Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator

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Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator
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The mission of the EDUCAUSE Center for Applied Research is to foster better decision making by conducting and disseminating research and analysis about the role and implications of information technology in higher education. ECAR will systematically address many of the challenges brought more sharply into focus by information technologies.

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Foreword

The EDUCAUSE Center for Applied Research (ECAR) was launched on January 1, 2002, to create a body of research and analysis on important issues at the intersection of higher education and information technology. ECAR is fulfilling its mission through a program of symposia and through the publication of:

- biweekly research bulletins oriented to senior campus functional executives;
- detailed studies designed to identify trends, directions, and practices in an analytically robust fashion;
- case studies showcasing campus activities and highlighting effective practices, lessons learned, and other insights from campus leaders’ practical experience; and
- roadmaps designed to help senior executives quickly grasp the core of important technology issues.

Since ECAR’s inception, six symposia have been held and more than 125 research publications have been issued.

IT Networking in Higher Education

During the past three decades, providing robust, high-quality networking services to their constituents has evolved as a priority for college and university administrators. In the early days, when BITNet was the norm, we marveled that electronic mail could be delivered in a day or so—or even hours—if the forwarding scheme worked optimally. Over time, people discovered e-mail’s usefulness and the paramount power of the network, and the value of these services continues to increase daily.

During the past 10 years, the network has evolved into a mission-critical resource in higher education; some would say it is as essential to institutional success as libraries, faculty, and buildings. Whether supporting a scholar’s research or enhancing education, the network and its services are central to the enterprise.

Today, campus networking strategies go far beyond merely installing a high-capacity connection to the Internet or to Internet2. Campus networks are strategic, indispensable, and technology rich. Networking strategies must deal with deployment issues both on campus and among multiple institutions in ways not envisioned 15 or even 10 years ago. For example:

- On-campus networks are integrating (converging) voice, data, and video.
- Increasingly, science curricula and content can be found on the network.
- Many large funded research and curricular projects are either interinstitutional or multi-institutional.
- Distance or distributed education strategies are becoming mission central for many institutions.
- An expanding number of higher education and K–12 science projects use the network for collaboration purposes.

It’s no wonder that campus IT executives are contemplating strategies to ensure that...
their constituencies can assume “dial-tone reliability” and availability of networked resources and services in a converged network environment. Understanding the network’s evolution and its future is the rationale for this study.

Despite the national attention and ongoing efforts of EDUCAUSE, Internet2, and other organizations to foster cross-communication about networking in higher education, our knowledge of the current state and future plans of college and university networking has been largely anecdotal. Indeed, we could write extensively about such terms as authentication, encryption, H.323, data collaboration, video directories, numbering schemes, converged services, organizational structures, financing models, Session Initiation Protocol, standards, certificates, bandwidth management, quality of service, and streaming technologies and not begin to cover the topic. Furthermore, although campus initiatives continue to advance understanding and deployment of networking technologies, universities and colleges have limited summative information on implementation trends in networking technologies to support their instructional, research, and community service missions. It is interesting to see how things have changed. Consider Educom’s (now EDUCAUSE) effort in 1988 to inform the U.S. higher education establishment about campus networking strategies. Not one of the technologies and strategies we’ve just listed (or dozens more like them) appeared in the text.¹

EDUCAUSE has long been a major participant in national efforts to advance higher education’s communications and computing initiatives, with noteworthy results. The outcome of an EDUCAUSE/NET@EDU Voice over IP (VoIP) Summit sponsored by the National Science Foundation offers an excellent example. The resulting report, which lists more than 50 issues facing campus executives today, notes that VoIP is only one facet of campus networking. These issues represent a framework for a much larger set of items that affect our universities’ ability to support their research, science, and education agendas.² Of particular note are four EDUCAUSE NET@EDU working groups addressing the issues of integrated communications strategies, broadband policy, wireless, and security. These working groups address themes that are central to campus networking today and in the future, and readers will find elements of each contained in this study’s outcomes.

This ECAR study considers a wide range of campus networking issues and has engaged a broad audience, from large public research institutions to small private colleges. It is designed to provide a fact-based and national perspective on higher education’s networking environment that can ultimately improve networking efforts. It establishes a baseline for higher education networking—where things stand today and how they’re evolving. Institutions will be able to compare their investments and practices with those of peer institutions. We’ve obtained results at several levels: planning and policy, technical solutions, operations, and future trends.

Important Contributions

I was honored when asked more than four years ago to serve as chair of the EDUCAUSE/NET@EDU Integrated Communications Strategies (ICS) Working Group. Eighteen months ago, ECAR asked the ICS for guidance on a study that would assess the national status of higher education networking. This important initiative is central to ICS’s work—that of understanding the status of networking in our colleges and universities. My colleagues on the ICS steering committee provided significant contributions to this work: co-chair Jim Jokl, University of Virginia; Doug Carlson, New York University; Tammy Closs, Georgetown University; Mike Enyeart, Indiana University;
Mark Katsouros, University of Maryland; Holly King, Northwestern University; Chris Peabody, L Robert Kimball & Associates; Steve Updegrove, Penn State University; Jose Valdes, Colorado State University; and Wendy Wigen, EDUCAUSE staff liaison. Special note goes to Mark Luker, EDUCAUSE vice president and head of the Net@EDU program, for his continued support of the working groups and especially for the initiative that launched this study.

ECAR research studies are the result of a team effort. Judith A. Pirani and Gail Salaway, ECAR Fellows, coauthored this report with guidance from EDUCAUSE Vice President Richard Katz. John Voloudakis, former ECAR fellow and now with Bearing Point, spearheaded the creation of the IT networking survey, the results of which form the foundation of this report. Others volunteered to participate in our networking case studies: R. David Vernon and Scott Sheavly of Cornell University, Steve Relyea and Elazar Harel of the University of California at San Diego, and Jack Duwe of the University of Wisconsin at Madison shared their efforts in creating new network funding models; Daniel Sidebottom of the State University of New York College at Cortland made his staff available for an on-site review of SUNY Cortland’s VoIP service; and SURF, a Dutch higher education and research partnership, collaborated with EDUCAUSE on a case study of higher education applications of mobile technology in The Netherlands.

Of course, the real team in any ECAR study is the EDUCAUSE community. The ability to develop a good understanding of practices, policies, and directions in higher education depends on the goodwill of ECAR’s associates. Hundreds of busy chief information officers and networking officers shared their experiences and expertise by responding to our online survey, and dozens more generously gave their time for interviews. In addition, at the summer 2004 ECAR symposium, Dewitt Latimer of Notre Dame, Douglas Hurley of the University of Memphis, Karen Steinbrenner of the University of North Carolina at Charlotte, and Eric Jackson of Morehouse University participated in an informal discussion on critical networking issues and provided insight and direction for the study. This report also would not have been possible without the wonderful support of the EDUCAUSE staff. Its commitment to excellence is evident in all that they do. Thank you.

Finally, ECAR, while enjoying the support of more than 300 college and university subscribers, continues to depend on the generous support of a small and dedicated cadre of corporate sponsors. Datatel Inc., HP, Microsoft, Oracle, PeopleSoft, Sungard-SCT, and Sungard Collegis not only provide direct financial support but are also generous with their advice and skilled resources.

This study reminds us that the opportunities and challenges networking poses demand both technological and cultural responses. Networking in higher education is ultimately a story of people at the user, management, and leadership levels. In the end, realizing higher education’s networking potential will depend on creativity, leadership, investment, vision, and technical sophistication, combined with communication, education, awareness, and training. Networking, with its awesome power to catalyze change and strengthen what we already do, is in its infancy. It’s going to be a great ride!

E. Michael Staman, Macon State College; Co-Chair, Net@EDU Integrated Communications Strategies Working Group

Endnotes

Most of us recognize that IT networks are now fully integrated into higher education’s core operations and are essential to its research mission, increasingly essential to business and administration, and growing in importance to its overall mission of teaching and learning. At the most fundamental level, institutions must provide a network infrastructure that is reliable, scalable, secure, adaptable, and fault tolerant. Achieving these seemingly basic underpinnings is fraught with challenges on any number of fronts—financial, political, environmental, managerial, and technical.

Nevertheless, colleges and universities are not only focusing their efforts on these basic requirements but are also further leveraging their networks to strategic ends. They’re using networking capabilities in diverse and creative ways to enhance institutional competitiveness and facilitate strategic goals. Perhaps most interesting is a sense within our community that networking’s promise as envisioned in the 1980s and 1990s is finally happening today; we now see the real possibility that current networking environments can enable transformational change in our core mission of improving student learning while also reducing instruction costs. And as network reach increases—even in many rural areas, where high-speed wireless access is now being installed—and as our campus, state, regional, and national research and education networks come together, a new wave of innovation in higher education is in sight.

At the same time, research and development of new technologies continue at an accelerated pace. Mobile devices are proliferating and evolving at light-speed, embedded chip connectivity applications are close at hand, and high-performance and grid computing are generating countless exciting opportunities for both research and teaching. Looking further out, we see that higher education continues to play a role as network pioneer, with leading-edge projects throughout the academy investigating a scope of technologies that almost defies the imagination. As one survey respondent commented, “We are just getting started. The growth we have seen in the last 10 years is only the tip of the iceberg.”

It is within this context that ECAR decided to conduct an in-depth study of IT networking in higher education. The navigational diagram at this chapter’s beginning frames our discussion throughout subsequent chapters. The diagram’s center shows the key components—the campus network itself and its related network
practices. Impinging on the campus network are four major external forces: opportunities for connectivity to external networks; the institutional context of organization, leadership, and management; current and emerging technologies and converged networks; and the future of networking.

**Methodology and Study Participants**

ECAR used a multifaceted research methodology to collect both quantitative and qualitative data about IT networking:

- a literature review to identify and clarify the study’s major elements and create a working set of hypotheses to be tested;
- consultation with the EDUCAUSE Net@EDU Integrated Communications Solutions Working Group to validate the most interesting research questions and hypotheses that would frame the quantitative survey instrument;
- a quantitative online survey of 517 EDUCAUSE member higher education institutions;
- qualitative telephone interviews with 19 higher education IT executives and managers at 13 institutions about general networking issues;
- qualitative telephone interviews with 12 higher education leaders about their view of the future of IT networking in higher education; and
- three case studies, including an institution study of voice over Internet Protocol (VoIP) at the State University College of New York at Cortland; a study of networking funding models used at Cornell University, the University of California San Diego, and the University of Wisconsin–Madison; and a study of higher education applications of mobile technology in The Netherlands done by SURF, a Dutch higher education and research partnership.

**Key Findings**

We learned much about IT networking in higher education, and several themes emerged as we reviewed our results. These themes cover a wide range of networking issues, from technical and managerial practices to speculation on future directions. Here we integrate and summarize our findings.

**Network Strategy and Goals**

Our data show that respondents believe higher education leadership fully recognizes their networks’ criticality and strategic value. Respondents overwhelmingly agree that their leadership views the campus network as

- more important than it was three years ago (94 percent),
- an essential resource (98 percent), and
- critical infrastructure (89 percent).

Further, 81 percent of respondents said their institution’s leadership also considers the campus network a strategic resource. And 28 percent of respondents characterized networking at their institution not only as strategic but also as a “strategic differentiator” for the campus.

More specifically, we looked at what respondents considered to be the primary network goal at their campus, on a scale ranging from minimizing costs to providing leading-edge services. Interestingly enough, campus approaches differ widely, and Table 1-1 shows a fairly even distribution among these goals.

This breadth of goals holds even within each Carnegie classification, with some exceptions. As we would expect, doctoral institutions cite a “leading-edge” networking goal (43 percent) much more often and a “cost-minimizing” goal (9 percent) much less often than others. Associate’s institutions are least likely to report a goal of providing “high speed for all” networking (only 19 percent) and more often opt to provide network per-
formance and services to users on the basis of their needs (33 percent). We also found that institutions that focus on providing a leading-edge network, as well as those that consider the network strategic, rate the quality of their network infrastructure—optimally designed, secure, and fault tolerant—higher than others.

Our interviewees told us they perceive their network goals as generally aligned with overall campus goals, and our data support this perception. The two most commonly identified investment drivers for networking have an institutional and academic focus: 52 percent of respondents point to needs identified by the academic community, and 47 percent point to adherence to a strategic IT plan. However, despite this reported academic focus, fewer than 15 percent of respondents say that academic leadership and faculty are usually or always involved in networking decisions about infrastructure and architecture, capacity and service levels, or funding.

### Network Funding

Given the difficult financial situations at many campuses, we were not surprised to find that 59 percent of our respondents identify inadequate funding as a barrier to the delivery of network services. However, regardless of whether funding is considered a barrier to networking, respondents report that network spending is up. Two-thirds say that network spending has increased over the past three years (mid-2001 to mid-2004), and three-fifths expect that it will again increase over the next three years (mid-2004 to mid-2007). Doctoral and master’s institutions were slightly more bullish on the future of network spending: they predicted a 10 percent (median) increase, versus a 5 percent (median) increase predicted by baccalaureate and associate’s institutions. Nationally, Forrester Research predicts “network equipment spending to grow modestly at an average CAGR (compound annual growth rate) of 4 percent.”

Further, those who don’t perceive funding as a network barrier rate the quality of their network infrastructure higher than others.

The centrality of the network infrastructure to the institution is reflected in the fact that the annual budget allocation is almost always the funding source for both central networking operations (93 percent) and network upgrades or improvements (80 percent). More than half of institutions also use capital budget allocations to fund network upgrades and improvements. About one-third of institutions use student technology fees to help finance network operations. Other chargeback mechanisms and per-port

<table>
<thead>
<tr>
<th>Primary Goal</th>
<th>Descriptor</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Provide reliable performance and services at the lowest possible cost</td>
<td>Cost minimizer</td>
<td>20%</td>
</tr>
<tr>
<td>Provide appropriate levels of performance and services to different users on the basis of their needs</td>
<td>Demand driven</td>
<td>28%</td>
</tr>
<tr>
<td>Provide high-speed networking to the entire institution</td>
<td>High speed for all</td>
<td>26%</td>
</tr>
<tr>
<td>Provide leading-edge network performance and services to the institution</td>
<td>Leading edge</td>
<td>26%</td>
</tr>
</tbody>
</table>
usage fees are less common, with only about 10 percent of respondents indicating their use for funding operations.

Outsourcing Networking Activities

Our respondents do not generally embrace outsourcing of networking activities. Almost three-fourths say that they are either very unlikely (56 percent) or unlikely (17 percent) to outsource any networking activities in the next two years. One factor may be that colleges and universities tend to keep in house those functions they deem strategic, and as we have seen, colleges and universities largely perceive the network as strategic. About half of respondents also indicate that the diversity and complexity of the institution are sufficient to make networking best managed by the institution. Another 20 percent said that although they believe that networking will become a routine function, the costs of providing this function within the institution will remain lower than if outsourced. Only 3 percent indicated that networking would become a commodity that can be outsourced to external providers.

Other possible reasons for not outsourcing surfaced, including the fact that colleges and universities have access to a cheap, but intelligent, labor source—science, engineering, and other students. Further, higher education may be more likely to consider shared services with other institutions than traditional outsourcing. Some even posit that at institutions where the voice communications function is currently outsourced, the move to VoIP may cause institutions to bring that function back in house.

Higher education’s general reluctance to outsource is in contrast with the private sector where, according to Gartner, Inc., “Outsourcing is becoming the dominant way that enterprises buy IT services” driven by “a focus on core business, access to critical technical expertise, and optimized IT operations.” And even though network outsourcing is not common in higher education, our data does show a significant contingent of institutions (20 percent) that say they are already outsourcing at least some networking activities or are likely to do so in the future. These institutions report a variety of approaches, from outsourcing select functions such as network architecture design, user support, or residence hall networking, to outsourcing all of the IT function, including networking. Those we queried about their outsourcing practices were very positive about their experiences.

Service-Level Agreements

About one-quarter of our respondents use service-level agreements (SLAs) in some fashion. Most frequently they are in place for the institution as a whole or for one or more departments or schools. In a few cases, respondents said SLAs were in place for external customers, affiliate organizations, or constituent groups such as students, faculty, or staff. The most common specifications in these SLAs are for user support and the availability of specific network services. This focus on user services is consistent with Network Computing’s mid-2003 annual reader survey, which found that “the most dramatic growth spikes in SLAs were for help desks (53 percent), internal Web sites (33 percent), and external Web sites (40 percent).” Penalties for unmet SLAs most often involve an escalation process within the IT organization or the university administration; rarely are subscribing users/organizations owed some financial compensation or granted a reduced charge or fee.

We noted some controversy over SLAs’ benefits and usefulness in the IT networking context. Some respondents are very positive, indicating that SLAs allowed them to clarify expectations, roles, and responsibilities of both the university IT department and the
user. They indicate that the process and resulting contract can help avoid misunderstandings and resolve questions that will arise in the future. One observer noticed that institutions are doing more sharing of sample SLAs, and some think SLA usage is on the rise. This may be economically driven by the need to do more with less, motivating network organizations to document user relationships and specify what fees are for what services.

However, most of our respondents (74 percent) don’t use SLAs at all. There is a sense that as people have come to depend on the network for everything, the institution needs to ensure a fully reliable network, with a quick response system to handle problems that do arise. The pressure for the network to perform is so great (for example, an SLA penalty clause cannot recapture a lost e-learning class) that there is some question as to whether an SLA will buy the institution anything extra.

**The Wired Infrastructure**

Much of higher education is now fully hardwired. Respondents report that almost all faculty and staff offices are now hardwired, as are most libraries, residence halls, classrooms (single connection), and research laboratories. Institutions also report some progress in hardwiring indoor public spaces. Associate’s institutions have the strongest showing in the number of classrooms with all seats hardwired, perhaps reflecting their early focus on integrating basic technologies into teaching. Baccalaureate institutions have the strongest showing in hardwiring indoor public spaces, perhaps reflecting their focus on student community.

Respondents unequivocally tell us that they keep a strong focus on the network infrastructure, and Table 1-2 provides a snapshot of transmission media, standards, and bandwidth for our higher education sample. Although this profile looks at all institutions, we note that those with larger and more complex network environments often use higher bandwidths and transmission standards than those listed in this table.

Our campus networks are well used: the majority of respondents tell us that 90 percent or more of their staff, faculty, and students (at institutions with residence halls) log on to the network at least once a day. Student usage is significantly lower for institutions without residence halls. We also asked our respondents if they believed their network meets the needs of their primary constituencies. Most are confident that the network meets staff needs (91 percent agree), with fewer respondents perceiving that the network meets

<table>
<thead>
<tr>
<th>Table 1-2. Elements of the Networking Infrastructure</th>
<th>Most Common</th>
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<tbody>
<tr>
<td>Backbone transmission medium</td>
<td>Multimode fiber optic cable</td>
</tr>
<tr>
<td>Backbone bandwidth</td>
<td>1 to 4.99 gigabits per second</td>
</tr>
<tr>
<td>Backbone transmission standard</td>
<td>Gigabit Ethernet</td>
</tr>
<tr>
<td>Backbone-to-end-device transmission medium</td>
<td>Category 5 and 5e twisted pair</td>
</tr>
<tr>
<td>Backbone-to-end-device wired transmission standard</td>
<td>Fast Ethernet</td>
</tr>
<tr>
<td>Backbone-to-end-device wireless transmission standard</td>
<td>802.11b</td>
</tr>
<tr>
<td>Commodity Internet bandwidth</td>
<td>4.6 to 89 megabits per second</td>
</tr>
</tbody>
</table>
faculty needs (78 percent agree) and especially student needs (only 67 percent agree).

The Wireless Infrastructure

Campuses have made good progress in building their wireless network infrastructure, and they are not stopping. Wireless network expansion is especially prevalent in areas that were not as quickly hardwired, whether because of structural issues or cost and priority. For example, indoor public spaces (from commons and dining halls to medical waiting rooms) now show an almost equal split between wired and wireless network connectivity. And wireless is finally making our vision of the 1980s realistic—to have every classroom seat connected to the network. Our data show that we now have more classroom seats connected wirelessly than via hardwire.

In addition, campuses are actively wiring outdoor spaces, with almost two-thirds of institutions providing some level of outdoor wireless and 11 percent reporting a considerable number of outdoor spaces with wireless access. Numerous respondents say that providing mobility to their students is an essential part of their campus strategic goals, and others are even providing wireless into the community. To date, doctoral institutions report the greatest installation of wireless access in classrooms, indoor public spaces, and outdoor public spaces.

Most of our respondents view wireless connectivity as supplemental to hardwired connectivity, especially where bandwidth and security are important. However, one-fifth of respondents plan to actually replace wired technology with wireless networking in one or more areas on campus—most often in classrooms, indoor public spaces, and libraries. Those who do not plan such replacement indicate three primary reasons: the insufficient performance of wireless, the fact that the wired network already provides adequate coverage, and security concerns.

National, Regional, and State Research and Education Networks

We noted much energy and enthusiasm around creating and joining private education and research networks. Two-fifths of responding institutions connect to a university system-wide network, and 43 percent connect to a state educational and research network. Regional gigaPOPs connect 25 percent of responding institutions. Which external networks institutions join relates strongly to their Carnegie class. Doctoral institutions are most often connected to all types of higher education networks, whereas master’s, baccalaureate, and associate’s institutions are more likely to join a state research and educational network and use this for any further external network connectivity.

At the state and regional level in the United States, 34 research and educational networks are now in place or being implemented, and most are moving toward a model of regional facility-based networking built with owned assets. These regional networks connect constituents to external networks, and their constituencies are growing. Completion of a national higher education research and education network infrastructure requires bringing all these individual pieces together—campus, state, regional, and national networks. The key players creating these networks also explicitly state that the higher education community has both an opportunity and a responsibility to ensure that eventually every citizen has access to these educational networks and the resources and services they offer.

These private-network initiatives have taken advantage of market conditions in the telecommunications sector by acquiring unused, or dark, fiber at affordable prices. As of September 2004, dark fiber acquisition by U.S. research and education groups is conservatively estimated to be at 25,900 segment miles. Our data supports this trend,
showing that about one-third of institutions have acquired dark fiber, and about one-third of these plan to acquire more.

**Network Reliability**

Our respondents underscored the growing importance and challenge of ensuring network reliability. As campuses have focused on building their network infrastructure and adding services, the user base has become fully dependent on the network. Yet institutions haven’t kept pace in ensuring that this now-critical infrastructure and its related services can meet the basic user expectation that it will always work. Indeed, more than half of institutions report having had one or more significant network outages within the past two years.

Network redundancy is an important part of network reliability, and our data show that we have a long way to go toward full redundancy. At the same time, we know that network redundancy must be considered in the context of institutional risk assessment as a whole: institutions often cannot afford to opt for full redundancy of their water, electrical, or life-support systems, and network redundancy can compete for the same sources of funding. Although most institutions report that they have implemented redundancy for some single points of failure (74 percent), very few (9 percent) have implemented redundancy for all single points of failure. In addition, a relatively small showing of campuses have established multiple routes off campus (37 percent), multiple routes on campus (43 percent), or multiple service providers (28 percent). Not surprisingly, given the higher risks associated with larger, more complex networks, larger institutions more likely have implemented these redundancy measures. Further, paying attention to network redundancy may make a difference. Those institutions that do so report more than others that their backbone network is both more fault tolerant and more optimally designed to meet future needs.

Perhaps more revealing is that 40 percent of our respondents report that they have no disaster recovery plan for data networking on campus. This may be a matter of priorities, funding, and perceived risk. Joel Hartman, vice provost, information technologies and resources, University of Central Florida (UCF), reports that UCF’s network and all core online services were fully operational through the three hurricanes that struck the Orlando campus in fall 2004. And again, taking the step to create a disaster recovery plan matters: institutions with a disaster recovery plan agree more often that their network infrastructure is secure, fault tolerant, and optimally designed to meet future needs.

**Network Security**

We covered IT security in higher education extensively in a 2003 ECAR study and therefore consider it outside this networking study’s scope. Nevertheless, security is very much on respondents’ minds. Almost all (97 percent) said their central IT networking group is directly responsible for data networking security, and most (69 percent) said their responsibility extends to include overall campus IT security. The executives and managers we interviewed consistently pointed to security issues as their top challenge. Brian Voss, associate vice president for telecommunications at Indiana University, agrees in his top 10 best practices countdown for 2004–2005 about choosing security as the number-one issue. “Pay attention to network security—the most critical need facing CIOs and telecommunications officers today.”

Our data corroborates this qualitative finding. Of all barriers to the delivery of network services, respondents identified security most often (63 percent). Further, security is also a strong concern when it comes to wireless and mobile connectivity. Almost half of
respondents (47 percent) identified security concerns as a reason for not replacing wired connectivity with wireless. Security may be the top issue in the private sector as well. Cisco Systems CEO John Chambers talks to between 5 and 10 customers a day when he is on the road. When asked, “If you had to boil it down to one issue that seems to come up in conversations with customers over and over, what is that?” his answer is security.\textsuperscript{6}

**Converged Networks**

Higher education, like other sectors, is actively converging network infrastructures for data, voice, and video. Most respondents tell us that they lie on the adoption curve somewhere between evaluating and actually running converged networks for some applications. About half of respondents indicate that IP video streaming or desktop video conferencing is already in limited or wide use on their campuses. And most other institutions are either planning to implement or evaluating these video technologies. There is less current use of VoIP—about one-quarter of institutions. An even smaller number of institutions are currently implementing other converged services such as cable TV over the network and integrated messaging (IM). Larger institutions, including many of the doctoral institutions, are furthest along the adoption curve for converged services.

The top reason for moving to converged services reflects a user focus: to provide enhanced services (63 percent) and to combine infrastructure and support staff (42 percent) for both user convenience and cost savings. Those not yet considering convergence offer extremely practical reasons for not doing so. Most often they have higher IT priorities (65 percent) or don’t require converged services at this time (60 percent). Others (42 percent) don’t see an acceptable return on investment (ROI) or are unwilling to discard their investment in legacy technologies (33 percent). We must also note that a significant number of respondents (20 percent) are not yet considering converged services because their current network infrastructure cannot support them.

How does this trend affect the central network organization? Of those considering or implementing converged networks, the most common area of change is the organizational structure (143 institutions). Somewhat fewer organizations said they have made changes to central networking operations, user support, or network policies. And only 53 institutions report that they’ve changed the financial model for funding and charging for network services. Yet our qualitative interviews revealed keen interest in restructuring the funding model to reflect convergence of voice and data, a transformation seen as both desirable and necessary.

Of those institutions that have implemented converged networks, 43 percent say they have achieved cost savings and another 26 percent expect to experience cost savings eventually. In the private sector, a Meta Group survey found that “57 percent of respondents said they’ve seen marked reductions in operational costs and 60 percent cited lower circuit costs. But 36 percent reported an increase to staffing costs; 44 percent cited an increase in infrastructure costs.”\textsuperscript{8}

**Voice over Internet Protocol**

Looking at VoIP in more detail, we find it to be a forefront issue both in the press and in our higher education IT community. Our data show that as of the date of our survey (June 2004), two-fifths of institutions had already committed to VoIP: 27 percent had VoIP in limited or wide use, and another 15 percent were either implementing, or will do so within the next 12 months. This adoption level falls just short of that found in an October 2004
CIO Magazine survey, in which 25.5 percent of CIOs polled said they had already installed a VoIP system and 25.9 percent said they would implement one in the next 12 months.9

Again, larger institutions or those with a primary networking goal of providing a leading-edge network are more likely to be pursuing VoIP than smaller institutions.

The most common implementation approach is to use both legacy and VoIP phones for some transition period (73 percent); smaller institutions are more likely to replace all legacy phones with VoIP phones rather than use both over a transition period. Most institutions have already combined the voice communications and data networking functions so that they report to the same organization or department (65 percent).

Institutional experience with VoIP has been mixed. Some respondents report great success; others say their implementations and pilots have been problematic. The key challenge is to attain the same level of reliability in the converged network that has been there historically with traditional voice telephony. The consensus is that VoIP is inevitable, but that caution and patience are the wisdom of the day.

Network Management

Network management, software tools, restrictions, policies, and support are increasingly crucial parts of the campus network and its practices. Looking at network management software tools, we find, as expected, extensive use of stand-alone vendor products (71 percent). However, we also found that open source network management tools—such as MRTG (multirouter traffic grapher) and Netdisco—are also in very wide use (67 percent). Another 40 percent use homegrown applications. Specifically, institutions actively use monitoring tools, most commonly for monitoring traffic, network components, server performance, and security vulnerabilities. Many also use metrics, mostly for tracking network capacity utilization and uptime. Fewer institutions track packet loss, network speeds, user satisfaction, or network latency. Network directories are almost a given, with only 20 institutions reporting that they don’t use them.

Restricting bandwidth, devices, applications, or access to external devices is very common practice, but approaches vary widely among campuses. Institutions most commonly restrict e-mail relay and access to selected TCP/IP ports, connections to selected network equipment such as hubs and routers, and use of port scanners and packet sniffers. Further, most campuses (70 percent) use packet shaping to minimize the impact of peer-to-peer (P2P) file sharing and other bandwidth-consuming applications. Institutions with resident students often separate the residence halls (51 percent). Notably, associate’s institutions place more restrictions on applications and devices than do other institutions, likely because of the relatively high level of centralization and standardization found in many two-year institutions.

Formal network policies and procedures appear to be standard practice, in place at 78 percent of institutions. Respondents characterize these policies as easily accessible and clear and easy to read. We noted less enthusiasm about their comprehensiveness, currency, and consistent enforcement. Those institutions that do have policies, and especially those that enforce them consistently, rate their network infrastructure quality higher than others.

Campuses are finding ways to provide increasing network support hours. Today, more than one-third of institutions provide extended-business-hours user support, and one-quarter now provide 24 x 7 support. Again, these tend to be larger institutions, most likely responding to their diverse and complex application set, as well as many users working off-hours.
Network Complexity

We found striking differences between small institutions and large institutions (which include most of the doctoral institutions), particularly in their profiles of networking practices. Large institutions must contend with many more network users, running a much wider and more diverse set of applications, with higher-volume operations. Researchers and graduate students often make cutting-edge use of the network, and working off-hours is the norm. Further, large institutions more often have the resources and staff to allow for early adoption of new technologies, to buy new equipment with enhanced capabilities, and to implement software management tools. As the network scales up, automation becomes imperative. While smaller institutions can often keep it simple, larger institutions do not have this luxury.

These factors translate into differences found in our survey data. For example, larger institutions are more likely to
◆ use single-mode fiber optic cable;
◆ provide higher bandwidth and transmission speeds on their backbone networks;
◆ implement network redundancy measures;
◆ provide remote access to users;
◆ require login to authentication servers;
◆ provide 24 x 7 network support hours;
◆ use advanced technologies such as storage area network (SAN) and IP multicast;
◆ implement the converged services of VoIP, video conferencing, and video streaming;
◆ use open source and homegrown network management tools;
◆ use virtual local area networks (VLANs), especially to separate organizations and to connect geographically separated users; and
◆ have formal networking policies and procedures.

Many institutions are facing these issues as they grow. E. Mike Staman, Macon State University’s Peyton Anderson Professor of Information Technology, notes that “we grew from around 2,000 to over 6,000 students almost overnight, and discovered that the networking solutions of the past no longer worked. Nothing scaled, and all of a sudden we had faculty and students demanding their choice of e-mail clients, access locations, and desktop systems. Then mobility became an issue, and next people began worrying about security, authentication, and authorization. Sometimes I’m reminded of a teenager, legs going one way, arms another, and the body (our CIO and his staff) working feverishly as they try to hold things together while they build sufficient mass and capability to sustain us into the future.”

Topics for Further Study

This study covers a wide breadth of issues, looking at today and into the future—both near-term and the 5- to 10-year time frame. While discussing the study results, we identified several areas of interest to the higher education community as future ECAR research possibilities, as either full ECAR studies or shorter research bulletin efforts. Some of the most frequent suggestions are
◆ an update of IT security practices and issues;10
◆ network reliability and business continuity practices;
◆ mobility—technology, issues, and implications;
◆ embedded connectivity—technology, issues, and implications;
◆ shared services as an alternative to traditional outsourcing; and
◆ identity management.
Endnotes


7. The actual numbers may be larger because some respondents in the sample are only “considering” implementing converged services and may or may not have made changes to reflect the nature of converged services.


10. R. Kvavik et al., op. cit.
Introduction

Today the world changes so quickly that in growing up we take leave not just of youth, but of the world we were young in.

—Sir Peter Brian Medawar

Providing a high-quality campus network—reliable, secure, adaptable, scalable, and fault tolerant—has become table stakes for entering and staying in the game of higher education. And the stakes are rising. Higher education’s access to information resources and services, whether they support core research and teaching missions or business administration, is increasingly central to enhancing reputation, competitiveness, client satisfaction, revenue, and accountability.

Overwhelmingly, those responding to this study indicate that their institutional leadership views their network as critical infrastructure, as a strategic resource, and as more important to the institution’s strategic goals than it was three years ago.

For some, the network is much more than table stakes. One-quarter of our respondents tell us that the network is, or will become, a competitive differentiator for their institution. This can take many imaginative forms, such as using the network to create unique student learning environments, operating successful distance-learning programs, leveraging early adoption of emerging or experimental technologies, providing a lifelong link to alumni, or enabling bleeding-edge research via very high-performance computing. A fully robust network is again the most basic underpinning for these strategic initiatives.

Perhaps this strategic focus reflects that for the first time in the history of computing, there is a real likelihood that advances in computing and communications will enable genuine breakthroughs not just in research and business, but in our core production function of learning and instruction. We sense a feeling among higher education IT leaders interviewed that the full promise of networking envisioned during the 1980s and 1990s is finally beginning to happen today. And although higher education has been cautious in adopting network-enabled teaching and learning tools, the potential is now there to truly revolutionize the delivery of education.

The pieces of the networking puzzle needed to make this a reality are coming together quickly. At the campus level, institutions are investing substantial financial and human resources to keep pace, continually reshaping campus technical architectures to support evolving technologies and applications and to support their growing and diverse campus needs. In fact, the 2004 EDUCAUSE top IT issues survey found that maintaining and upgrading network and IT infrastructure was ranked as the second highest campus IT expenditure for all Carnegie classes, public and private institutions, and both small and large institutions.1 External to the campus,
the higher education community is actively building a set of interconnecting private state, regional, and national research and education networks. Further, our community is committed to the vision of every citizen having access to our networks and is taking a proactive role in making sure this happens over the next several years.

**Higher Education as Network Pioneer**

Since networking’s inception, higher education has played a pioneering role. Partnerships between higher education, government, and industry have been instrumental in the creation and evolution of networking. Higher education’s contribution to the Internet, for example, has been not just prominent but essential. For decades, colleges and universities have been deeply involved not only in technology development but also in policy, administration, and oversight.

- **1960s.** Three ideas emerging from MIT provided the foundation for today’s global networking. J.C.R. Licklider envisioned a “Galactic Network” of a globally interconnected set of communicating computers. Leonard Kleinrock’s concept of packet switching, together with Lawrence Roberts’s successful experimentation with time-sharing computers, made this vision possible.

- **1970s.** Under ARPA² funding, four universities—UCLA, Stanford, UC Santa Barbara, and the University of Utah—joined to create ARPANet. The first computer-to-computer chat then took place at UCLA in 1972. The TCP/IP protocol was also developed during this era, based on the work of a Stanford team led by Vint Cerf, an MIT team led by Dave Clark, and others.

- **1980s.** City University of New York instigated the BITNet cooperative and supported listserv servers, e-mail, and file transfer between higher education colleagues. Also, NSFNet (created from ARPANet) connected supercomputers at Cornell, Pittsburgh, UC San Diego, Princeton, and the University of Illinois at Urbana–Champaign.

- **1990s.** Gopher was developed at the University of Minnesota, and the World Wide Web was born at CERN, the European university consortium for high-energy physics research.

Today, bleeding-edge research on an extremely wide variety of networking technologies continues to flourish within the domain of higher education. At one end of the spectrum, Larry Smarr and the OptIPuter project at the University of California, San Diego, are creating a new architecture that will let scientists generating terabytes and petabytes of data interactively visualize, analyze, and correlate their data from multiple storage sites connected to optical “supernetworks.”³ At the other end, Deborah Estrin at the UCLA Center for Embedded Network Sensing is developing tiny embedded networked sensing systems and applying this revolutionary technology to critical scientific and social applications.⁴

In addition to many such research projects, the higher education IT leadership community continues to come together to accelerate progress on myriad challenging issues such as middleware, identity management, and security.

**What’s Different about Higher Education Networking?**

In the networking arena, as in most areas of higher education, the common belief is that our institutions vary significantly from other industries. The diversity of campus missions, variety of user types, breadth of technologies supported, and decentralization issues together create a higher education networking environment that differs significantly from those found in the corporate world.⁵
Mission, User, and Equipment Diversity

Higher education institutions engage in an extremely wide range of activities. In addition to the core functions of teaching and research, they often operate student dorms, retail stores, food services, entertainment venues (sports, theater, arts), and any number of other business and cultural enterprises. Further, college and university network users can include just about anyone. Although students, staff, and faculty are the core users, remote or onsite visitors can access libraries, Web-enabled services, public kiosks, and public computer labs. This innately diverse environment translates into a diverse technical environment and a challenge for the campus network.

The technologies found at typical colleges or universities, even small ones, tend to be much more diverse than at a corporation. Institutions often don’t own many of the machines that connect to the network, such as students’ private machines connected through the dorms or libraries. Further, it is common for an institution to have computers from many vendors, running multiple operating system versions—Windows 95 to XP, several MacOS versions, and several Linux operating system variants. Server environments are also often diverse, and the overall number of standards in use can be problematic.

A Research Environment

Institutions with a research mission and focus have additional network technology and administration issues. Much research requires a network that supports experimentation, bleeding-edge technology, specialized computing (hardware and software) equipment, extremely high bandwidth requirements, protection of sensitive data, and compliance with rules covering research contracts and grants. While the corporate world can build a network to support specific, known applications, higher education network engineers have to build networks to support unknown applications. Such networks must ensure that Professor Smith can plug into the supercomputer without the campus network grinding to a halt. As University of California, San Diego’s, Larry Smarr observed, “Tracking the progress of hurricanes requires the real-time movement of terabytes of data across networks. Delays in transmission mean forecasts that can miss by miles.”

Decentralization

A decentralized culture characterizes many colleges and universities, especially those that are larger or more research intensive. In these environments, diverse schools, departments, research laboratories, hospitals, and business units can establish, tailor, and control their own local networks. This contrasts with typical corporate environments, where centralization is the norm and the central IT organization closely controls the network architecture and management, security, hardware and software purchases, user support, and most other aspects of computing within the organization. In these environments, attaining high levels of reliability, efficiency, and security is not as challenging as it is in decentralized higher education environments.

The Need for More Study: ECAR’s Role

Despite the national attention and ongoing efforts of EDUCAUSE, Internet2, the National LambdaRail, and other organizations involved in moving IT networking forward in higher education, our knowledge of colleges’ and universities’ current state of and future plans for networking is largely anecdotal. We have little quantitative information from which to benchmark IT networking.

This ECAR study is designed to provide detailed empirical information about the higher education networking environment, from both an everyday practice perspec-
tive and a strategic view. It identifies what networking technology and practices are currently in place and what future directions are anticipated and planned. Systematically gathered quantitative data can help institutions make more informed decisions about their networking approaches and plans and, we hope, contribute to the improvement of networking in higher education.

We note that although network security is critical to higher education networking, security practices and issues are outside this study’s scope. This area of investigation was covered in detail in the 2003 ECAR study Information Technology Security: Governance, Strategy, and Practice in Higher Education.

A navigational diagram will be used throughout this study as a framework for our discussion of findings; it appears on the title page of this chapter. At the center of our discussion is the campus network itself and its related set of network practices. Impinging on the campus network are four major forces: external networks; emerging technologies and converged networks; the future of networking; and the institutional context of organization, leadership, and management. Each of these topics will be covered as we proceed through the study chapters.

Endnotes

2. The Advanced Research Projects Agency (ARPA) changed its name to Defense Advanced Research Projects Agency (DARPA) in 1971, then back to ARPA in 1993, and back to DARPA in 1996.
5. The ECAR study Information Technology Security: Governance, Strategy, and Practice in Higher Education (Kvavik et al., Boulder, Colo.: EDUCAUSE Center for Applied Research, Research Study, Vol. 5, 2003) also discusses these issues as they relate to IT security in higher education.
6. Ibid.
Methodology and Overview of Respondents

Tell the truth and run.
—Yugoslavian proverb

The ECAR study on IT networking used a multifaceted research methodology to gather both quantitative and qualitative data from 517 higher education institutions (487 U.S. and 30 Canadian institutions). The data provide a view of one segment of higher education’s collective experience with IT networking as well as in-depth institution-specific perspectives.

Research Approach

We undertook four data collection and analytical initiatives: a literature review, a quantitative Web-based survey, qualitative telephone and e-mail interviews, and three case studies.

The literature review helped us identify and clarify issues and create a working set of hypotheses to be tested. Although abundant literature exists on the subject, the vast majority of both the academic and professional literature focuses on business rather than academia. Some exceptions are the publications of EDUCAUSE, the Chronicle of Higher Education, and Campus Technology magazine.

Because networking technologies and practices are undergoing such rapid change, probably the best information available is on the Web. We appended a short bibliography (Appendix D) that includes the Web sites and publications we found useful. The bibliography is not intended to be comprehensive.

The quantitative Web-based survey was designed by ECAR fellows and John Voloudakis, former fellow and now of Bearing Point. EDUCAUSE staff sent an e-mail invitation with the survey’s Web address and access code information to 1,477 EDUCAUSE member institutions from Canada and the United States. Senior IT leaders, most of them CIOs or networking administrators, from 488 institutions responded to the survey. Another 29 institutions that aren’t EDUCAUSE members asked to be included, giving a total of 517 institutions responding. These responses provided a detailed understanding of how higher education approaches IT networking. The survey questions appear on the EDUCAUSE Web site at <http://www.educause.edu/ir/library/pdf/ecar_so/ers/si/esi05a.pdf>. Appendix A lists the names of institutions that participated in the survey. All information collected is confidential.

We conducted qualitative telephone interviews with 19 IT executives and managers at 13 EDUCAUSE member institutions. To obtain depth and breadth of practice, we chose to interview respondents from institutions of varying size and mission, and we included...
both public and private institutions. We also selected institutions representing a range of institutional goals for their networks, from providing reliable performance and services at the lowest possible cost to providing leading-edge performance and services. We also hosted a small informal group discussion among four CIOs at the 2004 ECAR Symposium about their top networking issues. We interviewed 12 leaders in higher education networking to better understand anticipated networking directions and issues over the next 5 to 10 years. And finally, we sent e-mail follow-up queries to selected respondents for clarification and further description on some topics, including outsourcing of networking activities, use of service-level agreements, cost savings from converged networking, and how networks are used as a strategic differentiator in higher education. We received responses from 21 respondents. Appendix B lists all institutions interviewed via phone, personal conversation, or e-mail.

Three in-depth case studies were also undertaken. Designed to complement the core study, each case focuses on a single aspect of IT networking strategy and practice. Topics include higher education applications of mobile technology in The Netherlands (done by SURF, a Dutch higher education and research partnership), funding models for IT networking (Cornell University, University of California at San Diego, and the University of Wisconsin–Madison), and voice over Internet protocol (State University of New York, Courtland).

Carnegie Class as a Distinguishing Factor

The study grouped the sample by a modified Carnegie Classification of Institutions of Higher Education. The Carnegie taxonomy describes the institutional diversity in U.S. higher education. Most higher education projects rely on this classification to ensure a representative selection of participating individuals and institutions. The study collapsed the categories as follows to obtain larger numbers for statistical and descriptive purposes:

- **Doctoral/research universities (DR).** The study grouped the doctoral-extensive and -intensive universities together. These institutions typically offer a wide range of baccalaureate programs and graduate education through the doctorate degree. Doctoral-extensive institutions award 50 or more doctoral degrees per year in at least 15 disciplines. Doctoral-intensive institutions award at least 10 doctoral degrees per year in three or more disciplines, or at least 20 doctoral degrees per year overall.
- **Master’s colleges and universities (MA).** The study grouped master’s colleges and universities I and II together. These institutions typically offer a wide range of baccalaureate programs and graduate education through the master’s degree. Master’s I and master’s II institutions differ in the number of degrees offered.
- **Baccalaureate colleges (BA).** The study combined the three baccalaureate college groups (baccalaureate colleges–liberal arts, baccalaureate colleges–general, and baccalaureate/associate’s colleges) into a single group. Baccalaureate colleges are primarily undergraduate colleges with major emphasis on baccalaureate programs.
- **Associate’s colleges (AA).** These institutions offer associate’s degree and certificate programs but, with few exceptions, award no baccalaureate degrees.
- **Specialized institutions (Specialized).** These institutions offer degrees ranging from the baccalaureate to the doctorate and typically award most degrees in a single field. Specialized institutions include theological seminaries and other specialized faith-related institutions; medical schools (for medical and other health professions);
schools of engineering and technology; schools of business and management (which award most of their degrees in business or business-related programs); schools of art, music, and design; schools of law; and teachers colleges. The data presented for these schools must be interpreted in light of the enormous diversity of institutions within this category.

We also provide data, where appropriate, for the 9 U.S. higher education systems offices and 30 Canadian institutions in our study, recognizing that they vary by size and mission. For purposes of analysis, this study combines the Specialized and Systems Offices Carnegie class categories into one class, labeled “Other.”

Figure 3-1 compares the responding institutions’ distribution by their 2000 Carnegie class, EDUCAUSE membership, and the universe of higher education institutions in the United States. The responding schools mirror much more closely the EDUCAUSE membership than the national population of institutions by Carnegie class. Proportionally, we have strong participation from doctoral-extensive (60.5 percent) and doctoral-intensive (44.6 percent) institutions and weaker participation from the other Carnegie classifications.

Note also that because the study relied on volunteers and because participating institutions are drawn from the EDUCAUSE membership rather than from a random sample of all higher education institutions, results are not generalizable to all higher education institutions. Nevertheless, the overall 33 percent response rate from EDUCAUSE member institutions gives us confidence that the study’s respondents portray a reasonable image of the EDUCAUSE membership, especially for doctoral institutions.

A statistical analysis of the data’s representativeness proved inconclusive. The findings do not support the conclusion that the institutions surveyed represent the population as a whole. Nor do they support the conclusion that the respondents fail to represent the EDUCAUSE membership. Neither conclusion is statistically significant.

![Figure 3-1. Survey Respondents, by EDUCAUSE Membership and Carnegie Class*](http://www.carnegiefoundation.org/Classification/CIHE2000/Tables.htm)
Analysis and Reporting Conventions

We followed the following conventions in analyzing the data and reporting the results:

◆ Some tables and figures presented in this study have fewer than 517 respondents. They were adjusted for missing information.
◆ A glossary of networking-related terms is included in Appendix C. These terms are not again defined in the text as they are used.
◆ The data for each question in the online survey is analyzed for differences in patterns of response among Carnegie classes (including doctoral-intensive versus doctoral-extensive institutions), Canadian and U.S. institutions, private and public institutions, and institutions of varying size. Institution size is determined by the number of full-time students. Any differences found that are both meaningful and statistically significant are noted in the text and/or the supporting figures and tables.
◆ The Likert scales used in the online survey are footnoted in the tables and figures showing results for these survey questions.

Profile of Responding Institutions

For this study, the median student enrollment of institutions was 4,107. Figure 3-2 shows institutions divided into the six groups that will be used for analysis. Smaller institutions dominated our study, as they do higher education: 47.7 percent have 4,000 or fewer enrolled students, and only 5.5 percent have more than 25,000 students.

Figure 3-3 shows the number of devices connected to institution networks. Fifty-eight percent of the institutions in our study have 5,000 or fewer devices, and 76.4 percent have 10,000 or fewer. Only 5.5 percent have more than 40,000 devices on their networks.

Figure 3-4 shows a similar pattern for the number of institutional users supported on the campus network. Forty-five percent of institutions have 5,000 or fewer institutional users, and 77.6 percent have 20,000 or fewer. Only 7.8 percent provide networking capabilities for more than 40,000 users.

Our responding institutions are deeply involved in voice telecommunications. Eighty-two percent own a private branch exchange (PBX), and almost all support phones operationally (see Figure 3-5).
Figure 3-3. Number of Devices on Institution Networks (N = 508)

Figure 3-4. Number of Institutional Users (N = 513)

Figure 3-5. Number of Phones Supported Operationally (N = 508)
The survey was distributed to EDUCAUSE primary representatives and was completed largely by senior IT leaders, reflecting their experiences, observations, and opinions about IT networking. As shown in Figure 3-6, our respondents bring much experience to our study and provide a broad view of IT networking in higher education. Almost a fifth of respondents (18.7 percent) report more than 20 years’ experience in IT networking. Further, 30.5 percent indicated that they focus on data networking full time.

We are gratified by the number of respondents, which makes the findings more than simply the observations of a small subset of the industry. In the following chapters, we present respondents’ collective view of IT networking in higher education.

Endnote

1. See <http://www.carnegiefoundation.org/Classification/CIHE2000/defNotes/Definitions.htm>. The study notes that the Carnegie Classification of Institutions of Higher Education recognizes 1,669 associate’s institutions, whereas the American Association of Community Colleges (AACC) membership includes 1,171. The AACC numbers are based on the definition of colleges eligible for membership in the AACC constitution: colleges that award the associate’s degree and are regionally accredited. The Carnegie count includes career colleges and colleges accredited by the Accrediting Council for Independent Colleges and Schools.
The Campus Network

The most important thing is simple and straightforward; if there is one dollar to spend, spend it on infrastructure.
—Alan Bjornsen, Cerami & Associates

Reflecting the breadth of higher education activities, a typical day might find a faculty member directing his students to a Web site showcasing artwork at the Hermitage Museum, a researcher repositioning a remotely operated telescope to focus on another star cluster, or a staff member processing a recently received admission application online. One constant—networking—facilitates all these endeavors. Indeed, meeting the myriad networking requirements for these activities is exceedingly complex and is getting more so.

This chapter first describes the networking context within an institution: networking goals, investment drivers, and perceived barriers to delivering network services—that contribute to an institution's overall networking approach.

Institutional Context Sets the Stage

Our data support the idea that a college’s or university’s mission and strategic directions set the context for its networking goals. This section examines several elements—network goals and vision, investment drivers, and barriers to delivering network services—that contribute to an institution’s overall networking approach.

Institutional Networking Goals

To better understand an institution’s primary goal for its network, our survey asked

Institutional Networking Goals

Key Findings

- Institutions are now “wired,” providing network access to almost all students, faculty, and staff. Most institutions are also actively supplementing the wired network with wireless access.
- Respondents overwhelmingly agree that networking will continue to be managed by the institution, rather than being outsourced, over the next three years.
- Most campus networks have a long way to go before they have the full redundancy required to ensure continued network availability. Larger institutions are more likely to have implemented redundancy measures.
- Almost two-fifths of institutions report that they have no disaster recovery plan for data networking.
- More than half of respondents report one or more significant unplanned network outages within the last two years.
- Security is most often identified as a top barrier to providing network services. Inadequate funding is the second most often reported barrier.
respondents to select which of four goals best described their institution’s overall philosophy for providing networking services. Table 4-1 lists these goals as well as a short descriptor that we will use to reference these network goals throughout this report. Our responding institutions are almost evenly divided among these four primary network goals. Slightly more institutions (28.4 percent) chose “demand driven” as their institution’s primary networking goal, and slightly fewer institutions (19.8 percent) chose “cost minimizer.”

Our respondents described these varying network goals. For example, Ohio State University, a research-oriented institution, built a new center “designed to be a showcase for the school’s high-tech operations and aspirations, so a super-speed network was essential.” For rural institutions like Genesse Community College, “reliability is huge,” states Mary Jane Heider, director of academic computing. “It needs to be simple, straightforward, and ubiquitous.”

Careful technology investments drive Brandeis University. Perry Hanson, CIO and associate provost for academic technology, said he “spends every dollar carefully—everywhere—not just in networks. We don’t need a Rolls Royce, but we need the best, in part because we have a small staff and things need to work.”

York College of Pennsylvania focuses on enhancing user activities. Robert L. Robinson, director of information technology, looks at the network as a complement to the education process. “If the technology can assist in the academic delivery process without becoming the process itself, then the technology is within mission. When the campus network can extend the academic tools, it can be thought of as a strategic differentiator.”

Figure 4-1 shows differences in network goals among Carnegie classes. Not surprisingly, doctoral institutions most often identified a goal to provide “leading-edge” networking (42.6 percent). “Demand-driven” networking was the primary goal for 33.3 percent of associate’s and for 32.1 percent of master’s institutions. “High speed for all” was a common goal for all Carnegie classes, with the exception of associate’s institutions (only 19.0 percent). “Cost minimizer” was also a common goal, except in doctoral institutions (only 9.3 percent). Although we found much diversity of primary networking goals within each Carnegie class, these findings seem generally in keeping with the mission differences incorporated in the Carnegie classification system.

In addition to current networking goals, the ECAR survey asked respondents how they envision networking’s future at their institu-

<table>
<thead>
<tr>
<th>Primary Goal</th>
<th>Descriptor</th>
<th>Percentage</th>
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<tr>
<td>Provide reliable performance and services at the lowest possible cost</td>
<td>Cost minimizer</td>
<td>19.8%</td>
</tr>
<tr>
<td>Provide appropriate levels of performance and services to different users on the basis of their needs</td>
<td>Demand driven</td>
<td>28.4%</td>
</tr>
<tr>
<td>Provide high-speed networking to the entire institution</td>
<td>High speed for all</td>
<td>25.9%</td>
</tr>
<tr>
<td>Provide leading-edge network performance and services to the institution</td>
<td>Leading edge</td>
<td>25.9%</td>
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tion (Table 4-2). Almost half (48.9 percent) believe that the institution’s diversity and complexity are sufficient to make networking best managed by the institution. The next two most common responses view the future of networking as a “strategic differentiator” (27.9 percent) or a “routine function” (20.4 percent). Very few respondents (2.8 percent) envision their network becoming an “outsourced commodity.” We note that 36.4 percent of doctoral institutions identified “strategic differentiator,” and 30.6 percent of baccalaureate institutions identified “routine function” as the best description of their institution’s future view of networking.

**Investment Drivers for Networking**

Respondents also identified the top drivers of continued investment in networking technologies. They most often indicated that “needs identified by the academic community” (52.4 percent) and “adherence to the IT or networking strategic plan” (47.4 per-

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**Table 4-2. View of Institutional Networking’s Future (N = 509)**

<table>
<thead>
<tr>
<th>View</th>
<th>Descriptor</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Networking will become a commodity that can be outsourced to external providers</td>
<td>Outsourced commodity</td>
<td>2.8%</td>
</tr>
<tr>
<td>Networking will become a routine function, but the costs of providing this function within the institution will remain lower than if outsourced</td>
<td>Routine function</td>
<td>20.4%</td>
</tr>
<tr>
<td>The diversity and complexity of the institution are sufficient to make networking best managed by the institution</td>
<td>Complex function</td>
<td>48.9%</td>
</tr>
<tr>
<td>Networking involves perpetual innovation at the institution and is a strategic differentiator</td>
<td>Strategic differentiator</td>
<td>27.9%</td>
</tr>
</tbody>
</table>

---

**Figure 4-1. Institution’s Primary Goal for Its Network, by Carnegie Classification (N = 514)**

- Leading edge
- Demand driven
- High speed for all
- Cost minimizer
cent) were the top drivers (Figure 4-2). It’s important for the investment drivers to be in sync with the institution’s primary network goal. Ron Stauss, vice chancellor, information technology and telecommunications, North Harris Montgomery Community College District, gives an example when he says his institution’s goal is to “give students a more collegial experience than they might have in other community colleges—so that the only experience they might not have if attending a four-year college would be living on campus in dorms. Our network goal and strategic plan, then, is to provide the best-quality network to all students, faculty, and staff—for basic day-to-day work.”

We noted only two differences related to Carnegie class: 46 of the 49 institutions that identified “needs identified by researchers” as a top networking investment driver were doctoral institutions, and 40 of these institutions were doctoral extensive. Doctoral institutions were less likely to identify “needs of the administration” as a top networking investment driver than were other Carnegie class institutions.

Barriers to Delivering Network Services

Finally, we asked respondents about their barriers to network service delivery, and Figure 4-3 shows the results. Overwhelmingly, respondents point to security issues (63.3 percent) and funding issues (59.0 percent) as their dominant barriers to networking. With respect to security, our findings corroborate the 2003 ECAR study on security: while most institutions identified security issues as a barrier, larger institutions with more attached devices were even more likely to do so. Inadequate funding as a top networking barrier, however, is generally consistent across institutions of varying size, type, and Carnegie class, with one exception. Doctoral-extensive institutions were less likely (50.6 percent) to say funding was a barrier than were doctoral-intensive institutions (73.2 percent said yes).

We also saw other notable differences. Overall, 19.3 percent of respondents said that nonacademic student usage (including P2P file sharing and gaming) was one of their top three barriers to networking. Yet only 5.9 percent of associate’s institutions identified this as a barrier, most likely because of their lack of residential students. Institutions with larger student enrollments reported a decentralized culture/organization as a top barrier. Only 9.4 percent of institutions with student enrollments of 8,000 or less identified decentralization as a barrier, and 36.7 percent of institutions with more than 8,000 students did so.

The Backbone Network

Our story about the campus backbone begins with the physical building blocks of the campus network. Transmission media technologies and standards, bandwidth capacity, and network configuration and redundancy all work in concert to ensure a network’s scalability, reliability, fault tolerance, security, and adaptability. What is the higher education installed base in these areas, and where are we headed?

Transmission Media

We asked respondents to what extent their campus backbone uses common transmission media (Table 4-3). With respect to the installed base of fiber optic cable, multimode is by far the most common, with 75.3 percent reporting that a “considerable” part or “almost all” of their backbone currently uses multimode fiber optic cable. The next most common medium is single-mode fiber, with 46.7 percent reporting that a “considerable” amount or more is in use. There is currently minimal installation of composite fiber, with only 10.5 percent of institutions using a “considerable” amount or more. As
Figure 4-2. Top Drivers of Investment (Three Responses Allowed)

Figure 4-3. Barriers to the Delivery of Network Services (Three Responses Allowed)

Table 4-3. Extent of Transmission Media Used in the Network Backbone

<table>
<thead>
<tr>
<th>Transmission Medium</th>
<th>Almost All</th>
<th>Considerable</th>
<th>Some</th>
<th>A Little</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimode fiber optic cable</td>
<td>35.6%</td>
<td>39.7%</td>
<td>14.5%</td>
<td>6.5%</td>
<td>3.7%</td>
</tr>
<tr>
<td>Single-mode fiber optic cable</td>
<td>14.0%</td>
<td>32.7%</td>
<td>22.3%</td>
<td>15.8%</td>
<td>15.2%</td>
</tr>
<tr>
<td>Category 5 twisted pair</td>
<td>6.4%</td>
<td>19.5%</td>
<td>15.3%</td>
<td>12.6%</td>
<td>46.2%</td>
</tr>
<tr>
<td>Category 5e twisted pair</td>
<td>5.8%</td>
<td>20.9%</td>
<td>12.7%</td>
<td>15.0%</td>
<td>45.6%</td>
</tr>
<tr>
<td>Composite fiber</td>
<td>4.0%</td>
<td>6.5%</td>
<td>9.2%</td>
<td>10.5%</td>
<td>69.8%</td>
</tr>
<tr>
<td>Wireless</td>
<td>2.4%</td>
<td>8.9%</td>
<td>26.1%</td>
<td>19.8%</td>
<td>42.8%</td>
</tr>
<tr>
<td>Category 3 twisted pair</td>
<td>1.5%</td>
<td>5.3%</td>
<td>7.2%</td>
<td>12.7%</td>
<td>73.3%</td>
</tr>
<tr>
<td>Coaxial cable</td>
<td>1.5%</td>
<td>7.1%</td>
<td>7.7%</td>
<td>13.7%</td>
<td>70.1%</td>
</tr>
<tr>
<td>Category 6 twisted pair</td>
<td>0.2%</td>
<td>5.7%</td>
<td>12.8%</td>
<td>17.1%</td>
<td>64.2%</td>
</tr>
</tbody>
</table>
for wireless technology, more than one-tenth (11.3 percent) of institutions use wireless for a "considerable" amount or more of their backbone.

Our data show that approximately one-fourth of institutions report that a "considerable" part or "almost all" of their backbone is Category 5 or Category 5e twisted pair. These numbers are much higher than expected. This finding may indicate that some respondents included the building risers in their definition of their backbone. In fact, our interviewees tell us that fiber is dominant in the backbone and copper is dominant in the horizontal plant. Jose Valdes, associate director for telecommunications, Colorado State University, says, "Our campus backbone is based on single-mode fiber optic cable. Inside buildings between communication rooms we may install copper, but the emphasis is on fiber optics. Copper is rapidly becoming isolated to the horizontal cable plant."

The data show that patterns of backbone fiber optic cable installation vary with institution size. Figure 4-4 tabulates institutions that use a "considerable" amount of or "almost all" fiber in their campus backbone. While smaller institutions use more multimode fiber, larger institutions use more single-mode fiber and composite fiber optic cable. This makes sense: multimode is an older technology, with less capacity over less distance, and cannot handle data traffic types such as video signals as efficiently as single-mode fiber can. Larger institutions often have a more extensive application set, which may help drive the need for single-mode fiber. Also, institutions with a more complex upgrade environment (again, typically larger institutions) may be more inclined to use composite fiber because it adds flexibility and compatibility with older equipment. Beyond differences associated with institution size, we found little difference between Carnegie classifications, and Canada mirrors the United States in fiber optic cable use.

**Bandwidth Capacity**

Many of our interviewees were adamant about positioning their network backbone to accommodate anticipated increases in bandwidth capacity demand. Doug Van Houweling, president and CEO of Internet2, talks about "disruptive" high-end research applications whose fundamental nature requires transferring huge amounts of data. He cites radio astronomers, pathologists analyzing tissue banks, and high-energy physicists, among others. "We need to understand how to manage these disruptive applications without disturbing the other applications, in a scalable fashion..."
because today’s disruptive application will be tomorrow’s production application.”

We asked our respondents about the total bandwidth capacity on their backbone network today. Overall, 56.2 percent of responding institutions report a total bandwidth in the 1-Gbps to 4.99-Gbps range, and 63.3 percent of Canadian universities report this bandwidth capacity. Figure 4-5 shows the distribution by Carnegie class. As expected, doctoral institutions report the highest bandwidth, with 10.9 percent providing 5 to 10 Gbps and 18.0 percent providing more than 10 Gbps. On the lower end, there is a group of MA, BA, and AA institutions providing considerably less bandwidth, in the 11- to 100-Mbps range.

That research institutions are making faster progress toward 10-Gbps bandwidth is in keeping with the demands of the research environment. Yet other institutions are moving in the same direction. Indiana University’s Brian D. Voss, associate vice president, information technology (telecommunications), has outlined his top 10 best practices for his “networking line of attack for 2004–2005.” His second-to-top recommendation is that “10-gigabit campus backbones should be on every CIO’s one- to three-year horizon.”

Besides these Carnegie class differences, we also find differences based on institution size (see Figure 4-6). Small institutions with 2,000 or fewer students most often report low bandwidth (32.5 percent have less than 100 Mbps), and very large institutions with more than 15,000 students report the highest bandwidth (32.9 percent have 5 Gbps or more). This makes sense, given the increased traffic that comes with more users (students, staff, and faculty) and their varied applications.

An institution’s primary networking goal also correlates with total backbone bandwidth. In fact, regardless of Carnegie class or research orientation, institutions whose networking goal is to provide “leading-edge” network performance and services have significantly

![Figure 4-5. Total Bandwidth Available on the Backbone, by Carnegie Class (N = 515)](image-url)
higher bandwidth than other institutions. In contrast, institutions identifying their primary goal as providing network performance and services at the lowest cost—“cost minimizers”—report less bandwidth on their backbone than other institutions.

Transmission Standards

Ethernet is the dominant networking transmission standard for wired networks. C. William Day of the KBD Planning Group summarized the state of wired network transmission standards in education. “Gigabit Ethernet is growing, and 10-Gigabit Ethernet is well on its way, and 10/100Base-T [Ethernet/Fast Ethernet] is declining.” Table 4-4 shows that in our higher education sample, the clear leader is Gigabit Ethernet (86.1 percent of all institutions), followed by Fast Ethernet (67.1 percent of all institutions). More than 10 percent (11.0 percent) are using 10-Gigabit Ethernet. Doctoral institutions and larger institutions make more use of both Gigabit and 10-Gigabit Ethernet.

Interestingly, higher education’s implementation may be ahead of the corporate sector’s. According to a Cabling Installation and Maintenance Web survey on corporate networks, “Only 7 percent of the respondents indicated they think their network now requires 10-Gigabit Ethernet, but 44 percent indicated that their network will require 10-Gigabit Ethernet in five to 10 years.” The asynchronous transfer mode (ATM) and Fiber Distributed Data Interface (FDDI) technologies have low use, with only 7.9 percent of institutions using FDDI and 13.9 percent using ATM.

Hosting multiple technologies at once is always an issue, especially in terms of support. We were therefore curious to know how many different transmission standards and media types our campuses are currently using and supporting on their backbone, and to what extent they have standardized. Figure 4-7 shows that of the nine transmission media queried (refer to Table 4-3), only 18 institutions (4.1 percent) have kept their backbone to one media type, and of these, 12 are small campuses with student enrollments of 4,000 or less. More commonly, institutional backbones now use two (20.2 percent) or three (18.9 percent) transmission media types. And 56.8 percent have an installed base consisting of four or more media types. The median number of backbone media types supported per institution is four.

With respect to the six transmission standards queried (Table 4-4), some institutions appear to have only one standard (28.7 percent), but most are supporting either two
Multiple Backbones

Multiple backbones give campuses additional conduits for network transmission that they can use in various ways.\(^8\) Table 4-5 illustrates that most institutions don’t currently use multiple backbones (58.0 percent overall). Of those that do, the most frequently cited reason is to segment user populations from one another, such as students and researchers (24.4 percent). Here we found some differences between doctoral-extensive and -intensive institutions. Fewer doctoral-extensive institutions use separate backbones to segment user populations (19.1 percent versus 41.5 percent for doctoral-intensive institutions) or to segment core data traffic from other services such as VoIP or video (11.2 percent versus 29.3 percent). Predictably, doctoral institutions are more likely to provide a separate backbone for experimentation with emerging technologies (16.2 percent versus 11.2 percent overall).

Table 4-4. Standards Used for Data Transmission on the Backbone (Multiple Responses Allowed)

<table>
<thead>
<tr>
<th>Data Transmission Standard</th>
<th>DR</th>
<th>MA</th>
<th>BA</th>
<th>AA</th>
<th>Other</th>
<th>Canada</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigabit Ethernet</td>
<td>93.8%</td>
<td>89.1%</td>
<td>81.8%</td>
<td>75.3%</td>
<td>83.3%</td>
<td>86.7%</td>
<td>86.1%</td>
</tr>
<tr>
<td>Fast Ethernet</td>
<td>56.2%</td>
<td>71.5%</td>
<td>70.7%</td>
<td>74.1%</td>
<td>61.1%</td>
<td>70.0%</td>
<td>67.1%</td>
</tr>
<tr>
<td>Ethernet</td>
<td>31.5%</td>
<td>36.5%</td>
<td>35.4%</td>
<td>40.0%</td>
<td>8.3%</td>
<td>43.3%</td>
<td>34.0%</td>
</tr>
<tr>
<td>Asynchronous transfer mode (ATM)</td>
<td>17.7%</td>
<td>13.1%</td>
<td>13.1%</td>
<td>16.5%</td>
<td>8.3%</td>
<td>3.3%</td>
<td>13.9%</td>
</tr>
<tr>
<td>10-Gigabit Ethernet</td>
<td>17.7%</td>
<td>7.3%</td>
<td>5.1%</td>
<td>9.4%</td>
<td>11.1%</td>
<td>23.3%</td>
<td>11.0%</td>
</tr>
<tr>
<td>Fiber Distributed Data Interface (FDDI)</td>
<td>5.4%</td>
<td>6.6%</td>
<td>9.1%</td>
<td>14.1%</td>
<td>5.6%</td>
<td>6.7%</td>
<td>7.9%</td>
</tr>
<tr>
<td>Other</td>
<td>3.1%</td>
<td>4.4%</td>
<td>0.0%</td>
<td>2.4%</td>
<td>8.3%</td>
<td>3.3%</td>
<td>3.1%</td>
</tr>
</tbody>
</table>
Network Reliability

Because networks have become indispensable to higher education institutions’ operation, network reliability is of increasing concern. In fact, many of our interviewees identified the challenge of reliability as second only to that of security. Increasingly, if you ask users what they need from a network, it is like asking them what they need from a telephone: it has to work. In fact, 26.7 percent of our respondents said they’ve had a significant unplanned network outage within the past two years, and another 24.5 percent have had more than one such outage.

CIOs and network directors must anticipate the occasional backhoe, natural disaster, or other events that can compromise network availability. This necessarily makes redundancy an urgent issue. Peter Morrissey, a Syracuse University faculty member, warns in *Network Computing*, “You may be looking for areas to scale back, but we can assure you, network redundancy is always worth the investment. Always, especially at the core. After all, if a core router or switch goes, the network is down.”

Planning and investment paid off for Joel Hartman, vice provost, information technologies and resources, University of Central Florida (UCF), who reports that the UCF network and all core online services remained operational throughout the three hurricanes that struck the Orlando campus in fall 2004. And during the Loma Prieta earthquake of 1989, when the telephone switch went down at the University of California at Santa Cruz, campus emergency communications were conducted via the data communications network.

Although our data indicate that most institutions have taken some steps in providing backup, such as installing uninterruptible power supply (UPS) equipment, general network redundancy is not fully established. While many institutions have addressed some single points of failure (74.1 percent overall), only 9.1 percent of institutions have accounted for all single points of failure on their network. And 30 of our respondents—all but two of these having fewer than 5,000 connected devices—report that at present they have no redundancy precautions in place at all. Mike Enyeart, scientist, Indiana University Information Technology Services,

<table>
<thead>
<tr>
<th>Reason</th>
<th>DR</th>
<th>MA</th>
<th>BA</th>
<th>AA</th>
<th>Other</th>
<th>Canada</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not have multiple backbone networks</td>
<td>53.8%</td>
<td>54.0%</td>
<td>68.7%</td>
<td>58.8%</td>
<td>52.8%</td>
<td>63.3%</td>
<td>58.0%</td>
</tr>
<tr>
<td>Segment user populations from one another</td>
<td>26.2%</td>
<td>29.2%</td>
<td>18.2%</td>
<td>21.2%</td>
<td>27.8%</td>
<td>20.0%</td>
<td>24.4%</td>
</tr>
<tr>
<td>Segment core data traffic from other services</td>
<td>16.9%</td>
<td>19.7%</td>
<td>8.1%</td>
<td>21.2%</td>
<td>19.4%</td>
<td>16.7%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Isolate and protect sensitive information</td>
<td>20.0%</td>
<td>18.2%</td>
<td>14.1%</td>
<td>8.2%</td>
<td>13.9%</td>
<td>13.3%</td>
<td>15.7%</td>
</tr>
<tr>
<td>Separate networks that have evolved over time</td>
<td>12.3%</td>
<td>16.1%</td>
<td>5.1%</td>
<td>5.9%</td>
<td>19.4%</td>
<td>20.0%</td>
<td>11.8%</td>
</tr>
<tr>
<td>Experiment with emerging technologies</td>
<td>16.2%</td>
<td>11.7%</td>
<td>6.1%</td>
<td>11.8%</td>
<td>5.6%</td>
<td>10.0%</td>
<td>11.2%</td>
</tr>
<tr>
<td>Other</td>
<td>2.3%</td>
<td>6.6%</td>
<td>1.0%</td>
<td>3.5%</td>
<td>2.8%</td>
<td>3.3%</td>
<td>3.5%</td>
</tr>
</tbody>
</table>
is convinced that power reliability is the most important factor in network reliability. “The only way I see to solve this reliability issue is with new power technologies such as fuel cells, ‘cold fusion,’ etcetera, or to build networks that don’t require power (for example, passive fiber optic systems).”

One reason for this lag may be that the technology adoption outpaces the IT department’s ability to react to resulting redundancy requirements. Dan Updegrove, vice president for information technology at The University of Texas at Austin, cites the rapid adoption of his institution’s course management system, which grew from a pilot project in summer 2000 to a user base of hundreds of faculty and 42,000 students by spring 2003. “Yet we still do not have the multiple servers, the parallel data storage, 24 x 7 on-call staff, and the other resources that you would like to have in place to meet their unstated, but implicit, expectations of absolute reliability.” He adds, “We would like to tell our customers that there are no single points of failure anywhere in our infrastructure, but we are a long way from that.”

As might be expected, institutions with large networks have paid more serious attention to redundancy (see Figure 4-8 and Figure 4-9). Where networks support 1,000 or fewer devices, only 6.8 percent of institutions have redundancy for all points of failure. In contrast, 17.5 percent of institutions with networks supporting more than 20,000 devices report redundancy for all single points of failure. Looking at Carnegie class, we see that 16.9 percent of doctoral institutions have implemented redundancy for all single points of failure, in contrast with only 2.4 percent of associate’s institutions.

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**Figure 4-8. Central Network Redundancy, by Number of Devices (Multiple Responses Allowed)**

<table>
<thead>
<tr>
<th>Number of Devices on Network</th>
<th>Redundancy of some single points of failure</th>
<th>Redundancy for all points of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 or Fewer</td>
<td>69.3%</td>
<td>17.5%</td>
</tr>
<tr>
<td>1,001–5,000</td>
<td>59.3%</td>
<td>17.2%</td>
</tr>
<tr>
<td>5,001–10,000</td>
<td>6.8%</td>
<td>8.6%</td>
</tr>
<tr>
<td>10,001–20,000</td>
<td>6.2%</td>
<td>82.8%</td>
</tr>
<tr>
<td>More than 20,000</td>
<td>6.2%</td>
<td>79.4%</td>
</tr>
</tbody>
</table>

---

**Figure 4-9. Multiple Physical Routes, by Number of Devices (Multiple Responses Allowed)**

<table>
<thead>
<tr>
<th>Number of Devices on Network</th>
<th>Multiple physical routes on campus</th>
<th>Multiple physical routes off campus</th>
<th>Multiple service providers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 or Fewer</td>
<td>15.3%</td>
<td>20.3%</td>
<td>6.8%</td>
</tr>
<tr>
<td>1,001–5,000</td>
<td>32.0%</td>
<td>30.3%</td>
<td>19.1%</td>
</tr>
<tr>
<td>5,001–10,000</td>
<td>49.5%</td>
<td>36.6%</td>
<td>29.0%</td>
</tr>
<tr>
<td>10,001–20,000</td>
<td>44.8%</td>
<td>43.1%</td>
<td>31.1%</td>
</tr>
<tr>
<td>More than 20,000</td>
<td>76.2%</td>
<td>73.0%</td>
<td>66.7%</td>
</tr>
</tbody>
</table>
With respect to providing alternate routes on and off campus, 42.9 percent of institutions have multiple physical routes on campus, 37.3 percent have multiple physical routes off campus, and 28.0 percent use multiple service providers. And once more, network size matters (see Figure 4-9). While one-fifth or fewer of very small institutions (1,000 or fewer devices) provide these backup routes, two-thirds or more of very large institutions (more than 20,000 devices) do so.

Yet we were surprised that 38.9 percent of respondents indicate that they have no disaster recovery plan for data networking at their campus. Perhaps it is a matter of priorities, funding, and perceived risk. IT security is a high-profile issue, viewed as a “clear and present danger,” whereas many view a potential catastrophe—an earthquake, hurricane, flood, or act of terrorism—as much less likely.

North Harris Montgomery Community College District is one of the institutions that gives network redundancy and disaster planning high priority. The institution purchased 12 strands of fiber that they configured in a ring with bidirectional traffic. According to Chris Smith, director of networking, “Because the Houston area is growing very fast, we had frequent cable cuts causing campus network outages for an afternoon or a day. This problem has virtually disappeared, because if a cable is cut, the fiber ring heals in about 100 milliseconds and sends the traffic the other way.”

**Desktop Connectivity**

Our data have created a picture of campus network backbones in terms of building blocks and basic capabilities—and how they differ across types of institutions. We now turn our attention to the desktop and look at connectivity from the backbone to end devices.

**Transmission Media**

Table 4-3 reported findings about transmission media used in the campus backbone itself. Table 4-6 shows the horizontal transmission media used to connect end devices to that backbone. Here, twisted pair rather than fiber optic cable is the medium of choice. Category 5 and 5e twisted pair are the most common, with 57.6 percent of institutions using Category 5e and 49.6 percent using Category 5 to connect a “considerable” number of or “almost all” end devices to the backbone. There is also some Category 6 installed.

<table>
<thead>
<tr>
<th>Transmission Medium</th>
<th>Almost All</th>
<th>Considerable</th>
<th>Some</th>
<th>A Little</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 5e twisted pair</td>
<td>17.2%</td>
<td>40.4%</td>
<td>18.0%</td>
<td>12.3%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Category 5 twisted pair</td>
<td>14.6%</td>
<td>35.0%</td>
<td>24.2%</td>
<td>12.4%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Multimode fiber optic cable</td>
<td>6.4%</td>
<td>10.1%</td>
<td>12.2%</td>
<td>33.4%</td>
<td>37.9%</td>
</tr>
<tr>
<td>Category 6 twisted pair</td>
<td>3.9%</td>
<td>12.0%</td>
<td>23.6%</td>
<td>21.7%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Single-mode fiber optic cable</td>
<td>2.3%</td>
<td>4.2%</td>
<td>7.7%</td>
<td>19.0%</td>
<td>66.8%</td>
</tr>
<tr>
<td>Wireless</td>
<td>2.0%</td>
<td>15.6%</td>
<td>41.9%</td>
<td>29.3%</td>
<td>11.2%</td>
</tr>
<tr>
<td>Category 3 twisted pair</td>
<td>1.3%</td>
<td>9.3%</td>
<td>14.1%</td>
<td>16.2%</td>
<td>59.1%</td>
</tr>
<tr>
<td>Coaxial cable</td>
<td>0.9%</td>
<td>4.0%</td>
<td>6.4%</td>
<td>14.9%</td>
<td>73.8%</td>
</tr>
<tr>
<td>Composite fiber</td>
<td>0.2%</td>
<td>1.3%</td>
<td>1.3%</td>
<td>4.9%</td>
<td>92.3%</td>
</tr>
</tbody>
</table>
Brian Voss of Indiana University describes his institution’s strategy: “Much of our campus horizontal plant (over 80,000 jacks) is wired with Category 3 wire, which will not support 100 Mbps. Given the high cost of a complete campus upgrade, and balanced with the current desktop needs for the vast majority of users being well met by a strategy to continue to use 10-Mbps jacks, the wire plant upgrade strategy is to replace those jacks with current standards (Category 6e, capable of 100 Mbps or more) on an ‘as-needed’ basis to meet specific higher-speed applications. Since the mid-1990s we have been using Cat 5 or better wire when installing new jacks, and those jacks operate at 100 Mbps or more.”

Rich Sousa, director of professional services for networking communications technologies, notes that “customers still see a sizable cost difference when it comes to installing copper cable. We are squeezing more bandwidth out of copper [twisted pair] today. Every hurdle that is put in front of a copper manufacturer seems to be leaped and gone over.”

For example, the Category 6 Consortium is studying the feasibility of running faster transmission standards like 10-Gigabit Ethernet over twisted pair. Analysts report that fiber-to-the-desk installations still represent less than 10 percent of the market, but some sense a change coming, with “early adopters like government institutions, universities, and medical facilities seeking out 10 Gb-E [10-Gigabit Ethernet] high-bandwidth potential.”

The data also suggest that wireless has become more integrated and accepted as a way of doing business. Only 11.2 percent of institutions use no wireless at all, 71.2 percent use wireless “a little” or “some,” and 17.6 percent use wireless a “considerable” amount or for “almost all” end devices. To date, doctoral institutions have made more use of wireless than other institutions.

How does the type of transmission media used for the backbone itself compare to the media used to connect to end devices? Figure 4-10 summarizes these findings. Fiber optics (single and multimode) are used mostly

![Figure 4-10. Comparison of Transmission Media Used a “Considerable” Amount or More (Multiple Responses Allowed)*](image)

*Percentage of institutions reporting the media type constitutes a “considerable” amount or “almost all” of their media in use.
for the backbone, while Category 5 and 5e twisted pair are used most often to connect end devices to the backbone. Twisted pair continues to evolve, is more cost-effective, and meets the needs of the typical desktop application set.

Indeed, institutions often use a mixture of transmission media, running fiber in their backbone and copper to the desktop. As Genesee Community College’s Mary Jane Heider, director, academic computing, explains, “There is the cost/benefit ratio to consider. It does not solve any problems for us to run fiber to the desktop. Sometimes the lack of speed is at the application end. I can get to ‘the front door’ quicker, but the administrative system is not going to cough up the information any faster.”

Transmission Standards

For wired connectivity from the backbone to the desktop, Fast Ethernet is by far the leader, with fully 81.5 percent of institutions currently using Fast Ethernet a “considerable amount” or for “almost all” connectivity (see Table 4-7). Token ring has a small installed base, with only 3.7 percent of campuses still using this standard. As with transmission standards on the backbone itself, higher education appears to be ahead of the corporate sector. Meta Group estimates that Fast Ethernet constitutes only 50 percent of the typical corporate enterprise connectivity environment. More than a quarter of installed LAN equipment uses the 10-Mbps standard, and token ring and asynchronous transfer mode make up another 8 percent. Eventually, analysts say, the standard approach will be to deploy 10-Gigabit on the core network and Gigabit Ethernet to the desktop. C. William Day of the KDB Planning Group describes the situation in the wireless world, where “802.11b is declining, 802.11a never got off the ground, and 802.11g is growing.” Indeed, Table 4-8 shows that respondents identified the 802.11b (11 Mbps) standard as

### Table 4-7. Wired Transmission Standards for Connecting to End Devices

<table>
<thead>
<tr>
<th>Transmission Standard</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Adoption Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Ethernet (100BaseT)</td>
<td>4.14</td>
<td>0.893</td>
<td>Considerable to almost all</td>
</tr>
<tr>
<td>Switched Ethernet (10BaseT)</td>
<td>2.83</td>
<td>1.219</td>
<td>A little to some</td>
</tr>
<tr>
<td>Gigabit Ethernet (1000BaseT)</td>
<td>2.54</td>
<td>1.041</td>
<td></td>
</tr>
<tr>
<td>Shared Ethernet (10BaseT)</td>
<td>1.80</td>
<td>0.888</td>
<td>None to a little</td>
</tr>
<tr>
<td>Token ring (4 or 16 Mbps)</td>
<td>1.05</td>
<td>0.260</td>
<td></td>
</tr>
</tbody>
</table>

1=none, 2=a little, 3=some, 4=considerable, 5=almost all

### Table 4-8. Wireless Transmission Standards for Connecting to End Devices

<table>
<thead>
<tr>
<th>Transmission Standard</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Adoption Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b (11 Mbps)</td>
<td>2.74</td>
<td>0.963</td>
<td>A little to some</td>
</tr>
<tr>
<td>802.11g (54 Mbps)</td>
<td>2.01</td>
<td>0.916</td>
<td>A little</td>
</tr>
<tr>
<td>802.11a (54 Mbps)</td>
<td>1.42</td>
<td>0.663</td>
<td>None to a little</td>
</tr>
</tbody>
</table>

1=none, 2=a little, 3=some, 4=considerable, 5=almost all
the most common standard deployed—used by 90 percent of the institutions surveyed. The 802.11g standard, backward compatible with 802.11b and currently the preferred standard, is also gaining—used by two-thirds (66.0 percent) of the institutions.

We looked at how many of these transmission media and standards for desktop connectivity campuses host simultaneously (Figure 4-11). The median number of transmission media types in use (of the nine shown in Figure 4-7) between the backbone and the desktop is five, one more than for media used in the backbone itself. For wired connectivity to the desktop, most institutions say they are currently using three or four standards, with the median being three.

Campuses most commonly support two of the three wireless standards surveyed (42.2 percent). This is not surprising, as wireless standards continue to evolve rapidly. As Yvonne (Bonnie) Davis, director of network engineering and operations, California State University at Northridge, explains, “When standards change and equipment comes to the end of its life span, we revisit and upgrade our wireless infrastructure accordingly.”

**Wired Networks Complete; Wireless Networks Gaining**

The data in Figure 4-12 clearly show that our respondents are now generally “hard-wired.” Nearly all respondents said that “almost all” of their administrative offices

![Figure 4-11. Number of Transmission Media and Standards Supported (Backbone to Desktop)](image-url)

![Figure 4-12. Comparison of Wired and Wireless Installations (Mean Value)](image-url)
and faculty offices were hardwired. Only one respondent said that administrative offices were less than “considerably” hardwired, and only three respondents said the same of faculty offices. Most institutions also report that “almost all” of their libraries (78.5 percent), residence halls (71.8 percent), research facilities (67.2 percent), and classrooms (69.8 percent have a single connection) are hardwired. Of those that don’t say “almost all” are hardwired, most say that these spaces are at least “considerably” hardwired. Again, only a handful of institutions report little wiring in these areas. Further, standard deviations for responses are very small, indicating strong agreement about these findings.

Wireless access is making inroads across the board as well; almost all of our interviewees mentioned that wireless deployment was well under way. Rocky Jenkins, director of network and systems services, Eastern Michigan University (EMU), notes, “Although wireless by itself is not necessarily a strategic application, it has the potential to make a massive impact on learning and to improve efficiencies. For example, those handling work requests around campus now have more efficient information access. It also facilitates better emergency access to information by first responders. EMU is only in the beginning stages of fleshing out how wireless will impact our university over the long term, but its potential is immense.”

Wireless networking expansion is especially prevalent in areas that were not as quickly hardwired, whether because of structural issues or because of cost and priority. Although higher education is “hardwired,” much of that wiring is no longer up to date, and this may motivate a leap to wireless as an alternative to investing in upgrading the hardwiring in some areas. Also, indoor public spaces (such as dining halls, lounges, and lobbies) and classroom seats show an almost equal split between wired and wireless network connectivity. Clifford Lynch of the Coalition for Networked Information notes, “We all remember the rhetoric in the 1980s about the wired classroom, built with Ethernet to every desktop. A few were built at very high cost, and they were scheduled from dawn to dusk. It was such a nuisance to get access to these rooms that most faculty didn’t deal with the notion of student connectivity during the class—thinking about what classes were and how to teach them. Now we have actually done it with wireless—realized the wired classroom vision of the 1980s on a very broad scale.”

Colleges and universities have also made some progress in providing wireless access in outdoor spaces. Only about a third of institutions (36.3 percent) do not yet provide wireless access in outdoor spaces, and 11.0 percent reported that a “considerable” number of or “almost all” outdoor spaces are now wireless. Standard deviations for wireless standards are larger than for wired standards, indicating a wider range of opinions about wireless access implementation.

Differences in desktop wiring patterns emerged on the basis of Carnegie class (Figure 4-13).15 Doctoral institutions report more wireless access in classrooms and public spaces (indoor and outdoor). Also interesting is the strong showing of associate’s institutions when it comes to hardwiring all seats in a classroom, possibly reflecting their early focus on integrating basic technologies into teaching. Another interesting finding is the link between an institution’s primary network goal and wireless implementation: respondents from institutions with a goal to provide “leading-edge” network performance and services report more wireless deployment in all areas.

**Wireless Replacing Wired Networks**

Most institutions are expanding their wireless networks and see them as supple-
mentary to the hardwired infrastructure, especially where bandwidth is important. Alan Bjornsen, in an American School of University article, says that “Wireless allows the user to unplug from the wall and have more mobility, and also allows several users to share the same wireless connection, but at the cost of having to share the same limited bandwidth.”

Joanne Kossuth, CIO at Franklin W. Olin College of Engineering, describes how students discover the pros and cons of wireless networking: “First-year students use wireless for everything—email, Instant Messaging, and Web access,” she observes. “Then students see the difference between plugging into a switched network versus a shared network when they use advanced modeling and simulation applications in their second or third year. They learn how the application influences their network access preferences. Even if we get up to 802.11n, which enables a gig wireless transmission, the available bandwidth will be less than half due to sharing with other wireless users.”

We did find, however, that 19.5 percent (101 institutions) of our respondents actually plan to replace wired technology with wireless networking in one or more campus areas. Figure 4-14 shows that places where students congregate are the primary areas for replacement of wired technology, including indoor public spaces (93 institutions), classrooms (72 institutions), and libraries (67 institutions). Less popular areas include lab and research facilities (43 institutions), residence halls (23 institutions), faculty offices (14 institutions), and administrative offices (11 institutions). Jose Valdes of Colorado State University notes that “these common open areas are ideal for wireless technology for mobile computing. In contrast, the physical structure of offices and labs is less conducive to ad hoc sitting arrangements, although in many of these areas a complementary wireless infrastructure is being deployed. I believe that mobility is a predominant network driver and will push wireless throughout the campus.”
As Figure 4-15 illustrates, institutions shy away from replacing wired network access with wireless primarily because of wireless technology’s insufficient performance (54.5 percent) and the existing wired network’s adequate coverage (54.0 percent). Insufficient performance was of particular importance at 72.3 percent of institutions exceeding a 15,000-student enrollment, but it was less important at institutions with fewer than 2,000 students enrolled (39.7 percent).

Funding is an issue at some institutions. “The problem is one of available funding and/or budgeting. We prioritize our wired infrastructure ahead of any wireless and are committed to a plan that provides wireless as an (overlay) technology to augment, rather than replace, our wired infrastructure,” explains Phil Trivilino, manager of network infrastructure, St. Lawrence University.
Endnotes


3. As mentioned in Chapter 3, “Methodology and Overview of Respondents,” detailed definitions of terms appear in the Glossary, Appendix C.

4. The members of the EDUCAUSE/Net@EDU Integrated Communications Strategies (ICS) Working Group feel these numbers are extremely high and offered this explanation.


8. The survey did not differentiate between physical and logical backbones. We are assuming respondents answered in terms of multiple backbones separating network usage on the same physical infrastructure.


11. “Copper Weighs in ...,” op. cit.


15. These findings concur with those in B.L. Hawkins et al., EDUCAUSE Core Data Services 2003 Summary Report (EDUCAUSE, 2004). The authors found that the highest level of penetration occurs in libraries and that doctoral institutions have incorporated wireless access into classrooms and open spaces to a greater extent than other Carnegie classes. And overall, wireless access is least available in residence halls, open spaces, and research facilities.

Increasingly, higher education’s thinking about networks extends beyond its physical borders. Commodity Internet access is now pervasive for access to myriad campus services such as student services portals, course management systems, and library resources. And colleges and universities are connecting to a growing infrastructure of state, regional, and national research and education networks that offer a range of services—from production networks to a cutting-edge research networking environment. This chapter looks at how students, faculty, and staff access institutional resources from off campus and how they connect to resources external to campus.

**The Commodity Internet**

Today, students, faculty, researchers, and staff all rely on the commodity Internet for many of their campus activities. For example, Eastern Michigan University’s Rocky Jenkins, director of network and systems services, says their CIO “has given us a guiding principle as we select and implement new technologies: Deliver everything via a Web browser to enable our users to access any resource just as easily from a hotel room in Seattle as from their campus office.” As Figure 5-1 illustrates, our responding institutions make substantial bandwidth available from the commodity Internet. Bandwidth ranging from 4.6 Mbps to 89 Mbps accounts for 60.6 percent of institutions. And almost a tenth (9.9 percent) of our respondents tell us they provide 300 Mbps or more bandwidth. Of these institutions, 32 out of 51 are doctoral universities.

**Key Findings**

- Higher education institutions and organizations are actively building a private infrastructure of state, regional, and national research and education networks. Approximately 26,000 segment-miles of dark fiber have been acquired as part of these initiatives.
- Doctoral institutions are most likely to connect to all of these national research and education networks. Master’s, baccalaureate, and associate’s institutions are most likely to connect to a state educational and research network.
- Institutions are moving away from providing remote access via internally managed modem pools. Doctoral and large institutions are most likely to still use these campus modem pools.
- Although most institutions connect to the commodity Internet via leased circuits to an Internet service provider (ISP), there is a trend to use private fiber connections or to co-locate network facilities, especially among doctoral institutions.
- Institutions widely use virtual private networks to provide remote access, especially to staff and faculty.
Not surprisingly, our data show a clear relationship between the size of the campus network and the availability of Internet bandwidth (see Figure 5-2). Most very small networks of 1,000 or fewer devices (46.6 percent) make 4.5 Mbps or less bandwidth available from the commodity Internet, while most very large networks of more than 20,000 devices make 300 Mbps or more available (41.3 percent).

We also asked how institutions physically connect to the Internet. Figure 5-3 shows that most use leased circuits from ISP locations (73.3 percent). However, there is a trend to co-locate network facilities at the ISP (11.6 percent), especially among doctoral institutions (25.4 percent). There is an even stronger trend to connect to the Internet through a private fiber connection (28.4 percent of respondents). Again, doctoral institutions are more likely to have private fiber connections (40.0 percent). Canadian institutions surveyed also show a preference for private fiber connections, with over half (53.3 percent) connecting to the Internet in this way.

**Remote Access**

Today, most institutions and corporations must support remote access for users who...
are becoming ever more mobile—working extended hours from home and communicating from other cities. In higher education’s fluid environment, where students and faculty often live and spend much time off campus, this is especially important. Overall, 77.4 percent of institutions do provide remote network access to their campus backbone, with doctoral institutions most likely to do so (92.3 percent) and associate’s institutions least likely to do so (65.9 percent). However, Figure 5-4 shows that the clearest trend is based on institution size. Large institutions most often provide remote access; in fact, only three institutions with more than 15,000 students didn’t provide remote access to their users. We found no significant differences between public and private or between Canadian and U.S. colleges and universities.

Figure 5-5 illustrates that institutions most commonly provide remote access via an internally managed modem pool (58.0 percent). Fewer than one-tenth of institutions use other methods, such as outsourcing a modem pool (6.6 percent), obtaining discounts with ISP accounts (9.7 percent), or subsidizing ISPs (8.9 percent). Doctoral institutions are more likely to have an internally managed modem pool (73.8 percent). Canadian institutions have a different profile, with only 50.0 percent having an internally managed modem pool. Instead, they more often outsource their modem pool (23.3 percent). Size also plays a role in an institution’s choice to arrange ISP discounts: while only 5.0 percent of institutions with an enrollment of 4,000 or less provide ISP discounts, 18.1 percent of institutions with enrollments over 15,000 do so. It makes sense that larger institutions can better leverage their populations to negotiate discounts.
In light of the rapid rise of dial-up providers and increasing availability of broadband, many institutions are phasing out their internal modem pools. As Colorado State University’s Scott Baily, associate director for networking, observes, “Less than 5 percent of our students subscribe to the university’s modem service. Though modem pool usage has steadily declined over the past several years, CSU feels strongly about providing this service. Many faculty, staff, and retirees like it and feel it is a bargain. That group makes up two-thirds of the current subscriber base. As long as the modem pool satisfies a need and is self-sustaining, we’ll continue to support it.”

This trend away from internally managed modem pools is corroborated by the ECAR study on security, which found that in mid-2003, 76.2 percent of institutions were using a campus modem pool. This 2004 study finds that only 58.1 percent are doing so. And recently, from a student perspective, the ECAR 2004 study on students and information technology reported that only 8.6 percent of seniors and 14.7 percent of freshmen used a university-operated dial-up modem service. Brian D. Voss of Indiana University sums up by saying that “modem pools are dinosaurs” and further recommends “getting out of the biz of being an ISP.”

Institutions are choosing to implement virtual private networks (VPNs) as part of providing remote access (see Figure 5-6). “VPNs do a couple of things for us,” explains Spero Bowman, CIO/associate vice president for academic resources and planning, California State University at Northridge (CSUN). “They provide us with an additional security layer, as well as give us a little more flexibility. We also provide a modem pool. Home computers, however, can be an enormous source of infections, which needs to be addressed.”

Almost three-fourths of institutions provide VPN capability to staff (70.1 percent),
more than half of our institutions provide this service to faculty (55.8 percent), and more than one-quarter of institutions provide this service to students (28.0 percent). Half of institutions (49.5 percent) provide access to both faculty and staff, and more than one-fourth (26.7 percent) of respondents said they provide VPNs to all of these user groups—staff, faculty, and students. We found a relationship between institution size and VPN provision: larger institutions are more likely to make VPNs available to campus constituents. Canadian institutions mirrored U.S. institutions in VPN deployment.

**Connections to External Networks**

Our interviewees told us there is currently much effort and energy devoted to creating and/or joining external educational and research networks. Figure 5-7 shows the major types of external networks and the extent to which institutions are participating in these networks. We find that 39.3 percent of institutions connect to a university system-wide network. State educational and research networks are also quite popular, with 43.0 percent of respondents participating. Regional gigaPOPs connect 24.8 percent of our responding institutions.

The choices institutions make as to which external networks they join relates strongly to their Carnegie class. Doctoral institutions are most highly connected to all types of the higher education networks shown in Figure 5-8. State research and educational networks are the most common choice among master’s, baccalaureate, and associate’s institutions.

---

**Figure 5-7. Connection to External Networks (Multiple Responses Allowed)**

**Figure 5-8. Connection to External Networks, by Carnegie Class (Multiple Responses Allowed)**
Doctoral institutions clearly have the most connectivity to external research and education networks, as research needs demand access to external resources and are increasingly multi-institutional. For example, not long after her appointment as Hampton University’s first CIO, Debra S. White, a former IBM executive, found that in addition to managing a campus IT network upgrade, she had to contend with demanding scientists conducting nationally acclaimed and highly advanced research involving elements that far eclipse typical administrative and educational needs. Indeed, a U.S. Department of Energy study found that the network requirements for scientists in high-energy physics, astrophysics, fusion energy, climatology, bioinformatics, and other data-intensive fields will reach the terabit-per-second range within the next decade.

External Networks: Putting the Pieces Together

Completion of a higher education national research and education infrastructure requires that all these individual efforts come together—state, regional, and national networks. At the national level, Internet2 created the Abilene network, operational since 1998, to address higher education’s high-performance needs not met by the commodity Internet. It now has more than 300 Internet2 university, corporate, and affiliate member institutions and considers its mission to not only provide a leading-edge national network and enable revolutionary applications, but also to ensure the transfer of new network services and applications to the broader Internet community.

The National LambdaRail (NLR) nationwide infrastructure, very recently conceived, is being constructed by installing optical equipment on fiber acquired from telecommunications companies. NLR’s goal is to support a set of multiple, distinct, experimental and production networks specifically for the U.S. research and education community. Tom West, president of NLR says that “NLR is a natural evolutionary step in meeting high performance research needs. It somewhat mirrors the behavior of the research and education community where physicists want to communicate with physicists, astronomers with astronomers, etc. If they have an option to have their own dedicated network for a project or the discipline, they will.”

At the state and regional level, 34 research and education networks are now in place or being implemented. Most of these are moving toward a model of facility-based networking built with owned assets, called regional optical networks (RONs). These regional networks give their constituents connectivity to external networks, and their constituencies are growing. Jim Dolgonas, president and COO of the Corporation of Education Network Initiatives in California (CENIC), describes their evolution toward supporting the larger education and research community. “CENIC has gone way past its original vision as a network just for research institutions to including K–12 (currently about 85 percent of school districts and 80 percent of schools are connected), the California State University (CSU) system, and all of the community colleges. There are gigantic economies of scale. Economically it just makes sense to operate a statewide network.”

Internet2’s Doug Van Houweling considers working with state and regional initiatives one of Internet2’s most challenging roles—to share vision and ensure a common architecture and proper integration. “It all needs to come together as a higher education network. For example, Louisiana does not benefit from just Louisiana connectivity. They need connectivity to the U.S. and the world—the local must be incorporated into the national. The investments are regional, but the benefits go far beyond the region.” NLR President Tom West is also a strong advocate of the research
and education network infrastructure helping to reach all citizens. He says, “I believe that the research and education community has a stewardship role to the larger community. We must provide connectivity to every location in the country.”

As these efforts build the educational infrastructure outward into the community, metropolitan wireless technology is now helping small towns reach these networks. Mark Luker, EDUCAUSE, reflects that “the missing link is that last mile, where cities and rural areas are not fully wired, where the telcos won’t go. Here, the huge breakthrough is wireless. Small towns are starting to install wireless—putting antennas on grain silos and water towers. This is happening on a wide scale, with hundreds of small towns across the country. They can network the whole town in one day for very little money, and that brings high speed access to them all at once.”

These private initiatives have benefited from the market conditions in the telecommunications sector by acquiring unused (dark) fiber at affordable prices. Ed Gubbins, in a Telephony article, says that “The low price of distressed assets, combined with new federal funds from the National Science Foundation, has tempted a number of states and universities to build their own fiber networks.” Several telecommunications providers—for example, Level 3 and Qwest Communications—have sold large amounts of dark fiber to research and education groups, and AT&T donated 6,000 miles of fiber plus associated optical equipment to the Southeastern Universities Research Association (SURA). An Internet2 presentation in fall 2004 summarized dark-fiber acquisitions by U.S. research and education groups (Table 5-1), and Internet2 considers this a conservative estimate.

Our study findings show that about one-third (34.1 percent) of our respondents have acquired dark fiber, with more than one-third of these planning to acquire more. Another 15.7 percent have not yet acquired dark fiber but plan to do so in the future. Doctoral institutions are much more likely to have acquired dark fiber (56.4 percent) than are master’s (25.1 percent), baccalaureate (20.2 percent), or associate’s (22.3 percent) institutions. Doctoral institutions are also the most likely to be planning future dark-fiber acquisition.

Table 5-1. Dark Fiber Acquisitions by U.S. Research and Education Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Location</th>
<th>Segment-Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENIC</td>
<td>California + nationwide</td>
<td>6,200</td>
</tr>
<tr>
<td>FiberCo</td>
<td>Nationwide</td>
<td>5,600</td>
</tr>
<tr>
<td>SURA</td>
<td>Southern United States</td>
<td>6,000</td>
</tr>
<tr>
<td>NLR Phase 2</td>
<td>National</td>
<td>4,000</td>
</tr>
<tr>
<td>OARnet</td>
<td>Ohio</td>
<td>1,600</td>
</tr>
<tr>
<td>ORNL</td>
<td>Southeastern United States</td>
<td>900</td>
</tr>
<tr>
<td>Other regional projects</td>
<td>Various states</td>
<td>1,600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>25,900</strong></td>
</tr>
</tbody>
</table>
Endnotes

1. B. L. Hawkins et al., *EDUCAUSE Core Data Service 2003 Summary Report* (Boulder, Colo.: EDUCAUSE, 2004). The 2003 Core Data Service Summary Report shows a similar pattern for bandwidths from 4.6 Mbps to more than 1,000 Mbps, but its data show significantly more respondents (21.6 percent) for bandwidth of 4.5 Mbps or less. This may be due to the difference in sample populations for the ECAR study and the core data survey, especially its larger number of small institutions.


5. The ECAR survey asked, “To which of the following does your institution connect?” so that the responses would reflect both direct and indirect connections.


9. Ibid.

10. Ibid.

Organization, Leadership, and Management

The real problem is not whether machines think, but whether men do.
—B. F. Skinner

Organization of Networking

Chapters 4 and 5 examined the infrastructure of an institutional network, its components, its desktop connectivity, and its external links. This chapter covers the human dimension of networking, focusing on organization, institutional attitudes and involvement, and management practices that facilitate optimal networking operations.

Key Findings

- Overwhelmingly, institutional leadership perceives the campus network as an essential resource and critical infrastructure. Most also consider the network a strategic resource.
- The functions for voice communications and data networking are largely converged, reporting either to the same organization or department or to the same executive.
- Data network spending has increased over the past three years and is expected to continue increasing over the next three years.
- The largest network investment anticipated over the next three years is for network components and software and for wireless networking.
- CIOs and networking directors are strongly involved in network-related decisions. Academic leadership and faculty are not very involved.
- About one-fourth of respondents use service-level agreements (SLAs) with some user groups. Penalties for unmet SLAs are seldom employed.

networked file services, and network applications such as e-mail—responsibilities handled perhaps by other parts of the central IT organization or distributed outward to local school or departmental IT staff. Size also plays a role: larger institutions (more than 8,000 students) are less likely than their smaller counterparts

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to report that the central networking unit provides networked print services, networked file services, and network applications.

Integration of the institution’s voice communications and data networking functions is commonplace. Overall, 66.3 percent of respondents’ central networking units manage both voice and data communications, and 42.6 percent handle video services as well. Figure 6-2 illustrates that at almost two-thirds of responding organizations (65.0 percent), both voice and data functions report to the same department or organization. Karin Steinbrenner, associate provost and CIO, University of North Carolina at Charlotte, describes her IT area’s integration. “Over a year ago, I took charge of the telecom operation that used to report to Facilities. I would like to go even further and integrate the help desk staff and the technical staff in both the telecom and networking groups into a single unit.” Results were consistent across Carnegie class, institution size, and private versus public status, with the exception of baccalaureate institutions: 26.3 percent stated that voice communications and data networking report to different executives, compared with 14.5 percent of total respondents.

### Staffing

Several interviewees mentioned adequate staffing as a critical issue. As Lucinda Lea, vice president for information technology and CIO, Middle Tennessee State University, points out, “The growing number of network connections, the expansion of wireless capability, and the escalation of security issues all impact staffing requirements.” One testament to networking’s importance is that IT leaders continue to hire more networking staff. A 2004 national poll of 1,400 CIOs conducted by Robert Half International, the professional

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**Table 6-1. Central Network Organization Responsibilities (Multiple Responses Allowed)**

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data networking hardware (such as routers)</td>
<td>99.0%</td>
</tr>
<tr>
<td>Data network security</td>
<td>97.3%</td>
</tr>
<tr>
<td>Data networking cable plant</td>
<td>90.5%</td>
</tr>
<tr>
<td>Networked applications such as e-mail</td>
<td>74.9%</td>
</tr>
<tr>
<td>Networked file services</td>
<td>74.5%</td>
</tr>
<tr>
<td>Networked print services</td>
<td>69.5%</td>
</tr>
<tr>
<td>Overall IT security</td>
<td>69.2%</td>
</tr>
<tr>
<td>User account management</td>
<td>68.5%</td>
</tr>
<tr>
<td>Voice communications</td>
<td>66.3%</td>
</tr>
<tr>
<td>Data center operations</td>
<td>64.6%</td>
</tr>
<tr>
<td>Enterprise directory services</td>
<td>64.6%</td>
</tr>
<tr>
<td>Desktop support</td>
<td>49.9%</td>
</tr>
<tr>
<td>Help desk</td>
<td>49.9%</td>
</tr>
<tr>
<td>Video services</td>
<td>42.6%</td>
</tr>
<tr>
<td>Other</td>
<td>19.7%</td>
</tr>
</tbody>
</table>
staffing firm, found that networking was the specialty experiencing the most growth within IT departments, followed by information security and application development.¹

Considering the variation in responsibilities assumed by central networking, and differences in institution enrollment, geography, mission, and network goals, we weren’t surprised to find a wide range of staffing levels. Table 6-2 shows that 39.3 percent of respondents employ five or fewer full-time-equivalent (FTE) staff and 28.8 percent employ between 6 and 10 staff (these numbers include student FTE). More than one-third of doctoral institutions (36.4 percent) employ more than 25 staff, and almost half of doctoral-extensive institutions (47.7 percent) do so. Additionally, 43.9 percent of institutions with 15,000 or more students have more than 25 staff in the central networking unit.
Table 6-3 shows the median number of central network staff for institutions of varying sizes.

**Outsourcing**

Given the wide range of responsibilities, activities, and staffing levels in central networking organizations, we were curious as to how likely higher education is to outsource any networking activities. Almost three-fourths (73.0 percent) of respondents say that they are either very unlikely (55.7 percent) or unlikely (17.3 percent) to outsource any networking activities in the next two years. Mark Katsouros, communications integration engineer, University of Maryland, College Park, postulates that “one reason outsourcing is not prevalent is that colleges and universities have access to a cheap, but intelligent, labor source—computer science, engineering, and other students. Many are ‘campus forever’ types who get a job on campus and never get around to leaving.”

Jim Jokl, director of communications and systems at the University of Virginia, also notes that institutions “tend not to outsource functions that they think are strategic.” Our data support this notion in that 81.2 percent of respondents said institutional leadership views the campus network as a strategic resource. Further, we reported earlier that more than one-fourth of institutions (27.9 percent) view their network, now or in the future, as a strategic differentiator for the campus. Jokl also

<table>
<thead>
<tr>
<th>Number of Central Network Staff</th>
<th>Percentage of Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 or fewer</td>
<td>12.0%</td>
</tr>
<tr>
<td>3–5</td>
<td>27.3%</td>
</tr>
<tr>
<td>6–10</td>
<td>28.8%</td>
</tr>
<tr>
<td>11–15</td>
<td>10.3%</td>
</tr>
<tr>
<td>16–20</td>
<td>4.8%</td>
</tr>
<tr>
<td>21–25</td>
<td>2.8%</td>
</tr>
<tr>
<td>More than 25</td>
<td>14.0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student Enrollment (FTE)</th>
<th>Median Number of Central Network Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,000 or fewer</td>
<td>3–5</td>
</tr>
<tr>
<td>2,001–4,000</td>
<td>3–5</td>
</tr>
<tr>
<td>4,001–8,000</td>
<td>6–10</td>
</tr>
<tr>
<td>8,001–15,000</td>
<td>6–10</td>
</tr>
<tr>
<td>15,001–25,000</td>
<td>11–15</td>
</tr>
<tr>
<td>More than 25</td>
<td>More than 25</td>
</tr>
</tbody>
</table>
guesses that “there may be more insourcing over time for institutions now outsourcing voice communications. As they move to VoIP, they may bring the function back in house.” Qualitative research revealed various reasons for not outsourcing. One is cost. Perry Hanson, CIO and associate provost for academic technology, Brandeis University, explains, “About every five years, I receive a request from our president or a trustee to evaluate outsourcing our help desk. Every time I get down to the dollar and cents, I find our IT organization manages it at a fraction of the outsourcing company’s proposed costs.” Another reason is the perceived uniqueness of the higher education IT environment, which precludes cookie-cutter outsourcing solutions. As observed earlier in Table 4-2, almost half (48.9 percent) of respondents feel that the institution’s diversity and complexity suffice to make networking best managed by the institution.

Higher education’s reluctance to outsource contrasts with the corporate environment where, according to Gartner, Inc., “Outsourcing is becoming the dominant way that enterprises buy IT services.” Allie Young, research vice president for Gartner’s sourcing group, further states that “the imperatives for enterprises that are considering outsourcing are constant—focus on core business, access to critical technical expertise, and optimized IT operations.” Cost is also a driver causing corporations to reduce expenses through the “global sourcing” of IT services. And Scott McNealy, Sun Microsystems’ CEO, predicts that “companies will have to lay off up to 90 percent of their IT staff and outsource the bulk of their systems to remain competitive.” He questioned the wisdom of IT directors managing their own e-mail servers, enterprise resource planning, and human resources systems, noting that they are very similar and “no longer give firms an edge over their rivals.”

Our data do indicate that a contingent of respondents, almost one-fifth (19.7 percent), are considering outsourcing. Perhaps some of these institutions don’t have access to a strong student labor source. Some respondents are already outsourcing networking activities and report successful experiences. For example, Clive Houston-Brown, CIO at the University of La Verne, partially outsources network support activities to provide expertise and additional staffing during and after his institution’s network infrastructure upgrade process. “Once the project is complete,” he says, “the university network staff has the opportunity to upgrade their skill sets to fully manage the new infrastructure. The partial outsourcing solution will provide the university with ongoing network expertise, support, and resources without having to hire additional network staff.”

Jackie Zelman, vice provost and college CIO at Miami Dade College, reports positive results in outsourcing portions of the network architecture design function and all of its copper and fiber cabling installation and maintenance.

Two respondents outsource all technology management, including networking. Dale Marchand, CIO at Immaculata University and a SunGard Collegis employee, says, “The outsourcing arrangement allows the institution to focus on its core mission of education without having to expend a lot of energy on hiring and staffing information technology, which can be especially difficult in a geographical area such as ours that is very high-tech oriented.” Raritan Valley Community College has a contract with SunGard SCT, and Chuck Chulvick, vice president, learning and technology services, says, “We are very pleased with the results—the technical competence as well as the staff stability and continuity of service.”

Southwestern University recently outsourced its Internet access and residence hall...
network (ResNet). The vendor, Apogee Tele-
com, delivers a 10-Mbps connection for the
academic and administrative users and a man-
aged 35-Mbps connection for the residence
halls. They also provide core and edge net-
work equipment to support ResNet and offer
a university-subsidized low-speed connection
for free. Apogee is responsible for bandwidth
management, customer support on network
issues, billing, and all other network-related
issues. Bob Paver, associate vice president of
information technology services, says, “We are
quite pleased with the results. The university
has much-improved Internet service, especially
for students, with minimal capital expense. Stu-
dents benefit from a predictable service at a
reasonable rate. The university benefits from an
Internet connection that is more than twice as
fast for approximately the same cost.”

Funding and Purchasing Practices
To understand data network funding levels
in higher education, we first asked respon-
dents to estimate the portion of their total
central IT budget that is spent on data net-
working. More than one-half (54.3 percent) of
respondents report that data networking con-
stitutes 20 percent or less of the total central
IT budget (excluding voice communications
and data center operations). Voice communi-
cations generally makes up a smaller portion
of the budget; 57.3 percent of respondents
spend 10 percent or less of their total central
IT budget on voice communications. As with
staffing levels, these numbers reflect the great
variation in institutional size and mission, and
the networking responsibilities and goals.

The good news is that our data suggest
many institutions do recognize the network’s
importance and are prepared to finance it de-
spite difficult financial situations at many cam-
puses. Figure 6-3 shows that 66.7 percent of
respondents said their institution’s spending
on data networking increased during the past
three years, and 74.6 percent anticipate this
positive trend will continue in the upcoming
three years. When we examined spending
changes by Carnegie classification, doctoral
and master’s institutions were slightly more
bullish on future spending: they predicted a 10
percent (median) increase over the next three
years, versus a 5 percent (median) increase
predicted by baccalaureate and associate’s
institutions. Nationally, Forrester Research
predicts, “Network equipment spending will
grow modestly at an average CAGR (com-
pound annual growth rate) of 4 percent,”
driven by the “need to replace aging LAN
equipment and investments in network se-
curity applications.”

It is interesting to note that this pattern
of past and future network spending is con-
sistent for institutions whether or not they
identify inadequate funding as a barrier to
delivering network services. And we found

![Figure 6-3. Change in Data Network Spending](image)
no differences between public and private institutions. This finding is consistent with the recent ECAR study on IT funding in higher education,\(^8\) which reported that public institutions believed their projected levels of IT funding wouldn’t keep pace with technology advancements in any area except data communications. ECAR’s IT funding study further found network services to be the area most often identified as having the largest one-time IT investments over the past three years. Network services was also identified as a top area of planned investment for the next three years.\(^9\) And further, network equipment was identified as one of the two fastest growing IT budget items, both in the last three years and anticipated for the upcoming three years.\(^10\)

**Funding Sources**

By far the most common funding source for central data networking operations is an annual IT budget allocation (93.2 percent), as Figure 6-4 shows. Gavin Leach, associate vice president for finance and planning, explains how this worked at Northern Michigan University. “When we designed our network and computing initiative, we built in funding not only for the computer itself but also for the software, maintenance, and the network. The network is a primary piece of the puzzle. The user utilizes the notebook to log on to the network to gain access to applications.” Further, half of respondents (50.8 percent) rely solely on the annual budget allocation; more than one-third (36.0 percent) rely on two funding sources, and 13.2 percent rely on three funding sources.

We found some differences based on Carnegie classification and institution size. Compared with total respondents, a higher percentage of doctoral institutions use per-port usage fees (28.5 percent) and other chargeback mechanisms (24.6 percent). Figure 6-5 shows that larger institutions are also more likely to use per-port usage fees and other chargeback mechanisms.

![Figure 6-4. Primary Funding Sources for Central Data Network Operation (Three Responses Allowed)](image1)

![Figure 6-5. Per-Port Usage Fees and Other Chargeback Mechanisms, by Institution Size (Three Responses Allowed)](image2)
The annual data networking budget is also the most frequent funding source (79.5 percent) for central networking upgrades and improvements (Figure 6-6). We found no meaningful differences when comparing institutions by Carnegie classification and institution size. Not surprisingly, fewer private than public institutions use legislative allocation (0.5 percent of private institutions versus 8.1 percent of public institutions) or bonds (3.6 percent of private versus 10.4 percent of public) to finance their initiatives. Only 11.8 percent of institutions report making contributions to a reserve fund.

Figure 6-7 shows what respondents predict will be their largest networking investments over the next three years. Institutions plan to invest most in network components and software (64.4 percent) and wireless networking (60.5 percent). A higher percentage of larger institutions plan to invest in cable plant expansion or upgrades, perhaps due to the physical requirements of handling the larger user population and application sets. For example, only 27.8 percent of institutions with fewer than 2,000 students plan to invest in this area, whereas 50.6 percent of institutions with more than 15,000 students do. Elazar Harel, assistant vice chancellor, University of California, San Diego (UCSD), speaks to this issue. “When we installed Category 5 cabling, we expected it to have a 15- or 20-year life cycle, but as UCSD provides Gigabit Ethernet speed to desktops, we are now using Category 6...
wiring, which is only a two- or three-year-old standard. Now there is even talk about a new standard—Category 7. Replacement is a very expensive proposition, and now we find we have to do it more frequently.”

Interestingly, staff-intensive investments such as additional networking staff (20.1 percent) and user support (6.6 percent) generated the lowest response.

Purchasing Strategies

We asked our respondents what strategy best described their network hardware purchases (Figure 6-8). Most institutions pursue a predominantly single-vendor strategy (65.2 percent), with 20.9 percent using a best-of-breed strategy. In contrast, a 2003 Networking Computing poll shows that the corporate environment is more equally divided between single-vendor and best-of-breed purchasing strategies: “52 percent favor single-vendor versus 48 percent use the best-of-breed strategy.”

Although many vendors’ products and platforms exist in the user environment, some respondents believe that a one-vendor solution lets them exert greater control over the underlying network infrastructure. “We decided to standardize on [network] equipment, to limit the variety of equipment and make things more manageable,” explains Ron Stauss, vice chancellor, information technology and telecommunication, North Harris Montgomery Community College District. Others cite the broad benefits that partnering with one vendor offers. “Our network vendor gave us a good trade-in for our old equipment,” says Phil Trivilino, manager of network infrastructure at St. Lawrence University. “In addition, they helped us to redesign our network upgrade, introducing us to a three-point distributed core design that we may not have considered otherwise. The vendor arranged for design and implementation consultants to help us.”

Doctoral institutions (26.9 percent) and Canadian institutions (31.0 percent) tend to employ a best-of-breed strategy more often than other institutions. In contrast, smaller institutions purchase network components on a case-by-case basis more often than others. For example, 24.4 percent of institutions with 2,000 or fewer students evaluate network hardware purchases on a case-by-case basis, compared with 13.1 percent overall.

Specifically, we asked what factors are most important when selecting network hardware components (Figure 6-9). As we might

Figure 6-8. Strategy for Network Hardware Purchases (N = 489)
expect, the top three factors were network hardware features (61.9 percent), cost (52.4 percent), and performance (51.5 percent). Vendor reputation, scalability, and support for standards were also important. Almost one-tenth (8.9 percent) of respondents said they were part of a larger purchasing group, and these were more likely to be public institutions (13.7 percent) than private institutions (1.5 percent). At smaller institutions, cost appears to be relatively more important. For institutions with 2,000 or fewer students, 65.9 percent rated cost in their top three criteria, versus only 45.7 percent for institutions with more than 15,000 students.

We also note that an institution’s primary networking goal relates to what factors are most important in choosing network hardware. Campuses with a goal to provide “leading-edge” network services and performance are more likely to identify support for emerging technologies (21.0 percent) and scalability (33.8 percent) as top factors, while campuses with a goal of “cost minimizing” more often identify cost as a top factor (72.5 percent).

**Leadership Perceptions and Involvement**

Today, the network is integral to most campus day-to-day activities and often strategic to long-range goals. It’s therefore important to understand senior leadership perspectives and involvement in networking decisions, and our survey asked respondents to rate their senior leadership’s perceptions about their campus network. Table 6-4 illustrates that respondents overwhelmingly believe that senior leadership views the campus network as both an essential resource (97.9 percent agree) and critical infrastructure (88.5 percent agree). And most also report that the institution’s leadership see the network as a strategic resource (81.2 percent agree), especially those institutions with a primary networking goal of providing “leading-edge” services.

A 2004 study released by Bain & Co. supports the importance of senior leadership perceptions. It found that “among executives who see IT as a growth enabler, 42 percent of IT spending goes to new systems and capabilities versus maintaining existing platforms.
But spending on new systems and capabilities drops to 30 percent in companies where managers judge IT as an inhibitor." Marist College is one institution committed to its network. “The network is seen as a key element in helping us to meet our strategic goals—in particular around e-learning and providing services at a distance,” describes Vice President and Chief Information Officer Joe Aulino. “Within the last two years, Marist installed a full Gigabit Ethernet backbone. We now have 100-Mbps connections to everyone, every office and lab. About 75 percent of our classrooms have full multimedia capabilities. We look for ways to leverage the infrastructure and generate revenue. Marist has a tremendous commitment to the infrastructure, and it is a hallmark of the institution.”

Despite the strong consensus about the network’s importance, central IT may not always know what users are planning. Only half (50.8 percent) of respondents agree that users work with the data networking group when developing or deploying new bandwidth-intensive applications—despite the potential for their activities to impact overall network performance. And again, where the institution’s primary networking goal is to provide “leading-edge” services, respondents agreed more that they worked with users in these situations.

### Table 6-4. Leadership Perceptions About the Central IT Network

<table>
<thead>
<tr>
<th>Perception</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The network is an essential resource for most members of the institutional community to perform their daily tasks.</td>
<td>4.70</td>
<td>0.597</td>
</tr>
<tr>
<td>Leadership considers the network to be a critical infrastructure, similar to dial tone or electricity.</td>
<td>4.31</td>
<td>0.842</td>
</tr>
<tr>
<td>Leadership considers the network to be a strategic resource for the institution.</td>
<td>4.07</td>
<td>0.908</td>
</tr>
<tr>
<td>Networking needs are considered when the institution undertakes construction projects (such as new building or renovation of existing structures).</td>
<td>4.06</td>
<td>1.019</td>
</tr>
<tr>
<td>Institutional users/departments work with the data networking group when developing or deploying new, bandwidth-intensive applications.</td>
<td>3.36</td>
<td>1.061</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

### Constituent Involvement

Additionally, we wanted to understand the institution’s decision-making process with regard to network architecture and infrastructure, network capacity and service levels, and network funding. We asked respondents to rate the involvement of their institution’s leadership—the director of networking, the CIO, senior administrative leadership, advisory committees, and the academic leadership and faculty. Not surprisingly, the networking director and CIO are most frequently involved in network-related decisions; other constituents are less frequently involved, especially the academic leadership (see Table 6-5). Respondents characterized senior administrative leadership and academic leadership and faculty as being involved only “seldom” or “some of the time.” One respondent commented that “networking is not rocket science. Collaboration, professionalism, realistic group efforts, courtesy, and communication will do more to enhance...”
an institution’s network than any set of electronics or infrastructure.”

Both CIOs and the senior administrative leadership are more involved in network funding decisions than in other networking decisions. However, according to the 2003 VARBusiness State of the Enterprise Spending Study, “A shift is taking place in the IT-enterprise spending world. CIOs still wield tremendous power, but they are handing off more purchasing and investment decisions to their lieutenants.” CIO involvement with networking decisions related to infrastructure and network services varies with Carnegie classification. As Figure 6-10 shows, the CIO is more frequently involved in these decisions at associate’s institutions than at doctoral institutions. Involvement in funding decisions, however, does not vary across Carnegie class.

### Management: Network Policies, Service-Level Agreements, and Metrics

In addition to the value of executive support and adequate funding, several network management practices are key. Most institutions use network policies and metrics to

#### Table 6-5. Constituents' Involvement in Networking Decisions

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Network Architecture and Infrastructure Decisions</th>
<th>Network Capacity and Service-Levels Decisions</th>
<th>Network Funding Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Director of networking</td>
<td>4.82</td>
<td>0.438</td>
<td>4.80</td>
</tr>
<tr>
<td>CIO</td>
<td>4.08</td>
<td>1.081</td>
<td>4.11</td>
</tr>
<tr>
<td>Senior administrative leadership</td>
<td>2.93</td>
<td>0.986</td>
<td>2.89</td>
</tr>
<tr>
<td>Advisory committee(s)</td>
<td>2.79</td>
<td>1.105</td>
<td>2.67</td>
</tr>
<tr>
<td>Academic leadership/faculty</td>
<td>2.65</td>
<td>0.885</td>
<td>2.55</td>
</tr>
</tbody>
</table>

1=never, 2=seldom, 3=some of the time, 4=most of the time, 5=always
evaluate their network, and some go further in using service-level agreements (SLAs).

**Policies and Procedures**

Much attention has focused on network security policies and procedures, including access control, data security, and desktop PC practices. But effective network policies and procedures in general are also important. One example is wireless technology, where the ease of installation and affordability make it simple for departments—and even students—to set up their own individual wireless networks. This can lead to incompatibility, security lapses, and other problems. Stan Schatt, vice president at Forrester Research, believes that “the set of corporate policies governing the use of wireless networks can go further than any software application in making those networks both reliable and secure.”

We found that data networking policies and procedures are fairly commonplace in our higher education sample. Nearly 8 of 10 survey respondents (77.9 percent) now have formal policies and procedures to manage data networking activities. Size of enrollment seems to play a role: only 74.4 percent of institutions with 4,000 or fewer students have network policies, whereas 91.6 percent of institutions with 15,000 or more students do. Respondents also rated the characteristics of their networking policies, and Table 6-6 shows the results. While respondents are most positive about their policies’ readability and accessibility, there is less enthusiasm about their comprehensiveness, enforcement, and currency.

**Service-Level Agreements**

Numerous responding institutions have established SLAs, and some are more comprehensive than others. Jovan Miladinovic, manager of connectivity services and IT services at the University of British Columbia (UBC), outlines the typical SLA components at UBC: service definition, fees, normal maintenance windows, problem reporting escalation procedure, problem resolution expectation, customer obligations, and liability limitations.

SLAs can help set expectations among different constituencies. Middle Tennessee State’s Lucinda Lea explains, “As the network gains mission criticality and complexity, we need users to understand the central IT organization’s first priority and resource utilization in an emergency situation.” Mike Dyre, director IT research and development, University of Louisville, elaborates further: “We believe SLAs allow us to accurately spell out the expectations, roles, and responsibilities of both the university IT department and the user. This establishes a contract that can

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**Table 6-6. Network Policy Characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easily accessible</td>
<td>3.84</td>
<td>0.817</td>
</tr>
<tr>
<td>Clear and easy to read</td>
<td>3.75</td>
<td>0.704</td>
</tr>
<tr>
<td>Applied consistently across the institution</td>
<td>3.50</td>
<td>0.937</td>
</tr>
<tr>
<td>Enforced consistently</td>
<td>3.32</td>
<td>0.969</td>
</tr>
<tr>
<td>Regularly updated</td>
<td>3.19</td>
<td>0.891</td>
</tr>
<tr>
<td>Comprehensive</td>
<td>3.14</td>
<td>0.950</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
help avoid misunderstandings and resolve questions that arise in the future.”

SLAs can also help IT organizations understand their services’ usage and value to their customer base. “If it is worth the expense to deploy a new network service, it’s worth the expense to know if the service is supporting the business goals that drove its deployment,” comments Jon Saperia, co-chair of the IETF SNMP Configuration Working Group.

One-quarter of our sample (124 respondents) use SLAs in some fashion. These SLAs occur more frequently between central IT and one or more departments or schools within the institution (71 respondents) or between central IT and the institution as a whole (53 respondents). They are used less frequently with other institutional constituents (see Figure 6-11). SLAs are more common among larger institutions. Only 13.3 percent of institutions with fewer than 2,000 students have SLAs with one or more departments; 41.0 percent of very large institutions with 15,000 or more students do.

Respondents’ SLAs vary: 99 respondents track user support, 84 respondents track availability of certain services, 38 respondents negotiate specified levels of available bandwidth, and 40 respondents specify network uptime. The focus on user support is consistent with Network Computing’s 2003 annual reader survey, which noted that “the most dramatic growth spikes in SLAs were for help desks (53 percent), internal Web sites (33 percent), and external Web sites (40 percent).” The survey also found that network availability (70 percent), throughput (52 percent), user response time (50 percent), and transaction response time (43 percent) were most frequently measured.

When SLAs are not met, the most frequent course of action is an escalation process within the institution’s IT department (66 respondents) or no penalty at all (44 respondents). Financial consequences are seldom used: only 17 respondents reported that the user would not be charged all or part of a fee or would be owed some financial compensation (see Figure 6-12). Even if ramifications for not meeting service levels are limited, SLAs can still serve a useful purpose. For example, more than half of enterprises surveyed by the Open Group’s Quality of Service Task Force say that SLAs are useful even if there are no penalties involved.

However, most of our respondents (73.9 percent) do not use SLAs at all. Perhaps Marist
College’s Joe Aulino speaks for many when he says, “As people depend on the network for everything, users need quick response and a network that doesn’t go down. If you lose a whole e-learning class, you can’t get that class back with a penalty clause in an SLA. The pressure to perform is so great that I am not sure an SLA will buy you anything. Better to have someone with a stake in the game who will suffer as much as you if there is a problem.” On the other hand, Mark Katsouros, communications integration engineer at the University of Maryland, says that “we are seeing a recent trend to use SLAs more. I see institutions sending sample SLAs back and forth. This seems to be economically driven by the need to do more with less and to be as stringent as possible, which drives us to document our interdepartmental/-unit relationships and what exact fees are for what exact services.”

Network Metrics

Metrics offer another means for the central networking IT organization to evaluate and improve network operations—the key being to collect the right kind of data. Jon Saperia emphasized in a *Network Computing* article that “just because you can gather a lot of data doesn’t mean that you should. There’s a real cost associated with collecting and analyzing network data.”

As Table 6-7 illustrates, the two most common network-related metrics used by our responding institutions are network capacity utilization (77.9 percent) and network uptime (75.2 percent). This finding corroborates the Open Group’s Quality of Service Task Force research study on current practices related to services and SLAs, which noted that “one-third [of respondents] had the most basic measure of packet loss, but 25 percent lacked uptime stats.”

![Figure 6-12. Actions if SLAs Are Not Met (Multiple Responses Allowed)](image)

Table 6-7. Network Metrics Used (Multiple Responses Allowed)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network capacity utilization</td>
<td>77.9%</td>
</tr>
<tr>
<td>Network uptime</td>
<td>75.2%</td>
</tr>
<tr>
<td>Packet loss</td>
<td>41.2%</td>
</tr>
<tr>
<td>Packet loss</td>
<td>41.2%</td>
</tr>
<tr>
<td>Actual network speeds</td>
<td>39.3%</td>
</tr>
<tr>
<td>User satisfaction</td>
<td>35.2%</td>
</tr>
<tr>
<td>Network latency</td>
<td>34.0%</td>
</tr>
<tr>
<td>Other</td>
<td>2.5%</td>
</tr>
</tbody>
</table>
We also found that larger institutions made more use of metrics for packet loss and capacity utilization. Only 63.5 percent of small institutions (2,000 or fewer students) track network capacity utilization, whereas 92.8 percent of large institutions (15,000 or more students) do so.

Respondents use network metrics for both diagnostic and planning reasons. Phil Trivilino offers a typical scenario: “I monitor the network regularly for bandwidth demand problems,” he explains. “Currently we are problem free, but monitoring bandwidth will help us to determine when to move forward with a 10-gigabit platform.” As Table 6-8 illustrates, 83.6 percent of institutions use metrics to identify and correct network problems, followed by planning for future upgrades (73.7 percent) and improving service to users (69.2 percent). And once again, institution size matters. Larger institutions are more likely to use metrics to identify and correct network problems, identify network constraints, and plan for future upgrades.

Table 6-8. Purpose of Network Metrics (Multiple Responses Allowed)

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying and correcting network problems</td>
<td>83.6%</td>
</tr>
<tr>
<td>Planning for future upgrades</td>
<td>73.7%</td>
</tr>
<tr>
<td>Improving service to users</td>
<td>69.2%</td>
</tr>
<tr>
<td>Identifying capacity constraints</td>
<td>64.4%</td>
</tr>
<tr>
<td>Justifying the need for investment in the network</td>
<td>55.9%</td>
</tr>
<tr>
<td>Reporting to management</td>
<td>51.3%</td>
</tr>
<tr>
<td>Other</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

Endnotes

3. Ibid.
5. The survey did not identify institutions that have implemented life-cycle funding, in which case their spending growth might be flat (allowing for inflation) or perhaps even negative.
7. Ibid.
10. Ibid., pp. 46–48.


17. Saperia, op. cit.

18. Ibid.
Networking Practices

This chapter discusses networking practices and how they vary among campuses. We pay particular attention to bandwidth consumption, virtual local area networks (VLANs), network directory services, network authentication, network restrictions, network management tools, and user support.

Bandwidth Consumption
Growing demand for bandwidth continues to be a major factor in network planning for most institutions. We asked our respondents to identify their top three bandwidth consumers and how they thought this would change over the next three years. Figure 7-1 shows a general consensus that, by far, the biggest bandwidth consumer is Web traffic (76.2 percent), followed by communication applications such as e-mail (52.4 percent). Close behind, 46.8 percent of respondents said that nonacademic student usage of the network for applications such as peer-to-peer (P2P) and gaming were a top consumer of network bandwidth resources. However, respondents also indicated that nonacademic student usage would drop relative to other bandwidth uses, with only 32.9 percent of respondents expecting this to be a top bandwidth consumer three years from now. This might result

Key Findings

◆ The top bandwidth consumers include Web traffic, communications applications such as e-mail, and nonacademic student usage—for example, peer-to-peer (P2P).
◆ Over the next three years, video streaming, interactive video conferencing, and IP telephony are anticipated to grow the fastest relative to their current bandwidth consumption.
◆ Almost all institutions have taken some action to minimize P2P file-sharing tools’ impact on network performance. Packet shaping is the method of choice, followed by separating the residence halls from the rest of the network and creating bandwidth consumption policies.
◆ Most institutions use multiple network management tools. The most common approach is to use stand-alone products from various vendors. However, two-thirds of respondents said they make some use of open source tools.
◆ Central networking staff at small institutions more likely have responsibility all the way to the desktop, while central networking staff at large institutions likely have responsibility only to the wall plate.
◆ About one-quarter of respondents say they provide 24 x 7 network user support. The rest provide business-hours or extended-business-hours support.
from institutions' becoming more aggressive with restrictions and policies regarding P2P usage, or because other uses may grow relatively faster.

Respondents expect applications associated with converged networks to grow most. For example, while only 7.0 percent of institutions identified video streaming as a top bandwidth consumer today, more than four times as many institutions (32.7 percent) said that in three years video streaming would become a top bandwidth consumer. This pattern holds as well for interactive video conferencing, IT telephony, and cable TV over the network. Interestingly, respondents also expect bandwidth usage by academic applications such as course management systems (CMS) and courseware as well as research computing (such as high-performance and scientific visualization) to increase significantly.

We noted some patterns with regard to Carnegie class (Figure 7-2). We expected research computing bandwidth consumption to be associated with doctoral institutions. In fact, of the 47 U.S. institutions reporting this as a top consumer, 43 are doctoral institutions and 37 of these are doctoral-extensive institutions. Although Carnegie class does not apply to Canadian institutions, our Canadian sample appears similar to doctoral institutions, with 10 out of 30 also reporting that research computing is a top bandwidth user. Another Carnegie class-related pattern emerges with respect to administrative and general academic (CMS and courseware) applications. Doctoral (23.8 percent) and baccalaureate (20.2 percent) campuses identify academic applications as top bandwidth consumers less often than do their master’s (35.8 percent) and associate’s (43.5 percent) counterparts.

We find that associate’s institutions do not report that P2P is a top consumer of bandwidth (only 14.1 percent), most likely because community colleges are not generally residential. In fact, 81 percent of associate’s institutions report that they don’t have residence halls. Canadian institutions also seem less concerned with P2P usage, with only 23.3 percent reporting it as a top bandwidth consumer.
Virtual Local Area Networks

Our responding institutions deploy virtual local area networks (VLANs) widely (see Figure 7-3). More than two-thirds use VLANs extensively or for nearly all users (68.2 percent). Only 7 percent of respondents say they do not use VLANs at all.

Given VLANs’ general benefits, we asked for more detail about how they are implemented. Figure 7-4 shows that institutions use VLANs for multiple reasons and in multiple ways. The most common usage is to segment various user populations (71.0 percent). The next most common uses are to separate organizations (43.7 percent) or data traffic types (45.6 percent).

We found doctoral institutions more likely to implement VLANs to separate organizations, support geographical separation of users, and facilitate user mobility. Larger institutions also show differences: they are more likely to use VLANs to separate organizations and to connect users in different geographical locations to the same network resources. Further, Figure 7-5 illustrates that of those institutions that deploy VLANs, most do so in multiple ways. A full 82.4 percent implement VLANs in more than one of the modes listed in Figure 7-4. The median number of types of VLAN implementations per institution is three.
Network Directory Services

We asked respondents about their use of network directory services to identify network resources (such as e-mail addresses, computers, and peripheral devices) and make them accessible to users and applications. Ideally, such a directory service should make the physical network topology and protocols transparent so that a network user can access any resource without knowing where or how it is physically connected. Figure 7-6 displays the network directory technologies used, and we found little variation among institutions. Only 3.9 percent (20 institutions) said they did not use network directory services. More than 70 percent used LDAP (Lightweight Directory Access Protocol) and/or Microsoft Active Directory. Only 2.3 percent of institutions use the pure X.500 standard (which does not support TCP/IP).

Our respondents told us what functions network directories serve at their institutions (Figure 7-7). Most use their network directory service to manage user accounts and passwords (88.4 percent), and respondents use the other functions listed more than half the time. This pattern of network directory use is consistent across private and public institutions and Carnegie class. However, institution size matters. Seventy-one percent of institutions with large networks (more than...
40,000 attached devices) use network directories to serve as a master source for user information (enterprise directory), compared with 49.3 percent of institutions with fewer than 5,000 attached devices. Larger institutions likely find it more difficult to maintain and coordinate multiple directories and are more motivated to move to a single source for storing access information. As Colorado State University’s Patrick Burns, associate vice president for information and instructional technology, explains, “Our single sign-on authentication matches against our LDAP directory, which allows us to authenticate and track users through one source.”

**Network Authentication Update**

Last year ECAR dedicated a full study to IT security in higher education,¹ which covered authentication issues in depth. Security, therefore, is considered outside the scope of the networking study. However, we did ask two questions about authentication modes, and Figure 7-8 shows the results.

![Figure 7-6. Network Directory Technologies (Multiple Responses Allowed)](image)

![Figure 7-7. Network Directory Functions (Multiple Responses Allowed)](image)
Login using an authentication server is most common, with more than two-thirds of institutions implementing this authentication method. But it is a method that “has its shortcomings, most notably the ease with which passwords can be compromised and the fact that passwords are only as good as the people setting them.”

For example, a study at the San Diego Supercomputing Center (SDSC) found that a modest Celeron-based PC could check 50 million possible passwords in about 20 minutes. Even InformationWeek’s 2003 U.S. Information Security Survey notes that “one-fourth of respondents experienced security incidents involving valid user accounts or permissions. Fourteen percent say attacks involved guessed passwords.”

As a result, more institutions are employing stronger means of authentication: more than two-fifths of institutions have implemented registration of machine access control (MAC) authentication. Although digital certificates remain new, almost 10 percent of institutions now use them. Notably, our data show no differences in these types of authentication used for wired and wireless networks. As Patrick Burns of Colorado State University points out, “The type of network infrastructure should not negate or mitigate the importance of security. In fact, wireless is more susceptible to security breeches, so it needs an elevated level of attention regarding IT security.”

Network Restrictions

As security threats loom and network usage continues to grow, IT departments are implementing various network restrictions to ensure adequate network resources and provide a safer user environment. We queried our respondents about their practices regarding network control and restrictions.

Jack Activation

A basic level of institutional control comes with jack activation policies. Do users plug in at any wall jack? Do they need to request activation? Is activation locally controlled? Table 7-1 shows no clear leader for the practice of activating jacks overall. However, we again see that practices vary strongly with institution size. Half (50.4 percent) of small institutions with 4,000 students or fewer leave all jacks active, while only 15.7 percent of large institutions with more than 15,000 students do so. This pattern may relate to the reduced staffing costs required in leaving jacks active.

We also looked at the practice of deactivating ports and found that the central networking group is authorized to deactivate a port at all but 13 institutions. At almost all institutions (90.3 percent), a port is deactivated when an issue is detected (such as virus infection). At another third (31.9 percent), the central network organization deactivates a port when an unauthenticated device connects to the port.
Restricting Access to External Destinations

Institutions implement various restrictions to control access to external network destinations. In fact, 65.2 percent of respondents reported that they do so, especially doctoral institutions (75.4 percent). Figure 7-9 shows this practice in more detail. Many institutions disallow relaying of e-mail (63.1 percent) or choose to restrict selected TCP/IP ports (54.4 percent). In larger institutions, TCP/IP port restriction is more common. And in keeping with the higher education culture, we found little censorship (only 7.9 percent of respondents restrict access to Web sites with objectionable content). Other than the differences identified above, these patterns are consistent across Carnegie class, institution size, private and public status, and U.S. and Canadian institutions.

Table 7-1. Jack Activation, by Institution Size (N = 506)

<table>
<thead>
<tr>
<th>Practice</th>
<th>4,000 or Fewer Students</th>
<th>4,001–15,000 Students</th>
<th>More than 15,000 Students</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All jacks are activated by user request</td>
<td>25.2%</td>
<td>33.1%</td>
<td>43.3%</td>
<td>30.9%</td>
</tr>
<tr>
<td>Jacks in public places are always active; jacks in private places activated by user request</td>
<td>20.7%</td>
<td>34.8%</td>
<td>25.3%</td>
<td>26.2%</td>
</tr>
<tr>
<td>Jacks are controlled by local authority (school, building, and so on)</td>
<td>3.7%</td>
<td>5.0%</td>
<td>15.7%</td>
<td>6.8%</td>
</tr>
<tr>
<td>All jacks are active by default</td>
<td>50.4%</td>
<td>27.1%</td>
<td>15.7%</td>
<td>36.1%</td>
</tr>
</tbody>
</table>

Figure 7-9. Restricting Access to External Destinations (Multiple Responses Allowed)
Bandwidth Utilization Restrictions

P2P file-sharing tools and other bandwidth-consuming applications can impact network performance, create security risks, and expose the institution to potential legal issues. Joan Kratz, vice president of marketing for BellSouth Business and previous CIO at Charleston Southern University, summarizes the dilemma: "We learned very early that we had to balance access versus abuse. When we first installed wireless access, one student was using 30 percent of the bandwidth, which leaves little access for the rest of the campus."5

Much attention continues to focus on P2P restriction practices, which is consistent with our earlier finding (refer to Figure 7-1) that nonacademic student network use (especially P2P file sharing) is a top consumer of campus bandwidth. Only 32 institutions (6.2 percent) have taken no action in this regard, and of these, 10 are associate’s institutions.

We asked our respondents what specific actions they were taking, and Figure 7-10 summarizes the findings. Overall, packet shaping is the method of choice (69.6 percent).6 The Chronicle Review predicts that “in the future, packet shapers will probably become ubiquitous, easier to use, and smarter about how they manage traffic on networks.”7 California State University, Northridge’s, Spero Bowman says they “use packet shaping to manage cyber attacks, to identify illegal file sharing, and to monitor traffic sources. If the traffic appears to be illegitimate, further analysis can be used to identify infected systems.” Separating the residence halls from the rest of the network also appears to be a preferred method.

![Figure 7-10. Actions to Minimize the Impact of P2P File Sharing, by Carnegie Class (Multiple Responses Allowed)](image-url)
Institutions described various approaches.  

◆ Thomas Danford, associate provost and CIO at the University of Dayton, said, “The peak rate of bandwidth consumption used to be roughly 30 Mbps. But when we blocked one-directional peer-to-peer traffic and installed bandwidth management, the rate fell to 17 Mbps within the first 30 minutes, giving us a 43 percent increase in bandwidth availability.”

◆ The University of Florida, Gainesville, implemented its homegrown Icarus (Integrated Computer Application for Recognizing User Services) software, which automatically terminates a student’s network connection when a file-sharing event is initiated. The result is a dramatic reduction of copyright violations cases sent to the campus judiciary, falling from “1,000 cases to four third-time violators.”

◆ Northern Michigan University’s IT department assigns a lower priority to any non-academic applications, allocating leftover bandwidth to students for general searching and other applications.

Associate’s institutions clearly show a different pattern. Their student populations are more likely to include adult and nonresidential students who use campus resources solely for college business, not for personal reasons. Indeed, Chris Smith of North Harris Montgomery Community College District found that their network had only “about 2 to 3 percent improper traffic, which is likely due to the lack of student dorms.” We found no other meaningful differences on the basis of private versus public status, size of institution, or U.S. versus Canadian institutions.

Device and Application Restrictions

Finally, we asked what devices or applications users were restricted from putting on the network. Here again, most colleges and universities do implement restrictions: only 38 institutions said they did not, and of these, 13 were doctoral institutions and 8 were Canadian. In Figure 7-11, we again see a different pattern for associate’s institutions. Their often highly centralized environment, focused on maintaining a cost-effective core business, is likely to have tougher networking standards. And in addition to these patterns for Carnegie class, larger institutions are more likely to restrict what devices and applications can attach to the network.

Network Management Tools

“Monitoring the network is increasingly critical because more and more of the core mission functions—academic and research—run on the network,” believes Marist College’s Joe Aulino. “The ability to monitor and restore a network very, very quickly is a big challenge, which is made more difficult by the security environment in which higher education resides.” IT departments do recognize the importance of network management and currently deploy an array of network management tools (Figure 7-12).

More than two-thirds of respondents (66.7 percent) report that they use some open source tools. Chris Peabody, director of enterprise network consulting for L. Robert Kimball and Associates (and formerly of Georgetown University), believes that network open source tools have become staples of most universities’ network performance management programs. “For example, MRTG (multirouter traffic grapher) is widely used by many schools to graphically display the volume of traffic on certain network segments. It’s an extremely basic, but effective, part of an overall performance management strategy. Another open source tool that is gaining in popularity is Netdisco. Originally developed at UC Santa Cruz, Netdisco allows you to locate the switch port of an end-user system by IP or MAC address. This can be a crucial tool to help locate...
Figure 7-11. Devices or Applications Restricted on the Network, by Carnegie Class (Multiple Responses Allowed)

Figure 7-12. Network Management Tools Used (Multiple Responses Allowed)
rogue users that may be broadcasting viruses or other ‘evil things.’”

Respondents also use homegrown software for network management (39.7 percent of institutions). Not surprisingly, doctoral and larger institutions more often use both open source and homegrown network management tools. It is also common practice for institutions to use more than one network management tool: 31.0 percent use two tools, 28.6 percent use three, and 13.5 percent use four.

Network monitoring was also a recurring theme—particularly its growing importance, difficulty, and cost. Ken Klingenstein, project director, Internet2 Middleware Initiative and chief technologist of the University of Colorado at Boulder, says, “We are beginning to understand how much of a network management nightmare we’ve created from some of our security approaches, and it splashes into security, network management, and other things. If a user is blocked from doing an application, who or what is blocking the path? It is very difficult to figure out whose problem it is, given the many parties and policies involved. We also lack adequate tools, and diagnostics are deteriorating. New network policy devices such as packet shapers, automated copyright/piracy detectors, etc., can do strange things at the network level and make manageability hard.” University of Washington’s Director of Networks and Distributed Computing Terry Gray agrees: “I believe passionately that the biggest threat to IT organizations is the growing complexity of the systems we deploy and the diverse decentralized organizational structures we attempt to support in universities. And I advocate a renewed focus on the plight of operations staff. With each request or bright idea for a new service, we need to think about how the folks in NetOps, SecOps, ComputerOps will cope.” Gray sees part of the answer in the increased investment in monitoring and diagnostic tools.

Our data indicate that institutions are using the network monitoring tools available today. By far, the majority of institutions actively monitor the network items listed in Table 7-2. Interestingly, although respondents identified security as a top barrier to networking (refer to Figure 4-3), intrusion detection is currently the least-used monitoring tool (62.9 percent).

Table 7-2. Network Monitoring Practices (Multiple Responses Allowed)

<table>
<thead>
<tr>
<th>Practice</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring network traffic levels and patterns</td>
<td>91.4%</td>
</tr>
<tr>
<td>Monitoring utilization of network components</td>
<td>89.7%</td>
</tr>
<tr>
<td>Identification of faulty network components</td>
<td>85.2%</td>
</tr>
<tr>
<td>Monitoring the availability and performance of key servers</td>
<td>84.2%</td>
</tr>
<tr>
<td>Selected events trigger automated notification to staff</td>
<td>80.3%</td>
</tr>
<tr>
<td>Identification of security vulnerabilities</td>
<td>77.7%</td>
</tr>
<tr>
<td>Identification of devices connected to the network</td>
<td>73.6%</td>
</tr>
<tr>
<td>Monitoring the availability of services or applications</td>
<td>72.9%</td>
</tr>
<tr>
<td>Intrusion detection</td>
<td>62.9%</td>
</tr>
</tbody>
</table>
Network Support

We looked at the level of campus support the central network group provides. Does the central network organization have responsibility to the building wall, to the wall plate, or to the actual desktop computers? Overall, institutions are fairly evenly divided between providing support all the way to the desktop (52.7 percent) and providing support just to the wall plate (42.5 percent). Only 3.1 percent reported that their responsibility ended at the building walls.

Two of our interviewees say they not only provide support to the desktop but standardize their equipment as well. “By standardizing notebooks and support, we provide students with excellent support with minimal manning and costs,” explains Larry Bryant, director, academic computing at the U.S. Air Force Academy. Cadets pay a $5-per-month fee, and a third-party contractor, Sigma Electronics, provides a staff of three to support them. Gavin Leach, associate vice president for finance and planning, says that Northern Michigan University provides each student, faculty member, and a majority of its staff with a new notebook computer every two years, which the IT department then supports. Leach notes that those that don’t have laptops have desktop computers.

Figure 7-13 shows that the extent of central networking staff’s network support responsibilities relates strongly with the size of the campus network. Network organizations at the smallest institutions with fewer than 1,000 attached devices are likely to ensure all network components’ operation, from the backbone to the desktop (87.9 percent). Network organizations at very large institutions with more than 20,000 attached devices, on the other hand, are more likely to ensure the operation of core network services, with responsibility ending at the wall plate (70.8 percent) or building walls (17.2 percent).

As institutional operations and programs become increasingly technology embedded and require network services, central IT networking units are responding in terms of user...
support. The University of Texas at Austin’s Dan Updegrove observes, “What a naïve notion it is to believe that problems will occur and nasty things will originate from the Internet only between 8:00 and 6:00.” Table 7-3 shows that all institutions but three (0.6 percent) currently provide users with at least business-hours network support or more. Fully one-fourth of institutions now provide 24 x 7 network support, and more than one-third (36.6 percent) provide extended-business-hours support. The same pattern with respect to size of network appears here: larger networks come with more extended support (Figure 7-14). This may relate to the increased number and complexity of network applications. Further, almost one-fourth (22.5 percent) of respondents reported that the network support levels they provide vary by constituent group, such as faculty, students, organizations, schools, and so on.

Table 7-3. Network Support Hours (N = 517)

<table>
<thead>
<tr>
<th>Support Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial business hours</td>
<td>0.6%</td>
</tr>
<tr>
<td>Business hours</td>
<td>29.4%</td>
</tr>
<tr>
<td>Extended business hours</td>
<td>36.6%</td>
</tr>
<tr>
<td>24 x 7</td>
<td>25.5%</td>
</tr>
<tr>
<td>Other</td>
<td>7.9%</td>
</tr>
</tbody>
</table>

Figure 7-14. Network Support Hours, by Number of Devices (N = 471)
Endnotes


6. The 2003 EDUCAUSE core data survey found that in their sample, only 9.9 percent of respondents did not use packet shaping for any purpose. Our survey asked this question specifically in relation to P2P file sharing.


Emerging Technologies and Converged Networks

Previous chapters focused on current networking technologies and practices in higher education. We now cast our gaze into the near future and examine campus adoption plans for emerging network technologies, converged networks and services, and advanced high-speed network applications.

Advanced and Emerging Technologies

Evaluating and implementing new technologies is a key role of many central IT organizations. Middle Tennessee State University’s Lucinda Lea describes this situation as “a revolving door. There are so many new technologies associated with networking that many times we are in the testing, piloting, or implementing phase of adoption.” To better understand this technological “revolving door,” we asked respondents to identify the adoption stage of several advanced or emerging technologies at their institutions.

Of the technologies listed in Table 8-1, storage-area networks (SANs) are most frequently cited as being “in wide use” (26.2 percent of institutions), and another 21.8 percent indicate SANs are “in limited use.” Indeed, storage requirements continue to escalate as applications—research, administrative, and academic—become increasingly data intensive.

Key Findings

◆ At least one-third of institutions are now using the advanced or emerging technologies of storage-area network, IP multicast, 10-Gigabit Ethernet, and 802.11g wireless Ethernet.
◆ About half of institutions are using IP video streaming or desktop video conferencing, or both. Larger institutions are more likely to do so.
◆ About one-fourth of institutions are using voice over Internet protocol (VoIP). Larger institutions are more likely to do so.
◆ The primary reason identified for implementing converged services is to provide enhanced services, followed by the intent to combine infrastructure and support staff. One-fifth of institutions also indicate their interest in reducing long-distance calling costs.
◆ Of those considering or committed to converged services, fewer than one-third have a formal, documented implementation strategy.
◆ Institutions have not yet made extensive changes in organization structure, central operations, user support, or policies to reflect the nature of converged services. Few have made changes to their financial model.
◆ Two-fifths of institutions have achieved cost savings from implementing converged networks. Another quarter of institutions expect to do so in the future.
◆ Most institutions (70 percent) now have a high-speed campus network (more than 100 Mbps). Larger institutions are more likely to have one.
Mark Clark, director of information systems, University of Manchester, notes that “the nature of documents is increasingly trending to compound documents that incorporate image, data, text, and voice annotation. E-mail is likely to shrink as a way of sharing documents, giving way to the increased use of collaborative working environments for document development analysis, editing, and even drafting. Video conferencing, particularly that on the high end associated with technologies such as access grid, are showing exponential growth. Increasingly, virtual communities will be built upon networks as the glue to provide social cohesiveness.”

One-fifth (19.1 percent) of institutions report that 10-Gigabit Ethernet is in wide use, and several of our interviewees who are not yet using 10-Gigabit Ethernet mentioned that they are moving in this direction. Fewer institutions, about 10 percent, report wide use of other technologies, including quality of service (QoS), IP multicast, and 802.11g wireless Ethernet. Further, deployment of these technologies is often associated with institution characteristics. While 10-Gigabit Ethernet is more likely to be found in doctoral institutions, IP multicast and SANs are highly associated with institution size (see Figures 8-1 and 8-2).

Table 8-1. Adoption of Advanced/Emerging Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>In Wide Use</th>
<th>In Limited Use</th>
<th>Currently Implementing</th>
<th>Implementing in Next 12 Months</th>
<th>Currently Evaluating</th>
<th>Not Considering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage-area network</td>
<td>26.2%</td>
<td>21.8%</td>
<td>9.6%</td>
<td>8.3%</td>
<td>20.0%</td>
<td>14.1%</td>
</tr>
<tr>
<td>10-Gigabit Ethernet</td>
<td>19.1%</td>
<td>15.2%</td>
<td>8.6%</td>
<td>8.4%</td>
<td>26.9%</td>
<td>21.8%</td>
</tr>
<tr>
<td>Quality of service</td>
<td>11.4%</td>
<td>22.1%</td>
<td>9.4%</td>
<td>15.1%</td>
<td>25.1%</td>
<td>16.9%</td>
</tr>
<tr>
<td>IP multicast</td>
<td>11.0%</td>
<td>35.7%</td>
<td>6.9%</td>
<td>5.3%</td>
<td>18.5%</td>
<td>22.6%</td>
</tr>
<tr>
<td>802.11g wireless Ethernet</td>
<td>10.5%</td>
<td>22.1%</td>
<td>21.9%</td>
<td>21.1%</td>
<td>20.3%</td>
<td>4.1%</td>
</tr>
<tr>
<td>IP video streaming</td>
<td>9.2%</td>
<td>43.8%</td>
<td>7.2%</td>
<td>7.8%</td>
<td>23.4%</td>
<td>8.6%</td>
</tr>
<tr>
<td>Smart cards</td>
<td>8.1%</td>
<td>10.5%</td>
<td>2.6%</td>
<td>3.4%</td>
<td>30.3%</td>
<td>45.1%</td>
</tr>
<tr>
<td>Voice over Internet protocol (VoIP)</td>
<td>7.0%</td>
<td>19.6%</td>
<td>6.2%</td>
<td>8.7%</td>
<td>43.7%</td>
<td>14.8%</td>
</tr>
<tr>
<td>IP PBX</td>
<td>6.9%</td>
<td>8.9%</td>
<td>3.9%</td>
<td>4.3%</td>
<td>40.1%</td>
<td>35.9%</td>
</tr>
<tr>
<td>Unified messaging (e-mail and voice mail)</td>
<td>5.1%</td>
<td>9.7%</td>
<td>2.2%</td>
<td>8.9%</td>
<td>36.8%</td>
<td>37.3%</td>
</tr>
<tr>
<td>IP competitive local exchange carrier (CLEC)</td>
<td>3.6%</td>
<td>3.4%</td>
<td>0.2%</td>
<td>0.8%</td>
<td>14.4%</td>
<td>77.6%</td>
</tr>
<tr>
<td>Desktop video conferencing</td>
<td>2.9%</td>
<td>47.0%</td>
<td>3.3%</td>
<td>5.3%</td>
<td>23.3%</td>
<td>18.2%</td>
</tr>
<tr>
<td>IPv6</td>
<td>0.6%</td>
<td>5.1%</td>
<td>2.8%</td>
<td>3.2%</td>
<td>39.9%</td>
<td>48.4%</td>
</tr>
<tr>
<td>Biometrics</td>
<td>0.2%</td>
<td>5.4%</td>
<td>0.2%</td>
<td>1.0%</td>
<td>20.7%</td>
<td>72.5%</td>
</tr>
<tr>
<td>Wireless CLEC</td>
<td>0.2%</td>
<td>1.0%</td>
<td>0.2%</td>
<td>0.4%</td>
<td>11.4%</td>
<td>86.8%</td>
</tr>
</tbody>
</table>
Our interviewees almost all mentioned giving priority to expanding their wireless networks. The data show that nearly one-third of respondents report either limited (22.1 percent) or wide use (10.5 percent) of the 802.11g standard, which is the latest in the maturing wireless networking industry. In fact, all but a few campuses report they are somewhere in the process between evaluating this standard and fully deploying it.

Other technologies have far more limited adoption. More than three-fourths of respondents aren’t even considering IP CLEC or wireless CLEC. IPv6 also shows very little adoption. As Peter Morrissey, a Syracuse University faculty member, observes, “All roads may lead to IPv6 eventually, but it is going to be a long, bumpy ride, and most of us have nothing to gain by climbing on board early. It could take 20 years for IPv4 address space to run out.”

**Quality of Service**

Table 8-2 indicates that 17 percent of institutions aren’t currently considering QoS and that another 15.9 percent aren’t sure. The problem that QoS schemes set out to solve is one of ensuring either that critical services are always available (dial tone, for example) or that selected bandwidth-intensive applications are guaranteed network capacity as required (a violin lesson, for example). In either example, a lack of bandwidth on demand would cause the application’s failure. The networking com-

---

Figure 8-1.
Storage-Area Network (SAN) in Limited or Wide Use, by Institution Size

Figure 8-2.
IP Multicast in Limited or Wide Use, by Institution Size
community is not in full agreement regarding the best approach to this problem. According to E. Michael Staman, Peyton Anderson Professor of Information Technology at Macon State College, “We see two philosophies on the question of QoS. Some prefer to deal with the issue by providing adequate bandwidth, ‘over-provisioning’ where necessary, as a way to ensure the availability of services. That is, ‘just throw bandwidth at the problem.’ Others approach the problem with the philosophy that involves a higher level of intervention and complexity, believing that the only way to guarantee that selected services will be continually available is to develop a relatively complex solution, such as invoking a QoS algorithm or segmenting the network by application or class of users.”

Here again, institution size matters. While 89.2 percent of institutions with more than 15,000 students are considering or implementing QoS, only 69.8 percent of institutions with 2,000 or fewer students are doing so. Respondents give three primary reasons: providing enough bandwidth for important applications (49.9 percent), laying the foundation for VoIP (45.3 percent), and preventing noncritical applications from consuming excessive bandwidth (41.8 percent).

### Table 8-2. Reasons for Considering Quality of Service (Three Responses Allowed)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not considering QoS</td>
<td>17.0%</td>
</tr>
<tr>
<td>Not sure yet—just experimenting</td>
<td>15.9%</td>
</tr>
<tr>
<td>To provide enough bandwidth for important applications</td>
<td>49.9%</td>
</tr>
<tr>
<td>To lay the foundation for VoIP</td>
<td>45.3%</td>
</tr>
<tr>
<td>To prevent noncritical applications from consuming excessive bandwidth</td>
<td>41.8%</td>
</tr>
<tr>
<td>To lay the foundation for IP video</td>
<td>30.8%</td>
</tr>
<tr>
<td>Capability came with our networking equipment</td>
<td>7.7%</td>
</tr>
<tr>
<td>Needed for another specific application</td>
<td>3.7%</td>
</tr>
<tr>
<td>Other</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

Video Streaming and Video Conferencing

Video-related technologies show the most use overall, with more than half of respondents reporting that video streaming and/or desktop video conferencing are in limited or wide use, and again we see an association with institution size (see Figures 8-3 and 8-4). A 2004 *InformationWeek* industry-wide survey that profiled use of converged services found that about half of their respondents had deployed video conferencing. “Ninety-two percent use their converged networks for data, 87 percent for messaging, 80 percent for database and storage services, 76 percent for groupware, 64 percent for security devices, 56 percent for video conferencing, 53 percent for collaborative and presentation tools such as whiteboards, 50 percent for voice traffic, 49 percent for Web conferences, Web chats, and voice mail, 44 percent for call centers.”

As more institutions incorporate faster networks, high-quality video becomes more feasible for academic and research applications. Elazar Harel, assistant vice chancellor, University of California at San Diego (UCSD), envisions two-way video interactions. “Most people do not have cameras on their computers yet because the bandwidth is limited and..."
the quality is not great—even though the cameras are quite cheap. But as bandwidth increases, there is no reason not to have two-way streams between faculty and students, with multiple video windows.” University of Washington’s Terry Gray looks forward to high-quality video conferencing for a different reason. “While in general, high-end research will drive high-bandwidth connectivity, there is one notable exception. The reason video conferencing has not yet made a dent in air travel is because current systems aren’t very good. An interesting hypothesis is that if really high-quality (lots of resolution, very low latency) conferencing were achieved, then many of us could spend less time on airplanes.”

Other factors may also contribute to the deployment of video-related services. Video conferencing is largely a new service rather than a replacement service; video streaming is increasingly feasible as institutions replace obsolete and decaying cable TV plants; and end-user empowerment is shifting video streaming away from broadcast or legacy centralized services. Importantly, real-time communications (instant messaging, voice, video) will become much more closely integrated as they converge on the Session Initiation Protocol (SIP) standard and are built into common operating system modules.

**Voice over Internet Protocol**

VoIP is currently a hot topic, with much press coverage and interest among both higher education and corporate entities. C. William Day of KBD Planning Group writes
that “it is inevitable that voice over data networks will become a standard application in educational environments. VoIP will grow in popularity as it will become more cost-effective in the long run, more flexible and easier to deploy than traditional telephony.... If a school needs to buy a new phone system but isn’t ready for VoIP, it should purchase a system that provides a migration path to VoIP.”

In fact, Allan Sulkin, president of TEQConsult Group in Hackensack, New Jersey, reports that “new VoIP lines are on track to hit 40 percent of all U.S. lines installed this year and should pass the 50 percent mark in 2005.”

Our survey data in Table 8-1 show that 41.5 percent of respondents are currently committed to VoIP, with 26.6 percent of institutions reporting that VoIP is already in use, 6.2 percent currently implementing VoIP, and another 8.7 percent planning to implement VoIP in the next 12 months. This adoption pattern is comparable to that found in an October 2004 CIO Magazine survey, which also found that about half of respondents were committed to VoIP. In their survey, 25.5 percent of CIOs polled indicated that they had already installed a VoIP system (the ECAR survey shows 26.6 percent) and 25.9 percent said they would implement one in the next 12 months (the ECAR survey shows somewhat less at 14.9 percent).

Figure 8-5 further shows that larger institutions, by far, have led the way. While 68.7 percent of institutions with more than 15,000 students are now committed to VoIP, only 26.1 percent of institutions with 2,000 or fewer students are committed. Doctoral universities have also embraced VoIP, with 58.4 percent running or implementing VoIP within the next 12 months.

Many are waiting for VoIP to mature and are positioning their networking environment accordingly. At Colorado State University, Jose Valdes has “upgraded our legacy telephone system software and hardware to prevent us from being forced to make an immediate decision on full-scale VoIP deployment. In about three years, our current software version may not be supported, and in the interim we will be planning for the eventual conversion to VoIP.” St. Lawrence University’s Phil Trivilino notes that “there are some integration solutions that could add VoIP to the telephone switch we purchased three years ago. Most people are not yet impressed with the advanced phone features VoIP offers; people like to pick up a phone, dial a number, and talk.”

Others are taking an approach consistent with a 2004 Meta Group study that found “the most commonly cited reason for choosing convergence is either to outfit a new branch or building or the end of life or contract for PBX, Centrex, or messaging platforms.” Brandeis University originally planned to update their current telephone system but opted for VoIP. “We had an aging phone sys-
tem, failing copper underground plant, and an aging data plant. We wanted a solution to fix all these issues,” recalls Mike Fitzgerald, senior data network engineer, Brandeis. “We built a network to handle VoIP in the short run and to position ourselves to run other applications over the network in the long run.”

Most institutions use or plan to use a mixed approach to implementing VoIP. Nearly three-quarters of institutions (72.6 percent) plan to use both legacy and VoIP telephones at least during a transitional period. “We began by converting from Centrex to the VoIP system with an analog converter for our existing phones,” explains Steve Fitzgerald, chief technology officer, California State University at Northridge. “Then we deployed VoIP instruments onto the campus slowly. Most of the feature sets are limited at this point, but a standard set of features is being used by folks.”

George Mason University offers VoIP at three remote sites through Nortel Remote Office 9150 VoIP gateways, explains Randy D. Anderson, director of network engineering and technology. “This enabled us to use our standard Meridian digital phone sets at two of our sites and tie them back into our main PBX over IP connections. This gives each site a full range of phone service, just as if they were on campus, without incurring the ongoing expense of OPX circuits.” George Mason University’s third remote site uses Nortel i2004 IP phone sets, again using a single T1 line that carries both voice and data back to the IP-enabled main PBX. “If the IP phone sets continue to work out well, as they have for the past six to eight months,” Anderson continues, “we expect to install more of them in selected locations over the next few years, primarily in new buildings and in areas with recently upgraded data networks.”

Figure 8-6 shows that smaller institutions are far more likely to switch over entirely to VoIP phones: almost one-third (30.0 percent) of institutions with 2,000 or fewer students plan to replace all legacy phones with VoIP phones. Brandeis University, with a student enrollment of approximately 5,000, followed this strategy also. Anna Tomecka, associate CIO and director of information technology services, believes that “most of our users probably don’t know that it is VoIP. The only thing that has changed is the look and feel of the new instrument and the fact that the phone has to be plugged into the network jack, not the phone jack.” Conversely, no institutions with more than 15,000 students endorse this strategy.

Implementation, however, does present its challenges. “It’s a real challenge to increase the reliability of the data network to the 99.99-plus reliability of the typical voice network,” observes The University of Texas.
at Austin’s Dan Updegrove. “No one wants to pick up a dead telephone or experience voice delays in their conversations.” Mike Enyeart, scientist, Indiana University Information Technology Services, is convinced that power reliability is the most important factor in network reliability. “The only way I see to solve this reliability issue is with new power technologies such as fuel cells, ‘cold fusion,’ and so on, or to build networks that don’t require power (for example, passive fiber optic systems).”

An InformationWeek survey surfaced another interesting finding: a few organizations that did implement converged networks reverted back to separate networks. “Of those who combined their voice and data traffic onto one network, 16 percent went back to separate networks. Half of them say administrative and management problems prompted the split; 44 percent cite insufficient infrastructure. Some 38 percent also cite consistency of service issues and difficulties in resolving service problems.”

Mobile Devices on the Network

Our interviewees tell us they are closely tracking the rapid evolution of mobile devices. Mike Roberts, former Educom vice president and now of the Darwin Group Inc., believes that “the major planning assumption in the future is ‘you have to tell me why we are not going to operate it [a network] on wireless.’ We are going to assume that everyone has a wireless communicating device.” A number of our interviewees are experimenting with applications such as providing mobile devices for traveling technicians, making such administrative information as calendars and e-mail available to staff, and making basic student information available to students on limited platforms (pocket PCs, for example). Discussions raised several challenging issues related to mobility.

Reliability

The University of Washington’s Terry Gray says that “wireless networking expectations are running high already, driven by students, faculty, and staff. It has always (in my view) been a goal for IT to support ‘anytime/anyplace’ multimodal data communication. What’s new is that technology is starting to make it possible to achieve the goal. The benefits of converging Wi-Fi VoIP phones with conventional cell phones (as well as smartphone camera, Web, e-mail, and calendaring capabilities) will dramatically increase pressure on vendors and IT organizations to make it all work reliably.”

Security and Privacy

Security and privacy are big issues. UCSD’s Elazar Harel asks, “How do you deal with security across all these devices? It is bad enough to deal with security on the network with PCs, Macs, UNIX, and pocket PCs, and now you have cameras and phones. And RFID [radio frequency identification] chips are coming. How do you make them all secure?”

Integration

Terry Gray also raises the issue of application integration. “As bandwidth and penetration of wireless improve, a greater variety of applications will become indispensable via both LAN and WAN wireless. Regrettably, they will be indispensable on several different mobile platforms, and many won’t work very well for a while, thereby driving up support costs. However, cell phones have demonstrated that people will put up with really bad quality if they see a convenience or time benefit to the service.”

Business Model

Jim Dolgonas of CENIC looks at the external business model. “Wireless is really going to grow, but one problem is that the business model is not right. For example, if
you are traveling, at Los Angeles International Airport, you may pay 10 dollars to get wireless service, and then when you get to Chicago, that airport wants another 10 dollars, etc. I think it should be a monthly subscription, with new agreements that allow for roaming. EDUCAUSE’s Mark Luker adds that “The regulatory structure is designed for wires used for voice communications, and taxed by the line, etc. When convergence happens, all this has to collapse and be replaced, a huge change in our business structures to support communications. This can’t happen too rapidly or the whole network will collapse with it. This is a collision waiting to happen.”

**Moving to Converged Services**

As the previous discussions show, higher education institutions are definitely moving toward converging their network infrastructures to include data, voice, and video. Table 8-1 showed that most of our respondents are somewhere on the adoption curve between evaluating and actually running converged networks for some applications, including VoIP, IP video streaming, and desktop video conferencing. Many also expressed interest in other applications for their converged network, including cable TV, advanced telephony features, and integrated messaging.

Formal planning doesn’t appear to be common practice when it comes to converged networking. Of those respondents who indicated they are considering, implementing, or using converged services, only 28.4 percent have documented their strategy for implementing converged services: 5.6 percent have a separate, documented strategy, and the remaining institutions (23.8 percent) include converged services as part of their documented overall network services strategy. One of our survey respondents commented on this: “Convergence is likely an area where there will be those who feel compelled to ‘keep up with the Joneses,’ without a well-thought-out strategic plan.”

**Reasons for Choosing Convergence**

Figure 8-7 illustrates that for those 70 percent (360 institutions) that say they are considering or implementing converged services, by far the most common reason for doing so is to provide enhanced services to users (62.9 percent). Indiana University’s Mike Enyeart looks at convergence in terms of student behavior, where “one sees that they simultaneously use multiple IM sessions, e-mail, streaming audio media, streaming video media, multiple Web browsers, [and] collaborative software, all while carrying on live conversations.”

![Figure 8-7. Reasons to Implement Converged Services (Three Responses Allowed)](image-url)
next most commonly reported reason for convergence is to combine infrastructure and support staff (42.4 percent). Less compelling were other cost-saving reasons: only 23.2 percent of respondents identified reducing fees and reliance on external voice or video service providers as a reason for converged services, and only 20.1 percent identified the reduction of long-distance calling costs as a reason.

A 2004 *InformationWeek* survey found that cost was uppermost on their respondents’ minds as they considered converged networks. “Four out of five identified reduction of costs, 64 percent identified improved productivity, 43 percent identified the ability to provide anytime/anywhere access to company data, 43 percent stated better quality of service and applications, 35 percent said better collaboration through the use of tools such as video conferencing and video chat, 35 percent said the implementation of a unified in-box to hold voice and e-mail messages.”

Organizational Changes to Reflect Converged Services

We wanted to know what organizational and administrative changes those institutions that indicated they were considering or implementing converged services were making—in organizational structure, central operations, user support, policies, or financial models. Figure 8-8 shows that the most common change is in the organizational structure (143 institutions). Brian D. Voss describes Indiana University’s organizational changes and their impact: “We disintegrated the user services portion of the telecom services and integrated it with our overall IT support structures. By moving voice services representatives into alignment with our other user services functions, we were able to streamline the infrastructure and systems portion of the function, making it much more compact and focused, and led by a single senior manager. Our user services are now completely integrated from both a user and organization perspective, more closely matching the use of information technology by the community. I know I was initially resistant to this change, but it has worked exceedingly well for us. Make the plunge; you’ll be glad you did.”

Changes in the network financial model are least common, with only 53 institutions who are considering or implementing converged networks having implemented changes in this area. Institutions are using varying philosophies as the basis for their new financial models.

Cost Savings

Of those institutions that have actually implemented converged networks, 43.2 percent indicate that they have achieved cost savings; another 26.3 percent expect eventual cost savings. Again, Brian D. Voss at Indiana University
mentions that integrating telecom services into the larger IT organization has lowered staffing costs, especially through fewer management positions. Further, “By running our intercampus/interswitch voice connections across the same optical fiber infrastructure, we have reduced costs paid to outside telco providers. Using technology to converge these ‘backbone’ infrastructures has given us the flexibility to expand services as needed to our community, along commodity technology advancement price/performance curves, and to do so within existing budgets.”

UCSD’s Elazar Harel also details some of their cost savings from not only converged services but also from a new funding model with one charge to cover both voice and data services:

- **Centralized router maintenance and management** provide cost savings in the number of personnel dedicated to the function, training costs, and lower administrative overhead in maintenance contract management.
- **Equipment costs dropped** because centralizing equipment purchasing results in increased leverage with vendors for pricing and delivery terms, and lower costs to maintain a smaller spares/repair pool.
- **Contractor management became more efficient** because centralized, experienced project management for cabling upgrades results in lower cost, efficient installations, and shorter time frames.
- **Long-distance rates as well as other voice rates charged to the campus were drastically reduced.** Other voice rates were previously subsidizing data network costs.
- **A consistent charging methodology to all areas of the campus** eliminated the need for departments to implement cost-avoidance strategies such as installing hubs to avoid IP address charges.
- **Firmer footing with regulatory agencies** resulted because the new financial model is consistently applied and was found to be acceptable by independent auditors.

Interestingly, Elizabeth Ussher, vice president, Meta Group, notes a mixed response to their survey: “57 percent of respondents said they’ve seen marked reductions in operational costs and 60 percent cited lower circuit cost. But 36 percent reported an increase to staffing costs; 44 percent cited an increase in infrastructure costs.”

**Reasons for Not Choosing Convergence**

We were also curious why some campuses say they will not consider converged networks within the next two years (see Table 8-3). Two very practical reasons stand out: these institutions report that they have higher IT priorities (65.1 percent) and/or don’t require converged services at this time (59.5 percent). And 42.1 percent reported that they don’t see an acceptable ROI.

Almost one-third (30.2 percent) of respondents reported that they are waiting for standards to mature, perhaps reflecting that “the technology industry has been slow to adopt standards for video and voice over IP, forcing many organizations to put their convergence plans on hold or choose from among competing, proprietary solutions.” But that is changing. For example, “Session Initiation Protocol (SIP) is emerging as the protocol of choice, which is moving the vendors from offering just proprietary to interchangeable, standardized equipment solutions. This, in turn, makes converged networks and services easier and hopefully more affordable to implement, fostering mainstream adoption.”

Note that one-fifth of respondents (19.8 percent) indicated that their network infrastructure cannot support converged services at this time. Industry wide, Forrester Research found that “in most organizations, existing networks were not properly configured to support IP telephony.” A 2004 *InformationWeek*
survey studied the changes required: half of their respondents “upgraded network routers and network switches, nearly half upgraded bandwidth and servers, and slightly more than one-quarter enhanced network cabling and network management software.” In addition, Forrester Research says that “many IT buyers were unaware that security for IP telephony is separate and supplemental to data network security.”

Table 8-3. Reasons for Not Considering Converged Services in the Next Two Years (Three Responses Allowed)

<table>
<thead>
<tr>
<th>Reason</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher IT priorities</td>
<td>65.1%</td>
</tr>
<tr>
<td>Don’t require converged services now</td>
<td>59.5%</td>
</tr>
<tr>
<td>Don’t see an acceptable ROI</td>
<td>42.1%</td>
</tr>
<tr>
<td>Unwilling to discard investment in legacy technologies</td>
<td>33.3%</td>
</tr>
<tr>
<td>Waiting for technology/standards to mature</td>
<td>30.2%</td>
</tr>
<tr>
<td>Network infrastructure cannot support converged services</td>
<td>19.8%</td>
</tr>
<tr>
<td>Fragmented management structure</td>
<td>19.0%</td>
</tr>
<tr>
<td>Lack of real, understood applications</td>
<td>14.3%</td>
</tr>
<tr>
<td>Financial model unclear</td>
<td>11.9%</td>
</tr>
<tr>
<td>Funding not available</td>
<td>8.7%</td>
</tr>
<tr>
<td>Can obtain functionality we need with currently owned OS/applications</td>
<td>8.7%</td>
</tr>
<tr>
<td>Security concerns</td>
<td>6.3%</td>
</tr>
<tr>
<td>Other</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

Advanced High-Speed Networks

Figure 8-9 shows that most colleges and universities now have an advanced high-speed network greater than 100 Mbps (65.2 percent overall). This is especially true in larger institutions, where 90.4 percent of institutions with more than 15,000 students have an advanced high-speed network, compared with 47.6 percent of institutions with 2,000 or fewer students. In addition, a higher percentage of doctoral-extensive institutions (92.1 percent) use high-speed networks than their doctoral-intensive counterparts (70.7 percent). An institution’s primary networking goal may also drive adoption. We find high-speed networks in 83.5 percent of institutions that focus on providing a “leading-edge” network but in only 45.1 percent of institutions that focus on “cost minimizing.”

Higher network speeds permit enhanced network applications. For example, Northern Michigan University’s Gavin Leach plans to explore TV broadcasting over their network when their current CATV contract expires. “Our backbone can handle it; we have gigabit links all over campus, and the students’ notebooks could become their TV.” Table 8-4 shows that institutions have focused mostly on implementing new and enhanced educational applications, fol-
allowed by the sharing of high-bandwidth content across institutions, and new and enhanced collaboration tools.

Predictably, the adoption of grid computing is most prevalent at doctoral institutions (especially doctoral-extensive institutions), nearly half of which report that grid computing is already in limited use (49.4 percent). We see the same pattern in doctoral institutions’ usage of research applications, sharing of high-bandwidth content across institutions, and legitimate peer-to-peer applications.

Table 8-4. Adoption of High-Speed Network Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>In Wide Use</th>
<th>In Limited Use</th>
<th>Currently Implementing</th>
<th>Implement in Next 12 Months</th>
<th>Currently Evaluating</th>
<th>Not Considering</th>
</tr>
</thead>
<tbody>
<tr>
<td>New and enhanced educational applications</td>
<td>14.2%</td>
<td>24.7%</td>
<td>9.0%</td>
<td>8.1%</td>
<td>38.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Sharing of high-bandwidth content across institutions</td>
<td>7.1%</td>
<td>27.0%</td>
<td>8.1%</td>
<td>6.8%</td>
<td>23.3%</td>
<td>27.7%</td>
</tr>
<tr>
<td>New and enhanced collaboration tools among institutions</td>
<td>3.9%</td>
<td>30.5%</td>
<td>5.2%</td>
<td>7.3%</td>
<td>37.0%</td>
<td>16.1%</td>
</tr>
<tr>
<td>Legitimate peer-to-peer applications</td>
<td>2.8%</td>
<td>28.1%</td>
<td>3.1%</td>
<td>1.9%</td>
<td>30.6%</td>
<td>33.5%</td>
</tr>
<tr>
<td>Medical applications</td>
<td>2.8%</td>
<td>15.0%</td>
<td>2.5%</td>
<td>2.5%</td>
<td>11.9%</td>
<td>65.3%</td>
</tr>
<tr>
<td>Research applications</td>
<td>2.2%</td>
<td>32.9%</td>
<td>6.5%</td>
<td>5.5%</td>
<td>23.7%</td>
<td>29.2%</td>
</tr>
<tr>
<td>Grid computing</td>
<td>0.9%</td>
<td>18.8%</td>
<td>3.1%</td>
<td>5.3%</td>
<td>24.4%</td>
<td>47.5%</td>
</tr>
</tbody>
</table>
Endnotes


7. Our sample for this finding is based on those who indicated they were considering or were implementing converged services. This is a subset of all institutions implementing VoIP, as some institutions that said they are implementing VoIP did not say they were considering converged services.

8. Travis, op. cit.

9. This finding is from that subsample of institutions that are “considering or implementing” converged services (N = 360). This number may be low, as not all institutions that said they are considering or implementing VoIP or IP video technologies also said they were considering or implementing converged services.

10. Travis, op. cit.

11. This finding is from that subsample of institutions that are “considering or implementing” converged services (N = 360). This number may be low, as not all institutions that said they are considering or implementing VoIP or IP video technologies also said they were considering or implementing converged services.

12. Ussher, op. cit.


14. Ibid.


17. Saran, op. cit.
Network Success: What Matters?

Frankly, when the network goes down around here, people don’t know how to work.
—Larry Bryant, U.S. Air Force Academy

This chapter focuses on how our respondents perceive both their network’s quality and its impact on the institution. We asked their opinions about network outcomes in four areas: the network’s increasing importance; perceived network usage by students, faculty, and staff; whether the network meets user needs; and the quality of the networking infrastructure.

The Network’s Growing Importance

We asked our respondents if they agreed with the statement “the institution’s data network is much more important to our institution’s ability to meet its strategic goals than it was three years ago.” Figure 9-1 shows an overwhelming consensus that networking is increasingly important to campus success. A full 93.5 percent agree, and of those, 61.8 percent agree strongly. Only 13 respondents did not agree. Our interviewees concurred, and some even pointed to the network as a strategic differentiator for their institution.

Joe Aulino gives an example of Marist College’s online master’s programs. “If we can structure online education in ways that are unique, to fit certain groups of people with certain needs and become leaders in meeting those needs, then we can be as successful as [the University of] Phoenix and others in that market. I see Phoenix as one model for providing a service to students who cannot get that service another way, and they have helped

Figure 9-1.
Institution’s Network Is Much More Important to Our Strategic Goals than Three Years Ago (N = 517)

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drive us to service our students better. Marist brings a culture to our online programs in a different way with a goal that students would say, ‘Marist is the best place in the world to get that experience.’”

Other respondents agree with Dewitt Latimer, deputy CIO and chief technology officer at Notre Dame, who feels that “a robust network is not so much a competitive advantage if you have one, but certainly a competitive disadvantage if you don’t. If you have buildings that drop network connections every 15 minutes or so, you have a problem. If your network is up five-nines, it doesn’t matter. When is the last time someone listed a stable electrical grid as a ‘competitive advantage’?”

**Network Utilization**

Next, we asked respondents what percentage of the institution’s students, faculty, and staff use the network at least once per day. Responses indicate that networking is now embedded in the lives of these higher education constituents. The majority of respondents report significant faculty and staff network usage: most institutions (75.8 percent) report that 90 percent or more of their staff log on to the network at least once a day, and somewhat fewer institutions (61.4 percent) report that 90 percent or more of their faculty log on to the network at least once a day.

Student use of the campus network depends a great deal on whether the campus has residence halls (see Figure 9-2). More than half of institutions (54.0 percent) with residence halls report that 90 percent or more of their students log on to the network at least once a day. Indeed, the recent ECAR study of students and information technology reported that students spend from two to five hours for each of these network activities: surfing the Web for pleasure, e-mail, and Instant Messaging. Larry Bryant of the U.S. Air Force Academy notes they used to have to tell students to read their e-mail at least daily. Now, he says, “You have to tell them to stop reading their e-mail. In my class, I have to tell them not to do Instant Messaging or e-mail. I have to say, ‘Close your notebooks, I want your attention up here.’”

**Network Meets User Needs**

Our respondents also indicated their level of agreement with the statement “my institution’s faculty, students, and staff perceive that the institution’s data network supports their needs.” Most respondents do agree that the network meets their primary constituents’ needs (see Figure 9-3). However, they are less likely to strongly agree, perhaps acknowledging room for improvement. We also see an
interesting stair-step pattern in respondent perceptions about how well the network supports the needs of staff (91.4 percent of respondents agree), faculty (77.8 percent agree), and students (only 66.5 percent agree). In fact, one in 10 respondents (11.7 percent) don’t think that students perceive the network as meeting their needs.

Clifford Lynch of the Coalition for Networked Information sees a time coming when students living on campus may see a better network life than those living off campus. “Currently, there is not much consumer market for fast broadband to the home. The bandwidth needed to deliver good video to the home is still not there. And you have got that in place in the university environment. So the future for students in the next couple of years is about video and fast image transfer as well as other kinds of interactive high-resolution stuff. I’m thinking of games, for example. There may be a very significant ‘what you can do’ gap between on and off campus.”

**Network Infrastructure Quality**

We looked at network quality indicators and posed a set of statements about the campus network’s design, security, and reliability (see below). We include a short descriptor in parentheses that we use to identify these questions throughout this chapter.

- My institution’s central network backbone is optimally designed to meet our needs for the foreseeable future (backbone optimally designed).
- My institution’s desktop connectivity is optimally designed to meet our needs for the foreseeable future (desktop optimally designed).
- My institution’s wireless connectivity is optimally designed to meet our needs for the foreseeable future (wireless optimally designed).
- My institution’s network is secure (network secure).
- My institution’s network is fault tolerant (network fault tolerant).

Figure 9-4 shows institutions’ responses to our outcome statements about the campus network design. Most respondents agree or strongly agree that their campus backbone (73.6 percent) and desktop connectivity (71.0 percent) are optimally designed. There is significantly less comfort with the current design of wireless networks: only 34.7 per-
cent agree or strongly agree that they are optimally designed. This is not surprising, given that wireless networks are both new and evolving.

Figure 9-5 shows that respondents agree more that their network is secure (43.7 percent) than they do that their network is fault tolerant (36.4 percent). This makes sense, because security is a high-profile issue with clear and present danger. Although ensuring fault tolerance is also crucial, the topic may not garner the same attention, effort, and priority.

Network Quality: What Matters?

One of our survey respondents commented, “Data networking is the engine that drives every aspect of IT in a modern organization. Administrative, academic, and personal applications simply don’t function anymore without a robust, fault-tolerant, secure network infrastructure.” We now look at what factors are associated with such a high-quality network—one that is secure, fault tolerant, and optimally designed to meet future needs. We find that campus leadership and their primary networking goal, network funding, network
policies, network restrictions, and network reliability all matter. Especially interesting is that these quality drivers of the network infrastructure show few meaningful differences between Carnegie classes, institutions of different size, or private versus public institutions.

**Strategy and Goals Matter**

Some perceptions about networking are now fully ingrained in higher education leadership thinking—for example, that the network is critical infrastructure (97.9 percent) and is an essential resource for everyday work (88.5 percent). Most also report that their leadership considers the campus network to be a strategic resource (81.2 percent), and this appears to be important. First, we found that institutions that consider the network to be strategic rate the quality of their network infrastructure higher. Second, these institutions also believe that their network better meets the needs of faculty and students, but not of staff (see Table 9-1.)

We also found differences based on an institution’s primary networking goal. Table 9-2 shows that institutions striving to provide a “leading-edge” network also rate the quality of their network infrastructure—design of the backbone, desktop connectivity, and wireless networks, as well as network security and fault tolerance—higher than other institutions. It makes sense that a focus on creating a leading-edge network would translate into a stronger network infrastructure.

**Table 9-1. Network Meets User Needs, by Network Viewed as a Strategic Resource**

<table>
<thead>
<tr>
<th>Network Viewed as Strategic Resource</th>
<th>Supports Needs of Staff</th>
<th>Supports Needs of Faculty</th>
<th>Supports Needs of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>4.20</td>
<td>3.91</td>
<td>3.68</td>
</tr>
<tr>
<td>Disagree</td>
<td>4.00</td>
<td>3.47</td>
<td>3.26</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree

**Table 9-2. Network Infrastructure Quality, by Primary Network Goal**

<table>
<thead>
<tr>
<th>Primary Network Goal</th>
<th>Backbone Optimally Designed</th>
<th>Desktop Optimally Designed</th>
<th>Wireless Optimally Designed</th>
<th>Network Secure</th>
<th>Network Fault Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost minimizer</td>
<td>Mean 3.60</td>
<td>3.65</td>
<td>2.88</td>
<td>3.08</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td>Std. deviation 0.957</td>
<td>0.961</td>
<td>1.070</td>
<td>0.875</td>
<td>0.996</td>
</tr>
<tr>
<td>Demand driven</td>
<td>Mean 3.72</td>
<td>3.58</td>
<td>2.90</td>
<td>3.17</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>Std. deviation 1.017</td>
<td>0.993</td>
<td>0.980</td>
<td>0.839</td>
<td>0.883</td>
</tr>
<tr>
<td>High speed for all</td>
<td>Mean 3.82</td>
<td>3.70</td>
<td>2.78</td>
<td>3.23</td>
<td>2.92</td>
</tr>
<tr>
<td></td>
<td>Std. deviation 1.054</td>
<td>1.015</td>
<td>0.968</td>
<td>0.942</td>
<td>1.020</td>
</tr>
<tr>
<td>Leading edge</td>
<td>Mean 4.16</td>
<td>3.89</td>
<td>3.27</td>
<td>3.44</td>
<td>3.35</td>
</tr>
<tr>
<td></td>
<td>Std. deviation 0.982</td>
<td>0.982</td>
<td>1.169</td>
<td>0.873</td>
<td>1.031</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Money Matters

We found several factors related to money and investment to be associated with respondents’ perceptions about the quality of their network infrastructure. Figure 4-3 reported that 59.0 percent of respondents pointed to inadequate funding as a barrier to delivering network services. Doug Hurley, vice president for information technology and CIO at the University of Memphis, says that overall, “I see state support for public universities continuing to decline—both as an absolute and as a real percentage of our operating budget. We will never again see funding percentages at the historical levels we are used to.” It makes intuitive sense, then, that those not experiencing inadequate funding would rate their network infrastructure stronger. This finding is especially true for the optimal design of desktop connectivity and for network fault tolerance.

We also looked at the top drivers for investment in networking technologies. Not surprisingly, Table 9–3 shows that investment drivers are associated with network infrastructure outcomes. For example, respondents who say that “needs identified by students” is a top investment driver also report more that their wireless infrastructure is optimally designed, whereas respondents identifying “needs identified by researchers” as a top investment driver report more that their network backbone is optimally designed and that their network is fault tolerant.

Similarly, Table 9–4 shows where respondents intend to make their top networking investments in the next three years and how this associates with perceived network infrastructure quality. For example, institutions reporting that a top investment will be for cable upgrades or network components and

<table>
<thead>
<tr>
<th>Investment Drivers</th>
<th>Backbone Optimally Designed</th>
<th>Desktop Optimally Designed</th>
<th>Wireless Optimally Designed</th>
<th>Network Secure</th>
<th>Network Fault Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of new technology</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
</tr>
<tr>
<td>Obsolescence of existing technologies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Needs identified by students</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Needs identified by researchers</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Yes indicates the investment driver is positively associated with the network outcome.

<table>
<thead>
<tr>
<th>Top Investments in Next Three Years</th>
<th>Backbone Optimally Designed</th>
<th>Desktop Optimally Designed</th>
<th>Wireless Optimally Designed</th>
<th>Network Secure</th>
<th>Network Fault Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable upgrade</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Network components and software</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wireless networking</td>
<td>Yes</td>
<td>-</td>
<td>Yes</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Convergence of voice, data, video</td>
<td>-</td>
<td>Yes</td>
<td>Yes</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Yes indicates the top investment is positively associated with the network outcome.
software report more often that their backbone is optimally designed for the foreseeable future. UCSD’s Elazar Harel speaks to the investments required in this area: “The network has to evolve on a relatively short cycle—we are getting to the place where we have to replace cabling and wiring that is not too old. We used to be able to replace cable and wiring every 15 to 20 years or so. Right now, to do Gigabit Ethernet to the desktop, which we are implementing, we need to have Category 6 cable. That was only made available a few years ago. Replacement is very expensive.”

Network Policies Matter

The 2003 ECAR study on IT security found that institutions with security policies in place characterized their IT security programs as more successful. A similar pattern occurs with formal networking policies. While most institutions report that their policies are clear, easy to read, and easily accessible, fewer report that their policies are consistently enforced, comprehensive, or regularly updated. Table 9-5 shows that institutions with formal network policies and procedures, and especially those reporting that they enforce their policies consistently, will more likely rate the quality of their network infrastructure higher. For Larry Bryant of the U.S. Air Force Academy, policies and enforcement are forefront. “Our high-speed network is necessary for our command and control environment. We have a cadet home page with the latest news from the base, uniform of the day, personal schedules, and events. It is where all new policies are promulgated.” Unlike other higher education institutions, they have the Uniform Code of Military Justice. “We can enforce policies; we can actually court-martial a cadet, and we actually have in some instances.” A similar pattern, although not as strong, holds for institutions that say they have comprehensive policies or update them regularly.

Table 9-5. Networking Infrastructure Quality, by Network Policies

<table>
<thead>
<tr>
<th></th>
<th>Backbone Optimally Designed</th>
<th>Desktop Optimally Designed</th>
<th>Wireless Optimally Designed</th>
<th>Network Secure</th>
<th>Network Fault Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institution has network policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Mean</td>
<td>3.88</td>
<td>3.75</td>
<td>3.05</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td>Std. deviation</td>
<td>0.999</td>
<td>0.960</td>
<td>1.040</td>
<td>0.880</td>
</tr>
<tr>
<td>No</td>
<td>Mean</td>
<td>3.65</td>
<td>3.47</td>
<td>2.59</td>
<td>2.97</td>
</tr>
<tr>
<td></td>
<td>Std. deviation</td>
<td>1.069</td>
<td>2.071</td>
<td>1.098</td>
<td>0.889</td>
</tr>
<tr>
<td>Institution enforces network policies consistently</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agree</td>
<td>Mean</td>
<td>4.07</td>
<td>3.85</td>
<td>3.21</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>Std. deviation</td>
<td>0.963</td>
<td>0.924</td>
<td>1.055</td>
<td>0.879</td>
</tr>
<tr>
<td>Disagree</td>
<td>Mean</td>
<td>3.58</td>
<td>3.49</td>
<td>2.60</td>
<td>3.01</td>
</tr>
<tr>
<td></td>
<td>Std. deviation</td>
<td>1.105</td>
<td>1.147</td>
<td>0.992</td>
<td>0.923</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Network Reliability Matters

Our interviewees repeatedly spoke of the criticality of network reliability. Vace Kundakci, deputy vice president, academic information systems at Columbia University considers reliability strategic. “Our network is a strategic differentiator, and the differentiators we care about are availability, reliability, security, and capacity of the network. We strive to improve each of these, without creating a sense of extra bureaucracy, unnecessary control, and of course huge spending.” Implementing network redundancy measures is an important part of this effort. Table 9-6 confirms the expectation that institutions that report more redundancy measures also report more that their backbone network is optimally designed and, especially, that the network is more fault tolerant. Notice that the strongest positive association occurs for those few campuses (N = 47) that have implemented redundancy for all single points of failure.

Table 9-6 also shows that institutions with a documented disaster recovery plan for their network characterize the quality of their network infrastructure more positively. Ron Stauss of North Harris Montgomery Community College District has not only put high priority on disaster recovery for the network itself but also says that “the network has allowed us to build our own disaster sites—in case of tornado, fire, or other emergencies. We can be operational for our entire district.

Table 9-6. Network Infrastructure Quality, by Redundancy Measures

<table>
<thead>
<tr>
<th>Redundancy</th>
<th>Backbone Optimally Designed</th>
<th>Network Fault Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. deviation</td>
</tr>
<tr>
<td>Some single points of failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3.82</td>
<td>0.987</td>
</tr>
<tr>
<td>No</td>
<td>3.85</td>
<td>1.100</td>
</tr>
<tr>
<td>All points of failure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4.32</td>
<td>0.862</td>
</tr>
<tr>
<td>No</td>
<td>3.78</td>
<td>1.018</td>
</tr>
<tr>
<td>Multiple physical routes off campus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4.03</td>
<td>0.940</td>
</tr>
<tr>
<td>No</td>
<td>3.71</td>
<td>1.042</td>
</tr>
<tr>
<td>Multiple physical routes on campus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4.03</td>
<td>0.924</td>
</tr>
<tr>
<td>No</td>
<td>3.68</td>
<td>1.057</td>
</tr>
<tr>
<td>Multiple service providers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4.02</td>
<td>1.003</td>
</tr>
<tr>
<td>No</td>
<td>3.75</td>
<td>1.013</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
in about four or five hours. In the first year of operation it was a warm site; now we are ready to make it a hot site.”

Even though the topic of security is outside this study’s scope, we note that both our survey respondents and our interviewees resoundingly pointed to security as an enormously important and complex issue that is likely to be with us for the duration. We did ask a few questions about authentication and found that digital certificates, while still a new technology, are used by about 10 percent of our respondents. These institutions feel that their network is more secure than those not using digital certificate authentication. Mark Clark, director of information systems at the University of Manchester, feels that “the nature of access will place significant demands on directory services and authentication and access control mechanisms. Increasingly, the role for digital certificates and related technologies will escalate. The big challenges will be how we are going to establish authorities to handle the scale of requirement to generate, issue, and control certificates without creating a ‘Big Brother’ culture!”

### Endnotes


### Table 9-7. Network Infrastructure Quality, by Disaster Recovery Plan

<table>
<thead>
<tr>
<th>Has Disaster Recovery Plan</th>
<th>Backbone Optimally Designed Mean</th>
<th>Desktop Optimally Designed Mean</th>
<th>Wireless Optimally Designed Mean</th>
<th>Network Secure Mean</th>
<th>Network Fault Tolerant Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>3.92</td>
<td>3.80</td>
<td>3.08</td>
<td>3.33</td>
<td>3.18</td>
</tr>
<tr>
<td>Std. deviation</td>
<td>0.984</td>
<td>0.893</td>
<td>1.109</td>
<td>0.870</td>
<td>0.961</td>
</tr>
<tr>
<td>No</td>
<td>3.68</td>
<td>3.52</td>
<td>2.77</td>
<td>3.11</td>
<td>2.72</td>
</tr>
<tr>
<td>Std. deviation</td>
<td>1.052</td>
<td>1.094</td>
<td>1.098</td>
<td>0.903</td>
<td>1.005</td>
</tr>
</tbody>
</table>

1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree
Effective Practices and Lessons Learned

Experience joined with common sense, to mortals is a providence.
—Matthew Green

This report provides baseline information on current and anticipated higher education networking technology and practices, drawn from ECAR’s online survey of 517 higher education institutions and in-depth interviews with 19 IT executives and managers at 13 EDUCAUSE member institutions. Chapters 4 through 8 follow the report’s navigational diagram, describing the campus network; external connectivity; networking practices, organization, leadership, and management; and emerging technologies and converged services. Chapter 9 examines success factors. The sidebar summarizes ECAR’s research findings about institutions that feel their institution has a higher-quality network infrastructure—one that is secure, fault tolerant, and optimally designed to meet future needs.

This chapter presents relevant lessons learned and effective practices synthesized from ECAR’s research on IT networking in higher education. Some may be recognizable from other ECAR research studies; others are inherent to networking. They all, however, underscore the importance of maintaining a core portfolio of good IT practices to effectively serve the institution at large.

Which Institutions Report a Higher-Quality Network Infrastructure?
Institutions that...
◆ consider the network to be a strategic resource
◆ have a primary network goal to provide leading-edge network performance and services
◆ do not consider inadequate funding a barrier to the delivery of networking services
◆ have formal policies and procedures that cover networking issues and are comprehensive, enforced consistently, and regularly updated
◆ provide more redundancy measures for the institution’s central network
◆ have a disaster recovery plan for the institution’s data networking capabilities

"Soft" Practices Complement Technical Strategies
ECAR noted in its report Information Technology Security: Governance, Strategy, and Practice the importance of both sophisticated technologies and human and cultural factors of campus life in creating a secure institutional IT environment. We observe a similar trend in this ECAR research on IT networking. A

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higher-quality network infrastructure is usually associated with technical characteristics such as adaptability, fault tolerance, reliability, scalability, and security. Yet one of the more interesting findings is the role that nontechnical factors play in creating a higher-quality network infrastructure. Both survey results and interviews show that although technology is indeed important in network design and management, the network is also contextually shaped and constrained by factors like senior leadership attitudes, funding resources, and institutional mission. ECAR’s research highlights several practices that focus on IT networking’s “softer,” or nontechnical, side.

**Cultivate Senior Leadership Awareness**

We noted in Chapter 9 that institutions where the network is considered strategic rate the quality of their network infrastructure higher. “It is important to build trust with leadership,” explains Joanne Kossuth, CIO, Franklin W. Olin College of Engineering. “Our senior administration never questions whether the IT department did due diligence to the nth degree and tested alternatives during the network design process. In fact, when our trustees read that VoIP is gaining popularity or networks are now converged, they remark what a great idea we had.”

Given senior leadership’s varying proclivities for technology, the recognition of networking’s strategic implications might not be initially straightforward. Interviews revealed different approaches to ensure that senior leadership understands the institutional network’s intricacies—and importance. Ron Stauss, vice chancellor, information technology and telecommunications, North Harris Montgomery Community College District, stresses the importance of an IT leader’s participation in the president’s or chancellor’s cabinet, serving as an on-the-spot networking advocate and educator: “If the IT leader is not present at the cabinet meetings, you must rely on someone who doesn’t fully understand IT (it’s not their job) to present the network initiative. If a question arises, it is typically tabled until those questions can be answered. If I’m present, I can respond to any inquiries, and it makes a remarkable difference.”

Olin College’s Joanne Kossuth takes a more formal approach, providing such educational opportunities as show-and-tell sessions for college constituencies, including senior administrators, to tour network facilities such as wiring closets, server rooms, and the network core. These opportunities help end users better understand exactly what makes the network tick. “Before actually seeing the facilities, our end-user constituencies, including administrators, understood the network based on either their own user experience or on PowerPoint presentations,” she explains. “The people that took advantage of the tours now have the added experience of the ‘wow’ factor. The visual effect of the number of cables and amount of equipment gets across the complexity of the network and helps them understand that it is not just about pushing a button.”

**Ensure Ample Network Investment**

Alan Bjornsen, writing in *American School & University*, says, “Laying the groundwork for a fast, efficient information technology system is not as complicated as it first seems. The most important thing is simple and straightforward; if there is only a dollar to spend, spend it on the infrastructure. Once the school is on a solid foundation, it can run an application to solve virtually any problem and meet virtually any educational or administrative need.” In Chapter 9, ECAR research also shows that those institutions that feel they are not experiencing inadequate funding would rate their network infrastructure as stronger, especially for the optimal design of
desktop connectivity and for the fault tolerance of the network.

Interviewees discussed ways to ensure adequate investment in their networks. Olin’s Joanne Kossuth leverages her relationships with vendors. “We believe that a partnership is a two-way street,” she explains. “Some institutions define partnership as getting their 50 percent discount. Olin, however, volunteered up front to serve as vendor reference sites, hosting user groups, providing live equipment demonstrations for potential customers, and encouraging our students to participate in focus groups about future product development. If my annual budget falls a little short, my vendors and I work together to create a package to ensure that Olin continues to be properly equipped to serve as the best reference site for them.”

Gavin Leach, associate vice president for finance and planning, Northern Michigan University (NMU), tries “to buy everything so it is reusable. As new technology becomes available, we can move the older equipment to lower-priority areas. As a result we have been able to put dollars into networking each year in a way so that we always remain current or slightly ahead of the curve with our technology.” Joe Aulino, vice president and CIO, Marist College, goes one step further by “looking at ways to leverage the infrastructure to generate revenue by providing some value-added or new services.”

Align the Institution and Its Network

Networking’s higher education origins may lie in research and academic pockets, but the advent of the Internet, administration systems, and course management systems enabled the network to extend its reach throughout the institution. When the network and institution become more interwoven, “an understanding of the institution’s big picture is very important,” advises Mike Fitzgerald, senior data network engineer, Brandeis University. “You don’t want to do networking by the seat of your pants.” IT leaders increasingly must consider both technical and institutional factors in network planning. ECAR’s research bears this out: we found that Carnegie class, student enrollment, and network size can impact campus network profiles. For example, doctoral institutions report higher bandwidth, higher-speed transmission standards, and more wireless access. Use of single-mode fiber and remote access rises as student enrollment rises. Bandwidth from the commodity Internet rises as the number of devices increases. The presence of student resident halls promotes greater concerns about P2P file sharing.

Our qualitative interviews also highlighted different IT activities and attitudes based on primary network goal. Network managers at leading-edge institutions typically have to future-proof the network to meet an extensive and diverse set of needs; deploy emerging technologies; and support innovative research. ECAR’s research noted that institutions whose primary network goal is to provide leading-edge network performance and services to the institution rate the quality of their network infrastructure—design of the backbone, desktop connectivity, and wireless networks, as well as network security and fault tolerance—higher than other institutions. For example, Steve Updegrove, senior director, information technology services at The Pennsylvania State University, describes his institutional infrastructure as one that contains “advanced, integrated telecommunications and networking services, which have been critical to the overall accomplishments of those within the university.”

In contrast, self-described “cost minimizers” have different aims. “We manage our network core cost-effectively and pragmatically,” explains Jose Valdes, associate director for telecommunications, Colorado State University. “We believe in being ‘early
testers’ of technologies, but we don’t push things. For example, we experimented with unified messaging three years ago, but we returned the system because it was not the right technology for our environment. However, we continue to explore emerging technologies in this and other areas because upgrade costs and performance of our legacy systems are going to force us to implement more advanced and cost-effective solutions.”

Phil Trivilino, manager of network infrastructure at St. Lawrence University, concurs: “We don’t offer Internet2 connectivity here. There is limited demand for it because we are a liberal arts college. When we reviewed our Internet connectivity contracts, we chose our local broadband service provider because it offered a more competitive price package than our local Internet2 provider.”

The IT leader must understand the overarching institutional characteristics and act accordingly. The different activities we find at leading-edge and cost-minimizer institutions are neither right nor wrong; they are appropriate to achieve the institutional network goal.

**Networking Technology Practices**

“Soft” elements contribute to a higher-quality network infrastructure, but effective technical practices are clearly important as well. ECAR’s research reveals network-related practices and lessons learned in several areas, including infrastructure planning, convergence, mobility, external connectivity, and reliability.

**The Network Is Never Done**

Balancing network supply and demand can be a tricky proposition. As writer Anne Donker observes, “CIOs assume the network will always be there, until they find it doesn’t meet their new applications requirements. Then they remember that infrastructure matters, too.” IT leaders find maintaining a network infrastructure to be a very fluid process because they must constantly meet evolving user demands.

IT departments typically keep abreast of the current user demand and implement accordingly. A prime example is wireless technology. The *ECAR Study of Students and Information Technology: Convenience, Connection, and Control* notes rising student ownership of mobile devices. Marist College’s Joe Aulino also observes, “Students will have invested money in wireless technology and come to college with an expectation that wireless will be available.” Unsurprisingly, institutions are responding accordingly. Chapter 4 notes that wireless network access continues to rise, especially in areas that are not as hardwired, like indoor public spaces (dining halls, lounges, and lobbies), classroom seats, and outdoor spaces.

Other IT leaders, like Olin’s Joanne Kossuth, go a step further by conducting external environmental scans to anticipate future networking needs. When she plans, she researches the current network capabilities that math and science high schools—Olin student recruitment venues—provide their students. Kossuth explains, “Students will come to our college expecting us to do one better.”

In Chapter 9, ECAR research noted varying levels of agreement that the network supports staff, faculty, and student needs. Some institutions, however, use service-level agreements (SLAs) to help them understand the usage and value of their service offerings to their customer base. Jon Saperia, co-chair of the IETF SNMP Configuration Working Group, comments, “If it is worth the expense to deploy a new network service, it’s worth the expense to know if the service is supporting the business goals that drove its deployment.”

Not all needs, however, can be calculated. Unlike the corporate world, which typically builds its network to support specific needs,
higher education thrives on discovery and experimentation. The network can’t grind to a halt when a professor plugs in a new supercomputer or adds video conferencing to a course curriculum. IT departments, therefore, must try to build ahead of the user demand curve. Anna Tomecka, associate CIO and director of information technology services, Brandeis University, explains, “We know the faculty will want new services, but we don’t know what it will be—most likely video. So we continue to upgrade our network, waiting for this outburst of activity that we expect any day, any week.” St. Lawrence’s Phil Trivilino also looks ahead “to providing Gigabit Ethernet to the desktop in support of emerging arts technology as well as the new science complex that is currently under construction.”

Consider Organizational as Well as Network Convergence

Technology issues naturally arise when institutions converge their network, but this also gives IT departments an opportunity to rethink and redesign their IT organizations. “A big mistake some make is to equate telecom convergence with VoIP,” explains Indiana University’s Brian D. Voss. “The latter is just a subset (and one might argue a small one) of the former. Converge your organizations, converge your WAN links, and converge your cost/funding models!”

Voss describes organizational convergence’s benefits for IU. “When we streamlined the infrastructure and systems portion of the function, our new infrastructure and systems division was much more compact and focused. We could effectively lead it with a single senior manager. Our user services—now completely integrated from a user and organization perspective—are much more tightly integrated, closely matching the use of information technology by the community, and thus presenting a single, coordinated service interface to the users (that is, call one place for help or service for all IT areas). Within the technology division, we are now more tightly focused.”

When data and telecommunications staff members converge into a single unit, the entire IT organization benefits from the cross-pollination of their expertise. The Meta Group’s vice president, Elizabeth Ussher, observed that “a converged staff creates its own culture and will consider a variety of resolutions to a business problem, regardless of incumbent technology vendor…. As a result, converged staffs tend to be more business-solutions-oriented and regard technology as a tool to accomplish this. Cross-training has increased, but mostly this is done in house.”

Keep Mobility Strategies Open

Wireless and mobility “create networking requirements that must address when students, faculty, and staff are not necessarily in one fixed place anymore with anywhere/anytime access,” describes John P. Campbell, associate vice president of teaching learning technologies, Purdue University. Interviewees offer relevant thoughts and strategies.

Determine Which Devices to Integrate

Mobility has resulted in new means—such as laptops, cell phones, and PDAs—for users to access the network. IT departments have to determine which devices to integrate into the network, and this is no simple task. Varying device types may have dissimilar hardware, operating systems, and software issues, multiplying user support requirements. Network modifications may be required for various mobile devices to effectively use the network. Elazar Harel at the University of California, San Diego (UCSD), explains, “You need to design applications to understand the screen sizes on the various devices. Something that displays on a computer with its reasonably sized screen won’t show up on a cell phone
screen.” Both requirements could strain network staff resources.

**Focus on Security**

Wireless also adds another dimension to security issues. “It is a challenge to provide security on the network, with PCs, Macs, UNIX, and pocket PCs. Now we must add cameras and phones,” Harel explains. “How do you keep them all secure?” Some institutions, like St. Lawrence University, have implemented VLANs, “which gives us the flexibility as well as granular control over what people can do on the network,” Trivilino says. “We have four different VLANs, but only the guest VLAN is different, offering only Internet access.” Harel foresees the “eventuality of single sign-on because users will carry so many devices, there will have to be a better solution than everyone carrying several passwords and login IDs with them.” He envisions the cell phone as the future “smart card,” whereby the network sends the device a one-time password in real time, thus eliminating the need for static passwords. “You will have a mechanism to get your token via the phone and be able to sign in to different applications and services.”

**Consider Personal Privacy**

Wireless technology provides new means to penetrate personal privacy: GPS tracks user location, camera phones take unauthorized photos, people eavesdrop illicitly on cell-phone conversations. IT leaders must be cognizant of potential privacy backlash issues. Limited technical options exist, but institutions could proactively create relevant incident handling procedures to minimize institutional damage in the event of a crisis.

**Explore External Connectivity Opportunities**

Today’s institutions are increasingly reaching out to one another through external research and educational networks, creating extended educational communities. One driver of external networks is the current glut of dark, or unused, fiber optic cable. The telecommunications industry’s collapse has lowered prices, making it economically feasible for more institutions to build their own external high-speed networks rather than lease lines from the local carrier. “If you are going to lease a line, and there happens to be dark fiber for sale at an advantageous price, then it makes sense to own the line,” states Marist’s Joe Aulino.

**Collapsing Geographic Barriers**

External networks offer several possible benefits for institutions to explore. “IT networking helps to collapse geographic barriers,” states Garret Yoshimi, manager of telecommunications, University of Hawaii. “The locations of the University of Hawaii System (including 10 campuses on six islands) can connect with our global community of stakeholders and customers and effectively participate at the forefront of global research activities.” Even colleges and universities not as geographically isolated as the University of Hawaii are turning to external networks like Internet2, National LambdaRail, and regional optical networks to conduct multi-institutional research, hold cross-institutional classes, and in some cases co-manage administrative services.

**Leveraging Resources**

Multiple institutions can leverage resources and funds to solve common problems via external networks. For example, the 5C Consortium in central Massachusetts is building a fiber ring to provide high-speed bandwidth access to its members. Marist’s Joe Aulino envisions “multiple small institutions eventually banding together to monitor networks centrally to make it more affordable for all.” Multi-institutional wireless networks enable locally proximate institutions to tackle the previously discussed mobility issues together.
**Reaching Out to the Community**

External networks provide a new means of community outreach as colleges and universities offer their network resources to the community. NMU’s Gavin Leach noticed that, “as wireless access expanded on campus and the use of it took off, it started bleeding off campus. Students noticed this and began to automatically test for off-campus access. NMU approached the city to try to move the wireless network out to our 6,000-plus commuter students throughout the city. The city saw great value in this and has been very supportive of our efforts to push the network technology and high speed outward, not only to help our students, faculty, and staff, but in the long run to enhance the local community and the economy in the area.” Olin College is trying to financially justify bringing high-bandwidth capability to its hometown of Needham, Massachusetts, to enhance the town’s student educational experiences and facilitate interactivity among the townspeople via the town Web site.

**Meeting New Requirements**

IT departments may find that external connectivity breeds new requirements as well as benefits. For example, those institutions opting to build their own external networks become de facto carriers, requiring new skill sets to ensure the miles of fiber cables are properly lit and operational. However, Dan Updegrove at The University of Texas, Austin, notes that “the biggest benefit from external connectivity may not be the state-of-the-art network. What we’ve got are universities talking to each other in a shared governance environment. For the first time in Texas, we’ve got a nonprofit structure in which academic medical centers and nonmedical universities, public and private, urban and rural institutions from across the state are all at the same table. That’s exciting.”

**Balance Network Openness and Security Requirements**

ECAR published a full study dedicated to IT security in higher education in 2003, so security was not a primary focus of this study. Yet security concerns bubbled up throughout this research. Spero P. Bowman, CIO and associate vice president for academic resources and planning at California State University, Northridge, summarizes the situation: “The whole security issue is the biggest and most costly challenge, requiring more and more attention, resources, and compliance.”

One issue is higher education’s propensity to innovate in network environments—innovation that promotes the early adoption of new technologies, often before universally adopted standards emerge. “The problem with security is that we can’t implement a solution for our faculty members, students, and staff without the rest of the world doing it also,” states UCSD’s Elazar Harel. “When we implement new networking devices, we keep up with the technology and vendors. We choose the technology we think will be successful. It is a gamble sometimes, but we are pretty successful.”

Another security dilemma is higher education’s traditionally open culture. The network continues to support more administrative and academic functions, making confidential information more accessible. In addition, as the network edge expands, so does the security threat. The data modem pool once represented the last mile to campus, but now faculty, students, and staff access the university network remotely, putting the university at risk because it becomes unclear where the network user is located and where his or her device has been. “You have to provide secure access, limited to your faculty, staff, students, and people you want on your network,” summarizes NMU’s Gavin Leach.
Consequently, institutions and IT departments must constantly grapple with how “closed” to make their network through security measures. Some institutions have a naturally closed environment. Larry W. Bryant at the U.S. Air Force Academy reports, “We’re lucky in that we operate on an active-duty military base that follows DoD security regulations for both wired and wireless networks, which protects us from the outside. In addition, all users have Norton antivirus on their machine. We also push the latest patches for students and staff to ensure everyone is compliant with all the latest patches.” But at other institutions, if security activities go too far, it may promote discomfort among faculty, students, and staff.

One solution is the creation of formal network policies. As Indiana University’s Mark Bruhn noted in ECAR’s IT security study, “Several security commentators have expressed concern that IT security can be inimical to academic freedom, but we believe this depends on the policy driving the institution, not the tools themselves. Indeed, IT security can support academic freedom by ensuring ready and timely access to information by authorized users. This is a major reason for having a comprehensive IT security policy; it can embed the academy’s most important values into an area that some might find otherwise problematic.” ECAR research notes, too, that institutions possessing formal networking policies and procedures that are comprehensive, regularly updated, and enforced consistently will more likely rate the quality of their network infrastructure higher. Involving institutional constituencies in policy creation ensures that their academic freedom concerns are addressed as well as providing a forum for the IT department to learn about users’ networking requirements.

The 24 x 7 Network Needs Around-the-Clock Reliability

The network’s ever-growing complexity and importance raise the significance of 24 x 7 reliability. “With every passing year, the university’s business operations, instructional programs, research programs, and outreach programs are more dependent upon the rock-solid reliability of the network,” UT Austin’s Dan Updegrove succinctly states. “Yet we add more 24 x 7 services to a data network that really isn’t architected as a 24 x 7 infrastructure.” Unsurprisingly, ECAR research shows that institutions that implement redundancy measures consider their backbone network to be optimally designed and, especially, that the network is more fault tolerant.

In light of the evident growing need for network reliability, it is surprising that 40 percent of ECAR survey respondents indicate that they have no disaster recovery plan for data networking at their campus. “The constantly changing network environment is reliability’s biggest challenge,” states NMU’s Gavin Leach. “It’s an ongoing challenge as we are constantly pushed to upgrade and move to new technologies, which in turn impacts our ability to keep up with it. We have to support the network both from our end by keeping it operational as well as from the user end by providing support.”

ECAR research, however, notes that institutions that maintain disaster recovery plans characterize the quality of their network infrastructure more positively. Indeed, former mayor of New York Rudy Giuliani advises, “When planning for disaster recovery, plan well and plan hard.” Some institutions are following his advice by conducting preemptive planning and monitoring to augment redundancy efforts. “We spend many hours
troubleshooting problems because we know problems are going to occur,” states Mary Jane Heider, director of academic computing at Genesee Community College. “It is ‘when’ it breaks down, not ‘if’ it will break down.” Chris Piety, assistant director of network services, Middle Tennessee State University, determines network benchmarks. “Our department knows what is normal by monitoring our network with products that graph our network statistics,” he explains. “We also have a network management station that monitors every piece of equipment on the network. So if something goes down, we can be proactive, not reactive.”

Look Outside Higher Education

ECAR’s IT alignment study observed IT leaders’ reluctance to conduct environmental scans outside higher education when conducting IT planning. Higher education’s prominent role in networking’s evolution may encourage similar thinking as well. Networking boundaries, however, continue to encompass more and more devices, prompting forward-looking IT leaders to broaden their technical horizons into areas not typically associated with higher education.

A case in point is embedded technology. Retailers like Wal-Mart use radio frequency identification (RFID) technology for inventory control; pharmaceutical manufacturers plan to “chip” bottles of prescription drugs to prevent theft and counterfeiting. Eventually, embedded technology will find its way onto college and university campuses, perhaps in library books, student ID cards, or even the students themselves. This in turn will open a host of new integration, support, and security issues for IT leaders to face, which in some ways bear a general resemblance to the wireless concerns faced today. The cycle of adoption begins yet again. The innovative IT leader will be prepared.

Endnotes

1. ECAR’s networking survey asked respondents to give their opinions (strongly disagree, disagree, neutral, agree, strongly agree) to the following statements about the design, security, and reliability of their campus network: (a) My institution’s central network backbone is optimally designed to meet our needs for the foreseeable future. (b) My institution’s desktop connectivity is optimally designed to meet our needs for the foreseeable future. (c) My institution’s wireless connectivity is optimally designed to meet our needs for the foreseeable future. (d) My institution’s network is secure. (e) My institution’s network is fault tolerant.


4. ECAR’s networking survey asked respondents to select one of four statements describing their institution’s goal for the network on the basis of four report descriptors. The descriptors are, Cost Minimizer: Provide reliable performance and services at the lowest possible cost; Requirements-Based: Provide appropriate levels of performance and services to different users, based upon their need; High Speed for All: Provide high-speed networking to the entire institution; Leading Edge: Provide leading-edge network performance and services to the institution.


6. R. Kvavik et al., ECAR Study of Students and Information Technology, 2004: Convenience, Connection, and Control (Boulder, Colo.: EDUCAUSE Center for Applied Research, Research Study, Vol. 5, 2004). The study found that 82 percent of freshmen and seniors at 13 participating higher education institutions own cellular phones, 46.8 percent own laptops, and 11.9 percent own PDAs.


9. The 5C Consortium consists of Amherst College, Hampshire College, Mount Holyoke College, Smith College, and the University of Massachusetts, Amherst.


11. Ibid., pp. 70–71.


From Tin Cans to the Holodeck: The Future of Networking in Higher Education

Any sufficiently advanced technology is indistinguishable from magic.
—Arthur C. Clarke

Birth of a Medium: 1969–2004

In 1851, Nathaniel Hawthorne asked, in amazement, “Is it a fact or have I dreamt it—that by means of electricity, the world of matter has become a great nerve, vibrating thousands of miles in a breathless point of time?” Over a century later, Marshall McLuhan echoed Hawthorne’s sense of wonder when he observed that “the electric age … established a global network that has much the character of our central nervous system.” Electricity and the electrical grid became the foundation and defining technology of the Industrial Age. Similarly, networking and the Internet have become the defining technologies of the Information Age.

According to Jeffery I. Cole, director of the Center for the Digital Future at the University of Southern California, 2004 marks “the tenth anniversary of the Internet becoming generally available to the public.” The Internet in particular and data communications in general are immediate family members, if not offspring, of higher education. Historically, data communications, and more recently, new innovations like grids, wireless broadband, integrated communications services, and others, have found their earliest sympathizers, advocates, and pioneers on and between college and university campuses.

Internetworking Research and Development

While the history of computing can be traced to the abacus and, in modern times, the transistor’s invention in 1947, the Internet traces its roots to the U.S. Department of Defense’s ARPANet and to the first Interface Messaging Protocol (IMP) that was powered up in Leonard Kleinrock’s lab at the University of California, Los Angeles (UCLA), in September 1969. ARPANet’s first four nodes were universities: UCLA; Stanford (SRI); the University of California, Santa Barbara; and the University of Utah. That network was wired together via 50-Kbps circuits. Less than five years later, Vinton Cerf from Stanford and Robert Kahn from the Defense Advanced Research Projects Agency (DARPA) led the development of the Transmission Control Protocol/Internet Protocol (TCP/IP), a protocol for interconnecting devices on the network. By January 1, 1983, every device connected to ARPANet had to use TCP/IP, and the domain name system (DNS) was developed at the University of Wisconsin–Madison.
Commercializing the Internet

By 1988, the National Science Foundation (NSF) had tied together—like tin cans on a string—a backbone network supporting T1 speeds of 1.544 Mbps. By this time more than 50,000 host computers were connected to the national backbone network. Regional networks—largely funded, operated, and/or governed by universities—were responsible for much of this rapid growth in the number of networked host machines. By 1990, the number of hosts swelled to more than 300,000 while the NSF was installing the first T3 (45-Mbps) networks. In this same time frame, Sir Tim Berners-Lee of CERN, Europe’s high-energy-physics laboratory in Switzerland, implemented a hypertext system to facilitate information discovery, retrieval, and sharing over the Internet by the high-energy-physics community. CERN released this capability, dubbed the World Wide Web, for broad consumption in 1992. The Web was the “killer app” needed to catalyze the Internet’s widespread adoption and commercialization.

In 1996, then-U.S. President Bill Clinton aptly summarized the Internet’s rapid commercialization when he commented, “When I took office in 1992, only high-energy physicists had ever heard of what is called the worldwide Web.... Now even my cat has its own page.” By that time, speeds on the soon-to-be-commercialized NSFNet were 145 Mbps (ATM), and nearly 6.5 million hosts were connected to what was now called the Internet.4

The mid- to late 1990s were a time of great social and business experimentation, with network-based “e-services” dominating the rhetoric about a “New Economy.” The widespread adoption of new service and information delivery techniques via the network did indeed resolve what economists dubbed the “IT productivity paradox,” leading U.S. productivity to rise from 1995 to 2000 at an unprecedented (and unsustainable) rate. However, the economic recession early in the 21st century debunked the idea that humankind had entered a technologically mediated Eden in which all prior thoughts about business cycles were obsolete.5 The Internet’s commercial boom and its subsequent “pause” led humorist Dave Barry to declare that “the Internet is the most important single development in the history of human communication since the invention of call waiting!”

The Telecom Bust and Commoditytization of the Internet

Despite disappointment, recession, and considerable network overcapacity in the telecommunications industry, networking has continued to progress since the late 1990s. Network speeds continued to grow—again led by higher education. As this study demonstrates, a significant number of leading institutions now support networking at gigabit speeds, and we expect terabit networking to find its way out of the laboratory by the end of the decade. Switching technology now promises to multiplex laser beams, making it possible to segment and prioritize network traffic and quality of service (QoS) on demand.

The emergence of higher-bandwidth applications, mobile computing and communications, peer-to-peer (P2P) applications, and other demands and capabilities reemphasizes end-to-end networking, continuing the pressure on enterprises to switch from IP Version 4 (IPv4) to IP Version 6 (IPv6) in the coming years. IPv6 has the potential to alleviate network complexities (network address translation, mobile IP, IP security) and foster new network applications such as P2P. Over time, these features will make the case for its adoption, which will likely continue to be slow.

At this writing, networking and the Internet have been fully commoditized. According to Internet2’s Steve Corbato, “For the past 15 years, the Internet has doubled about once a year.”6 Although the Internet is the newest
medium, “it is the fastest growing new medium of all time, becoming the information medium of first resort for its users.” According to Nielsen/NetRatings, more than 600 million people worldwide have access to the Internet, and the average Internet user spends more than 11 hours per month online. In the United States, the average monthly use is many times higher. More than 30 billion e-mails are sent daily, representing a worldwide flow of more than 650,000 terabytes of e-mail information annually. Also interesting, in May 2002, 31 percent of U.S. business Internet users used Instant Messaging. According to e-Marketer, in November 2004 alone, more than $8.8 billion was spent online, excluding travel expenditures. Figure 11-1 illustrates the distribution of Internet users across the globe.

These data summarize the obvious: in the 35 years that have passed since the first Internet nodes were powered up, data communications has moved from a curiosity, to an experiment, to an academic enabler, to a commercial opportunity, to a business necessity, to a mass medium. Indeed, 81.5 percent of the nearly 4,500 students responding to ECAR’s survey of their IT uses reported enjoying access to broadband networks. This, despite the fact that nearly half of these respondents lived off campus. In fact, today’s networking rhetoric recognizes that in 35 years, networks have become part of the nation’s (and the world’s) “critical infrastructure”—assets on which core human activities are conducted and on which we now depend. We no longer hear much about e-business—not because e-business has failed but because it is now the way of all business. Someday, the “e” in e-learning will be similarly discarded as an unnecessary qualifier.

**Anatomy of a Success**

The remarkable early history of the Internet in particular and data communications in general owes much to the unique partnership between the U.S. Department of Defense, the National Science Foundation, and the higher education community. One of higher education’s leading contributors, Internet2 President Doug Van Houweling, attributes the Internet’s success in part to three important factors:

- scalable technology,
- broad reach, and
- collaborative effort.
According to Van Houweling, “The traffic [on the Internet] has been doubling every year for the past few years, and the underlying single optical circuit technology supports that rate of growth. For the first time since the 1980s, we are seeing a challenge as to whether this architecture will accommodate future expected growth. So we need to ask fundamental questions about network architecture and organization of the lowest layers.”

To think about how we may deliver Internet connectivity going forward, Van Houweling suggests that we ask ourselves, what made the Internet what it is today? To Van Houweling, the success of the Internet is due in part to the Internet’s scaleable architecture and, in additional measure, to what he calls the reach of the Internet: “[The Internet] is engineered so that everyone connected to it can reach everyone else. The Internet was not designed or developed as a set of connections between individuals. This is what made innovation on the Internet explode. This huge audience—along with the Web browser and search engines—has been an enormous motivator for people to introduce innovation and new content.”

Finally, Van Houweling argues that a third secret of the Internet’s success is that “over time, there have been substantial contributions by all participants in the Internet community to advance the Internet—new applications, content, and shared work on new standards. An enormous part of the Internet’s robustness is the result of many people volunteering to work together to improve it.”

Indeed, the early advocates of networking’s shift from a limited resource for the research communities of the military, big science and government, and higher education to a commercial medium—and ultimately a commodity service and mass medium—focused on universal access, rich content and services, open standards, growth and interconnection, and collaborative development. Terry Gray of the University of Washington reminds us that “networks suffer from the irresistible pressures to grow and connect. Metcalfe’s Law reminds us that the value of networked applications rises as the number of people connected to the network rises.”

The Future of Networking

Networking’s history has been breathtaking. The 1980s promise of information “anytime and anywhere” has been achieved and surpassed. Siebel Systems’ tag line updates this promise succintly: the network provides “what you need, when you need it.” Where the computer has indeed evolved into a sophisticated tool to compute and to store and edit files that reside on our desktops (and much, much more), the emergence of networking and the Internet have extended the computer’s reach and indeed have recast the computer as a communication tool. It is a tool for looking outward as well as inward. Sun Microsystems’ Bill Joy makes the point forcefully: “Disconnected from the network, my computer is nearly as useless as a cell phone in an area with no cellular service.”

It was in many ways easier to forecast networking’s progress to this point than to predict its future. Early advocates and pioneers who could anticipate and envision personal computers, a common user interface, search engines and the like could also foretell how linking more people and devices through a shared network would alter how we work, learn, socialize, and recreate. Looking ahead to the next 25 years isn’t so easy. In fact, most futurists refuse to speculate this far into the future and are quick to point out that Moore’s Law and other rules of thumb that predict the growth of storage devices, network connectivity, and number of network connections suggest growth by a factor of a million in fewer than 30 years. Such capabilities and their social, economic, and political implications more closely resemble science fiction.
than science, and it is reasonable to restrict our discussion to a shorter time frame, focusing on changes likely to occur on “this” side of the science–science-fiction boundary.

Two Shifts Ahead

In Figure 11-2, Gartner Research describes physical and logical networking as comprising two of the five major transformations that have occurred in IT’s history.

According to HP CEO Carly Fiorina, “We have entered an age now where every process and all content will become mobile, virtual, and personal.”12 In the higher education context, Fiorina’s characterization will likely present itself in the form of two interrelated shifts that will accelerate in the next 5 to 10 years. Figure 11-3 illustrates these shifts.

*Toward an Integrated Cyberinfrastructure*

Computers and networks have changed how research is conducted in many academic disciplines. New and emerging disciplines like computational chemistry, computational biology, bioinformatics, atmospheric informatics, and others bear witness to the revolution in scholarship that is under way. The 2003 report of the National Science Foundation Blue Ribbon Advisory Panel on Cyberinfrastructure described these changes as constituting “a revolution in how we create, disseminate, and preserve scientific and engineering knowledge.”13 The NSF panel described the concept of an advanced infrastructure layer on which “scientific and engineering research and education environments could be built.”14
This layer sits between the exponentially growing network and computing infrastructure and the complex of scientific instruments, data, knowledge, disciplines, and communities of practice. The envisioned cyberinfrastructure is a layer of “enabling hardware, algorithms, software, communications, institutions, and personnel [organized] ... for the empowerment of specific communities of researchers to innovate and eventually revolutionize what they do, how they do it, and who participates.” This layer would include “grids of computational centers ... comprehensive libraries of digital objects ... multidisciplinary, well-curated collections of scientific data ... thousands of online instruments and vast sensor arrays ... toolkits for resource discovery, modeling, and interactive visualization ... and the ability to collaborate with physically distributed teams of people using all of these capabilities.”

Recognizing the importance of such a coordinated cyberinfrastructure for all scholarship, the American Council of Learned Societies (ACLS) organized the Commission on Cyberinfrastructure for the Humanities and Social Sciences in 2004 and charged its members with

◆ describing the cyberinfrastructure’s current state for the humanities and social sciences,
◆ articulating the requirements and potential contributions of the humanities and social scientists to the cyberinfrastructure’s evolving definition, and
◆ recommending areas of emphasis and coordination between the ACLS and other organizations and institutions that will be developing the cyberinfrastructure.

The ACLS will disseminate its findings and recommendations in 2005.

Elements of the envisioned cyberinfrastructure already exist. Federally funded projects such as the Network for Earthquake Engineering Simulation (NEES), the National Virtual Observatory, and the Space Physics and Aeronomy Research Collaboratory (SPARC) represent cyberinfrastructure elements that support the physical sciences, while the Human Genome Project and the National Institutes of Health (NIH) Biomedical Informatics Research Network (BIRN) represent just two such elements that support the life sciences. States and regions are preparing the ground for the cyberinfrastructure by acquiring dark fiber and establishing governance structures that will link K–12 and higher education to enable collaboration among physically distributed teams of people described by the NSF panel.

Campuses, too, are building and linking elements of this envisioned cyberinfrastructure. Syracuse University, for example, is funding work on wireless grids to explore the intersection of wireless technology and high-performance grid supercomputing, while the Cal-(IT) 2 program at the University of California, San Diego (UCSD), explores the use of light pipes (lambdas) to provide researchers with a solid, “jitter free,” predictable network on which to build the grid.

The integration challenge will be daunting. Organizations like Internet2, the National LambdaRail (NLR), and the Globus Alliance are collaborating to develop and promote the standards and governance that will knit the disparate research networks, cybertools, and data sets into the envisioned cyberinfrastructure. Internet2’s Van Houweling counsels, “This time around, the technical issues are larger than they were in the past, so we need more brains and better cooperation than we had in the past. We have many efforts and activities in all these areas throughout the higher education community. We need to make sure that these efforts are integrated and use a common architecture, so our network infrastructure does not become Balkanized.”
Toward Pervasive and Personalized Intelligence and Communications

If the networking community’s battle cry of the 1980s was “[information] anytime, anywhere,” and if that cry evolved in the 1990s into “what you want, when you need it,” then perhaps networking’s driving vision in the future will be “all you can imagine, all the time.” This vision of the cyberinfrastructure suggests quite clearly what Frances Cairncross called the “death of distance” and the blurring of the lines between real and virtual in the context of learning and scholarship. In the coming years, the lines that distinguish the real from the virtual will indeed grow fainter, driven by four key trends:

- logical connectivity,
- smart and talkative devices,
- convergence, and
- personalized on-demand and reliable services.

These capabilities, of course, must be integrated and deployed in ways that are compellingly human and that foster community and not social isolation.

The Institute of Electrical and Electronics Engineers (IEEE) defines pervasive computing as systems that are mobile and ubiquitous. Mobility and ubiquity in turn depend on systems that are portable; untethered from desktops; always on, and in fact, scalable on demand; and that, as Sun Microsystems’ Bill Joy puts it, “unbottle” media and interactions from their conventional containers.

Logical Connectivity

Much of networking’s history has been the history of wires. In fact, UCSD’s Larry Smarr sums it up well when he proclaims, “Conduit is power.” Continuous engineering and management effort have been devoted over 35 years to expanding the number of bits that can be passed along electrical currents in copper wires and, more recently, to the transport of bits on light waves through optical fibers. These techniques, and the accompanying electronics, made networking a captive of the physical environment. In higher education, therefore, early and continuous attention has been paid to “wiring the campus”—that is, installing backbone networks and distribution systems across campuses and into offices, classrooms, laboratories, dormitories, and so forth, and connecting these backbones to access points to the Internet, Abilene, or other specialized external networks. The idea and benefits of transporting bitstreams on the backs of radio waves, microwaves, or other spectral waves that demand no wires, conduit, trenches, and building construction have long been understood and used, but the technologies and standards needed to make this possible cost-effectively are recent.

Today, as this report suggests, wireless networking is widespread throughout higher education. And as this technology penetrates higher education more broadly, and as wireless broadband and security solutions present themselves, higher education’s cyberinfrastructure managers are enlarging their views about wireless networks’ role and importance. The Darwin Group’s Mike Roberts notes, “Broadband wireless has a long way to go in terms of utility. But it has already changed computing more than the old-timers thought it would. Look at the extent to which everyone is assuming a wireless environment—in the classroom and now even homes.” Indeed, Intel now tracks and publicizes the “Most Unwired Cities,” and a recent survey of senior corporate executives revealed that the most popular technology among respondents was wireless Internet connections at home. Spending on home networking in 2004 reached $8.4 billion and is forecast to reach $17.1 billion by 2008. Figure 11-4 illustrates how senior executives in the United States are using technology devices.

To a great extent, campus networking has already gone wireless. In 2002, ECAR re-
ported that 7 percent of survey respondents had implemented comprehensive wireless networks and that an additional 52 percent had implemented a limited amount of wireless networking on campus. By 2004, more than 75 percent of those responding to this study’s survey had implemented or were planning to deploy 802.11g-based wireless networks widely in the next 12 months. Our students are responding as well. The 2004 ECAR Study of Students and Information Technology reported that 93.4 percent of the 4,374 freshmen and seniors who responded to this survey owned computers and that 46.8 percent of these owned laptop computers. Importantly, many laptop computers now come preconfigured with wireless access capabilities, and ownership of laptop computers among freshman respondents in the ECAR study is higher (52.7 percent) than among seniors.20

**Smart and Talkative Devices**

Another amazing and challenging aspect of the future of networking is the embedding of communicating “intelligence” in anything and everything. The Information Age is moving from the extreme early skepticism of those like Digital Equipment Corporation’s Ken Olsen or Microsoft’s Bill Gates, who could not imagine uses for home computers, to Wal-Mart’s mandate that its 100 largest suppliers were to have all of their cases and pallets “chipped” with radio frequency identification devices (RFID) by January 1, 2005.21

In terms of pervasive networking, placing a brain and vocal chords in things like paper, postage stamps, cases of wine, children’s backpacks, and so forth means that ultimately everyone and everything is reachable on the network. Today, for example, logistics and distribution management firms like United Parcel Service of America (UPS) and Federal Express (FedEx) integrate bar codes, scanners, wireless messaging, databases, and the Internet to track shipments’ progress from supplier to consumer. This complex of technologies fosters information resources and business processes that incorporate the customer, reducing customer phone calls and enabling things like proactive online customer alerts. Tomorrow, RFID chips and sensor networks will let packages, library books, and other objects announce themselves, their whereabouts, expiration dates, and condition to servers and ultimately to the Internet. These capabilities will enable orders

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**Figure 11-4. Use* of Technology Devices Among Senior Executives in the United States, 2004**

[Bar chart showing the use of various technology devices among senior executives in the United States, 2004]

*“Use” here means “often” or “sometimes”*

Source: Harris Interactive, Wall Street Journal, May 2004
Convergence

A second force driving the pervasiveness is the convergence of voice, data, and video networks and the deployment of converged services. In fact, Clifford Stoll describes the Internet as a “telephone system that’s gotten uppity!” According to Burton Group’s Irwin Lazar, “Disjointed forms of personal communications will rapidly converge into a unified application that combines voice, Instant Messaging (IM), video, collaboration, and presence. The result will improve organizational efficiency, allowing individuals or groups to communicate directly with each other through a common system, regardless of device or application.” Lazar goes on to describe the characteristics of a converged communications environment:

- Individuals control how they are contacted.
- Various forms of communication can interact.
- Communicators can learn about each other’s availability and location.
- Communications systems keep track of people’s accessibility regardless of the device or system they use.
- People can set the parameters for application-to-voice interactions.
- The converged environment will support legacy communications applications.

In the next few years, higher education’s IT leaders will be challenged to manage convergence on the technical, organizational, legal, and social levels. Technically, we will need to deploy sufficient bandwidth to accommodate the inevitable rise in video traffic on institutional networks. We will need to deploy an infrastructure—or acquire one—that will support unified messaging. We will need to review, acquire, and deploy tools that will let end users really integrate converged services and tools into their work. Indeed, the evidence is strong that when telephones got smart, most of us did not, and our phone systems’ “advanced features” today go largely unused. Technical convergence also signals a multiplicity of intelligent devices. The emergence of “integrated communicators” will pose tremendous support challenges as technical capabilities race, as always, with technical standards and human learning curves. Those
who manage the institution’s IT and information resources will have to make and continually revisit choices about which platforms to support and about the breadth, quality, and duration of help desk hours as devices cross the boundaries between institutional and personal use. The challenge, as Lazar suggests, is presence: the ability to convey real-time information about people’s current location and the forms of communication (audio phone, IM, video conference, and so on) they can use.

Convergence will also challenge traditional campus assumptions about networking control, as campus citizens walk in and out of campus networks’ range and into the range of cellular carriers and others (see The Vanishing Frontier—Regulation and Taxation, below). Harmonizing these disparate environments will prove complex from economic, technical, and policy perspectives.

Organizationally, convergence is already disrupting the college and university workplace. Voice communications are going digital, are ripe for technical convergence, and no longer represent an attractive source of institutional cost recoveries. As the economics of stand-alone voice communications become increasingly problematic and as the technical barriers to integrating communications services abate, most institutional leaders will move to invest not only in technical convergence but also in the organizational integration of often separately organized voice and data communication teams. Burton Group’s Irwin Lazar advises, “To understand and plan for this fundamental change, enterprises must bring together disparate teams responsible for separate individual applications into a unified convergence work group that will set strategic direction for enterprise communications.”

Convergence, in the end, is less a technical exercise than a social one. It promises technology-mediated collaboration and community.

According to the University of Manchester’s Mark Clark, “The nature of documents is increasingly trending to compound documents that incorporate image, data, text, and voice annotation. E-mail is likely to shrink as a way of sharing documents, giving way to the increased use of collaborative working environments for document development analysis, editing, and even drafting. Video conferencing, particularly that on the high end associated with technologies such as access grids, is showing exponential growth. Increasingly, virtual communities will be built upon networks as the glue to provide social cohesiveness.” Managing the deployment and then integration of converged technologies into a cohesive, converged service environment—and ultimately into the kind of rich collaborative environment Clark describes—will likely demand considerable attention in the future.

**Personalized ‘On-Demand’ and Reliable Services**

The commercial sector describes a world of “competitive Darwinism” in which “unstoppable drivers are creating a new on-demand environment where competition is intense, change is continuous, financial pressures are unrelenting, and threats are unpredictable.” These drivers are impelling businesses to deploy and manage technical environments (and business processes) that are focused, responsive, variable, and resilient. In higher education, this technical challenge is often described as grid computing, a vision of distributed computing wherein large-scale resources are shared in a flexible, secure, and coordinated manner among individuals, institutions, and resources.

The promise of grid computing, on-demand business, five-9s reliability, personalized “lambdas,” and other technical and organizational innovations and directions will lead to the creation of a
secure cyberinfrastructure that is
◆ highly leveraged (across individuals, institutions, and resources);
◆ responsive to real-time changes in demand; and
◆ available 24 x 7 in an uninterrupted manner.

Realizing these complementary visions will not only require flexible technical architecture, protocols, services, interfaces, and software development kits but will also depend on “coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations.”26

**Implications**

These shifts have enormous and exciting implications for global society in general and higher education in particular, including
◆ broadband for all;
◆ a new era of data-intensive scholarship; and
◆ increased virtuality, mobility, and community in the academy.

**Broadband for All**

Tom West, president of National Lambda-Rail builds on the point about networking’s collaborative imperative and on higher education’s past and future role: “I believe that the research and education community has a stewardship role to the larger community. We must provide connectivity to every location in the country—that means every school connected by fiber to state, regional, and national networks. Higher education has a part to play in our society’s challenge to make the capabilities of networking available to every citizen.”

This ethos impels initiatives like “One Gigabit or Bust” from the Corporation for Education Network Initiatives in California (CENIC). According to CENIC President Jim Dolgonas, “The [California] gigabit initiative is designed to stimulate one-gigabit broadband to all Californians by 2010. Our goal is to help the research sector serve our community best, by doing what the commercial sector isn’t doing.” Again, the tradition of collaboration in higher education networking is a paramount success driver. Dolgonas sees “a real challenge in creating and maintaining the sense of community necessary to bring about our higher education private networks. If I buy from a carrier, it is a traditional vendor-customer relationship, and supposedly I am in control. In contrast, in regional and national network consortia, we have equal players, requiring that some participants have to compromise. It is a bit like shared services and—if you can do it—the benefits are great and there are gigantic payoffs.”

The enthusiasm and optimism that suffuse this section do not intend to minimize the digital divide’s importance. EDUCAUSE Vice President Mark Luker reminds us that “the missing link is that last mile, where cities and rural areas are not fully wired.” For such locales, Luker advises “the huge breakthrough is wireless. Small towns are starting to wire whole communities with wireless—putting antennae on grain silos and water towers.” Technology is moving very fast and getting faster. Wireless is a true breakthrough for places that have been underserved.”

**The Era of Data-Intensive Scholarship**

UCSD Professor Larry Smarr describes the future as an “era of data-intensive science.”27 At the November 2004 ECAR Symposium, Smarr described some of the key layers and elements that will constitute this era and the place of the network amidst this complex mix of technologies, academic disciplines, and human behaviors (Table 11-1).

In November 2004, the U.S. Congress approved a bill that increases funding for supercomputing initiatives in the United States and extends greater access to such systems
to academic researchers. The bill, which both houses of Congress passed and President Bush is expected to sign, directs the Department of Energy to “deploy a high-end computing system that is among the most advanced in the world.” The bill also requires the Department of Energy to give academic researchers access to supercomputing systems. Although the bill does not appropriate funds, it authorizes the department to spend up to $165 million over three years. Daniel A. Reed, vice chancellor for information technology at the University of North Carolina at Chapel Hill, believes that in the past few years the United States has not devoted sufficient resources to high-tech research projects and said the bill will help put U.S. supercomputing “back on the front burner.”

The era of data-intensive science ahead will not just be defined by or confined to supercomputing and scientific uses of data. Today’s young social science investigators are exploring big econometrics, big sociology, and even big history, for example. Choreographers are using visualization and simulation techniques to model and teach dance, orchestral performers conduct master classes across great distances, and literature scholars are using algorithms to conduct content analyses of texts long believed to have been “mined out.” Geographers are experiencing an intellectual renaissance, having incorporated remote sensing, global positioning systems (GPS), and other data-intensive techniques into their research practice.

The scale of computing, storage, and networking is changing profoundly. Two University of Houston engineering professors recently won a $1.1-million grant from the National Science Foundation to develop a storage device using nanotechnology. This technology could allow the complete contents of the Library of Congress to fit on a handheld computer. Doug Van Houweling describes the era of data-intensive scholarship in terms of “disruptive applications,” which by themselves can take much of any shared bandwidth that is available. Such applications include

- real-time access by physicists to particle collisions at CERN, FermiLab, and elsewhere that require 6- to 7-gigabit throughput;
- access to pathology tissue banks for telemedicine, requiring gigabit speeds per simultaneous user; and
- access to data from distributed radio telescopes, microscopes, and other high-performance instruments.

According to Smarr and to Burton Group’s Daniel Golding, trends like these are changing how connectivity between data centers is architectured. Past models called for relatively small carrier circuits connecting many enterprise data centers. However, several recent developments suggest we rethink how data centers (and sources) are designed. In private industry, data-center consolidation efforts, combined with increasing regulatory burdens and more-serious disaster recovery planning,
are changing enterprise data-center design. In research-intensive universities, where Gigabit Ethernet traffic out of scientific instruments is becoming commonplace, institutions with greater bandwidth demands and more data and storage networks to pass between data centers are taking a new look at an established carrier technology: wave division multiplexing (WDM).

WDM lets an optical fiber carry many signals by combining several light wavelengths into a single transmission. Each light wavelength carries a discrete channel of data, and each channel can carry as much data as a classical optical network—10 gigabits or more. This multichannel approach allows many networks to be carried on a single fiber pair. The decision to support optical networking will in turn drive changes in wavelength capacities, network topology, and protection and restoration mechanisms. As with traditional network technologies, the economics, capacity, expandability, and manageability of optical networking solutions will vary, suggesting the ongoing need for sophisticated engineering talent within institutions that remain on the frontier of higher education networking capabilities. In an era of data-intensive scholarship, scholars in the humanities and social sciences will also need remote access to large data sets, instruments, and archives. These disciples might not have their own high-performance networks, suggesting the need for commercial access to bandwidth through Internet2 or NLR or through shared services arrangements with state, regional, or other academic network providers.

Mark Clark, CIO at the University of Manchester, raises important research questions that designers of tomorrow’s networks must answer: “How can the scholar handle complexity that is enabled by bigger and bigger supercomputers which are harder to program and where it is harder to understand the phenomena that are being simulated or analyzed? And how do we handle the data deluge? Data will be the problem of the future: handling larger and larger volumes, mining and visualizing complex data sets, and managing the data-sharing issues such as privacy, confidentiality, provenance, and archiving. There is a changing in the skills and education needed by the research, professional, and general workforce.”

Virtuality, Mobility, and Community in Academe

This chapter has, to this point, dealt exclusively with the potential of evolving network infrastructure and services to foster an era of data-intensive research. Of course, higher education’s mission is broader than discovery, and networking’s transformative potential on teaching, learning, community engagement, and administration is similarly exciting. Higher bandwidth, sound identity management, pervasive wireless networking, and the affordable availability of many computing and communications devices will open the door to the proliferation of rich-media virtual environments. The Web will likely become a three-dimensional environment with navigation that uses virtual portals and avatars. Progress on Web descriptors and locator frameworks will proceed as a continued race between growth in the number and size of virtual haystacks and the tools in place for finding virtual needles. Collaborative environments will likely become increasingly “human,” particularly as rendering tools and techniques from the gaming world become widely available, and usable, and as voice over IP (VoIP) enables those collaborating in virtual spaces to converse and to modulate, locate, and attenuate their voices in group settings. As the standard technologies for displaying network media improve (high-definition video and megapixel displays, for example), video conferences and other activities that incorporate the real and the virtual
will increasingly blur the boundaries between the two by tricking the senses. These environments exist today in limited scale.

These capabilities’ ongoing improvement, in concert with ongoing investments in network capacity and performance, will likely render debates about virtual, distance, hybrid, or face-to-face education meaningless. Questions of educational policy and practice will become simultaneously simple to ask and complex to answer: Whom do I teach? How do I teach? How, when, with whom, and at what cost do I learn? And how does all of this cool stuff get paid for? As network-mediated learning opportunities disrupt higher education’s traditional market segmentation, pricing strategies, brands, and so on, the focus of institutions will likely shift to the achievement of social and educational outcomes; of teachers, to pedagogy; and of learners, to affordability, lifestyle, and learning, career, and social goals. The question “Where did you go to college?” may in the long run yield to the question “With whom did you study?” Institutional personalization of experience will compete with faculty free-agency to determine whether higher education institutions, like many others, will be disintermediated by the network. Institutions wishing to compete in part on the basis of “place” will likely continue in what some have called an “arms race” of investment in the campus built environment and in student services.30 Changes like these led one higher education association to declare, “We have become a people unable to comprehend the technology we invent.”31

The emergence of plentiful, customizable, and secure bandwidth along with the eventual integration of rich media will also foster the formation and diversity of learning communities. As collaborative work tools are rendered more and more human, as the vision of a collaborative cyberinfrastructure matures, as humans become better acclimated to cyberspace, and as incentives are redrawn to foster interdisciplinary and interinstitutional work, new and rich linkages between teachers, learners, and others in the academy will prosper. The network has the potential to become the ultimate leveler of social distinctions in higher education as interests seek and find compatible interests, and talent seeks and finds compatible talent in cyberspace.

For wireless networking and mobility, the future is now. Wireless networking is already subtly changing all institutions, and once again higher education is in the fray. In some cases, these changes force reconsideration of long-standing space-usage practices and could lead ultimately to reconsiderations of mission. For example, responding to reports showing strong demand for Internet access, officials at the British Library announced in November 2004 the implementation of a wireless network in the library’s reading rooms, auditorium, restaurants, and outdoor area. “A study recently showed that 86 percent of library patrons carry laptops and that 16 percent came to the library to use it as a business center.”32 The story on higher education’s campuses is no different. Many institutions appear to be “leading from the rear,” observing new patterns of student behavior enabled by mobile network access and then redefining common physical spaces into “information commons,” “flexible learning environments,” and so forth.

The shift toward wireless networks in higher education and mobility’s implications are important. Coalition for Networked Information Executive Director Clifford Lynch reminds us that “this ubiquity business is really important. We all remember the rhetoric in the 1980s about the wired classroom, built with Ethernet to every desktop. A few were built at very high cost, they were a specialized place, and they were scheduled from dawn to dusk.” Lynch goes on to remind us that when classroom networking is a scarce
good, faculty rarely have an incentive—or the means—to radically rethink their pedagogy to incorporate networked information resources. “Now,” says Lynch, “we have actually done it wirelessly—creating the wired classroom of the 1980s on a very broad scale. And a lot of faculty are freaked about this. Including the broad implementation of wireless networking in classrooms has led to reports of faculty requests to ‘turn the network off’ in failing attempts to curtail students’ Web surfing or, even worse, passing of derogatory instant messages and evaluations in class! These tales remind us of Arthur Schlesinger’s observation that ‘science and technology revolutionize our lives, but memory, tradition, and myth frame our response.”33

In the long run, virtuality, mobility, and community in higher education will also reshape its business landscape. In mitigating the effects of distance, the network is already enabling some institutions to rethink IT and resource governance. Soon more institutions will consider data-center consolidations as one means of curbing IT spending growth while assuring service levels, providing prudent backup, and the like. Over time, more institutions will use the network to reach beyond the campus to share or host services with other institutions, corporations, cultural institutions, or state governments. In the longer term, institutions could successfully implement service-oriented architectures that will permit invoking the services necessary to operate the enterprise on demand, over the network. In this longer-term vision, the service provider’s location, governance, or ownership will be transparent and irrelevant to that service’s consumer, except as regards service quality and cost. And advantages will accrue to the virtual. ECAR Senior Fellow Robert Albrecht reminds us that “traditional universities cannot handle the increasing number of students between now and 2015 when their numbers peak. Virtual universities—and those that blend the physical and the virtual—are not only better positioned to respond to this enrollment demand, but they can scale quickly as enrollments escalate and can thus continue to grow.”

Importantly, adopting highly distributed systems to operate higher education’s business enterprise will depend not only on reliable networks but also on a trust fabric woven in middleware and relationships.

The Vanishing Frontier—Regulation and Taxation

As Van Houweling and others have remarked, the Internet’s success stems in part from its reach. In turn, the Internet’s reach has depended largely on its open architecture and relatively loose governance. The Internet, as an outgrowth of higher education, has long been governed under principles that arise from academic values: dominantly those of unfettered trade in intellectual commerce, a predisposition to openness, free speech, and respect for intellectual property. These values exist in a healthy state of tension with opposing values that defined the early years of private internetworking in the corporate sector. The argument for openness is compelling, and its value in the academic endeavor has been long understood. J. Robert Oppenheimer argued eloquently that “the open society, the unrestricted access to knowledge, the unplanned and uninhibited association of men for its furtherance—these are what may make a vast, complex, ever growing, ever changing, and ever more specialized and expert technological world, nevertheless a world of human community.”34

The Internet’s open nature and the achievement of its full promise will be a challenge to enable and preserve in the future. Barriers to this critical legacy and promise will arise in at least five areas:

- technology and commerce,
- security and privacy,
Such trends as converged services and wireless networking challenge long-held beliefs and practices about institutional network control. UCSD CIO Elazar Harel observes that “we used to be able to control our campus network completely. With wireless, you can control the 802.11 Wi-Fi network, but you can’t control the cellular network because that is managed by the carriers and the Federal Communications Commission (FCC). If you cannot cover every single point with Wi-Fi, you will face the situation where the devices you carry must be smart enough to automatically and transparently shift from one wireless environment to another. For example, while walking on a remote part of the campus the only signal you may get is cellular phone service, then somewhere else you will get 3G cellular coverage, then Wi-Fi, and ultimately in the office you might plug into the wired Gigabit Ethernet.”

Compounding this challenge is the multiplicity of business models. CENIC President Jim Dolgonas looks at the external business model and says, “Wireless is really going to grow, but one problem is that the business model is not right. For example, if you are traveling, at Los Angeles international airport, you may pay 10 dollars to get wireless service, and then when you get to Chicago, that airport wants another 10 dollars, etc. I think it should be a monthly subscription, with new agreements that allow for roaming.” Further, standards will pose ongoing management challenges, particularly for wireless network security, home video distribution, and high-speed, low-power WLANS.

Managing network complexity will present another key technology problem. While dense wave division multiplexing (DWDM) techniques may ease some congestion issues of shared networks, the proliferation of embedded devices will pose daunting routing and congestion management challenges. Continued efforts to implement QoS will be needed. Also, the existence of Web Services technologies has stimulated the discussion of services-oriented architectures (SOAs), a discussion evolving since the Object Management Group’s Common Object Request Broker Architecture (CORBA) extended the promise of integrating applications on disparate heterogeneous platforms. The rise of different (and noncompliant) object standards has slowed the adoption of more-robust architectures that would allow simple, fast, and secure integration of systems and applications over the network.

The problems that such architectures are designed to solve persist, however, and they become more complex every year. Until and unless we can implement an architectural view unconstrained by technology, the vision and promise of “the network is the computer” will go unrealized. The vision here, of course, is to render the geographical locus of activity unimportant so that scholarly or administrative information resources can be identified and gathered in one set of locations, assembled and organized in real time in other locations, and displayed, modeled, visualized, or simulated in other locations. In our happiest imaginings, the invoking application need not be concerned with where the transaction will run, what language it is written in, or what route the interaction may take along the way. A service is requested, and a response is provided. Realizing the promise of grid computing, Web services, or services-oriented architectures will be complex and will require the adoption of standards, the maturity of network-based technologies such as TCP/IP, the evolution and adoption of software toolkits that provide for loosely coupled machine interactions, and a business culture...
that rewards distributed collaboration.\textsuperscript{35}

University of Washington network leader Terry Gray warns, “I believe passionately that the biggest threat to IT organizations is the growing complexity of the systems we deploy, and the diverse, decentralized organizational structures we attempt to support in universities. Will we ever be able to cope with current diagnostic problems (such as transient end-to-end performance problems) much less future ones?”

Middleware, too, represents a hurdle we must clear. Says Internet2’s Van Houweling, “The future of networking will depend not only on the bottom layers, which are crucial, but also on the middleware level. That [level] is just as complicated and needs just as much good technical thinking as the bottom levels.”

The other side of managing this extraordinary complexity, of course, is making sure that the new world we create works for humans. Bill Joy sets the bar high: “In this era of amazing change we will face a huge challenge of design: how to humanize our digital devices, our homes and offices, and our public places; how we will make them serve our needs; and how we will make the digitally enhanced places beautiful.”\textsuperscript{36}

Security and Privacy

Karl Krause reminds us that “the development of technology will leave only one problem: the infirmity of human nature.”\textsuperscript{37} The Internet’s growth and such openness and freedom as it has enjoyed do not come without a price. John Perry Barlow observed that “in Cyberspace, the first amendment is a local ordinance,” and notes that “our identities have no bodies so … we cannot obtain order through physical coercion.” From this, he concludes that from “ethics, enlightened self-interest, and the commonweal, our governance will emerge.”

Notwithstanding Barlow’s hopefulness and essential humanity, the Internet has become a somewhat treacherous and dangerous place. Virus and worm attacks launched over the Internet have cost businesses tens of millions of dollars, and in 2004 IDC reported that spam accounted for 12 billion e-mails received each day. This compared with 13 billion daily person-to-person e-mails. Identity theft is one of the fastest-growing and most vexing crimes, and IT security officers—a staple in corporate IS organizations—are perhaps the fastest-growing professional cadre in higher education. Darwin Group’s Mike Roberts astutely observes, “We have finally begun to realize that the Internet is going to be a source of pathological behavior as much as any other aspect of human existence. An open network founded on democratic principles has the same vulnerabilities as do other institutions in a democratic society.”

As early as January 2002, Microsoft Chairman Bill Gates announced that company’s “trustworthy computing initiative” and declared IT security to be the top priority for the company.\textsuperscript{38} Of course, declaring IT security to be a problem is only the first step. Cisco Systems CEO John Chambers made this point recently when he commented, “I think the fundamental change in the past six months is that most customers have realized that there has to be an in-depth architectural approach to security, or it just won’t work.”\textsuperscript{39} In the article, Chambers goes on to describe the next generation of self-defending networks.

Privacy, too, will present a continual policy challenge to networking. Embedded sensors, Internet-accessible databases, and eventual efforts to establish “presence” via implanted chips will keep privacy issues on national, state, and institutional agendas. Indeed, privacy concerns may ultimately slow down or inhibit the adoption of new and emerging technologies. Sun Microsystems’ Bill Joy warns that “we may find ourselves in a world where our every action will be watched the
way celebrities are scrutinized today."40 UCSD's Elazar Harel reminds us that "there could be a privacy backlash at some point if and when hackers or terrorists become more sophisticated or more malicious. We have not seen yet massive destruction of critical systems over the Internet, but it is not that difficult to do." Privacy issues will be made even more complex owing to significant legal, regulatory, and policy differences between the United States, the European Union, China, and others.

Some even worry about the emergence of counterfeit realities, leading to the emergence of an industry dedicated to the inspection, identification, and certification of digitally forged images, movies, and documents.

Regulation and Taxation

The current prevalence of open values in concert with a public policy that has shielded the Internet from both the regulation and taxation often associated with other common carriers accounts for much of its dizzying growth. We have borne witness to Shoshana Zuboff’s observation that "technology makes the world a new place."41 On taxation, for example, the U.S. House of Representatives agreed as recently as November 2004 to extend a ban on Internet taxes until November 2007. President Bush is expected to sign this extension, and congressional Republicans said they would continue to work in the next congressional session to make the ban permanent.42

Of course, issues remain regarding the ownership or use of the spectrum, in particular, possible specific content restrictions that could be placed on wireless network traffic. EDUCAUSE Vice President Mark Luker points out that "the regulatory structure is designed for wires used for voice and taxed by the line. When convergence happens, all this has to collapse and be replaced. This can’t happen too rapidly, or the whole Net will collapse with it. Industries have huge lobbying power, in states and nationally, so they will fight back the whole way so they can collect more money on their legacy investments. This is a collision waiting to happen." The Telecommunications Act of 1996 does not even consider the Internet, and work on successor legislation will likely be problematic, hard, and take years to complete.

One example of where convergence will challenge the legal and regulatory structure is CALEA, the Communications Assistance for Law Enforcement Act. It was passed originally in 1994 to facilitate court-approved wiretapping of "wires for voice," and the FCC has been petitioned by law enforcement agencies to broaden the scope of CALEA to include rights to tap "phone calls" made over the Internet via VoIP, as well as to eavesdrop on "conversations" using IM offerings such as AOL’s Instant Messenger. In August 2004, the FCC issued proposed rules that tentatively subject broadband Internet providers and operators of VoIP services, IM services, and others to CALEA’s requirements.

Other relevant and important areas of changing law and regulation include licensing, spam, surveillance, rights management, file sharing, and privacy. And making the regulatory issue even more complex is the plethora of regulatory philosophies and approaches taken by the EU, China, and others. Coming to grips with the myriad issues facing U.S. regulators and then harmonizing solutions in ways that leverage networks’ international reach will be an enormous challenge.

The Last Mile

As Internet2 President Doug Van Houweling reminds us, the Internet’s broad reach is largely responsible for its rapid adoption as a commodity medium. For many, that reach has meant networking to the home. Mike Roberts of the Darwin Group reminds us that "the last mile has been a big deal and expensive, and it was always assumed
that there had to be a physical link. The last hundred feet was actually going to be the most expensive piece, but now it turns out that wireless may save hundreds of dollars per residential broadband connection. About half of the matriculated undergraduate population in the U.S. does not live in a residential campus environment. So eight million students are dependent on the public Internet, not campus networks, to gain access to resources that are technology mediated. These resources include not just coursework, but professor-specified Internet resources.”

Clifford Lynch agrees: “It is important to watch the data about bandwidth to the home, because that has sizeable implications for lots of things—everything from video on demand, to lifelong learning applications, even to data backup applications. While at present, the gap between broadband service at home and campus residential network service has grown smaller in major markets, my suspicion is that this gap will open up again as institutions provide very high bandwidth access, leaving people off campus with substantially slower commercial broadband access.” The bottom line is access. EDUCAUSE Vice President Mark Luker reminds us that “in the future we will need to have connectivity to every location in the country to truly enable full participation in a high-quality education.”

**Intellectual Property**

The Internet’s emergence as a commodity mass medium was facilitated, as Van Houweling argues, by scalability, reach, and collaboration—attributes and behaviors that in turn fueled widespread innovation, content sharing, and collaboration. Stanford University Professor Lawrence Lessig frames this idea in terms of creativity and economic opportunity: “Digital tools dramatically change the horizon of opportunity for those who could create something new.” The Internet, the Web, improved search engines, metadata, and markup languages have hastened the digitization of everything. The ease of replication and sharing, on the one hand, and of monitoring, controlling, encrypting, accounting, and charging for digital content, on the other, threaten to disrupt the complex and fragile fabric of copyright law. This law seeks to promote innovation by protecting, for a time, the economic rights of content creators. U.S. copyright law is an artifact of a time before the Internet, digital content, printers, and photocopiers. The rights of copyright holders could be protected by the sheer impracticality of copying books by hand, allowing a doctrine of fair use to arise. This doctrine defines in general terms what the use rights of content consumers are and has underpinnings in the lending systems of libraries, among many things. The new economics of replication and sharing threaten the rights of copyright holders, putting the law and practice of fair use management at risk.

Similarly, copyright law is also an artifact of a world without digitally recorded music and motion pictures, and a world of limited literacy, where the economics of global information distribution limited copyright owners’ expectations about a copyrighted work’s future economic performance and life. Widespread content digitization and delivery over networks change these economics as well, leading rights owners to lobby for both extensions to the duration of copyright protection and the imposition of stricter sanctions for violations. Lawrence Lessig describes the growing tensions about the nature and duration of copyright protections as a “war about basic American values.” It is about “the values of balance and measure that should limit the government’s role in choosing the future of creativity.”

Futurists debate the options. Esther Dyson argues that most individual pieces of content on the Web will have short economic lives, leading to different strategies for recovering
the costs of innovation. First, content might
be sold outright to sponsors who then give
it away in bids to attract users to their Web
sites (where revenue options may abound).
Second, content owners may give away their
content in the belief that greater revenues will
arise from the popularization of this content
(sale of services, speaking engagements, and
the like). Finally, Ithiel de Sola Poole argued
that service rights may come into play. Under
this scenario, content may be free, but licenses
recover the costs of future updates, exten-
sions, and so on.45

Resolution of these issues will be complex
and likely painful. In the end, a workable sys-
tem, as suggested by Cairncross, must be
based on consent: “At its heart should be
the right to a fair return on an innovation
rather than the right to exclude others from
replicating it.”46 Intellectual property issues, in
the network context, will also be exacerbated
by differing international approaches.

Conclusion

Predicting the course of networking’s
future is simultaneously easy and difficult.
Predicting this future is also ultimately
unnecessary.

Prediction is easy because the broad out-
lines and vectors are clear:

◆ Networks will get faster.
◆ More things will be attached to net-
works.
◆ The “exponentials” are changing as
bandwidth begins to become cheaper
than storage.47
◆ More and more services will be delivered
over networks.
◆ Network bandwidth and services will be-
come easy to customize on demand.
◆ Distinctions between the real and the
virtual will become unclear.

Predicting the course of networking’s fu-
ture is difficult because of at least two factors.
First, the adoption rate and the ultimate shape
and texture of the networked information fu-
ture will depend, as always, on human factors.
And these will depend on how imaginative,
cost-effective, interoperable, secure, and easy
to use are the services that become available
over networks, and on humans’ abilities to
adapt to and toggle between virtual and real
environments. As Larry Smarr comments,
“What we really need are social scientists to
figure out what people need to work together
well over the network.”

Second, predicting our network future
proves difficult because we are at a nexus
point from which emanate several possible
futures that will be determined less by tech-
nology and funding and more by public policy,
regulation, trust, and human behavior. Tech-
nically, we will be able to deliver dedicated,
end-to-end terabit speeds affordably. We will
also be able to guarantee QoS, affordably.
The public policy questions relate back to the
fundamental issues of openness, scalability,
and collaboration raised by Internet2 Presi-
dent Doug Van Houweling: will the signal-
to-noise ratio on the “open Internet frontier”
be in such a balance that users of a shared
Internet will value the benefits of openness
(with noise) more highly than they do closed
networks, with reduced noise? These options
more likely will manifest themselves as a range
of choices among virtual political economies,
with unregulated democracy on the one ex-
treme and tight, private (totalitarian) controls
on the other. And of course, events like 9/11
will surely shape dominant directions within
the continuum of choice. The potential for
innovation posed by Van Houweling and Op-
penheimer could hang in the balance.

Within any of these future scenarios, too,
one can imagine social movements among
those wanting to go “off grid” and the
digital divide implications of such scenarios.
Massachusetts Institute of Technology’s Neil
Gershenfeld reminds us that “to a species that
seeks to communicate, offering instantaneous
global connectivity is like wiring the pleasure center of a rat’s brain to a bar that the rat presses over and over until it drops from exhaustion. Under any conditions, the network can and will amplify educational divides. Those who have neither literacy, numeracy, nor information literacy will be increasingly estranged from social institutions, cultural institutions, and government.

Predicting networking’s future is unnecessary because the network’s logic and its potential have been embedded in our global psyche. Nearly everyone would agree on the six trends described above. Indeed, the Center for the Digital Future recently identified 10 trends worth noting here:

- In the United States, the digital divide is closing but is not yet closed, as new divides emerge.
- The nation’s media habits have changed, and continue to change.
- The Internet’s credibility is dropping.
- We have just begun to see the changes to come in buying online.
- The Internet’s “geek-nerd” reputation is dead.
- Privacy and security concerns remain high.
- The Internet has become the number-one information source for its users.
- The Internet’s benefits and drawbacks for children are still coming into focus.
- E-mail: “E-nuff already.”
- Broadband will change everything—again.

The real prediction issues, then, are about when these eventualities will occur and who controls them, and not about what these eventualities are or whether they will occur. Antoine de Saint-Exupéry reminds us, “Machines do not isolate Man from the great problems of nature, but plunges him more deeply into them.”

For higher education, networks present great hope for the future, while our cultures continue to pose great challenges. California State University Executive Vice Chancellor Richard P. West says it best: “We are now at the stage when technology can really pervade what we do. This is how some of us who have been active for many years in higher education’s IT journey idealized it. Technology and our networks are prevalent in their use and will begin to have a significant compounding effect on our missions and our students. At Cal State, incoming students now take math placement assessments online and can take required courses online at their own pace. It really is anytime, anyplace-oriented learning—with outcomes-based learning. This simple application is extremely usable and embeds rich pedagogy, making it very much a Trojan horse. The challenge is getting the faculty to do things like this. Technology today is truly making it possible to revolutionize higher education delivery. We are going to need some sort of catalyst to make that happen, since even without any changes we continue to grow 3 to 5 percent per year. So why should the faculty change? Why should we change? Maybe when 2015 comes and the student population peaks, maybe there will be a change.”

Endnotes


8. Ibid., quoting Nielsen/NetRatings.


15. Ibid.

16. Ibid., p. 7.


20. R. B. Kvavik et al., op. cit., p. 32.


23. Ibid., pp. 7–8.

24. Ibid., p. 5.


44. Ibid., p. xvi.


46. F. Cairncross, op. cit., p. 206.

47. L. Smarr, op. cit.


Appendix A

Institutional Respondents to the Online Survey

Acadia University
Alvernia College
Amherst College
Anne Arundel Community College
Appalachian State University
Arizona State University West
Armstrong Atlantic State University
Assumption College
Auburn University
Auburn University at Montgomery
Babson College
Ball State University
Barnard College
Barton County Community College
Bates College
Baylor University
Bemidji State University
Benedictine University
Berea College
Berklee College of Music
Blinn College
Bluefield State College
Boise State University
Bowdoin College
Brandeis University
Brandon University
Brazosport College
Bridgewater State College
Brigham Young University–Idaho
Brock University
Brown University
Caldwell College
California State Polytechnic University, Pomona
California State University, Bakersfield
California State University, Channel Islands
California State University, Chico
California State University, Fullerton
California State University, Hayward
California State University, Monterey Bay
California State University, Northridge
California State University, Office of the Chancellor
California State University, Sacramento
California State University, San Bernardino
California State University, San Marcos
California State University, Stanislaus
Calvin College
Camden County College
Canisius College
Capital University
Carleton College
Carleton University
Carlow College
Catawba College
Cecil Community College
Cedarville University

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Naropa University
Nashville State Community College
Nebraska Wesleyan University
Nevada State College
New Jersey City University
New Jersey Institute of Technology
New Mexico Institute of Mining and Technology
New Mexico State University
New York Law School
New York University
Nipissing University
Norfolk State University
North Arkansas College
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North Carolina State University
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Rogers State University
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Rowan University
Rutgers, The State University of New Jersey, New Brunswick
Ryerson University
Sacred Heart University
Saint Anselm College
Saint Augustine's College
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Saint Leo University
Saint Louis Community College Center
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Saint Vincent College
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Sam Houston State University
Samuel Merritt College
San Jose State University
San Juan College
Santa Clara University
Santa Fe Community College
Scottsdale Community College
Seattle Pacific University
Seton Hall University
Seton Hill University
Shepherd University
Simmons College
Simon Fraser University
Sinclair Community College
Sonoma State University
Southern Illinois University Edwardsville
Southwest Missouri State University–West Plains
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Southwestern Community College
Southwestern University
Spring Hill College
St. Cloud State University
St. Lawrence University
St. Louis College of Pharmacy
St. Mary's College of Maryland
St. Olaf College
Stanford University
State Fair Community College
Stephen F. Austin State University
Stony Brook University
SUNY College at Cortland
SUNY College at Plattsburgh
SUNY College of Technology at Alfred
SUNY System Administration
Sweet Briar College
Temple University
Tennessee Technological University
Texas A&M University–Corpus Christi
Texas A&M University
Texas A&M University at Galveston
Texas A&M University at Qatar
Texas Christian University
Texas State University–San Marcos
The Banff Centre
The College of New Jersey
The College of Saint Scholastica
The George Washington University
The Graduate Center (CUNY)
The Ohio State University
The Pennsylvania State University
The University of British Columbia
The University of Iowa
The University of Memphis
The University of Western Ontario
Thiel College
Trinity University
Triton College
Tufts University
UCLA
Ulster County Community College
Union College
Union County College
United States Air Force Academy
Universidad Carlos Albizu
Universite du Quebec in Outaouais
University & Community College System of Nevada
University at Albany, SUNY
University at Buffalo
University College of the Fraser Valley
University of Akron
University of Alaska
University of Alaska Fairbanks
University of Arkansas
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University of Calgary
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Appendix B

Interviewees in Qualitative Research

Brandeis University
- Mike Fitzgerald, Senior Data Network Engineer
- Perry O. Hanson, Chief Information Officer, Associate Provost for Academic Technology
- Anna Tomecka, Associate Chief Information Officer and Director, Information Technology Services

California State University, Northridge (CSUN)
- Spero P. Bowman, Chief Information Officer and Associate Vice President for Academic Resources and Planning
- Yvonne Davis, Director, Network Engineering and Operations
- Steve Fitzgerald, Chief Technology Officer
- Bill Hardy, Director, User Support Services

California State University, Office of the President
- Richard West, Executive Vice Chancellor and Chief Financial Officer

Corporation for Education Network Initiatives in California (CENIC)
- Jim Dolgonas, President, Chief Operating Officer

Coalition for Networked Information (CNI)
- Clifford Lynch, Executive Director

Colorado State University
- Patrick Burns, Associate Vice President for Information and Instructional Technology
- Scott Baily, Associate Director for Networking
- Jose Valdes, Associate Director for Telecommunications

Concordia University (Austin, Texas)
- David Kluth, Vice President, University Services

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Columbia University
Vace Kundakci, Deputy Vice President, Academic Information Systems

Coppin State University
Ahmed El-Haggan, Vice President of Information Technology, Chief Information Officer, and Professor of Computer Science

The Darwin Group, Inc.
Michael M. Roberts, Principal

Eastern Michigan University
Rocky Jenkins, Director of Network and Systems Services

EDUCAUSE
Mark Luker, Vice President

EDUCAUSE Center for Applied Research
Robert Albrecht, Senior Fellow

Franklin W. Olin College of Engineering
Joanne M. Kossuth, Chief Information Officer

Genesee Community College
Mary Jane Heider, Director, Academic Computing

George Mason University
Randy D. Anderson, Director, Network Engineering and Technology

Georgia Institute of Technology
John Mullin, Associate Vice Provost, Associate Vice President, and Chief Information Officer for Information Technology

Immaculata University
Dale Marchand, Chief Information Officer

Indiana University
Brian D. Voss, Associate Vice President, Information Technology (Telecommunications), Office of the Vice President for Information Technology, and Chief Information Officer
Michael J. Enyeart, Scientist

Internet2
Doug Van Houweling, President and Chief Executive Officer
Greg Wood, Director of Communications
L. Robert Kimball and Associates
Chris Peabody, Director of Enterprise Network Consulting

Macon State College
E. Michael Staman, Peyton Anderson Professor in Information Technology

Marist College
Joe Aulino, Vice President and Chief Information Officer

Miami Dade College
Jackie Zelman, Vice Provost and College Chief Information Officer

Middle Tennessee State University
Lucinda T. Lea, Vice President for Information Technology and Chief Information Officer
Chris Piety, Assistant Director, Network Services

Morehouse School of Medicine
Eric L. Jackson, Chief Information Officer

National LambdaRail
Tom West, President

North Harris Montgomery Community College District
Ron Stauss, Vice Chancellor, Information Technology and Telecommunication
Chris Smith, Director of Networking

Northern Michigan University
Gavin Leach, Associate Vice President for Finance and Planning

The Pennsylvania State University
Steve Updegrove, Senior Director, Information Technology Services

Purdue University
John P. Campbell, Associate Vice President of Teaching and Learning Technologies

Raritan Valley Community College
Chuck Chulvick, Vice President, Learning and Technology Services

St. Lawrence University
Phil Trivilino, Manager of Network Infrastructure

San Jose State University
Bob Neal, Director, Network Services, University Computing and Telecommunications
Southwestern University
Bob Paver, Associate Vice President, Information Technology Services

United States Air Force Academy
Larry W. Bryant, Director, Academic Computing

University of British Columbia
Ted Dodds, Associate Vice President, Information Technology
Jovan Miladinovic, Manager, Connectivity Services and Information Technology Services

University of California, San Diego
Elazar Harel, Assistant Vice Chancellor and Chief Information Officer

University of Central Florida
Joel Hartman, Vice Provost, Information Technologies and Resources

University of Colorado at Boulder
Kenneth J. Klingensteini, Project Director, Internet2 Middleware Initiative, and Chief Technologist

University of Hawaii
Garret Yoshimi, Manager, Telecommunications

University of La Verne
Clive Houston-Brown, Chief Information Officer

University of Louisville
Michael H. Dyre, Director, Information Technology Research and Development

University of Manchester
Mark Clark, Director of Information Systems

University of Maryland, College Park
Mark Katsouros, Communications Integration Engineer

University of Memphis
Douglas E. Hurley, Vice President for Information Technology and Chief Information Officer

University of North Carolina at Charlotte
Karin Steinbrenner, Associate Provost and Chief Information Officer

University of North Dakota
Craig Cerkowniak, ITSS Associate Director
University of Notre Dame
Dewitt Latimer, Deputy Chief Information Officer and Chief Technology Officer, and Senior ECAR Fellow

University of Texas at Austin
Dan Updegrove, Vice President for Information Technology

University of Virginia
James A. Jokl, Director of Communications and Systems

University of Washington
Terry Gray, Director of Networking and Distributed Computing

York College of Pennsylvania
Robert L. Robinson, Director, Information Technology
Appendix C

Glossary

- 1 -

10-Gigabit Ethernet: A supplement to the 802.3 standard that defines Ethernet. The 10-Gigabit Ethernet version of Ethernet operates in full-duplex mode only and supports data transfer rates of 10 gigabits per second for distances up to 300 meters on multimode fiber optic cables and up to 40 kilometers on single-mode fiber optic cables. 10-Gigabit Ethernet is often abbreviated 10GbE. The IEEE formally ratified the standard on June 12, 2002.

10Base-T: One of several adaptations of the Ethernet standard for LANs. The 10Base-T standard (also called Twisted Pair Ethernet) uses a twisted-pair cable with maximum lengths of 100 meters. The 10Base-T system operates at 10 Mbps and uses baseband transmission methods.

100Base-T: A networking standard that supports data transfer rates up to 100 Mbps. 100Base-T is based on the older Ethernet standard. Because it is 10 times faster than Ethernet, it is often referred to as Fast Ethernet.

1000Base-T: A specification for Gigabit Ethernet over copper wire. The standard defines 1-Gbps data transfer over distances of up to 100 meters using four pairs of Category 5 balanced copper cabling and a 5-level coding scheme.

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802.3: A standard that defines the MAC layer for bus networks and is the basis of the Ethernet standard.

802.11: A family of specifications developed by the IEEE for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients. The IEEE accepted the specification in 1997. 802.11 applies to wireless LANs and provides 1- or 2-Mbps transmission in the 2.4-GHz band.

802.11a: An extension to 802.11 that applies to wireless LANs and provides up to 54 Mbps in the 5-GHz band.

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802.11b: An extension to 802.11 that applies to wireless LANs and provides 11-Mbps transmission (with a fallback to 5.5, 2, and 1 Mbps) in the 2.4-GHz band. 802.11b was a 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.

802.11g: Applies to wireless LANs and provides 20+ Mbps in the 2.4-GHz band.

Abilene: An Internet2 backbone network; a partnership among Internet2, Qwest Communications, Nortel Networks, Juniper Networks, and Indiana University.

ANSI (American National Standards Institute): Founded in 1918, ANSI is a voluntary organization composed of over 1,300 members (including all the large computer companies) that creates standards for the computer industry. In addition to programming languages, ANSI sets standards for a wide range of technical areas, from electrical specifications to communications protocols. For example, FDDI is an ANSI standard.

ASP (Application Service Provider): Refers to an arrangement with an application service provider to provide services remotely using high-speed private networks. A common example is a Web site that other Web sites use for accepting payment by credit card as part of their online ordering systems.

Asynchronous Transfer Mode (ATM): A network technology based on transferring data in cells or packets of a fixed size. The cell used with ATM is relatively small compared with units used with older technologies. The small, constant cell size allows ATM equipment to transmit video, audio, and computer data over the same network and ensure that no single data type hogs the line.

Authentication: The process of identifying an individual, usually based on a username and password. In security systems, authentication merely ensures that the individual is who he or she claims to be, but says nothing about the individual’s access rights. Most computer security systems are based on a two-step process. The first stage is authentication, which ensures that a user is who he or she claims to be. The second stage is authorization, which grants access to various resources on the basis of the user’s identity.

Authentication Server: A system that provides authentication services to other systems on a network.

Authorization: The process of granting or denying access to a network resource. Most computer security systems are based on a two-step process. The first stage is authentication, which ensures that a user is who he or she claims to be. The second stage is authorization, which grants access to various resources on the basis of the user’s identity.

Backbone: The network segment or segments that interconnect network concentration points (such as Ethernet switches). Multiple backbones can be implemented in shared fiber strands using VLANs or optical multiplexing (multiple lasers, for example).

Bandwidth: The amount of data that can be transmitted over a network in a fixed amount of time. Bandwidth is the fundamental networking parameter and is usually measured in kilobits, megabits, or gigabits per second (Kbps, Mbps, or Gbps).
**Baseband:** A type of data transmission in which digital or analog data is sent over a single unmultiplexed channel, such as an Ethernet LAN.

**Biometrics:** In computer security, biometrics refers to authentication techniques that rely on physical characteristics that can be automatically checked. Examples include computer analysis of fingerprints or speech.

**Broadband:** A type of data transmission in which a single medium (wire) can carry several channels at once. Cable TV, for example, uses broadband transmission. In contrast, baseband transmission allows only one signal at a time.

**Bus:** In networking, a bus is a central cable that connects all devices on a LAN. It is also called the backbone.

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**Category 3 Twisted Pair:** An unshielded twisted-pair cable used for telephone and networking connections, for voice and data on 10Base-T Ethernet. It supports up to 16 Mbps. The maximum recommended cable run is 100 meters (328 feet).

**Category 4 Twisted Pair:** A cable used primarily in 16-Mbps token-ring networks that supports up to 20 Mbps.

**Category 5 Twisted Pair:** A network cabling that consists of four twisted pairs of copper wire terminated by RJ45 connectors. Category 5 cabling supports 100 Mbps, 1000 Mbps (4 pair), 100-Mbps TPDDI, and 155-Mbps ATM. It is no longer supported, as it has been replaced by Category 5E twisted pair.

**Category 5E Twisted Pair:** Also called Enhanced Category 5, it is an eight-conductor unshielded twisted-pair cable with a plastic rib in the center of the cable to separate the pairs. It is used primarily for networking and computer connections, offering better near-end crosstalk than Category 5 twisted pair, which it replaced. It supports 1000 Mbps (10,000-Mbps prototype), 100-Mbps TPDDI, 155-Mbps ATM, and Gigabit Ethernet. The maximum recommended cable run is 100 meters (328 feet).

**Category 6 Twisted Pair:** An eight-conductor unshielded twisted-pair cable that differs from Category 5 twisted pair in that it uses all four pairs. It is rated up to 400 MHz and used for super-fast broadband applications. Category 6 is the most popular cabling for new installations.

**Category 6E Twisted Pair:** Enhanced Category 6 is field tested up to 500 MHz and rated up to 625 MHz. It supports 10-Gigabit Ethernet.

**Category 7 Twisted Pair:** An eight-conductor shielded twisted-pair cable, rated at 600 to 700 MHz to 1.2 GHz in pairs with Siemon connector. It is used for full-motion video and teleradiology in government and manufacturing environments. The maximum recommended cable run is 100 meters (328 feet).
Coaxial Cable: A type of wire that consists of a center wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference. Coaxial cabling is the primary type of cabling used by the cable television industry and is also widely used for computer networks, such as Ethernet. Although more expensive than standard telephone wire, it is much less susceptible to interference and can carry much more data.

Co-Location: Locating a server, usually a Web server, at a dedicated facility with resources including a secured cage or cabinet, regulated power, dedicated Internet connection, security, and support. Co-location facilities offer the customer a secure place to physically house their hardware and equipment as opposed to locating it in their offices or warehouse where the potential for fire, theft, or vandalism is much greater. Most co-location facilities offer high security, including cameras, fire detection and extinguishing devices, multiple connection feeds, filtered power, backup power generators, and other items to ensure the high availability that is mandatory for all Web-based, virtual businesses.

Competitive Local Exchange Carrier (CLEC): A telephone company that competes with an incumbent local exchange carrier (ILEC) such as a Regional Bell Operating Company (RBOC), GTE, ALLNET, and the like.

Composite Fiber Optic Cable: A cable sheath that contains some mix of multimode and single-mode fibers.

Converged Services: Network services that use two or more disparate disciplines or technologies. For example, many institutions offer new services that run over a converged network infrastructure of data, voice, and/or video.

Dark Fiber: Refers to unused fiber optic cable. Companies often lay more lines than needed to curb costs of having to do it repeatedly. The dark strands can be leased to individuals or other companies who want to establish optical connections among their own locations. In this case, the fiber is neither controlled by nor connected to the originating company. Instead, the company or individual provides the necessary components to make it functional.

Desktop Video Conferencing: A service that lets participants at different sites transmit audio and video data via their computer-mounted video cameras, microphones, and speakers by using computer networks.

Digital Certificate: An attachment to an electronic message used for security purposes. The most common use of a digital certificate is to verify that a user sending a message is who he or she claims to be, and to provide the receiver with the means to encode a reply.

Directory Service: A network service that identifies all resources on a network and makes them accessible to users and applications. Resources include e-mail addresses, computers, and peripheral devices such as printers. Ideally, the directory service should make the physical network topology and protocols transparent so that a user on a network can access any resource without knowing where or how it is physically connected.

Disaster Recovery: The ability of an infrastructure to restart operations after a disaster.
**Ethernet:** A LAN architecture developed by Xerox Corporation in cooperation with DEC and Intel in 1976. Ethernet uses a bus or star topology and supports data transfer rates of 10 Mbps. The Ethernet specification served as the basis for the IEEE 802.3 standard, which specifies the physical and lower software layers and a series of standards for telecommunication technology over Ethernet local area networks. Several adaptations of Ethernet exist, including Twisted Pair Ethernet or 10Base-T, Fast Ethernet or 100Base-T, Gigabit Ethernet or 1000Base-T, and 10-Gigabit Ethernet.

**Fast Ethernet:** See 100Base-T.

**FDDI (Fiber Distributed Data Interface):** A set of ANSI protocols for sending digital data over fiber optic cable. FDDI networks are token-passing networks and support data rates of up to 100 Mbps (100 million bits per second). FDDI networks are typically used as backbones for wide area networks. An extension to FDDI, called **FDDI-2**, supports the transmission of voice and video information as well as data. Another variation of FDDI, called **FDDI Full Duplex Technology (FFDT)**, uses the same network infrastructure but can potentially support data rates up to 200 Mbps.

**Gigabit Ethernet:** A version of Ethernet that supports data transfer rates of 1 gigabit (1,000 megabits) per second.

**gigaPOP (Gigabit Point of Presence):** A network access point that supports data transfer rates of at least 1 Gbps. Currently, only a few gigaPOPs exist, and they’re used primarily for accessing the Internet2 (I2) network. Each university that connects to I2 must do so through a gigaPOP, which connects the university’s local area networks and wide area networks to the I2 network. Originally, 12 gigaPOPs were planned, each one serving half a dozen I2 members, but the number of gigaPOPs is likely to grow. Whereas the POs maintained by ISPs are designed to allow low-speed modems to connect to the Internet, gigaPOPs are designed for fast access to a high-speed network, such as I2.

**Grid Computing:** A form of networking which, unlike conventional networks that focus on communication among devices, harnesses unused processing cycles of all computers in a network for solving problems too intensive for any stand-alone machine.

**Host:** (n.) (1) A computer system that is accessed by a user working at a remote location. Typically, the term is used when there are two computer systems connected by modems and telephone lines. The system that contains the data is called the host, while the computer at which the user sits is called the remote terminal. (2) A computer connected to a TCP/IP network, including the Internet. Each host has a unique IP address. (v.) To provide the infrastructure for a computer service. For example, many companies host Web servers. This means they provide the hardware, software, and communications lines required by the server, but someone else may control the server’s contents.

Internet2: A university-led effort to develop advanced network applications and the network technologies needed to support them. The 200+ U.S. universities that lead the project work closely with partners in industry and government, and with advanced networks around the world.

IP (Internet Protocol): The most common protocol currently used to send information across data networks. All Internet traffic uses this protocol.

IP (Internet Protocol) Address: An identifier for a computer or device on a TCP/IP network. Networks using the TCP/IP protocol route messages based on the destination’s IP address. The format of an IPv4 address is a 32-bit numeric address written as four numbers separated by periods. Each number can be zero to 255. For example, 1.160.10.240 could be an IP address. Within an isolated network, you can assign IP addresses at random as long as each one is unique. However, connecting a private network to the Internet requires using registered IP addresses (called Internet addresses) to avoid duplicates.

IP CLEC (Internet Protocol-based Competitive Local Exchange Carrier): A competitive local exchange carrier that provides local and/or long-distance services via IP.

IP (Internet Protocol) Multicast: Enables a network server to broadcast a message to many recipients simultaneously. Unlike traditional Internet traffic that requires separate connections for each source–destination pair, IP multicasting allows many recipients to share the same source, transmitting one set of packets for all the destinations.

IP (Internet Protocol) PBX: A private branch exchange or a private telephone network used within an enterprise, that uses IP.

IP (Internet Protocol) Video Streaming: A suite of services to provide customers with IP Web-based video and audio services.

IPv6: (Internet Protocol Version 6): The next version of the Internet Protocol. The current version is IPv4; IPv5 was an experimental real-time streaming protocol. IPv6 offers several improvements over IPv4, the most important of which is a vastly larger address space. IPv6 is designed as an evolutionary upgrade to the Internet Protocol and will, in fact, coexist with the older IPv4 for some time. IPv6 is designed to allow the Internet to grow steadily, both in terms of the number of hosts connected and the total amount of data traffic transmitted.

ISO (International Organization for Standardization): ISO is not an acronym; instead, the name derives from the Greek word isos, which means equal. Founded in 1946, ISO is an international organization composed of national standards bodies from over 75 countries. For example, ANSI belongs to the ISO.

ISP (Internet Service Provider): A company that provides Internet access to consumers, typically for a monthly fee. Equipped with the appropriate modem or broadband router, users can log on to the Internet and browse the World Wide Web and USENET, and send and receive e-mail. ISPs also serve large companies, providing a direct connection from company networks to the Internet.
ITU (International Telecommunication Union): An international organization headquartered in Geneva, Switzerland, in the United Nations System where governments and the private sector coordinate global telecom networks and services. The ITU Standardization Section develops internationally agreed-upon technical and operating standards and defining tariff and accounting principles for international telecommunication services.

LAN (Local Area Network): A computer network that spans a relatively small area. Most LANs are confined to a single building or group of buildings. However, one LAN can be connected to other LANs over any distance via telephone lines and radio waves. A system of LANs connected as such is called a wide area network (WAN). Most LANs connect workstations and personal computers. Each node (individual computer) in a LAN has its own CPU with which it executes programs, but it also is able to access data and devices anywhere on the LAN. This means that many users can share expensive devices, such as laser printers, as well as data. Users can also use the LAN to communicate with each other by sending e-mail or engaging in chat sessions.

Latency: The amount of time it takes a packet to travel from source to destination. Together, latency and bandwidth define a network’s speed and capacity.

LDAP (Lightweight Directory Access Protocol): A set of protocols for accessing information directories. LDAP is based on the standards contained within the X.500 standard, but is significantly simpler. And unlike X.500, LDAP supports TCP/IP, which is necessary for any type of Internet access. Because it’s a simpler version of X.500, LDAP is sometimes called X.500-lite. Because LDAP is an open protocol, applications need not worry about the type of server hosting the directory.

MAC (Machine Access Control) Address: The network level 2 address that allows a network interface to be uniquely identified.

Modem Pool: A group of modems that answer calls at a single phone number and connect callers to a specific resource. A user calls a single number and is forwarded to any one of a group of modems. Many offices use modem pools to connect callers to their LAN or WAN. Usually a phone switch takes care of the actual “pooling” of modems. Thus, if one modem is busy, it forwards calls to the next one.

Multimode Fiber Optic Cable: A cable made of glass fibers with a common diameter in the 50- to 100-micron range. Multimode fiber gives high bandwidth at high speeds over medium distances.
National LambdaRail, Inc. (NLR): A major initiative of U.S. research universities and private-sector technology companies to provide a national-scale infrastructure for research and experimentation in networking technologies and applications. NLR puts the control, power, and promise of experimental network infrastructure in the hands of scientists and researchers. When complete, NLR will be the largest higher-education-owned and -managed optical networking and research facility in the world. NLR will initially include four 10-Gbps light waves provisioned across approximately 10,000 route miles of dark fiber.

Network: (n.) A group of two or more computer systems linked together. (v.) To connect two or more computers together with the ability to communicate with each other.

Network Directory Service: A network service that identifies all resources on a network and makes them accessible to users and applications. Resources include e-mail addresses, computers, and peripheral devices such as printers. Ideally, the directory service should make the physical network topology and protocols transparent so that a user on a network can access any resource without knowing where or how it is physically connected.

Node: In networks, a processing location. A node can be a computer or some other device, such as a printer. Every node has a unique network address.

Open Source: A program in which the source code is available to the general public for use and/or modification from its original design free of charge, that is, open. Open source code is typically created as a collaborative effort in which programmers improve upon the code and share the changes within the community. Open source sprouted in the technological community as a response to proprietary software owned by corporations.

Outsource: Contracting with an external entity or vendor to provide IT services or infrastructure that an IT department might otherwise have employed its own staff to perform. It does not refer to an arrangement with another part of an institution or with a system office.

P2P (Peer to Peer): A type of network in which each workstation has equivalent capabilities and responsibilities. This differs from client–server architectures, in which some computers are dedicated to serving the others. Peer-to-peer networks are generally simpler, but they usually do not offer the same performance under heavy loads.

Packet: The unit of data sent across a network during transmission. Data is broken into packets of an efficient size for routing by the sending system and reconstructed at the destination.

Packet Sniffers (also known as Network Analyzers or Ethernet Sniffers): Software programs that can see the traffic passing over a network or part of a network. As data streams travel back and forth over the network, the program captures each packet and eventually decodes its content. Depending on the network structure, one can sniff all or only parts of the traffic from a single machine within the network.
**Port:** A logical connection in TCP/IP networking to connect a client to a service. Port numbers can range from 0 to 65536. Commonly used applications such as HTTP have pre-assigned port numbers (HTTP always uses port 80, for example).

**Port Scanner:** Software designed to search a network host for open ports. This is often used by network administrators to check the security of their network.

**PABX (Private Automatic Branch Exchange):** An in-house telephone switching system that interconnects telephone extensions to each other, as well as to the outside telephone network. See PBX.

**PBX (Private Branch Exchange):** A private telephone network used within an enterprise. PBX users share a certain number of outside telephone lines for making telephone calls external to the PBX. A PBX is usually much less expensive than connecting an external telephone line to every telephone in the organization. In addition, it’s easier to call someone within a PBX because the number you need to dial is typically just three or four digits. A variation on the PBX theme is the Centrex, which is a PBX with all switching occurring at a local telephone office instead of at the company’s premises. In this study, the concept of PBX also includes private automatic branch exchange (PABX).

**Protocol:** The protocol defines a common set of rules and signals that computers on the network use to communicate. Ethernet is one of the most popular protocols for LANs.

**QoS (Quality of Service):** A networking term that specifies a guaranteed throughput level to customers, ensuring that end-to-end latency will not exceed a specified level.

**Redundancy:** The duplication of system components with the intention of increasing the system’s reliability.

**Remote Access:** The ability to log on to a network from a distant location. Using an ISP, modem, or remote network, the remote computer actually becomes a full-fledged host on the network. For security reasons, remote access also uses VPN software. Access speed is limited by the lowest bandwidth segment in the route between the remote and local networks.

**Router:** A network device that connects multiple networks and forwards network packets to their destinations, based on a series of algorithms. Routers can be configured to allow or block different types of network traffic.

**Server:** A computer or device on a network that manages network resources. For example, a *file server* is a computer and storage device dedicated to storing files. Any user on the network can store files on the server. A *print server* is a computer that manages one or more printers, and a *network server* is a computer that manages network traffic. A *database server* is a computer system that processes database queries. Servers are often dedicated, meaning that they perform no other tasks besides their server tasks. On multiprocessing operating systems, however, a single computer can execute several programs at once. A server in this case could refer to the program that is managing resources rather than the entire computer.
**Shaping:** The adjustment of parameters on the campus Internet connection to limit use through various means, such as amount of traffic, type of connection, location of connection, direction of traffic, time of day, or other specific characteristics.

**Shared Ethernet:** The traditional type of Ethernet, in which all hosts are connected to the same backbone and compete with one another for bandwidth. (See also Switched Ethernet.)

**Single-Mode Fiber:** A single strand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. It carries higher bandwidth than multimode fiber but requires a light source with a high-intensity, narrow spectral width (laser). Single-mode fiber gives a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fiber has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.

**SLA (Service-Level Agreement):** A contract between an ISP or ASP (such as an institution’s central IT department) and the end user that stipulates and commits the ASP to a required level of service. An SLA should contain a specified level of service, support options, enforcement or penalty provisions for services not provided, a guaranteed level of system performance measured by downtime or uptime, a specified level of customer support, and what software or hardware will be provided and for what fee.

**Smart Card:** Refers to a small electronic device about the size of a credit card that contains electronic memory and possibly an embedded integrated circuit. Smart cards are used for various purposes, including storing information, storing digital cash, and providing a means to access computer networks.

**Storage Area Network (SAN):** A network that is designed to attach computer storage devices such as disk array controllers and tape silos to servers.

**Streaming:** A technique for transferring data such that it can be processed as a steady and continuous stream. Streaming technologies are becoming increasingly important with the growth of the Internet because most users do not have fast enough access to download large multimedia files quickly. With streaming, the data is displayed before the entire file has been transmitted. For streaming to work, the client side receiving the data must be able to collect the data and send it as a steady stream to the application that is processing the data and converting it to sound or pictures. This means that if the streaming client receives the data more quickly than required, it needs to save the excess data in a buffer. If the data doesn’t come quickly enough, however, the presentation of the data will not be smooth.

**Switch:** A device that filters and forwards packets between LAN segments. Switches operate at the data link layer (layer 2) and sometimes the network layer (layer 3) of the OSI Reference Model and therefore support any packet protocol. LANs that use switches to join segments are called switched LANs or, in the case of Ethernet networks, switched Ethernet LANs.

**Switched Ethernet:** An Ethernet LAN that uses switches to connect individual hosts or segments. Switched Ethernets are becoming very popular because they are an effective and convenient way to extend the bandwidth of existing Ethernets.
**TCP/IP (Transmission Control Protocol/Internet Protocol):** The suite of communications protocols used to connect hosts on the Internet. TCP/IP uses several protocols, the two main ones being TCP and IP. TCP/IP is built into the Unix operating system and is used by the Internet, making it the de facto standard for transmitting data over networks. Even network operating systems that have their own protocols also generally support TCP/IP.

**Token Ring:** A type of computer network in which all the computers are arranged (schematically) in a circle. A token, which is a special bit pattern, travels around the circle. To send a message, a computer catches the token, attaches a message to it, and then lets it continue to travel around the network.

**Topology:** The geometric arrangement of a computer system. Common network topologies include bus, star, and ring.

**Twisted Pair:** A type of cable that consists of two independently insulated wires twisted around one another. While twisted-pair cable is used by older telephone networks and is the least expensive type of LAN cable, most networks contain some twisted-pair cabling at some point along the network. Other types of cables used for LANs include coaxial cables and fiber optic cables. Types of twisted pair include Category 3, Category 4, Category 5, Category 5E, and Category 6, which are designed to handle different transmission speeds.

**Twisted-Pair Ethernet:** See 10Base-T.

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**Unified Messaging:** The integration of several different communications media such that users can retrieve and send voice, fax, and e-mail messages from a single interface, whether it be a wireline phone, a wireless phone, a PC, or an Internet-enabled PC.

**UPS (Uninterruptible Power Supply):** A power supply that includes a battery to maintain power in the event of a power outage. Typically, a UPS keeps a computer running for several minutes after a power outage, enabling users to save data and shut down the computer gracefully. Many UPSs now offer a software component that enables the user to automate backup and shutdown procedures if a power failure occurs while the user is away from the computer.

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**Video Conference:** Conducting a conference between two or more participants at different sites using computer networks to transmit audio and video data. For example, a point-to-point (two-person) video conferencing system works much like a video telephone. Each participant has a video camera, microphone, and speakers mounted on his or her computer. As the two participants speak to one another, their voices are carried over the network and delivered to the other’s speakers, and whatever images appear in front of the video camera appear in a window on the other participant’s monitor. Multipoint video conferencing allows three or more participants to sit in a virtual conference room and communicate as if they were sitting right next to each other.
VLAN (Virtual Local Area Network): A network of computers that behave as if they are connected to the same wire even though they may actually be physically located on different segments of a LAN. VLANs are configured through software rather than hardware, which makes them extremely flexible. One of the biggest advantages of VLANs is that when a computer is physically moved to another location, it can stay on the same VLAN without any hardware reconfiguration.

VoIP (Voice over Internet Protocol): A category of hardware and software that enables people to use the Internet as the transmission medium for telephone calls by sending voice data in packets using IP rather than by traditional circuit transmissions of the PSTN (public switched telephone network). One advantage of VoIP is that the telephone calls over the Internet incur no surcharge beyond what the user is paying for Internet access, much in the same way that the user doesn’t pay for sending individual e-mails over the Internet.

VPN (Virtual Private Network): A remote access system that allows remote users to securely connect to their home network or another IP network through an encrypted tunnel.

WAN (Wide Area Network): A network of local area networks (LANs) that provides communication and services over a geographic area larger than that served by a LAN.

Wireless CLEC (Competitive Local Exchange Carrier): A competitive local exchange carrier (a telephone company that competes with an incumbent local exchange carrier) that provides either local or long-distance services via wireless media.

Wireless Network: A type of local area network that uses high-frequency radio waves rather than wires to communicate between nodes.

X.500: An ISO and ITU standard that defines how global directories should be structured. X.500 directories are hierarchical, with different levels for each category of information, such as country, state, and city.

References
Appendix D

Bibliography


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