today, for example, for two small workstations at opposite coasts of the United States to completely saturate the vBNS, our largest network for scientific research. Experiments in high-energy physics and space-based observations of earth commonly acquire data at rates that far exceed our fastest networks; the largest capacity network in practical use today remains the cargo hold of an airplane.

Ultra-high-performance networking of machines, however, can offer revolutionary progress. One example is in the connection of a grid of remote telescopes to build, in effect, a larger telescope, one too large ever to exist as a single machine. (Even here, one must be careful regarding assumptions about network requirements. Atomic clocks, for example, might make it possible to accurately synthesize information that arrives with uncertain timing.) As with the example of video compression, there are fascinating ways in which computing power can be traded for network capacity in the overall “network-is-the-computer” system.

**Distance Learning.** The second academic application most often cited for an advanced Internet is distance learning. In currently popular asynchronous-learning models, the student normally works at a standard workstation at any time and any place, interacting with learning materials, tutors, and other students. The basic network requirements for this are similar to those for research collaboration—high quality video for each active participant. Although video segments must be located and delivered on demand in such designs, most transmissions are essentially one-way, as when viewing selected portions of a lecture or a demonstration. This format is amenable to many technological tricks to reduce network requirements. Many instructional designs, however, also require the active interaction of the learner with tutors and other students, bringing us closer to the realm of collaboration for research. Specialized tools can improve learning in a particular discipline, of course, just as they can in research.

Where distance learning really stresses today’s network is in access. Although it may be feasible to support research collaboration between a small number of labs, offices, and homes across the nation, such a distribution will miss most of the customers for distance learning. One of the principal values of distance learning is to provide access to those who cannot attend scheduled activities on campus. Access typically would be required everywhere existing students live on and around a campus, and everywhere new students are to be reached. In the end this demand for access might be reduced to the simpler characterization, “everywhere.” The broad geographic distribution of distance learning multiplies the base capacity requirements noted above to greatly exceed the performance of today’s Internet. Higher education is fortunate, however, in that the same basic capabili-
ties and distribution are required for electronic commerce and, especially, for entertainment.

As with research, Internet distance learning can harvest low-hanging fruit if it can provide affordable, high quality connections between potential learners and existing teachers and information. It is generally agreed that this will require an advanced Internet, but the capacity bottleneck is most likely to be the “last-mile” problem of high quality video to the home and office. Fortunately, this problem is under concerted attack by the communications industry, which is introducing a variety of new technologies such as the telephone-based xDSL, TV cable-modems, radio modems, and even digital satellites as a means of competing for services in the “local loop” for your general entertainment and communications dollar.

Again, as with research, a general improvement of the Internet for distance learning represents only a first step. The goal of “affordable access to quality education” almost assumes operations at very large scale in order to amortize the high cost of developing and managing quality interactive content. This, in turn, represents a very different model of instruction, at least for the average case, that replaces much of our present lecture system with various on-line experiences and mediates tutoring and group studies through the network. Only a few of our present institutions of higher education have really embraced this model with or without the Internet. A few, such as the British Open University, are already using this model with older technologies and can take advantage of improvements in the network as they arise.

Other applications frequently cited for an advanced Internet are administration and library services, remote medical diagnosis and treatment, other types of workgroups and consulting, electronic commerce, and entertainment. All depend to a large extent on the standard human collaboration tools mentioned above, and could further benefit from specialized information servers. (Entertainment applications have some of the most intriguing requirements and possibilities.)

The Larger Impact of an Advanced Internet

A full-featured advanced Internet as described above can be expected to have many far-reaching consequences. Some of these are natural extrapolations of current practices and directions and are quite easy to predict. Such a system can be expected to completely change the authoring, publishing, and distribution of all types of information. This revolution is well under way. On the other hand, such a system may also completely change the concept of information. A published series of monthly snapshots of a vital indicator might be replaced, for example, by a live Web page that shows the latest information on a second-by-second basis. How is this to be catalogued, referenced, and located? Which version is the real publication? Hyperlinks to related information already are creeping from Web pages into published documents. How can one define either the document or the version? Do we need to? What will happen to information sciences when voice and video documents and e-mail replace today’s typed versions? How about increasing fraction of all information that never reaches
human-readable form? How will all this affect our concepts of intellectual property?

The next Internet will completely change retail marketing. This too is already well under way. It will change wholesale marketing perhaps even more, since it often will be profitable for those in supplier/customer relationships to customize their communications and jointly re-engineer their corresponding operations. The American auto industry, in an alliance with major customers and suppliers, is now actively promoting an advanced Internet as the critical enabler of just-in-time inventory, customer sales and services, dealer training, rapid design, and flexible manufacturing.

Closer to home, an advanced Internet will “disintermediate” many white collar activities such as financial and stock market transactions, real estate and auto sales, library circulation, general and specialized information desks, and lecturing. This is well underway. It will “globalize” white collar professions such as computer programming, medical diagnosis, financial advice, library reference consulting, and expert tutoring. (Imagine the 24-hour, 7-day help desk that offers expert advice all around the world, but on calculus homework instead of computer problems.) These and related developments may dramatically increase choice, competition, and efficiency, but only at the expense of tremendous changes that taken together will bring us into the real information age.

Is this the end to new applications? Hardly. Network engineers are presently planning for an Internet with enough capacity to connect essentially every interesting object in at least the solar system. This will go far beyond the “smart” house that recognizes your face and obeys your spoken commands. (Did you ever see the movie Forbidden Planet? It tells the story of an advanced civilization, now extinct, that designed machines to detect and carry out their every wish.) More realistically, imagine that we have very small and inexpensive devices (on single chips?) that can track their own location with the Global Positioning System, monitor the status of their attached “payload,” and communicate globally by radio and the Internet. (Note that trucks and train cars currently have such systems, although they are not yet tiny or cheap.) What could we do with such systems? The post office is introducing primitive versions today to track the paths of sample envelopes through their delivery system. Of course this would put an end to lost dogs, cars, and even car keys, but what would it mean for traffic congestion, gas consumption, pollution, agriculture, and manufacturing? How much of our present activities involve tracking the status or location of things by manual observation and record keeping? What would happen if we could track virtually anything automatically, and then communicate in both directions with it through the network?

Peter Schneider, a former vice president of IBM, once described Coke machines that would “phone home” for replacement cans by number and type and exactly when needed. This simple change could have a major impact, since the transportation and human labor involved in checking and filling vending machines by far dominates the cost of the goods. Should we then resize or redesign the
machines? Schneider also imagined items that gradually reduce their individual price in the grocery as they age on the shelf. Vint Cerf recently mused about home recycling bins that add a bottle of milk to your grocery list when you drop an empty bottle in the bin, a home variant of just-in-time supply.

**Will It All Be Free?**

The common theme of all these applications is human communications and collaboration using audio and video tools with integrated information services. This is extremely important! It means that an advanced network that can support these basic services everywhere can meet most of the anticipated communications needs of most of the population. This, in turn, means that the dollars and the human resources dedicated to all these modes of communication today can be pooled to support a single infrastructure, the future Internet. For the household, this could mean a single wire with a single technology to a single service organization with a single bill sharing the resources now spent on television, telephone, data, and possibly even electricity. For the service provider, this means a single operations center, greatly simplified training for both staff and customers, and only one fleet of trucks. On a global scale, the coming inversion of the voice communications systems into the Internet is already underway because of inherent efficiencies. Perhaps the next Internet really will cost less than today's systems. In any case, it is clear that the dominant financial implications will arise from the applications of the network, not the cost of the network itself.

**How Can We Achieve an Advanced Internet?**

When the National Science Foundation privatized its NSFNET (the global Internet backbone of its day) in 1994, it was hoped that a vigorous new Internet industry would emerge and provide for not just connections, but high-performance connections, to everyone on an accelerated schedule. Although this strategy has succeeded dramatically in basic connections, progress in high performance connections has been very slow. In its first years, the fledgling Internet industry focused on establishing market share through low cost, flat rate services. Although bandwidth of the national trunks has been an important issue, there has been relatively little provision of high performance services to the consumer.

In the same period, many college campuses rewired themselves and began to provide high quality networking on campus through new campus departments of networking services. Research collaboration, which depends on good connections between labs and campuses, and other countries. This demand has proved difficult to meet, however, often leaving the campus as an isolated island of high-performance. Many campuses built modem pools to support basic Internet services to the students and faculty in their community, but lacked the technical or financial means to provide advanced services for distance learning outside the campus boundaries. Unlike in the earliest days of campus networking, this situation was recognized as an important prob-
lem in search of a solution. Remembering their success with the development of the first Internet, campus technical leaders are looking once again for solutions in partnerships with industry and government.

**Industry Investments in Advanced Networking**

Industry is now making huge investments in building out the present Internet and in developing new technologies for an advanced Internet. Some innovations such as Wave-Division-Multiplexing have proved an immediate success by multiplying the capacity of individual fibers. Others advances are more chaotic in that they propose promising but proprietary solutions to specific problems and hence require some combination of standards agreements and market competition to select a winning design. In this arena, higher education no longer enjoys the status of dominant customer and sometimes appears to be the tail trying to wag the dog of the commercial Internet. Our projects can add real value, however, in matters of research and development, and so still have considerable leverage in the design and implementation of the next generation.

**Government Investments in the Next Generation**

The role of the federal government in networking has changed dramatically since 1994. The National Science Foundation (NSF) has continued to fund a steady but diminishing trickle of campuses to make their first connection to the Internet. (Over 2,500 have been funded to date.) Defense Advanced Research Projects Agency (DARPA), the agency that developed the technology in the first place, has concentrated on “bleeding edge” research projects aimed at two generations in the future and more recently on mission (i.e., military) applications of advanced networking. NASA, the Department of Energy, and the Department of Defense are operating several advanced networks that support mission-related research, often with special-purpose links into specific university labs. Preliminary interconnections have been established between these networks to support broader collaborations, but these are sometimes hobbled by the conflicting rules and contracts that reflect the networks’ separate histories and goals.

The advanced networking programs of most direct significance to higher education have come from the NSF, which has implemented a twin focus of research on networks (research awards to individual computer scientists) and the provision of advanced network services to support research (including most of the sciences and engineering). The cornerstone has been the NSF network infrastructure program, which supports the development and operations of the vBNS national network (very high speed backbone network service) and a corresponding set of High-Performance Connections awards to universities to upgrade their campus networks and connect to the vBNS or other advance backbones. This program was designed in consultation with the campus community that built the first campus and national networks. It had the sometimes conflicting goals of supporting network
research while providing networking for research and of pushing the state of the art while remaining stable enough for the applications of the scientific community. The phrase “leading-edge but stable” rose to dominance in 1997 when the vBNS became the core network supporting a new NSF supercomputing program called the Partnerships for Advanced Computational Infrastructure (PACI), which unites dozens of universities and two major supercomputer centers in joint research projects. As of now, the NSF has made awards to some 130 universities for advanced connections.

Like many of our campuses, the federal government itself has realized the increasing importance of advanced computing and networking in recent years, and has come to understand the need for more coordination and interoperability of its widely scattered and diverse programs. In the fall of 1996 this took the form of a new program called the Next Generation Internet (NGI). With explicit interagency management and engineering teams, this program is designed to develop network technology at least 1,000 times better than we have today, to link over 100 universities with a research network at least 100 times better than today’s, and to develop a new family of important applications that highlight and depend on advanced networking.

The NGI program received congressional support for a combination of reallocated funds and partial new funding for 1998 and is slated for greater support for 1999. One key point is that the NGI strengthens the NSF funding and commitment to an advanced network infrastructure for important applications of higher education. Recent language for the NGI also stipulates that the government address “geographically disadvantaged” states with better support for networking, a sign of widespread recognition of the status and importance of the field.

Most recently, President Clinton (re)named the Presidential Information Technology Advisory Committee, a blue-ribbon committee of industry and academic experts charged with developing an integrated view of the entire federal investment in advanced computing and communications. Their initial report, just released, recommends significantly greater investments and the establishment of several new related research centers.

**Internet2: the Higher Education Response**

University leaders for information technology, many now representing merged and integrated campus operations for information technology, followed developments in advanced networking as well as the shortcomings of the existing Internet from the vantage point of the Networking and Telecommunications Task Force of Educom (now EDUCAUSE). This group had built and managed the original campus networks, and had helped with the design and operations of the regional and national networks. As bearers of the vision, they watched closely for any practical opportunity to significantly advance the state of networking for higher education. In 1997 they concluded that collective action would again be required, and organized an informal project called Internet2 within Educom to serve as a base of planning and action.

Internet2 has now been formalized as a project in a new nonprofit corporation called UCAID, the
University Corporation for Advanced Internet Development. UCAID now boasts some 130 university members, each of whom invests $25,000 per year in dues in addition to a projected $500,000 per year in development of an advanced campus network and connections. UCAID also has some 25 affiliate members, as well as 30 substantial corporate partners. It has a board with university presidential leadership and faculty representation, reaching well beyond the original organization and scope of the campus technology managers.

Since UCAID universities include most of the recipients of the NSF connections awards, the Internet2 project is a natural organizing body for the national coordination of advanced networking in higher education. In 1998 UCAID announced a significant partnership with the Qwest Corporation, a start-up company that is rapidly building a national/global network with new fiber and advanced technology. The resulting “Abilene” project will provide many Internet2 campuses with access to a reserved portion of the new Qwest backbone. This development is important because it provides parts of the higher education community with access to a second type of advanced technology and connections on which to develop applications for the next Internet. On a larger scale, it is important because it signals the emergence of new competition in the telecommunications industry and the shift of voice services to the Internet. A great deal of excitement and energy is presently focused on bringing the Internet2 Abilene project into operation.

The Future Role of Government

EDCAUSE recently hosted an NSF-sponsored workshop to distill the advice of prominent national leaders on the best ways for the NSF to support the further advance of networking after the vBNS network and University High-Performance Connections programs expire in April 2000. This group strongly agreed with two prior NSF review panels that an academic/government/industry partnership remains essential for the support of advanced networking for science and engineering as well as for the science of networking itself. On the other hand, there have been significant environmental changes since 1994, when NSF had no practical alternative but to commission and manage the vBNS network itself on behalf of the research and education community. This time there are multiple national (and even global) carriers with significant capacity, and new providers such as Qwest and Level3 emerging to compete. There are also large, formal partnerships such as UCAID, NGI, and PACI dedicated to the successful implementation of advanced network applications.

Many expert observers feel that NSF could best advance the vision in today's nascent world of advanced networking by defining an open-ended program of awards to organizations that will develop complete applications along with the new technologies, not just large networks. This integrated approach could be expanded as required to accommodate the recent recommendation of the Presidential IT Advisory Commission that NSF be the lead agency for a redoubled government efforts...
in advanced computing and networking. A challenge for NSF and all of its partners will be to ensure that a relatively consistent and stable collection of network services evolves through this process. This time it will not be too much to ask for both high performance and wider access.

The Leadership Role of Higher Education

Higher education is presented with several unique opportunities at the close of 1998. It has just reached critical mass in connections to the vBNS, the world’s first major higher-performance network for research and development. It is just completing the successful organization of UCAID, already recognized internationally for leadership in advanced networking. Higher education has solid relationships with a variety of industrial partners who wish to participate and contribute their skills. It is facing an era of government support that may increase in both dollars and flexibility. It enjoys broad and growing appreciating for “the vision” of advanced networking. And it faces calls to broaden participation beyond the initial leaders and those already connected. A careful but optimistic program of even broader partnerships can be expected to yield substantial rewards in both technical and social terms.

Related Issues and Debates

The quest for advanced networking has focused attention on a variety of interesting issues of technology, economics, and politics. A few of these issues are noted below.

Technical Choices. There has been vociferous debate at the levels of engineering and market-
creativity and the open exchange of academic information? Is it a basic social value if not a constitutional right?

Why Involve the Government? Is the government role in the three-way partnership still essential? Would industry actually meet the challenge this time, unlike in 1994? The argument for government participation is often illustrated with a spiral diagram, like the one shown in figure 7-1 below, that shows the different economics and players at each stage in the development of a new technology.

![Figure 7-1: Technology Spiral](image)

**Why Invest in Advanced Infrastructure?**
Should the government support advanced networks for the use of scientists and others, or should it fund only laboratory research in the technology of very advanced networks? Can campus technology managers and computer scientists really work together?

**Why Should Universities Invest in an Experimental Network?** This work is very expensive, and must be supported in addition to their standard Internet connections for normal business. What are the short and long-term benefits to the institution?

**What Are the Benefits to Other Campuses and to Society?** Defenders of the rather limited participation in advanced networking projects explain that these are special research and development projects, the results of which will be enjoyed by all through technology transfer into the commercial Internet. Experience with industry partners in the vBNS network has shown that this indeed can be the case. How can this transfer be simplified and optimized?

**What About the “Have-Nots” of Advanced Networking?** Some research campuses find it especially difficult to participate in the advanced networking partnerships due to the extremely uneven distribution of present telecommunications capacity. Some states, such as Alaska, have little fiber; in others, such as Hawaii, all existing fiber is in use. Some rural prairie states may find capacity only near the train tracks. Connections have sometimes proved to be impossible even in unexpected places (e.g., between two floors of a particular building in New York City). In most but not all cases, these problems translate into issues of very high prices for basic bandwidth. Often much of total bill goes to a provider that still has a monopoly in the region. Competition from new technologies and providers as well as deregulation of the telecommunications
industry is just beginning to have a major impact on this problem. In the meantime, Congress has funded special programs such as the Experimental Program to Stimulate Competitive Research (EPSCoR), as a partial solution and has asked NSF to address the larger issues. (Note the somewhat parallel arguments for “universal service” on the commercial Internet.)

**International Connections.** The price of international connections usually dwarfs even the highest domestic charges. A single link to another country can cost more than the entire NSF program for advanced networking infrastructure. Of course some of cost comes from the special expenses of operating transoceanic cables and satellites. In fact, international connections depend largely on the continued existence of government-regulated telecommunications monopolies in other countries and on their continued use of mixed academic/commercial networking models that were dropped in the United States during the privatization of NSFNET. The international problem is especially acute for certain segments of the U.S. research community such as high energy physics.

**Other “Have Not” Issues.** Even higher education institutions with fewer financial barriers find it a daunting task to operate a robust program in advanced networking. Problems of technical and political know-how and brain-drain to industry (and other campuses) are very real. Some of the most important activities of the Internet2 and NGI programs might be called member-sponsored professional development. More recently EPSCoR, AAAS (American Association for the Advancement of Science), EDUCAUSE, Internet2, CREN (Corporation for Research and Education Networking), and related organizations have begun to organize specific programs to address this need outside the membership of UCAID. Net@EDU, a new organization formed in EDUCAUSE from a merger of the NTTF (Networking and Telecommunications Taskforce of Educom) and FARNET (Federation for Academic and Research Networks), has received several NSF awards to build an ongoing program to help the “have-nots” obtain the skills and benefits of advanced networking on an accelerated schedule.

**Conclusion**

Although the costs and opportunities for advanced networking may seem very uneven now, one need only look at today’s Internet to see that, in the long run, these activities will prove to be a great equalizer. All are empowered once they gain access, however distant, and all benefit from the access of all others. When the dust settles after the construction of advanced networks, the real challenge will shift to the providers of information, communications, and knowledge services, including of course, higher education, who will have the opportunity, indeed the imperative, to rethink and transform their services.
Suggested References


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www.cise.nsf.gov/anir/ for the NSF programs for advanced networking

www.ngi.gov for the federal Next Generation Internet program

www.educause.edu for issues of information technology in higher education

Net@EDU for networking and network policy

www.educause.edu.nlii for distance learning

www.imsproject.org for standards for distance learning

www.nlanr.net for applications and engineering on advanced networks

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