Key Findings

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

Judith A. Pirani and Gail Salaway

Providing a high-quality campus network—reliable, secure, adaptable, scalable, and fault tolerant—has become fundamental in higher education. Higher education's access to information assets, whether they support core missions of research and teaching or business administration, is increasingly central to enhancing reputation, competitiveness, client satisfaction, revenue, and accountability. Consequently, networking capabilities are now used in diverse and creative ways to facilitate strategic goals, such as creating 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 robust network is the most basic underpinning for these types of initiatives, and IT leaders continue to enhance networks accordingly. At the campus level, institutions are investing substantial financial and human resources to continually refine campus technical architectures to support evolving technologies and applications and to support growing and diverse campus needs. Beyond the campus, the higher education community is actively building a set of interconnected private state, regional, and national research and education networks.

The higher education community is committed to the vision of every citizen having access to its networks and is taking an active role to ensure this happens over the next several years. At the same time, research and development of new technologies continues at a brisk pace. In the near term, mobile devices are proliferating; embedded chip connectivity applications are appearing in the commercial sector; and emerging technologies like wave division multiplexing and gird computing are paving the way for a coming "era of data-intensive scholarship." Looking further out, higher education continues to play a role as network pioneer—with leading-edge projects under way throughout the academy, investigating a scope of technologies that almost defies the imagination.

The EDUCAUSE Center of Applied Research (ECAR) study, *Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator*,[1] is designed to provide the first comprehensive empirical information about the higher education networking environment, both

from an everyday-practice perspective and from a strategic perspective. It identifies what networking technology and practices are currently in place and what future directions are anticipated and planned. Systematic quantitative data can help institutions make more-informed decisions regarding their networking approaches and plans, and they hopefully contribute to the improvement of networking in higher education.

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 EDUCAUSE member higher education institutions, with 517 responses
- 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
- Three case studies including an institution study of converged networks at the State University 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 network mobility done by SURF, a Dutch higher education research partnership

Significant Findings

Much was learned about the IT network's role in higher education in *Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator*. ECAR's study offers insight and guidance about current practices for the wired and wireless network infrastructures, national research and education networks, emerging technologies, and network management. Our research also highlights characteristics commonly found at institutions that agreed that their institution has a higher-quality network infrastructure.

The Wired Infrastructure

To a significant degree, higher education is wired. Respondents report that almost all faculty and staff offices are wired and that most libraries, residence halls, classrooms (single connection), and research laboratories are wired as well. Associate institutions have the strongest showing in the

number of classrooms with wiring to all classroom seats, perhaps reflecting their early focus on integrating basic technologies into teaching. Institutions also report some progress in wiring indoor public spaces, with baccalaureate institutions having the strongest showing, perhaps reflecting their focus on student community.

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

Table 1. Elements of the Networking Infrastructure

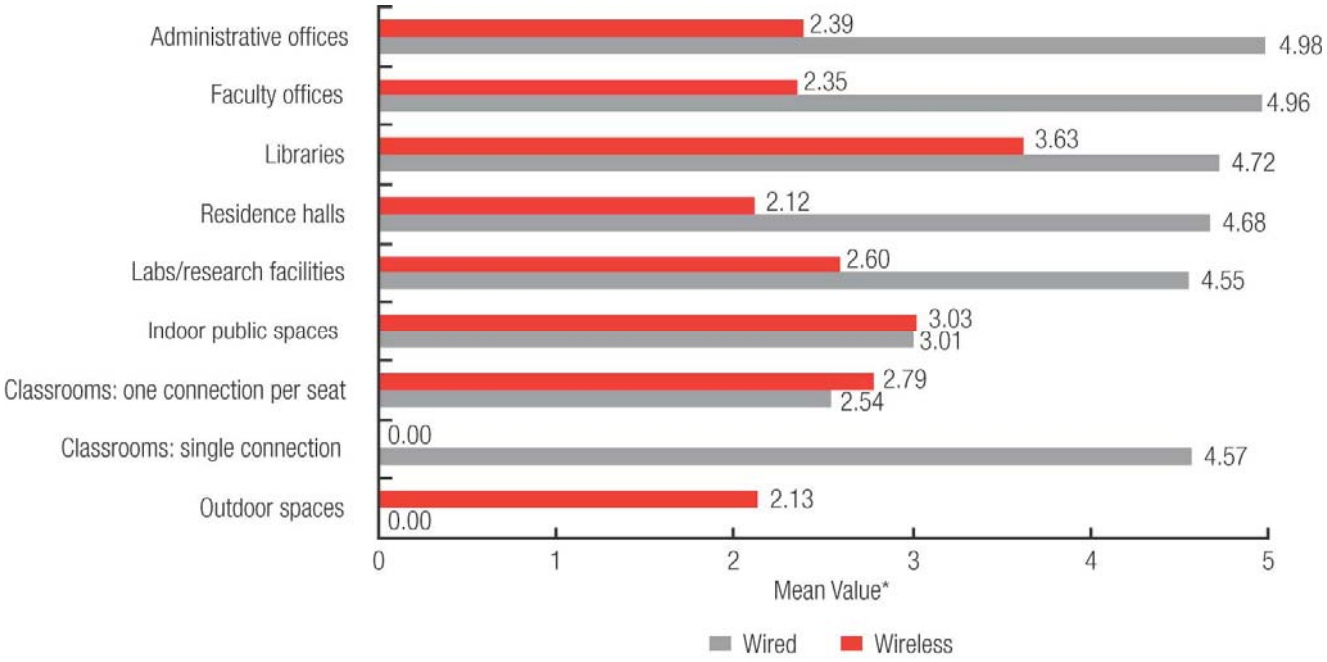
	Most Common
Backbone transmission medium	Multimode fiber optic cable
Backbone bandwidth	1 to 4.99 gigabits per second
Backbone transmission standard	Gigabit Ethernet
Backbone-to-end-device transmission medium	Category 5 and 5e twisted pair
Backbone-to-end-device wired transmission standard	Fast Ethernet
Backbone-to-end-device wireless transmission standard	802.11b
Commodity Internet bandwidth	4.6 to 89 megabits per second

Campus networks are 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 that do not have residence halls. The survey also asked whether respondents believe their network meets the needs of their primary constituencies. Most are confident that staff needs are met by the network (91 percent agree), but there is room for improvement when it comes to meeting faculty needs (78 percent agree) and student needs (only 67 percent agree).

The Wireless Infrastructure

Campuses have made considerable progress in building their wireless network infrastructure, and they are not stopping. Wireless network expansion is especially prevalent in areas that were not physically wired early, as a result of either structural issues or cost and priority. For example, as Figure 1 illustrates, 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 bringing our vision of the 1980s into reality—to have every classroom seat connected to the network. We have reached the point where more classroom seats are connected wirelessly than with wires.

Figure 1. Comparison of Wired and Wireless Installations (Mean Value*)



** Scale = 1 (none) to 5 (almost all)*

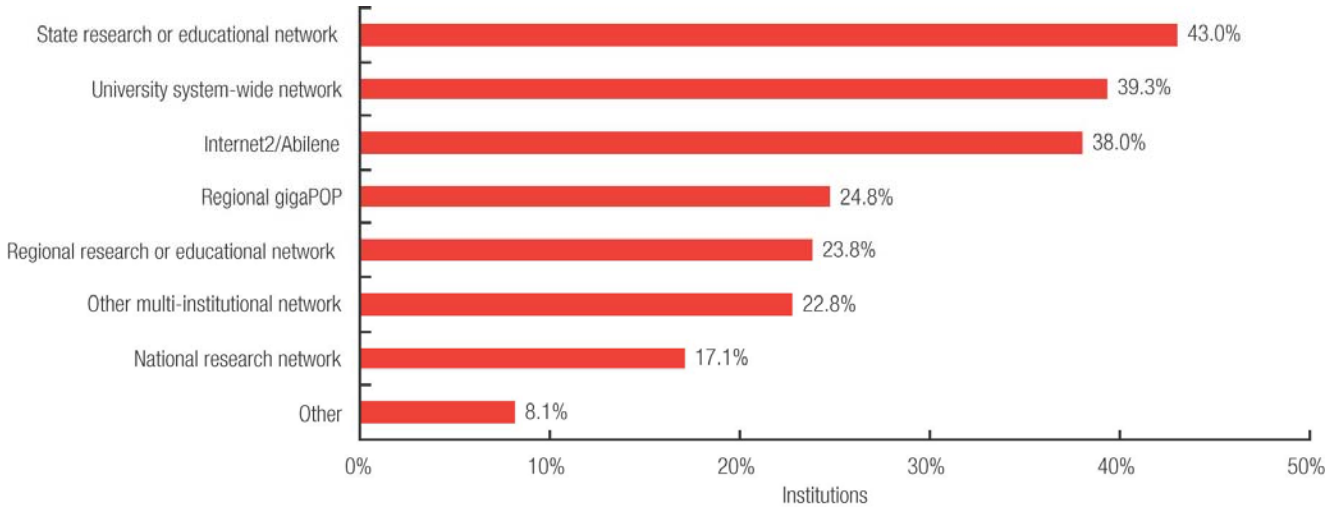
In addition, campuses are actively expanding network access to outdoor spaces, with almost two-thirds of institutions providing some level of outdoor wireless access and about 10 percent reporting a considerable number of outdoor spaces with wireless access. A number of respondents say that providing mobility for students is an essential part of their campus strategic goals, and others are even providing wireless into the community. To date, doctoral institutions report more installation of wireless access in classrooms, indoor public spaces, and outdoor public spaces.

Most respondents view wireless connectivity as supplemental to physical connectivity, especially where bandwidth and security are important. One-fifth, however, plan to 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.

State, Regional, and National Research and Education Networks

A great deal of energy and enthusiasm currently surrounds creating and/or joining private education and research networks (see Figure 2). 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.

Figure 2. Connection to External Networks (Multiple Responses Allowed)



The choices institutions have made regarding which external networks they will join are strongly related to Carnegie class. Doctoral institutions are most highly 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, 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, called regional optical networks (RONs). These regional networks provide their constituents with connectivity to external networks, and their constituencies are growing. Completion of a national higher education research and education network infrastructure requires that these individual pieces all come together—campus, state, regional, and national networks. There is also a stated goal among the key players creating these networks 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.

Emerging Technologies

Because user demands on campus are constantly evolving, maintaining a network infrastructure to meet those needs is a very fluid process, and evaluating and implementing new technologies is a key role of many central IT organizations. Unlike the corporate world, which typically builds networks to support specific needs, higher education thrives on discovery, experimentation, and the unknown. Shared networks must meet the high-performance requirements of video conferencing to support computational chemistry or music master classes, while supporting the steady rise of classes that incorporate course management systems and Web interactions.

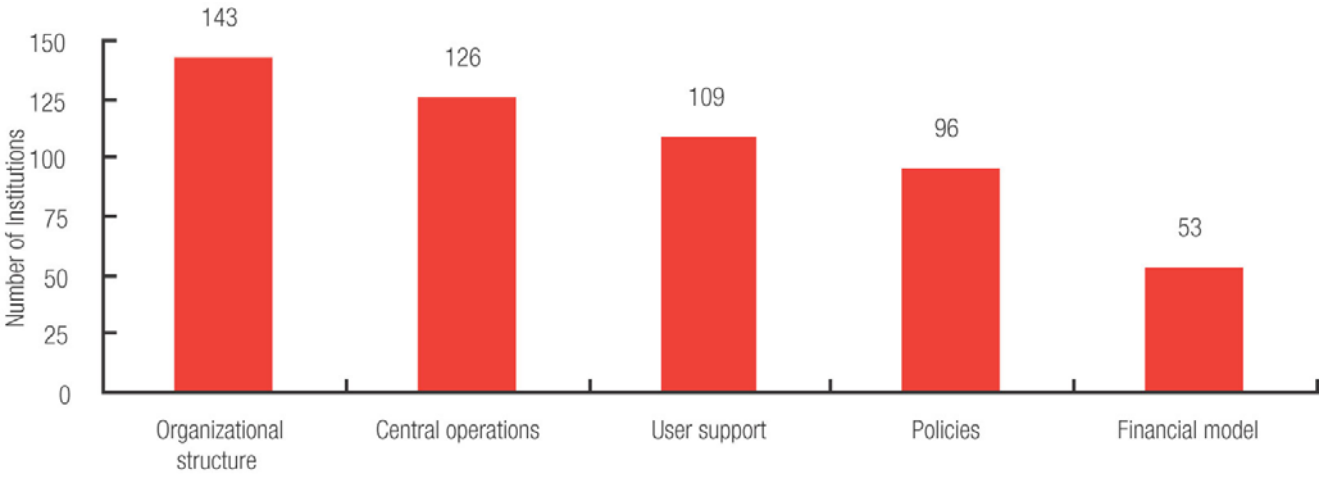
One area of particular focus is the convergence of the network infrastructures for data, voice, and/or video. Most respondents say they are somewhere on the adoption curve between evaluating and

actually running converged networks for some applications. About half of respondents indicate that IP video streaming and/or desktop video conferencing is already in limited use on their campuses, and most other institutions are either planning to implement or evaluating these technologies. There is less use of voice over Internet protocol (VoIP)—about one-fourth of institutions. An even smaller number of institutions are currently implementing other converged services such as cable TV over the network and integrated messaging. Larger institutions, which include 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 who are not yet considering convergence have extremely practical reasons for not doing so—most often they have higher IT priorities (65 percent) or they don't require converged services at this time (60 percent). Others do not see an acceptable return on investment (42 percent) or are unwilling to discard their investment in legacy technologies (33 percent). It is also important to note that a significant number of respondents (20 percent) are not yet considering converged services because their current network infrastructure cannot support them.

What is the impact of convergence on the central network organization? Figure 3 illustrates that among those considering or implementing converged networks,[2] the most common area of change is the organizational structure (143 institutions). Somewhat fewer organizations said that they have made changes to central networking operations, user support, or network policies. Fewest of all (only 53 institutions) report that they have made changes to the financial model for funding and charging for network services. In the qualitative interviews, however, the need to restructure the funding model to reflect convergence of voice and data was of keen interest, seen as both desirable and necessary. This reflects not only the new economic realities of converged services but also the rapidly declining revenues associated with traditional long-distance voice services.

Figure 3. Changes Being Made to Reflect Converged Networks (Multiple Responses Allowed)



As of June 2004, two-fifths of institutions surveyed are already committed to VoIP: 27 percent have VoIP already in limited or wide use, and another 15 percent are either implementing now or will do so within the next 12 months. 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 be able to replace all legacy phones with VoIP phones rather than use both during a transition period. Most institutions have already combined the voice communications and data networking functions so that they report to the same organization/department (65 percent). Institutional experience with VoIP brings mixed reviews. Some respondents report great success; others say their implementations and pilots have been problematic to some degree. The key challenge is to attain the same level of reliability in the converged network that is expected from traditional 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). Open source network management tools, however, such as MRTG (multi router traffic grapher) and Netdisco, are also in very wide use (67 percent), 40 percent also use home-grown applications. Specifically, monitoring tools are in active use, most commonly for monitoring traffic, network components, performance of servers, and security vulnerabilities. Metrics are also in active use, 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 do not use them.

Placing restrictions—on bandwidth, access to external devices, applications, or devices—is very common, but approaches vary widely among campuses. The most common practices are restricting relaying of e-mail and access to selected TCP/IP ports; restricting selected network equipment (such as hubs or routers) from being connected; and using port scanners and packet sniffers. Furthermore, most campuses (70 percent) use packet shaping to minimize the impact of P2P file sharing and other applications that consume large amounts of bandwidth. For those with students living on campus, institutions often separate the residence halls. Associate's institutions report using more restrictions on applications and devices than those representing other Carnegie classes.

Institutions Reporting a Higher-Quality Network Infrastructure

ECAR's research also found several similar characteristics among institutions that agreed that their institution has a higher quality network infrastructure—one that is secure, fault tolerant, and optimally designed to meet future needs (see sidebar).[3] Of particular note is the role that the "softer" or non-technical side of IT networking plays. Both survey results and interviews showed that while 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.

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

Network Is a Strategic Resource

Our data show that campus leadership fully recognizes the centrality of networks and their strategic value. Respondents overwhelmingly agree that their leadership views the campus network as more important than it was three years ago (94 percent), as an essential resource (98 percent), and as critical infrastructure (89 percent). Furthermore, 81 percent of respondents said their institution's leadership also considers the campus network a strategic resource, with 28 percent going so far as to characterize networking at their institution not only as strategic but also as a "strategic differentiator" for the campus. Leadership attitudes appear to make a difference: we found that institutions where the network is considered strategic rate the quality of their network infrastructure higher.

Primary Network Goal

ECAR investigated 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, campus approaches differ widely, showing a fairly even distribution among these goals (see Table 2).

Table 2. Primary Networking Goal for Institution

Primary Goal	Descriptor	Percentage
Provide reliable performance and services at the lowest possible cost	Cost minimizer	19.8%
Provide appropriate levels of performance and services to different users on the basis of their needs	Demand driven	28.4%
Provide high-speed networking to the entire institution	High speed for all	25.9%
Provide leading-edge network performance and services to the institution	Leading edge	25.9%

Our qualitative interviews also highlighted different IT activities and attitudes based on primary network goal. For example, network managers at "leading-edge" institutions typically have to future-proof the network to meet any need, any time, now or in the future, and their activities reflected this attitude. Interestingly, ECAR's research finds 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.

Network Funding Grows, but Is Never Enough

Given the difficult financial situation at many campuses, we were not surprised to find that 59 percent of respondents identify inadequate funding as a barrier to the delivery of network services. Regardless of whether funding is considered a barrier to networking, however, 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-fourths expect that it will again increase over the next three years (mid-2004 to mid-2007). ECAR research also shows that those institutions that feel they are not experiencing inadequate funding rate their network infrastructure as stronger, especially for the optimal design of desktop connectivity and for the fault tolerance of the network.

Network Security and Formal Networking Policies and Procedures

IT security in higher education was covered extensively in a 2003 ECAR study[4] and therefore was considered outside the scope of this networking study. Nevertheless, security is very much on the minds of our respondents. Of all barriers to the delivery of network services, security was identified most often (63 percent).

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. Another security dilemma is higher education's traditionally open culture. Institutions and IT departments must constantly grapple with how "closed" to make their network through security measures. Some institutions have a naturally closed environment, 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, especially if the IT department involves institutional constituencies in the development process. ECAR research found also that institutions that possess formal networking policies and procedures that are enforced consistently and comprehensively and are regularly updated are more likely to rate the quality of their network infrastructure higher.

Redundancy and Disaster Recovery

Network redundancy is an important part of network reliability, and our data show that we have a long way to go. Although most institutions (74 percent) report that they have implemented redundancy for some single points of failure, 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). Given the higher risks associated with larger, more complex networks, it is not surprising that larger institutions are the ones more likely to have implemented these redundancy measures. Furthermore, paying attention to network redundancy may make a difference in perceived network

quality—those institutions that do so report more than others that their backbone network is both fault tolerant and optimally designed to meet future needs.

Perhaps most revealing is the finding that 40 percent of our respondents report that they do not have a disaster recovery plan for data networking on campus. Perhaps it is a matter of priorities, funding, and perceived risk. Not surprisingly, ECAR research shows that institutions with a documented disaster recovery plan for their network characterize the quality of their network infrastructure more positively.

Conclusion

Our data provide a snapshot of IT networking practices and strategies in higher education—in terms of infrastructure, management and practices, and future planning. ECAR research also demonstrates that IT leaders cannot rest on their laurels because the network is "never done." Forward-looking IT leaders must constantly anticipate the next technology that will transform the institution yet again and, in its wake, address a new host of potential integration, support, and security issues. The innovative IT leader will be prepared as the cycle of adoption begins again.

Endnotes

1. J. Pirani and G. Salaway, *Information Technology Networking in Higher Education: Campus Commodity and Competitive Differentiator* (Boulder, Colo.: EDUCAUSE Center for Applied Research, Research Study, Vol. 2, 2005), <http://www.educause.edu/LibraryDetailPage/666?ID=ERS0502>.
2. The actual numbers may be larger, since some of the 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.
3. ECAR's networking survey asked respondents to give their opinions (strongly disagree, disagree, neutral, agree, strongly agree) for a series of statements about the design, security, and reliability of the 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, and (e) My institution's network is fault tolerant.
4. R. Kvavik et al., *Information Technology Security: Governance, Strategy, and Practice in Higher Education* (Boulder, Colo.: EDUCAUSE Center for Applied Research, Research Study, Vol. 5, 2003), <http://www.educause.edu/LibraryDetailPage/666?ID=ERS0305>.

Judith A. Pirani (jpirani@attglobal.net) is a Research Fellow with the EDUCAUSE Center for Applied Research and President of Sheep Pond Associates. Gail Salaway (gsalaway@educause.edu) is a Fellow with the EDUCAUSE Center for Applied Research.

A copy of the full study referenced above will be available via subscription or purchase through the EDUCAUSE Center for Applied Research (www.educause.edu/ecar/).

