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Username: ERS0202
Password: WIRELESS618
Wireless Networking in Higher Education
EDUCAUSE is a nonprofit association whose mission is to advance higher education by promoting the intelligent use of information technology.

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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Executive Summary

A walk around a college campus today reveals any number of students with cellphones glued to their ears, chatting to their friends while walking to their next class. But look a little closer and another sight emerges with growing frequency—a group of students sitting at a table in the student center, library, or classroom, clustered around their laptops and surfing the Web while working on a class project—with no network port in sight. The freedom of access that many students take for granted for voice is now expanding to data, as more higher education institutions implement wireless networks. Students use their laptops throughout the campus to check e-mail, study, or conduct research whenever and wherever it’s convenient.

Wireless technology opens a new dimension of computer networking in higher education. No longer are computers tethered to the nearest wall port or ceiling drop to connect to the network. Instead, strategically placed access points provide network access via radio transmission to any computing device within range that utilizes a compatible wireless network card. Now, students, faculty, and staff pop open their laptops in classrooms, libraries, or outdoors—wherever there’s an operational access point in range—to use the network. And as wireless technology expands, higher education institutions feel the impact of computing freedom throughout their operations.

This report presents the results of the EDUCAUSE Center for Applied Research (ECAR) investigation with IDC, a provider of market intelligence and industry analysis, into the state of wireless networking in higher education, undertaken in a three-phase research methodology.

- An online survey of 391 EDUCAUSE member institutions to establish the state of wireless networking in higher education and to understand its implementation characteristics.
- Follow-up, in-depth telephone and on-site interviews at 17 selected institutions with information technology (IT) personnel and university members directly involved with the creation, operation, or use of wireless networks. Their comments overlay and supplement the online survey findings throughout the report.
- Best practices cases studies with Carnegie Mellon University, Dartmouth College, Drexel University, Indiana University, Salt Lake Community College, and The University of Tennessee to gain a deeper understanding of what has—and, as appropriate, what hasn’t—worked in wireless
implementations. These case studies provide specific examples from which other institutions can benefit in their implementations.

**Key Findings**

Wireless LANs are undergoing mainstream adoption within U.S. higher education. Half of EDUCAUSE members have implemented a wireless LAN, and most others (all but 8 percent) are planning for wireless. Most institutions that have implemented wireless networks are expanding them. Doctoral institutions are the pioneers and leaders in implementing wireless networking, followed by master’s and baccalaureate institutions. Although associate’s institutions lag, some are nevertheless implementing wireless.

The leading driver of wireless networks has been the desire to provide a greater degree of anywhere, any time network access to students. Meeting future computing needs and improving classroom and faculty access to networks are other key drivers. IT departments have been the leading proponents of wireless networks.

Wireless networking is not replacing wired networks, although it does make networking available where wired networks are difficult, impractical, or impossible to install. Wired networks will continue to be maintained and will be complemented by wireless. Higher education institutions are not forecasting the replacement of wired networks by wireless at this time.

Students have readily incorporated wireless access into their day-to-day social and academic activities, and usage is expanding. A bigger challenge, one just beginning to gain recognition, is for faculty to meaningfully incorporate wireless into the classroom curriculum. The institutions studied are beginning to enjoy success on that front, but the impacts—good and otherwise—are more complex and not yet fully visible.

While laptop PCs are the leading device for accessing wireless networks, institutions are significantly increasing access for personal digital assistants (PDAs) and even somewhat for handheld PCs. These smaller, easily portable devices will provide another layer of utility for wireless networks.

Security is the leading challenge facing wireless networks, with unauthorized access to information or unauthorized usurping of network resources as key problems. Current solutions are limited. Wired equivalency privacy (WEP) is ineffective, and virtual private networks (VPNs) are costly and inefficient. Effective, efficient solutions, such as use of the Advanced Encryption Standard (AES) in VPNs, and IEEE 802.1x/EAP (extensible authentication protocol), are one to two years away. Smaller institutions may find that appliance servers provide an effective solution.

Support is another key issue. Wireless networks have increased the need for support—including new types of support, such as real-time classroom support.

The issue of equal access for students to wireless is being dealt with by piecemeal measures (for example, carts of laptops in labs or loaners in libraries). Mandatory laptops and wireless networking are in the beginning stages, usually in specific departments or colleges.

For those just implementing wireless networks, installation is a challenge. It is complex and time-consuming because of the inexact nature of access point placement and channel allocation. It requires learning, or at least the support of experienced wireless network contractors. Pilot implementations are valuable for learning.

Another technology challenge is bandwidth limitations of current technology (IEEE 802.11b). Most institutions are planning new technology implementations, although that also requires resources.
Overall, wireless is considered a success in higher education. The vast majority of institutions using wireless networks say they have met or exceeded their expectations. Wireless networks will increasingly be a requirement in higher education, just as wired networks already are.

**Wireless Adoption Drivers**

Wireless networking is not a new technology by today’s technology development cycles. Some institutions have used it since the mid-1990s, mainly in pilot implementations. What is new is wireless networking’s growing mainstream adoption by higher education. ECAR and IDC’s online survey of EDUCAUSE’s membership base reveals that three-quarters of its members implemented their first wireless network in the past two years. And using the EDUCAUSE membership base as a measurement, IDC found a high rate of penetration by wireless networking. About half of the members have implemented a comprehensive or specific wireless network at their institution. Another 31 percent are in the planning stages. (See Figure 1-1.)

The introduction of wireless technology standards and compliant equipment, lower network equipment and laptop costs, and the growing ranks of computer-savvy college students make it easier and more cost-effective to use wireless technology to create an instant access networking environment that students will increasingly expect. Higher education faculty demands are likely to grow as they become more familiar with wireless use in the classroom.

To understand the factors fueling wireless adoption, EDUCAUSE and IDC queried institutions in both the online survey and qualitative interviews about their reasons for implementation. The online survey respondents cited six leading factors driving the implementation of wireless networks. (See Table 1-1.)

- The most popular leading driver is the importance of improved network access for students. This is not surprising, because wireless technology untethers students, faculty, and others from traditional network access points, enabling them to work whenever, wherever they wish.
- The ability to meet future computing needs is also important to more than 40 percent of institutions, as is the ability to meet both a campus’ evolving computing needs and the expectations of prospective students.
### Table 1-1. Wireless Networking Decision Factors*

<table>
<thead>
<tr>
<th>Decision Factor</th>
<th>Total (N=370)</th>
<th>Doctoral (N=69)</th>
<th>Master’s (N=90)</th>
<th>Bachelor’s (N=81)</th>
<th>Associate’s (N=43)</th>
<th>FTE: 1-4,999 (N=198)</th>
<th>FTE: 5,000-9,999 (N=58)</th>
<th>FTE: 10,000-19,999 (N=55)</th>
<th>FTE: 20,000+ (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Student Network Access at Any Time</td>
<td>51%</td>
<td>54%</td>
<td>50%</td>
<td>56%</td>
<td>47%</td>
<td>51%</td>
<td>50%</td>
<td>49%</td>
<td>67%</td>
</tr>
<tr>
<td>Student/Teacher Access During Class</td>
<td>43%</td>
<td>33%</td>
<td>44%</td>
<td>44%</td>
<td>58%</td>
<td>49%</td>
<td>36%</td>
<td>29%</td>
<td>33%</td>
</tr>
<tr>
<td>Ability to Meet Future Computing Needs</td>
<td>43%</td>
<td>41%</td>
<td>46%</td>
<td>37%</td>
<td>49%</td>
<td>42%</td>
<td>48%</td>
<td>35%</td>
<td>48%</td>
</tr>
<tr>
<td>Improved Faculty Network Access at Any Time</td>
<td>41%</td>
<td>46%</td>
<td>46%</td>
<td>38%</td>
<td>42%</td>
<td>41%</td>
<td>41%</td>
<td>36%</td>
<td>62%</td>
</tr>
<tr>
<td>Solve Specific Problem/Application</td>
<td>38%</td>
<td>25%</td>
<td>42%</td>
<td>43%</td>
<td>44%</td>
<td>44%</td>
<td>31%</td>
<td>20%</td>
<td>48%</td>
</tr>
<tr>
<td>For Institution To Be Perceived as Leading Edge</td>
<td>35%</td>
<td>43%</td>
<td>32%</td>
<td>28%</td>
<td>40%</td>
<td>34%</td>
<td>38%</td>
<td>42%</td>
<td>29%</td>
</tr>
<tr>
<td>Improved Commuter Network Access at Any Time</td>
<td>30%</td>
<td>30%</td>
<td>40%</td>
<td>28%</td>
<td>30%</td>
<td>31%</td>
<td>29%</td>
<td>27%</td>
<td>38%</td>
</tr>
<tr>
<td>Easier to Move/Add/Change</td>
<td>24%</td>
<td>10%</td>
<td>29%</td>
<td>22%</td>
<td>44%</td>
<td>28%</td>
<td>16%</td>
<td>18%</td>
<td>19%</td>
</tr>
<tr>
<td>Competitive Pressures from Other Institutions</td>
<td>21%</td>
<td>22%</td>
<td>21%</td>
<td>23%</td>
<td>21%</td>
<td>22%</td>
<td>21%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td>Savings Over Installed Wired Networks</td>
<td>21%</td>
<td>12%</td>
<td>20%</td>
<td>20%</td>
<td>33%</td>
<td>23%</td>
<td>24%</td>
<td>5%</td>
<td>19%</td>
</tr>
<tr>
<td>Operating Costs Savings Over Wired</td>
<td>11%</td>
<td>7%</td>
<td>9%</td>
<td>7%</td>
<td>19%</td>
<td>11%</td>
<td>14%</td>
<td>5%</td>
<td>19%</td>
</tr>
</tbody>
</table>

* Percentage of respondents rating specific factors as Very Important (Rated 8, 9, or 10, where 1 = Not Important, 10 = Very Important). Base: Current/planned wireless network operators, by institution type. Note: The three factors that generated the highest percentage of importance ratings are highlighted.
The increasing number of individual colleges and departments that mandate laptops for their students pushes higher education institutions to provide an appropriate supporting network infrastructure.

◆ More than 40 percent of the survey respondents identified network access during class time as important. As more courses incorporate e-learning elements, users view wireless access as a facilitating technology, allowing students and faculty to go online in the classroom. This is especially important at associate’s institutions.

◆ Not surprisingly, improved network access for faculty is important because faculty are mobile and will need to promote wireless use in classrooms.

◆ Small baccalaureate institutions place particular importance on finding solutions to specific problems or specific applications.

◆ Doctoral universities find it especially important to advance the perception that they are on the leading edge.

Wireless Network Characteristics

Many institutions phase in their wireless networks, perhaps to test the technology in a controlled situation, fulfill a specific user application, handle a building’s specific requirements, or install it as funding allows. Currently, most wireless networks are not campus-wide. Over three-quarters of online survey respondents defined their wireless network as limited to a specific building, location, or cluster of buildings.

Online survey respondents most frequently identified the computer sciences, physical sciences, and business/management departments as providing wireless access. Wireless network implementations begin at some institutions as pilots for research and experimental purposes. In addition to those mentioned above, logical departmental candidates for this research include, perhaps, the engineering departments.

IT departments place access points in hard-to-wire places in classrooms, libraries, and research facilities where—because of current building design, historical architectural significance, or other factors—it is exorbitantly expensive or impossible to wire. Wireless technology enables the IT department to redesign rooms for efficiency, not network accessibility, because workstations no longer have to be located near wall jacks or wire drops.

To promote user adoption, some institutions seed wireless technology in areas where students generally congregate. A popular testbed is the library; almost 60 percent of online survey respondents identified the library as a building with wireless access.

Business colleges and departments are frequently early adopters because their larger endowments enable them to invest in new technology. Moreover, a mandatory wireless laptop requirement is gaining popularity among MBA programs.

Institution size influences the number of wireless networks in operation. ECAR/IDC’s online survey revealed a very clear correlation between institution size (as measured by full-time enrollment) and the number of wireless initiatives, the latter increasing with larger FTE. More than three-quarters of the respondents at institutions with 20,000-plus FTE operate three or more wireless networks, compared with just 20 percent of respondents at 1–4,999 FTE institutions. Individual colleges or departments may initiate their own wireless network, but typically individual wireless network initiatives follow an institution-wide strategy that most institutions exhibit. Generally, to ensure campus-wide network compatibility and address security issues, the IT department serves as the coordinator, and often the installer, for most wireless networks.

Responses analyzed by the size of student population suggest that smaller institutions can more easily blanket their entire
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campuses with wireless coverage. Almost one-quarter of 1-4,999 FTE respondents operate a campus-wide wireless network; only 10 percent of 20,000-plus FTE respondents do. Yet larger institutions do plan to catch up, perhaps gradually weaving together a campus-wide network from their multiple wireless initiatives currently in operation at various buildings. Outdoor access is a priority for institutions with indoor wireless networks only. Many institutions that provide outdoor access currently report that it is very popular with users. Students sit at tables, benches, on the grass, or anywhere and pop open their laptops.

Trends and Directions

ECAR research observes several distinct trends in wireless usage.

Users

Many higher education institutions implement wireless technology to provide greater network access for their students and faculty as they move about the campus. And most institutions that implement wireless networks report that students readily incorporate wireless technology into their day-to-day activities.

Fewer institutions report administrative use (see Table 1-2), primarily because staff work from assigned workstations and use the wired network for access. But as FTE size grows, wireless networking extends to all constituents of the academic community.

Wireless in the Classroom

Wireless technology facilitates many institutions’ plans to incorporate e-learning tools in the classroom. Placing access points strategically throughout class buildings enables professors to bring online and interactive elements into their courses now, instead of waiting for classrooms to be wired or scrambling to reserve wired classrooms. IT administrators and users reported several benefits and ramifications of wireless networking in the classroom.

◆ Greater collaboration and communication—According to various faculty members, students use wireless in the classroom to access databases from the Web for in-class manipulation, brainstorm in a foreign language via chat functions, and conduct real-time research in conjunction with a class topic. Wireless’ impact extends to students’ work in general because they are no longer tethered to desktop PCs. Students modify the environment—whether sitting together at a table or configuring their desks into a circle—to facilitate their collaboration.

◆ Greater access to resources—Wireless enables teachers to present relevant online

<table>
<thead>
<tr>
<th>Users</th>
<th>Total (N=299)</th>
<th>FTE: 1-4,999 (N=154)</th>
<th>FTE: 5,000-9,999 (N=50)</th>
<th>FTE: 10,000-19,999 (N=45)</th>
<th>FTE: 20,000+ (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergrads</td>
<td>77%</td>
<td>77%</td>
<td>78%</td>
<td>76%</td>
<td>75%</td>
</tr>
<tr>
<td>Faculty</td>
<td>73%</td>
<td>65%</td>
<td>80%</td>
<td>73%</td>
<td>90%</td>
</tr>
<tr>
<td>Administration</td>
<td>53%</td>
<td>45%</td>
<td>52%</td>
<td>69%</td>
<td>85%</td>
</tr>
<tr>
<td>Grad Students/Researchers</td>
<td>44%</td>
<td>27%</td>
<td>56%</td>
<td>53%</td>
<td>95%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
<td>6%</td>
<td>10%</td>
<td>2%</td>
<td>5%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.
material in class while lecturing. More importantly, faculty members report that students use the wireless network proactively to access Web sites online during class to enrich their knowledge of the subject under discussion.

- **Altered pedagogy**—Although it is just one aspect of an entire technological evolution impacting higher education pedagogy in general, wireless can accelerate this evolution. More faculty members are either motivated by wireless’ ease of network access or forced by mandatory wireless laptop requirements to incorporate online resources in their classes. In either case, it takes a significant time investment to learn how to use technology in the classroom—equipment, network, and application layers—and to rethink course elements and delivery methods.

- **Distraction in the classroom**—Wireless’ greater access in the classroom fuels another debate: inappropriate use. Some faculty members insist that wireless laptops provide a new source for student diversion. But people are divided on the issue. Many believe it is a new angle to an old problem, class management. Most of the faculty interviewed agree that it is the faculty member’s responsibility to engage students so that they are not tempted to seek diversions such as newspapers, classroom windows, or wireless laptops. Almost two-thirds of the online survey respondents agree that wireless does not encourage inappropriate use.

### Wireless Equipment

Desktop computers are still the dominant computing device on campus, but anecdotal evidence suggests that some students and faculty members are switching to laptops. Lower prices, growing computing power, and greater portability contribute to this trend. Unsurprisingly, almost all online survey respondents identified laptop computers as a means to access the wireless network. (See Table 1-3.)

Looming on the horizon, however, are handheld PCs and PDAs. Many IT administrators and users regard the laptop as only the first step in wireless evolution. Many discussed the potential of PDAs, tablet computers, and other handheld IT devices to facilitate wireless access throughout the campus. They regard laptops as still too cumbersome for instant access because of their size and weight. They are intrigued

### Table 1-3. Devices for Accessing Wireless Networks, by Carnegie Classification*

<table>
<thead>
<tr>
<th></th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master's (N=75)</th>
<th>Bachelor's (N=62)</th>
<th>Associate (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
</tr>
<tr>
<td>Laptop Computers</td>
<td>94%</td>
<td>10%</td>
<td>98%</td>
<td>11%</td>
<td>96%</td>
</tr>
<tr>
<td>Desktop Computers</td>
<td>46%</td>
<td>14%</td>
<td>41%</td>
<td>9%</td>
<td>43%</td>
</tr>
<tr>
<td>PDAs</td>
<td>39%</td>
<td>27%</td>
<td>53%</td>
<td>38%</td>
<td>40%</td>
</tr>
<tr>
<td>Handheld Devices</td>
<td>9%</td>
<td>22%</td>
<td>16%</td>
<td>25%</td>
<td>8%</td>
</tr>
<tr>
<td>Cellular Phones</td>
<td>4%</td>
<td>15%</td>
<td>5%</td>
<td>23%</td>
<td>3%</td>
</tr>
</tbody>
</table>

* Current and planned use. Equipment type most often mentioned by respondents is highlighted.
by the potential of tablet devices, citing their larger display size compared with a PDA and their lighter weight compared with a laptop. Many observers predict that students will be pulling PDAs from their pockets, not laptops from their backpacks, to access the network, especially as more wireless networks expand outdoors. It is easier to use a PDA than a laptop while strolling across campus, and PDAs cost considerably less.

**Installation and Security**

Wireless implementation is generally a team effort, with IT taking the lead, either to coordinate efforts by individual schools, colleges, and departments or to serve as a centralized resource for smaller institutions. Naturally, this arrangement varies by institution. Specific departments and colleges are likely to be involved at doctoral institutions, reflecting their larger scope.

The wireless network planning and implementation characteristics of online survey respondents differ at institutions according to their Carnegie classification. (See Table 1-4.) The complex nature of many doctoral institutions often affects the process: Implementation time is longer, costs are greater, and the number of students served is larger. Yet their large scope enables doctoral institutions to achieve economies of scale. Their median cost per user is far lower than at other institution types. Wireless network installation is a rather complex process, requiring significant planning and testing.

Many institutions support the IEEE’s current 802.11b wireless standard in their network. Some institutions incorporate dual-bay access points to enable them to upgrade to forthcoming 802.11a or 802.11g standards and to continue supporting legacy 802.11b users.

Wireless technology’s transmission medium—the air—makes it particularly susceptible to security breaches. As a result, security is a universal concern, although luckily no institution (in the phone/on-site survey) reported any major security breaches in their wireless network. Network complexity and resources seem to affect the type of security methods institutions use. Doctoral institutions, with their complex networks, greater research activities, and larger student populations, tend to take more aggressive security steps, whereas almost 30 percent of online survey respondents at bachelor’s

| Table 1-4. Characteristics of Wireless Network Operators, by Carnegie Classification |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
|                              | Total (N=299) | Doctoral (N=64) | Master’s (N=75) | Bachelor’s (N=62) | Associate’s (N=28) |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Median Planning Time (Months) | 6                          | 6                             | 6                             | 6                             |
| Median Implementation Time (Months) | 3                          | 5                             | 2                             | 2                             | 1                             |
| Median Amount Spent or Budgeted | $50,000                      | $80,000                        | $50,000                        | $20,000                        | $30,000                        |
| Median Number of Students/Faculty That Wireless Network Serves | 1,000                       | 3,000                         | 1,000                         | 610                           | 500                           |
| Median Cost per User | $50.00                       | $26.67                         | $50.00                         | $32.79                         | $60.00                         |
institutions report no encryption/authentication usage. (See Table 1-5.) A higher percentage of doctoral institutions use non-WEP solutions, mainly because of dissatisfaction with the WEP standard in general. IT administrators complain about its security flaws and lack of scalability. As a result, many institutions, larger ones in particular, turn to other solutions.

**Wireless Technology’s Adaptability**

Further analysis of ECAR’s online survey results indicates distinct wireless networking characteristics by institution type. Higher education institutions range from huge, city-like research institutions to bucolic liberal arts colleges. Wireless, as an IT tool, adapts to meet needs determined by an institution’s characteristics, IT resources, and culture. ECAR examined its member survey results by Carnegie classification to find distinguishing characteristics.

**Doctoral Institutions**

As the leading early implementers, doctoral institutions have the highest percentage of respondents (37 percent) that implemented their first wireless network before 2000. The wireless implementations reflect these institutions’ more complex organization. Almost 60 percent of doctoral respondents claim to operate at least three wireless networks at their institutions. Many parties besides IT personnel are involved in the planning and implementation, including specific colleges or departments (48 percent).

Many institutions of all types reported significant wireless access in libraries and classrooms, but doctoral institutions reported the highest wireless access rate in administration (36 percent) and research centers (27 percent).

Table 1-5. Encryption/Authentication Methods Used by Wireless Network Operators, by Carnegie Classification

<table>
<thead>
<tr>
<th>Encryption/Authentication</th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master’s (N=75)</th>
<th>Bachelor’s (N=62)</th>
<th>Associate’s (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>128-Bit WEP</td>
<td>33%</td>
<td>28%</td>
<td>36%</td>
<td>31%</td>
<td>46%</td>
</tr>
<tr>
<td>40-Bit WEP</td>
<td>17%</td>
<td>9%</td>
<td>21%</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>Firewall</td>
<td>24%</td>
<td>23%</td>
<td>27%</td>
<td>15%</td>
<td>46%</td>
</tr>
<tr>
<td>RADIUS</td>
<td>18%</td>
<td>30%</td>
<td>19%</td>
<td>10%</td>
<td>14%</td>
</tr>
<tr>
<td>IP VPNS</td>
<td>14%</td>
<td>25%</td>
<td>12%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Wireless Vendor Supplied Solution</td>
<td>9%</td>
<td>8%</td>
<td>8%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Extensible Authentication Protocol</td>
<td>5%</td>
<td>6%</td>
<td>4%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Third Party Hardware/Software</td>
<td>5%</td>
<td>13%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Kerberos</td>
<td>3%</td>
<td>8%</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>None</td>
<td>18%</td>
<td>14%</td>
<td>16%</td>
<td>29%</td>
<td>14%</td>
</tr>
</tbody>
</table>
Many different constituents use the wireless networks. Doctoral institutions reported the highest incidence of faculty (86 percent), administration (77 percent), and graduate students/researchers (80 percent) accessing their wireless networks. In addition, doctoral institutions reported higher usage of PDAs (53 percent), handheld devices (16 percent), and cellphones (5 percent) than other institutions.

**Master’s Institutions**

Respondents displayed a combination of traditional and innovative characteristics. Wireless technology is less entrenched in master’s institutions than in doctoral institutions, but its adoption surpasses that in baccalaureate institutions. Many master’s institutions are just implementing their first wireless network; 40 percent of respondents launched their initial wireless installation in 2001. Many master’s institutions are satisfied with the results, with 23 percent of respondents stating that wireless exceeded their expectations, a higher rating than any other Carnegie category.

**Baccalaureate Institutions**

Wireless networks are a relatively new capability for many baccalaureate institutions; over half of the respondents initiated their first wireless network in 2000. The library is the center of the baccalaureates’ wireless network. Just over 60 percent offer wireless access, and 61 percent of baccalaureate institutions with wireless access report that their libraries are involved in planning and implementation—a higher percentage than in doctoral and master’s institutions. Baccalaureate institutions maintain limited wireless network operations; 61 percent of respondents utilize one wireless network, 56 percent say their wireless network is confined to specific buildings, and less than half (47 percent) plan to expand to campus-wide coverage. This is unsurprising, as baccalaureate institutions believe their wireless network will serve only about 1,500 students and faculty members, the smallest average number of users among all Carnegie classifications.

**Associate’s Institutions**

Almost one-quarter of associate’s institution respondents claim that wireless networking has a low priority in terms of overall IT strategy. Perhaps this is why many associate’s institutions are recent implementers, with more than 40 percent implementing their initial network in 2001. Despite the late start, almost 60 percent of associate’s respondents reported at least two wireless networks in operation. Almost 80 percent report that their wireless networks are limited to specific buildings or locations. The limited scope translates into fast setup time. Associate’s institutions implemented their wireless networks in an average of 2.1 months. The research seems to indicate that wireless is used for limited, targeted classroom applications.

**Challenges**

Wireless networks do present some challenges. Online survey respondents identify security as their leading challenge, and IT administrators voiced similar concerns...
Throughout the research, Figure 1-2 identifies the concerns and challenges that IT administrators and users described in their interviews.

**Security**

While WEP is the most frequently used security measure, many institutions feel that WEP doesn’t provide strong security. Therefore, many institutions have already implemented, or plan to implement, a VPN, which enables them to provide a centrally managed security solution. But VPNs provide very inefficient throughput. Implementing 802.1x, when it’s available in another year or two, is another potential solution.

Some institutions tell students not to assume that the network is secure and encourage them to use Secure Sockets Layer (SSL) or Secure Shell/FTP (SSH). While few institutions report the creation of training classes specific to wireless networking, they may incorporate sections about wireless in general computer orientation sessions or post information on their Web sites.²

**Faculty Support Issues**

Before wireless networking, technology in the classroom was already impacting the traditional classroom experience. Faculty members had begun to incorporate online teaching elements in the classroom to augment traditional lectures and to create a hands-on learning experience. Wireless technology accelerates this trend by enabling easy expansion of network capability to more classrooms, so that more faculty members can use technology elements during class.

Many institutions were not prepared for the added support requirements—that is, the additional support to train faculty members on how to use the technology in the classroom and additional resources to help faculty members create these online teaching elements. This entails technology training, on-site tech support during class, advice on pedagogy, and additional personnel resources. Some institutions created a dedicated department within their IT organizations to address these issues, but there are no definitive

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* Base: Current/piloting wireless network operators.
results. Another question, though not a support issue, is whether to recognize the additional time investment faculty members must make to develop new teaching elements.

**Equal Equipment Access**

Although some IT administrators and users report laptop usage on the rise, many students still use desktop PCs as their primary computing device. Naturally, there is concern about the lack of equal access to laptops and how it affects nonusers’ educational experiences. For example, how do laptop owners and nonowners work together on a project?

Some institutions implement wireless laptop checkout programs for individual students at their libraries or student centers. Students check out the laptops at no cost for a specified period. This gives institutions a way to track potential wireless demand.

For classroom or lab applications, institutions maintain carts of laptops that faculty members reserve in advance. This scheme has advantages and disadvantages. During class, all students have equal access to the laptops.

Other institutions take a more proactive stance by mandating laptops for some or all of their students. Typically, a specific college or department requires laptop ownership, so the entire student body doesn’t need them. Only 6 percent of higher education institutions require notebooks of all students; most of these are small (less than 5,000 FTE) and/or privately controlled institutions. This notebook requirement drives wireless usage. More than half of the online survey respondents with a mandatory notebook requirement also require wireless access. The wireless requirement is logical because wireless access enables students to use their notebooks more frequently, generating a higher return on their mandatory laptop investment.

**Cost of Wired and Wireless Coexistence**

A few institutions report that they built their wireless network with the expectation that it would replace some parts of the wired network. This never occurred. Instead, as online survey respondents and most interviewees confirmed, coexistence developed between their wired and wireless networks. As a result, IT departments must finance and support parallel networks. Therefore, it becomes important for institutions to develop a cost recovery model to finance future wireless network upgrades. One advantage of coexisting networks is that most IT departments use the same support resources and tools for both, and they typically operate one help desk for both networks.

**Installation Issues**

Installing a wireless network is complex and requires considerable planning. As a result, many institutions warn against skimping on this process and recommend starting with a small pilot project to gain experience. Unfortunately, no institution reported a simple, straightforward process or algorithm that makes access point placement as easy as one-two-three. Each building and each room has unique characteristics that make trial and error part of the placement process. Building architecture, construction materials, channel allocation, transmission range, room size, and room applications all affect access point and antenna placement. Even with experience, IT departments make educated guesses, but they must always test to ensure optimal placement.

**Bandwidth**

Wireless’ limited bandwidth is another issue to address. On a shared network, an
individual’s activities impact those of other people in the same area, sharing the same access point. As a result, some institutions instruct faculty members to stagger students’ wireless network log-on. Some institutions discourage users from backing up files or transmitting data-intensive files on the wireless network. Again, continual education is key. Some institutions report that by employing the wireless network so frequently, users forget about the bandwidth issue. Most institutions are planning upgrades to 802.11a or 802.11g to provide increased bandwidth.

**User Satisfaction**

Most online survey respondents, IT administrators, and wireless users report overall satisfaction with their wireless networks. (See Figure 1-3.) Many track satisfaction qualitatively through user feedback, though some institutions incorporate quantitative tools as well: number of access points deployed, number of registered users, and performance readouts from network administration tools. Most institutions cited convenience as a key benefit, which in turn facilitates greater productivity. Some users believe wireless technology enhances the classroom experience by facilitating collaboration and engaging students actively in the learning process.

**Future Plans and Strategies**

Most IT administrators plan to maintain both their wired and wireless networks in tandem. Others want to continue expanding wireless networks throughout their institutions as a way to provide ubiquitous computing. Bandwidth needs to be addressed so that institutions can provide better service and enable users to employ the wireless network for data-intensive applications like video. Not surprisingly, many respondents are monitoring 802.11a and security developments for future implementation. Users plan to continue fostering wireless networking’s adoption in the classroom by promoting its capabilities to faculty mem-

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**Figure 1-3.** Wireless Network Results versus Expectations*

* As reported by wireless network operators ($N = 299$). Responses don’t total 100 percent because of “Don’t Know” answers.
bers and students and by enhancing applications. Future applications with PDAs and handheld devices intrigue both IT administrators and users.

**Wireless Networking an IT Requirement**

Wireless access has become an IT requirement for higher education institutions. The penetration percentage indicates it is becoming mainstream, and students increasingly will expect to access their institution’s network from practically any place and at any time. Students themselves are fueling this phenomenon. Their technology usage habits combined with their growing preference for laptops raises their expectations for immediate information or communication. At least one interviewee mentioned that an institution’s high-tech capability is a criterion when students select an institution to attend, and wireless access enhances an institution’s attractiveness. This is more likely to be true at technical and doctoral institutions.

Many higher education institutions already recognize this trend. Ninety-two percent will implement wireless networking, and many current operators plan to continue expanding wireless access throughout their campuses. While wireless is not revolutionizing higher education’s IT infrastructure, its impact will be felt throughout the campus. Wireless enables greater interaction and e-learning inside and outside the classroom, facilitates research through easier information access, and allows the design of more productive work spaces for staff.

**Endnotes**

2. Ibid.
Methodology and Demographics

In this report, ECAR examines the adoption and impact of wireless communications in higher education in the United States. In addition, by inquiring into higher education’s plans and opinions, this research investigates whether wireless communications will replace or supplement the wire-based IT infrastructure and how this evolution will occur. It also seeks to determine how wireless communication influences the socializing of information technology (IT) in higher education.

To accomplish this, ECAR and IDC, a leading provider of IT market intelligence and industry analysis, used a three-phase research methodology to conduct a multidimensional analysis of wireless networking in higher education.

Methodology

In the first phase, ECAR surveyed EDUCAUSE’s membership to establish the state of wireless networking in higher education. IDC and ECAR collaborated in developing the survey questionnaire. Questions focused on implementation characteristics, users, equipment, installation issues, security, challenges, and benefits. A small group of EDUCAUSE members also reviewed and tested the questionnaire, providing feedback and recommendations for questions on additional topics. IDC conducted the survey between November 27 and December 12, 2001. The primary contact at EDUCAUSE member institutions received an e-mail message on November 26, 2001, inviting them to participate in the survey. ECAR received 390 valid responses by December 12, 2001, on which day the survey was closed for input. IDC analyzed the data by current/planned wireless networking activities, Carnegie classification, institutional control, and student full-time equivalent (FTE), as presented in this report.

In phase two, IDC gathered qualitative information, drilling down into the why and how of wireless networking, and explaining and supplementing the findings of phase one research. During February and March 2002, ECAR invited 20 quantitative survey respondents with wireless network implementations to participate in follow-up interviews with IT personnel and university members directly involved with the creation, operation, or use of wireless networks. ECAR and IDC created a diverse qualitative interview sample by inviting a range of institutions to participate, selected on the basis of Carnegie classification, geographic location, and willingness to participate in further research.
IDC created interview guides to complement the quantitative research and solicit in-depth opinions on the topics examined in phase one. IT participants completed their interviews either by e-mail or telephone. IDC conducted most of the interviews of wireless network end users by telephone, and some on site. Their opinions add context to and supplement the quantitative research presented in this report. Some of the participants in this stage also participated in the cases studies, as discussed below.

Finally, IDC conducted several case studies that examine wireless network implementations at several higher education institutions, including Carnegie Mellon University, Dartmouth College, Drexel University, Indiana University, Salt Lake Community College, and The University of Tennessee. ECAR and IDC chose these institutions on the basis of the application, the maturity of the wireless implementation, and the institution type. ECAR presents the case studies separately. The goals of the case studies are to gain a deeper understanding of what has—and, as appropriate, what hasn’t—worked in wireless implementations and to provide specific examples from which other institutions can benefit in their implementations.

**Demographics**

EDUCAUSE used both quantitative and qualitative research to create a robust portrait of wireless networking activities in higher education. This section describes the sample composition in both research efforts.

**Quantitative Research**

The quantitative (online) survey generated a significant response among EDUCAUSE’s membership base. Almost 400 institutions, representing 28 percent of the EDUCAUSE membership base, participated. This large response base enables EDUCAUSE to analyze the state of wireless communications by several higher education classifications, including Carnegie category classification, institutional control, and FTE size. Table 2-1 compares the respondent composition with EDUCAUSE’s membership base, shown by Carnegie classification designation.

Two-thirds of the respondents are from

<table>
<thead>
<tr>
<th>Carnegie Category</th>
<th>EDUCAUSE Members</th>
<th>Respondents</th>
<th>Percentage of Members</th>
<th>Percentage of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctoral</td>
<td>240</td>
<td>71</td>
<td>30%</td>
<td>18%</td>
</tr>
<tr>
<td>Master’s</td>
<td>387</td>
<td>96</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>Baccalaureate</td>
<td>285</td>
<td>86</td>
<td>30%</td>
<td>22%</td>
</tr>
<tr>
<td>Professional Specialty</td>
<td>49</td>
<td>11</td>
<td>22%</td>
<td>3%</td>
</tr>
<tr>
<td>Associate’s</td>
<td>287</td>
<td>47</td>
<td>16%</td>
<td>12%</td>
</tr>
<tr>
<td>All Other</td>
<td>153</td>
<td>29</td>
<td>19%</td>
<td>7%</td>
</tr>
<tr>
<td>Canada</td>
<td>27</td>
<td>7</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,401</strong></td>
<td><strong>391</strong></td>
<td><strong>28%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
the baccalaureate, master’s, and doctoral categories. Response rates for these categories run from 25 to 30 percent. Respondent and membership compositions are nearly the same for master’s and associate’s institutions, but differ rather significantly for doctoral and baccalaureate schools. The response rates for professional specialty, all other, and Canada are so low that it is difficult to analyze these categories separately for significant trends. As a result, this report focuses primarily on the doctoral, master’s, baccalaureate, and associate’s Carnegie classification categories.

The survey results represent both publicly and privately controlled institutions, as shown in Table 2-2. Half of the respondents originate from publicly controlled institutions.

IDC tabulated the responses by FTE. The median response FTE is 3,382 students. Almost two-thirds of respondents represent small institutions. (See Table 2-3.) Respondent representation falls as FTE rises, as with real-world higher education demographics. The survey analysis doesn’t focus on the zero student (system offices) or the no answer categories because they yielded little meaningful data.

Table 2-4 illustrates that primarily IT personnel completed the survey. Almost three-quarters of the respondents are senior IT professionals at EDUCAUSE institutions.

**Qualitative Research**

Next, ECAR explored the hows and whys behind the online member survey results by interviewing representative IT administrators and users from responding institutions. The goal was not only to enrich the statistical data through in-depth discussions with IT administrators, but also to add another dimension to the analysis by talking with actual wireless network users. ECAR created a sample of approximately 25 institutions that responded to the original online survey and that also currently operate a wireless network.

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### Table 2-2. Quantitative Survey Respondent Demographics by Type of Institution Control

<table>
<thead>
<tr>
<th>Institution Control</th>
<th>Respondents</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>199</td>
<td>51%</td>
</tr>
<tr>
<td>Private</td>
<td>159</td>
<td>41%</td>
</tr>
<tr>
<td>No Answer</td>
<td>34</td>
<td>9%</td>
</tr>
<tr>
<td>Total</td>
<td>392</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Table 2-3. Quantitative Survey Respondent Demographics by FTE Size

<table>
<thead>
<tr>
<th>Full Time Enrollment</th>
<th>Respondents</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero</td>
<td>13</td>
<td>3%</td>
</tr>
<tr>
<td>1–4,999 Students</td>
<td>214</td>
<td>55%</td>
</tr>
<tr>
<td>5,000–9,999 Students</td>
<td>59</td>
<td>15%</td>
</tr>
<tr>
<td>10,000–19,999 Students</td>
<td>56</td>
<td>14%</td>
</tr>
<tr>
<td>20,000+</td>
<td>23</td>
<td>6%</td>
</tr>
<tr>
<td>No Answer</td>
<td>27</td>
<td>7%</td>
</tr>
<tr>
<td>Total</td>
<td>392</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Table 2-4. Quantitative Survey Respondent Demographics by Respondent Functional Job Class

<table>
<thead>
<tr>
<th>Functional Title</th>
<th>Respondents</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior IT</td>
<td>174</td>
<td>44%</td>
</tr>
<tr>
<td>CIO</td>
<td>113</td>
<td>29%</td>
</tr>
<tr>
<td>Academic Officer</td>
<td>20</td>
<td>5%</td>
</tr>
<tr>
<td>Support IT</td>
<td>17</td>
<td>4%</td>
</tr>
<tr>
<td>Dean</td>
<td>13</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>28</td>
<td>7%</td>
</tr>
<tr>
<td>No Answer</td>
<td>27</td>
<td>7%</td>
</tr>
<tr>
<td>Total</td>
<td>392</td>
<td>100%</td>
</tr>
</tbody>
</table>

* Job class as identified in the EDUCAUSE member database.
EDUCAUSE factored Carnegie classification, institutional control, and geographic location into the selection process to make the sample as representative as possible. In February 2002, ECAR e-mailed invitations for follow-up interviews to the online survey respondents, with a request for them to recruit a representative wireless network user for an additional interview. Table 2-5 shows a breakdown of the characteristics of the final roster of 18 participants:

- College of Mount Saint Joseph
- Dartmouth College
- Duke University
- Florida State University
- Harvey Mudd College
- Indiana University
- Maricopa Community College
- Middle Tennessee State
- Middlebury College
- Oberlin College
- Rockland Community College
- University of California, Berkeley
- University of California, San Diego
- University of Pennsylvania
- University of Toronto
- University of Wisconsin, Madison
- University of Wisconsin, Stout
- Wake Forest University

IDC created separate interview guides for the IT administrators and wireless network users to solicit opinions from their different points of view. During February and March 2002, IT participants completed their interviews either by e-mail or telephone. IDC conducted all the user interviews by telephone. Their opinions and experiences appear throughout the report wherever appropriate.

### Table 2-5. Breakdown of Qualitative Research Sample Participants by Carnegie Classification

<table>
<thead>
<tr>
<th>Carnegie Classification</th>
<th>Institution Control</th>
<th>Geographic Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctoral</td>
<td>10</td>
<td>Private 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Northeast 5</td>
</tr>
<tr>
<td>Master’s</td>
<td>2</td>
<td>Public 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Midwest 5</td>
</tr>
<tr>
<td>Bachelor’s</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>South 4</td>
</tr>
<tr>
<td>Associate’s</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>West 4</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>Total 18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total 18</td>
</tr>
</tbody>
</table>
Each wireless network evolves differently, depending on a higher education institution’s unique combination of academic programs, application requirements, IT infrastructure, and geographic characteristics. This chapter explores the scope of wireless networking’s penetration into higher education by the following parameters: the drivers for its implementation, its current penetration rate, and the scope of deployment on campus. Nonimplementers are examined briefly to determine their reasons for abstaining.

**Importance of Wireless in IT Strategy**

Most higher education institutions position their wireless network not as a replacement for the current wired infrastructure but as a means to enhance current network access. Dr. David G. Brown, vice president and dean of the International Center for Computer Enhanced Learning, Wake Forrest University, summarizes the outlook of many interviewees: “The wired network is our primary network. Wireless is provided on top of it. If the wireless network goes out, we are inconvenienced. If the wired network goes out, we are devastated.” As a result, almost two-thirds of respondents at institutions with current or planned wireless networks believe that wireless networking is important but not mission critical. More precisely, 21 percent gave it low importance, 13 percent gave it high priority over other IT initiatives, and 66 percent said it’s important but other initiatives have higher priority. (The base consists of current and planned wireless network operators, $N = 299$.)

**Penetration of Wireless Networks**

Today, many institutions deploy a wireless network in some form on their campuses. Using the EDUCAUSE membership base as a measurement, IDC found a high penetration rate for wireless networking: about half of the members have implemented a comprehensive or specific wireless network at their institution. Another 31 percent are in the planning stages, while 18 percent have a pilot implementation in place. Another 11 percent intend to implement wireless. Only 8 percent of the EDUCAUSE
members have no plans or intentions to implement a wireless network. (See Figure 3-1.)

IDC derived the overall penetration findings not only from ECAR’s online survey of 392 respondents but from a supplementary survey of nonrespondents as well. Theorizing that current implementers may have been self-selectively more inclined to participate in the online survey, IDC did a follow-up survey of nonrespondents to test for bias. IDC surveyed 150 additional higher education institutions selected randomly from nonrespondents (30 responses from each of five categories: doctoral, master’s, baccalaureate, associate’s, professional/other). IDC found that in fact nonrespondents to the online survey were not as likely to have implemented wireless networking. The results of the nonrespondent survey were weighted to represent the total of 1,009 nonrespondents and combined with the online survey responses to estimate the true penetration figures shown in Figure 3-1.

**Factors Driving Wireless Implementation**

With current or planned penetration exceeding 90 percent, wireless networking is becoming a mainstream network service in higher education. To understand the factors fueling its adoption, ECAR and IDC queried institutions in both the online survey and qualitative interviews about their reasons for implementation. Online survey respondents rated the importance of several implementation factors on a scale of 1 to 10 (1 = not important, 10 = very important). During interviews, IDC queried IT administrators and wireless network users directly about implementation drivers. Table 3-1 presents the percentage of online survey respondents that rated specific implementation factors as very important by giving it a score of eight or higher.

Improved network access is the universal reason for installing wireless networks. More than half of all respondents cited the importance of improved network access for their students in the implementation decision process. This is not surprising, as wireless technology untethers students, faculty, and others from traditional network access points, enabling them to work whenever, wherever they wish. Barry Walsh, director, Indiana University, explained, “Wireless networking is rapidly reaching maturity, and its

* Base: Online survey respondents plus survey of nonrespondents (N = 542).

**Figure 3-1. Stage of Wireless Networking Implementation***
Table 3-1. Rating of Implementation Factors in Wireless Implementation as Very Important*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Total (N=370)</th>
<th>Doctoral (N=69)</th>
<th>Master's (N=90)</th>
<th>Bachelor's (N=81)</th>
<th>Associate's (N=43)</th>
<th>FTE: 1-4,999 (N=198)</th>
<th>FTE: 5,000-9,999 (N=58)</th>
<th>FTE: 10,000-19,999 (N=55)</th>
<th>FTE: 20,000+ (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved Student Network Access at Any Time</td>
<td>51%</td>
<td>54%</td>
<td>50%</td>
<td>56%</td>
<td>47%</td>
<td>51%</td>
<td>50%</td>
<td>49%</td>
<td>67%</td>
</tr>
<tr>
<td>Student/Teacher Access During Class</td>
<td>43%</td>
<td>33%</td>
<td>44%</td>
<td>44%</td>
<td>58%</td>
<td>49%</td>
<td>36%</td>
<td>29%</td>
<td>33%</td>
</tr>
<tr>
<td>Ability to Meet Future Computing Needs</td>
<td>43%</td>
<td>41%</td>
<td>46%</td>
<td>37%</td>
<td>49%</td>
<td>42%</td>
<td>48%</td>
<td>35%</td>
<td>48%</td>
</tr>
<tr>
<td>Improved Faculty Network Access at Any Time</td>
<td>41%</td>
<td>46%</td>
<td>46%</td>
<td>38%</td>
<td>42%</td>
<td>41%</td>
<td>41%</td>
<td>36%</td>
<td>62%</td>
</tr>
<tr>
<td>Solve Specific Problem/Application</td>
<td>38%</td>
<td>25%</td>
<td>42%</td>
<td>43%</td>
<td>44%</td>
<td>44%</td>
<td>31%</td>
<td>20%</td>
<td>48%</td>
</tr>
<tr>
<td>For Institution to Be Perceived as Leading Edge</td>
<td>35%</td>
<td>43%</td>
<td>32%</td>
<td>28%</td>
<td>40%</td>
<td>34%</td>
<td>38%</td>
<td>42%</td>
<td>29%</td>
</tr>
<tr>
<td>Improved Commuter Network Access at Any Time</td>
<td>30%</td>
<td>30%</td>
<td>40%</td>
<td>28%</td>
<td>30%</td>
<td>31%</td>
<td>29%</td>
<td>27%</td>
<td>38%</td>
</tr>
<tr>
<td>Easier to Move/Add/Change</td>
<td>24%</td>
<td>10%</td>
<td>29%</td>
<td>22%</td>
<td>44%</td>
<td>28%</td>
<td>16%</td>
<td>18%</td>
<td>19%</td>
</tr>
<tr>
<td>Competitive Pressures from Other Institutions</td>
<td>21%</td>
<td>22%</td>
<td>21%</td>
<td>23%</td>
<td>21%</td>
<td>22%</td>
<td>21%</td>
<td>25%</td>
<td>10%</td>
</tr>
<tr>
<td>Savings Over Installed Wired Networks</td>
<td>21%</td>
<td>12%</td>
<td>20%</td>
<td>20%</td>
<td>33%</td>
<td>23%</td>
<td>24%</td>
<td>5%</td>
<td>19%</td>
</tr>
<tr>
<td>Operating Costs Savings Over Wired</td>
<td>11%</td>
<td>7%</td>
<td>9%</td>
<td>7%</td>
<td>19%</td>
<td>11%</td>
<td>14%</td>
<td>5%</td>
<td>19%</td>
</tr>
</tbody>
</table>

* Percentage of total respondents who chose a rating of 8, 9, or 10, where 1 = Not Important, 10 = Very Important. The highest ratings are highlighted. Base: current/planned wireless network operators by institution type. Note: The three factors that generated the highest percentage of importance ratings are highlighted.
Wireless networking in higher education has the potential for radically changing the way they do business. Potentially most significant is [that] no longer will students and faculty be bound by needing to connect to a fixed network connection in order to access network resources. Wireless networking frees them from the tyranny of place and allows them to work anywhere on campus with a notebook computer and a simple wireless modem.”

The ability to meet future computing needs is also important to more than 40 percent of institutions, not only to meet a campus’ evolving computing needs but also to meet prospective students’ expectations. “Network capability is definitely on parents’ and students’ checklists, but it is an axiom that a college will have it,” explained Dr. Timothy Rogers, vice provost, student affairs, The University of Tennessee. “Now the question is whether students will bring a desktop or laptop to school. And I can foresee wireless as the next hot button. While few parents ask about wireless capability on campus now, I think we will see the frequency of that question grow.” And the increasing number of individual colleges and departments that mandate wireless laptops for their students pushes higher education institutions to provide an appropriate network infrastructure.

More than 40 percent of the survey respondents identified network access during class time as important. As the pedagogy in more courses incorporates e-learning elements, users view wireless access as a facilitating technology, allowing students and faculty to go online in the classroom. “Wireless enables my classes to be more efficient because I can incorporate online elements in my class,” stated Pam Nelson, instructor in geology, Maricopa Community College.

Almost 40 percent of survey respondents used wireless technology to address specific problems and applications. Several institutions described situations in which wireless networking provided the easier and/or less expensive alternative for network access: remote stacks in a library, a new classroom building, chair-side network access at a dental school clinic, temporary classroom trailers, and renovations in an architecturally significant building.

Cost savings did not play a significant role in the implementation process. The likely reason is that campuses are already heavily wired; the wireless network is a parallel network. Larry Conrad, assistant vice president and CIO, Florida State University, Tallahassee, explained, “Wireless networks incur increased costs that are duplicative of existing wired plant investment, added management, and support load.” Associate’s colleges are something of an exception to this finding; they are most likely to cite cost savings as an important factor in implementation. Perhaps they are not as networked as other Carnegie segments. If this is true, other associate’s colleges will likely find cost savings to be an important factor in implementing wireless networks too.

**Institutional versus Departmental Initiative**

Most respondents (67 percent) consider wireless networking to be an institution-wide IT initiative. Twenty-nine percent consider it to be a local (school or departmental) initiative. Current implementations may be limited to certain departments or areas, but two-thirds of higher education institutions believe wireless networking can be applied throughout their IT operations. Individual colleges or departments may deploy initially to support their students’ wireless laptop requirements, or IT departments may test wireless capabilities in pilots that encompass only several buildings. While implementation may be localized, many interviewees felt that institution-wide planning and control is important. Elazar Harel, assistant vice chancellor, University of California, San Diego, explained,
“Campus coordination is critical in order to assure uniform secure access, minimize frequency interference, and control costs.”

Wireless networking is a relatively recent phenomenon at many higher education institutions. As Figure 3-2 illustrates, three-quarters of respondents installed their initial wireless network in the past two years. A closer examination reveals varying adoption patterns by Carnegie classification. More than one-third (37 percent) of doctoral institution respondents reported their initial wireless implementation occurred before 2000. Fewer than half that number—15 percent of bachelor’s colleges and 18 percent of associate’s colleges—report the same. Perhaps research activities at doctoral institutions drove early adoption of wireless technology for experimentation or to support a specific project or application. But as the results indicate, wireless networking is evolving from a specialized to a mainstream networking access method.

**Wireless Networking Operational Characteristics**

Higher education institutions exhibit numerous variations in terms of the number of networks, their scope, and the buildings targeted.

![Figure 3-2. Year of Initial Wireless Implementation, by Carnegie Classification*](image-url)
Multiple Initiatives and Interoperability

Institution size influences the number of wireless networks in operation. As Figure 3-3 illustrates, the number of wireless initiatives increases with institution size (as measured by FTE). More than three-quarters of respondents at institutions with 20,000-plus FTE operate three or more wireless networks, compared with just 20 percent of respondents at 1–4,999 FTE institutions.

By their nature, larger universities provide potentially more opportunities for wireless implementations throughout their campuses. First, they have more potential implementers. Larger universities support a comprehensive curriculum and operate a significant number of individual colleges and departments. Second, there is less centralization. Individual colleges may exercise greater independence and perhaps support their own IT departments and set their own program requirements. Finally, larger institutions comprise many buildings over a larger geographic area, to handle the higher enrollment and greater program diversity. This, in turn, fosters more opportunities to implement wireless networks for specific applications or to expand network access in previously inaccessible areas.

In some cases, individual and centralized activities operate in tandem. David Ferriero, vice provost and university librarian, Duke University, explained, “Central campus IT initiated the wireless network for the main campus, while some departments installed their own wireless networks. Both were installed to complement the wired networking in their areas of support.”

Nevertheless, most individual wireless network initiatives typically follow the institution-wide strategy. More than two-thirds

![Figure 3-3. Number of Wireless Network Initiatives, by FTE Size*](image-url)
of respondents maintain interoperability standards to handle both wired and wireless activities. Adoption of these standards varies little by institution type or size, but as Figure 3-4 illustrates, the frequency is higher (75 percent) at institutions that have implemented wireless networks.

Typically, the IT department manages interoperability (91 percent of respondents). According to IT administrators, the centralized policies provide a university-level authority to address interference, transmission, and operational issues. Greg Schaffer, director of network services, Middle Tennessee State University, summarized their policy: “We do not allow for ‘rogue’ access points; only IT can install an AP on the network. Again, this is consistent with the wired network policies.” Or as Larry Levine, director of computing, Dartmouth College, succinctly explained, “Computing Services owns the network—if you set up your own wired or wireless network and it causes trouble, we visit you.” To avoid potential interference problems, some institutions manage the airspace at the 2.4-GHz range—and now the 5-GHz range—to control devices that use the same frequencies at which wireless transmits.

Centralized interoperability policies do in fact offer a preventative measure; during their interviews, IT administrators reported few problems. Yet only half of the online survey respondents still in the wireless network planning stages have implemented similar standards. Judging by the decisions and experiences of current wireless implementers, planning institutions would be well advised to seriously consider interoperability standards.
Scope of Current Implementations

While most respondents say their wireless network has an institution-wide IT focus, most wireless networks currently are not campus-wide in scope. (See Figure 3-5.)

Many higher education institutions phase in their wireless networks for several reasons:
◆ To test or phase in the technology in a controlled situation. Elazar Harel, UC San Diego, explained, “Initial implementation was targeted with concentration on areas that would most benefit from the technology. These include large meeting places, eating places, classrooms, conference halls, etc.”
◆ To fulfill a specific user application. “Implementation was at the request of the department (teacher education) to provide laptops for curricular purposes,” stated Jeffrey Rehbach, special projects manager for library and information services, Middlebury College.
◆ To handle a specific building’s special requirements. “The college built a new science building where classrooms and labs were built around a central storage room. Even though the budget didn’t include computers for every lab, the department requested over 250 network ports. Wireless computers shared among the labs was an extremely cost-effective solution,” stated KC Hundere, director of network services, Glendale Community College.
◆ To install it as funding allows. Barry Walsh of Indiana University explained, “A targeted deployment was chosen initially to provide the most coverage for the minimum investment. Wireless funding was limited, and the initial plan was to let schools/departments deploy wireless as they saw the need (and could justify the expenditure), with the central IT organization providing standards and security infrastructure (VPN).”

Responses broken down by FTE size suggest that it is easier for institutions with a lower FTE to blanket their entire campuses with wireless coverage. Almost one-quarter of 1–4,999 FTE respondents operate a campus-wide wireless network; only 10 percent of 20,000-plus FTE respondents do. Mark Cain, executive director, information services and support, College of Mt. St. Joseph, said, “I wanted anytime/anyplace computing... We are a small place using technologies that have been employed successfully at much larger places.”

![Figure 3-5. Scope of Wireless Implementations*](image-url)
Yet larger institutions do plan to catch up with their smaller counterparts, perhaps gradually weaving together a campus-wide network from their multiple wireless initiatives currently operating at various buildings. (See Figure 3-6.) Barry Walsh of Indiana University described his institution’s expansion plans: “For campus-wide comprehensive we envision a plan that will build larger and larger islands of connectivity, which will eventually blend into a campus-wide coverage approach. Outdoors will be of interest in key gathering areas.”

Like Indiana University, many institutions see outdoor access as another priority. More than half of the wireless implementers have it now, and when we include those planning to add outdoor network access, the proportion rises to more than three-quarters of online survey respondents. (See Figure 3-7.)
Many institutions providing outdoor access report that it is very popular with users. Students sit at tables, benches, on the grass, or anywhere and pop open their laptops. It’s comparable to students’ walking around the campus with a cellphone glued to their ear. “In the future, I look to the attractiveness of flexibility in using outdoor spaces for study and classes, particularly in summer academic programs,” stated Jeffrey Rehbach of Middlebury College. Yet Jack McCredie, CIO and associate vice chancellor, information systems and technology, University of California, Berkeley, identified one problem: “Because the screens on many current laptops are very hard to read in bright sunlight, outdoor coverage may not be as popular as originally anticipated. However, we certainly see a lot of usage around coffee houses.”

With a significant percentage of institutions planning to expand wireless access campus-wide and/or to the outdoors, it is unsurprising that the mean percentage of campus geographic coverage (those with outdoor use) will increase from 25 percent to 52 percent in 24 months. (See Figure 3-8.) All classifications of institutions plan wireless network expansion; the current gap in average wireless network coverage areas between doctoral institutions and associate’s institutions will close within two years.

As the number of users and geographic coverage grow, institutions must balance roaming versus scalability. Some do this by assigning the wireless network to its own subnet, enabling users to roam while registering on the network only once. “Because of our use of VLANs [virtual local area network]..."
networks], users can roam all over the Harvey Mudd campus (and at a few spots, can roam onto neighboring Claremont College consortium campuses) without difficulties,” stated Dr. Richard Parker, CIO and director of computing and information services, Harvey Mudd College. “For anticipated possible expansion (for example, more bandwidth to some classrooms and the addition of a few outdoor spaces), we can add access points to the wireless VLAN.”

**Buildings with Wireless Access**

To promote user adoption, some institutions seed wireless technology in areas where students generally congregate. A popular testbed is the library; almost 60 percent of online survey respondents identified the library as a building with wireless access. (See Table 3-2.) For example, Drexel University’s IT department “paid for all the infrastructure; we gave the library 10 laptops and cards for students to check out, and then it expanded the number to 30,” explained Ken Blackney, core technology infrastructure director, Drexel University. “The students borrow the laptops for up to three hours for free as long as they don’t leave the building. We aimed for the students, rather than the faculty and staff. In the library, wireless was free and readily available.”

An IT representative at the University of Pennsylvania’s Van Pelt Library described typical student use: “It gives a lot of ways to provide access that we could not offer previously. We can offer network access anywhere in the building. … They can walk around the stacks … [and] access [the wireless network] from around the campus.”

The next step, stated Ira Winston, computers and information, School of Engineering, University of Pennsylvania, “is to promote usage … [so that wireless networks] evolve from a novelty to a real tool.” One method is to bring wireless access into the classroom, as one-third of online survey respondents plan to do. Many interviewees see wireless access as an enabling technology to facilitate e-learning in the classroom.

Installing the IT infrastructure is just the first step, however, as Harry Nelsen, director, Instructional Technology Center,

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**Table 3-2. Current and Future Buildings with Wireless Network Access***

<table>
<thead>
<tr>
<th>Building</th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master’s (N=75)</th>
<th>Bachelor’s (N=62)</th>
<th>Associate (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
</tr>
<tr>
<td>Administrative Buildings</td>
<td>32%</td>
<td>31%</td>
<td>36%</td>
<td>36%</td>
<td>28%</td>
</tr>
<tr>
<td>Library</td>
<td>57%</td>
<td>31%</td>
<td>66%</td>
<td>31%</td>
<td>59%</td>
</tr>
<tr>
<td>Classrooms or Lecture Halls</td>
<td>46%</td>
<td>33%</td>
<td>50%</td>
<td>39%</td>
<td>51%</td>
</tr>
<tr>
<td>Research Centers</td>
<td>16%</td>
<td>26%</td>
<td>27%</td>
<td>33%</td>
<td>17%</td>
</tr>
<tr>
<td>Dormitories</td>
<td>16%</td>
<td>24%</td>
<td>17%</td>
<td>28%</td>
<td>20%</td>
</tr>
</tbody>
</table>

* Percentage of respondents identifying current and future building plans for wireless network access. Building types cited by the highest percentage of respondents are highlighted. Base: Current/piloting wireless network operators by Carnegie classification.
Rockland Community College, warned: “Do not underestimate the fear associated with pedagogic change.” Proper training and support can help. “You need to actively encourage the faculty to use wireless,” stated David Dunne, adjunct professor of marketing, Joseph L. Rotman School of Management, University of Toronto. “We plan to host speakers to demonstrate how the faculty can use it in their classes... With technology, it is better not to progress in leaps, just to do it in small steps.”

**Intend to Implement but Not Yet Planning**

As noted earlier, 11 percent of online survey respondents intend to implement a wireless network but have not begun the actual planning process. (See Figure 3-1.) However, more than half of the future implementers plan to implement their initial wireless network in 2002. Table 3-3 compares the characteristics of current wireless network operators with those of potential operators not having actual plans. Many characteristics are the same. More than half plan to install wireless networking in a specific building or location initially. Anticipated users, departments, and equipment are similar to those of current wireless users.

Future implementers corroborate the trend of bringing wireless access to classrooms. Current wireless network operators most frequently identified libraries as the buildings with wireless access. More future implementers plan to offer wireless access in the classroom initially.

**Table 3-3. Characteristics of Current/Planning Respondents and Those Intending to Implement Wireless Networks**

<table>
<thead>
<tr>
<th></th>
<th>Already Implemented/Planning to Implement (N=299)</th>
<th>Intend To Implement, No Plans (N=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Building/Location</td>
<td>23%</td>
<td>53%</td>
</tr>
<tr>
<td>Campus-wide</td>
<td>23%</td>
<td>23%</td>
</tr>
<tr>
<td>Top Three Buildings</td>
<td>Library: 57%</td>
<td>Classrooms: 60%</td>
</tr>
<tr>
<td></td>
<td>Classrooms: 46%</td>
<td>Library: 53%</td>
</tr>
<tr>
<td></td>
<td>Administrative: 32%</td>
<td>Administrative: 33%</td>
</tr>
<tr>
<td>Top Three User Groups</td>
<td>Undergrads: 77%</td>
<td>Undergrads: 90%</td>
</tr>
<tr>
<td></td>
<td>Faculty: 73%</td>
<td>Faculty: 77%</td>
</tr>
<tr>
<td></td>
<td>Administration: 53%</td>
<td>Grad Students: 60%</td>
</tr>
<tr>
<td>Top Three Departments</td>
<td>Computer Science: 38%</td>
<td>Computer Science: 43%</td>
</tr>
<tr>
<td></td>
<td>Physical Science: 33%</td>
<td>Engineering: 33%</td>
</tr>
<tr>
<td></td>
<td>Business: 32%</td>
<td>Physical Sciences: 30%</td>
</tr>
<tr>
<td>Top Devices Access</td>
<td>Laptops: 94%</td>
<td>Laptops: 97%</td>
</tr>
<tr>
<td></td>
<td>Desktops: 46%</td>
<td>Desktops: 37%</td>
</tr>
<tr>
<td></td>
<td>PDAs: 39%</td>
<td>PDAs: 33%</td>
</tr>
<tr>
<td>No Wireless Card Standard</td>
<td>51%</td>
<td>87%</td>
</tr>
</tbody>
</table>
No Plans to Implement

A small number of respondents currently have no wireless network implementation planned. With such a small number, extrapolating the results to the general population can be risky, so the responses should be considered with some caution. Nevertheless, their plans mirror other survey findings. (See Figure 3-9.) Cost is not a significant issue; fewer than 20 percent of nonimplementers cited this as a factor. Rather, like current wireless network operators, they see wireless networking as only one of many IT needs. It is not yet a high enough IT priority to make a claim on resources. Security, a wireless network challenge identified by many current operators, is another factor deterring implementation.

Figure 3-9. Primary Barriers to Adopting Wireless*

* Base: Institutions with no wireless network implementation plans (N = 22).
Usage

Most institutions that implement wireless networking report that students readily incorporate it into their day-to-day activities. Students with wireless laptops like having immediate network access, whether studying in the library or checking e-mail on the quad. As one Carnegie Mellon student explained, “I am always hooked up to the wireless network. Over the past couple of years, I found it very hard to use my laptop without an Internet connection. Playing games and word processing are really a very small portion of what I do on a computer. I am always checking the e-mail and surfing the Web.”

But individual convenience represents just the first level of impact on campuses. Users report that wireless technology’s impact is far more comprehensive. Immediate network access facilitates the incorporation of online elements in the classroom, accelerating the current pedagogical and cognitive evolution that many institutions are experiencing.

User Characteristics

As Table 4-1 illustrates, many higher education institutions implement wireless technology to provide greater network access for their students and faculty as they move about the campus. Gregory Strong, director of technology, Florida State University School of Law, described typical wireless usage: “Students use wireless in the classroom to conduct research or do class exercises, and use it in our library of law for legal research. There is outside access, so people use it from picnic tables outside.” Fewer institutions reported administrative usage, primarily because administrative personnel work from assigned workstations and use the wired network for access. However, an IT representative from the Van Pelt Library at the University of Pennsylvania described how wireless access can increase workplace efficiency: “Wireless enables us to rethink how we can configure workstations in a room. All the desks no longer have to be near a wall for network access. Instead we can optimize the space for maximum efficiency—as, for example, the postcataloging area, which we wired 10–15 years ago. It is hard to get the workstations wired in the middle of the room; we tried all sorts of schemes and wires dangling from the ceiling. So why not install a wireless transmitter? We can move furniture around, and employees can move around to another part of the room as they process books.”
But as FTE size grows, it is apparent that wireless networking begins spreading throughout the academic community as constituents gain familiarity with it. Dewitt Latimer, executive director, IT infrastructure, The University of Tennessee, explained, “If you’re attending a meeting with 15 people, two or three use their laptops to take notes or check e-mail. It doesn’t take long for the others around the table to look and want to use it, too.”

While the percentage of institutions that report student access to their wireless networks remains steady, the actual percentage of students who have access to it varies by Carnegie classification, especially at associate’s institutions. (See Figure 4-1.)

Several factors could affect student access at associate’s institutions:
- less common student ownership of laptops,
- fewer institutional computer labs or laptop checkout programs to enable student access,

<table>
<thead>
<tr>
<th>Users</th>
<th>Total (N=299)</th>
<th>FTE: 1–4,999 (N=154)</th>
<th>FTE: 5,000–9,999 (N=50)</th>
<th>FTE: 10,000–19,999 (N=45)</th>
<th>FTE: 20,000+ (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergrads</td>
<td>77%</td>
<td>77%</td>
<td>78%</td>
<td>76%</td>
<td>75%</td>
</tr>
<tr>
<td>Faculty</td>
<td>73%</td>
<td>65%</td>
<td>80%</td>
<td>73%</td>
<td>90%</td>
</tr>
<tr>
<td>Administration</td>
<td>53%</td>
<td>45%</td>
<td>52%</td>
<td>69%</td>
<td>85%</td>
</tr>
<tr>
<td>Grad Students/Researchers</td>
<td>44%</td>
<td>27%</td>
<td>56%</td>
<td>53%</td>
<td>95%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
<td>6%</td>
<td>10%</td>
<td>2%</td>
<td>5%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.

Figure 4-1. Students with Access to Wireless Networks, by Carnegie Classification*

* Base: Current/piloting wireless network operators.
◆ fewer colleges or department programs with mandatory laptop requirements, and
◆ fewer opportunities to use wireless laptops in the classroom and/or on campus.

As Table 4-2 illustrates, online survey respondents identified most frequently the computer sciences, physical sciences, and business departments as providing wireless access. This is indicative of the gradual implementation approach many institutions take: installing wireless networks in selected buildings and locations.

Wireless network implementations begin at some institutions as pilots for research and experimental purposes. Logical candidates for this research are the computer science, physical science, and perhaps the engineering departments. Larry Levine, director of computing, Dartmouth College, explained his institution’s wireless networking expansion: “We chose to cover everything because we saw academic, administrative, and ‘daily-living’ value in a total wireless overlay. Technically, we’d already experimented with making some areas wireless: school of engineering, computer science, some library locations, student union building, some student eateries, and the central campus green.”

Business colleges and departments are frequently early adopters because their larger endowments enable them to invest in new technology. Moreover, a mandatory wireless laptop requirement is gaining popularity among MBA programs. David Dunne, adjunct professor of marketing, Joseph L. Rotman School of Management, University of Toronto, explained, “The school of management’s administration made the decision to implement wireless. The dean of the business school’s vision is to be one of the top 10 business schools in North America.”

Table 4-2. Departments Reported to Have Wireless Access*

<table>
<thead>
<tr>
<th>Department</th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master’s (N=75)</th>
<th>Bachelor’s (N=62)</th>
<th>Associate’s (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Sciences</td>
<td>38%</td>
<td>47%</td>
<td>36%</td>
<td>32%</td>
<td>18%</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>33%</td>
<td>41%</td>
<td>32%</td>
<td>34%</td>
<td>36%</td>
</tr>
<tr>
<td>Business</td>
<td>32%</td>
<td>55%</td>
<td>33%</td>
<td>19%</td>
<td>14%</td>
</tr>
<tr>
<td>Languages/History</td>
<td>23%</td>
<td>23%</td>
<td>17%</td>
<td>27%</td>
<td>25%</td>
</tr>
<tr>
<td>Engineering</td>
<td>21%</td>
<td>47%</td>
<td>13%</td>
<td>5%</td>
<td>14%</td>
</tr>
<tr>
<td>Social Science</td>
<td>21%</td>
<td>23%</td>
<td>19%</td>
<td>31%</td>
<td>11%</td>
</tr>
<tr>
<td>Math</td>
<td>18%</td>
<td>27%</td>
<td>13%</td>
<td>21%</td>
<td>11%</td>
</tr>
<tr>
<td>Law</td>
<td>10%</td>
<td>31%</td>
<td>4%</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>Medical</td>
<td>10%</td>
<td>23%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Other</td>
<td>39%</td>
<td>25%</td>
<td>57%</td>
<td>37%</td>
<td>43%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators. The three highest occurrences by Carnegie classification are highlighted.
America. The administration feels that utilizing leading-edge technology is an important factor in this goal. A number of competitor schools use wireless in some form or another, and we did not want to be left behind. As a rule, the business school has more money and can afford to implement new technologies more quickly than some of the other schools at the university.”

**Impact on Academic Process**

Before wireless networking, technology in the classroom was already impacting the traditional classroom experience. Faculty members began to incorporate online teaching elements in the classroom to augment traditional lectures and to create a hands-on learning experience. In some institutions, network access in the classroom did not keep pace with the availability of new teaching tools; faculty members often scrambled to reserve computer labs or wired classrooms. Frequently, the number of students outstripped the number of available computers or network ports. Wireless networking, however, is a relatively inexpensive way to guarantee Internet access in any classroom, providing new locations for hands-on teaching.

This freedom of access impacts the classroom experience. Joel Smith, vice provost and chief information officer, Carnegie Mellon University, described his changing teaching experience: “Students automatically sit down at class and open their laptops. While I’m presenting, they’ll access the network. They’ll instant-message each other or surf the Web for relevant class information. And just when you doubt they’re listening, one student will give you an incredible zinger that is completely pertinent to the class discussion. I think the combination of a portable device and the wireless networking is actually accelerating this apparent change in cognition. Research suggested that human beings are one-threaded beings, but there is data to suggest that this entire generation is now multithreaded.”

Other wireless users have noted ways in which wireless networking impacts the academic process.

**Greater Collaboration and Communication**

Wireless facilitates group collaboration in the classroom. David Dunne of the University of Toronto said, “I think wireless could change our teaching methods. The faculty uses a variety of group teaching exercises in the classroom. And we find that our students are incredibly adept with technology. The demand is there to adopt more technology-oriented elements in our classes, and it is a matter of time before we design teaching exercises for the classroom that use wireless.” Various users said that their wireless activities in the classroom include accessing databases on the Web for in-class manipulation, using chat functions to brainstorm in a foreign language, and conducting real-time research in conjunction with a class topic.

The impact of wireless extends to students’ work in general because they are no longer tethered to the constraints of desktop PCs. Students modify the environment—for example, sitting together at a table or configuring their desks into a circle—to facilitate their collaboration. “We’ll be sitting together as a group at a table with our laptops up,” explained Eric Williams, MBA student, The University of Tennessee. “We’ll all be accessing different information, talking about it at the same time so we can share information. And we flip back and forth between screens.”
Greater Access to Resources

“The speed of access and the exposure to a wider variety of information and material online enhances their learning,” stated Pam Nelson, instructor in geology, Maricopa Community College. She uses wireless technology to enable her students to access Web pages in class to look at large images of rocks and dinosaur fossils. “I can’t buy a $12,000 dinosaur fossil, so this is the next best thing,” explained Nelson. “In another lab, students analyze rock structures by looking at online photos of the Grand Canyon and other geologic landforms. The experience is more life-like because they are not analyzing some diagrams in a book.”

Students use the wireless proactively to access material during class. “You start to see students think differently,” explained Michael Stahl, professor of management and director, physicians MBA program, College of Business Administration, The University of Tennessee. “You start to see them automatically think when we’re approaching a subject or a review of a concept in class, ‘Let’s go to company X’s Web site to see how they do it.’”

Wireless enables faculty to share information on demand. Ira Winston, computer and information, School of Engineering, University of Pennsylvania, stated, “It gives faculty more flexibility whenever they meet colleagues and students. They bring their laptops to the lab and have the information right there. They can download information and project it on a big screen; it’s helpful when lecturing in large classes.”

Changes to Pedagogy

Wireless is just one aspect of the entire technological evolution impacting higher education pedagogy in general, but it can accelerate the process. More faculty members are either motivated by wireless’ ease of network access or forced by mandatory wireless laptop requirements to incorporate online resources in their classes. In either case, it takes a significant investment of time to learn how to incorporate technology into the classroom—equipment, network, and application layers—and to rethink course elements and delivery methods. “I am a new instructor, and basically I built my course from ground zero to incorporate online elements,” stated Pam Nelson of Maricopa Community College. “It is a big commitment, but it was worth it because it enhances the students’ learning experience.”

Many institutions, however, struggle with how to recognize the time commitment required to develop technologically enhanced course elements, especially where tenure-track activities are concerned. Indira Nair, vice provost of education, Carnegie Mellon University, reported, “We are trying to place a value on faculty’s computer-enhanced educational activities for tenure and promotion. We think we know how to weigh the value of research by counting the number of papers. And we have student/faculty evaluation. We know it is a big time investment, which means that a faculty member has less time to concentrate on other activities.”

Another issue is support for faculty. “I think universities will develop a middle layer of expertise to help faculty construct technology-based pedagogy, to help faculty with their ideas,” stated Joel Smith of Carnegie Mellon. This entails technology training, on-site tech support during class, advice on pedagogy, and additional personnel resources.

Many faculty members think the effort is worthwhile because it enhances the learning environment and the quality of students’ work. Gregg Humphrey, director of elementary education, Middlebury College, said, “In the pilot implementation, it became clear to me that I had to change, to make a huge leap forward in the way I dealt with my students.”
I had to accept multitasking among my students and realize that it is okay. Students were way ahead of me in terms of how to use the wireless laptop effectively. But I will never revert to the old way, because now they can accomplish twice as much in class in the same amount of time. It was an epiphany!

**Inappropriate Classroom Use**

Wireless’ greater access in the classroom fuels another debate—about inappropriate use. People are divided on the issue. Some faculty members insist wireless laptops provide a source of diversion, offering students, as one faculty member described it, “fun and sexy ways to wander during class. Instead of making grocery lists, students pull up Internet sites.” Others complain that typing sounds are a distraction, which magnifies as more students use their laptops in class.

Yet many believe it is a new angle to an old problem: class management. Chris Jernstedt, professor of psychological and brain sciences, Dartmouth College, explained, “Students can check their e-mail during lectures, but because they are so engaged, they tend not to. It is a question then of ensuring student engagement or else the opposite will occur—distraction. When a class is well taught, wireless distraction is a non-issue. Wireless tends to amplify the climate of learning in that particular classroom, not change the direction.” Almost two-thirds (63 percent) of the online survey respondents with wireless access agreed with Dr. Jernstedt’s assessment. Only 18 percent saw inappropriate access as a problem. Nineteen percent didn’t know or did not answer.

**Printing**

Freedom of wireless access throughout a college campus does not necessarily translate into freedom of printing. About two-thirds of online survey respondents offer wireless printing capability for their wireless users. (See Figure 4-2.) Where printing is available, users can select from several distributed printing devices. Sometimes institutions offer wireless printing after studying wireless usage patterns. “We realized it made no sense to offer wireless in the library and then make students wait at public-access labs to print,” explained Stan Pinkleton, director of OIT customer services, The University of Tennessee.

Wireless printing raises two questions: Who pays for the toner and paper? Who maintains the printers? Because wireless technology enables access from anywhere, individual departments may pay for the printing of nondepartmental wireless users who happen to be in the area, unless the university uses a centralized cost-recovery model. Moreover, printers serving the wireless community may be “orphans” because local departments may not handle their maintenance. To avoid this problem, The University of Tennessee, for example, tries to place wireless network printers near centrally funded computer labs, enabling lab assistants to maintain them.

* Base: Current/piloting wireless network operators (N = 299).

**Figure 4-2. User Access to Wireless Printing***
Wireless technology provides many benefits, but only to those who use a wireless-enabled computing device. Desktop computers are still the dominant computing device on campus, although anecdotal evidence suggests that some students and faculty members are beginning to prefer laptops. Lower prices, growing computing power, and greater portability contribute to this trend. Looming on the horizon, however, are handheld PCs and PDAs, which some believe could spur the mainstream adoption of wireless networking in higher education.

**Laptop Ownership**

As Figure 5-1 illustrates, online survey respondents' estimate that approximately 20 percent of students currently own a laptop computer, and anecdotal evidence shows laptop ownership rising.

David Dunne, adjunct professor of mar-

---

![Figure 5-1. Students with Notebook Computers*](image_url)

* Base: Current/piloting wireless network operators that do not require notebooks.
keting, Joseph L. Rotman School of Management, University of Toronto, estimated that "about one-quarter of second-year students bring laptops into classes. This is, however, expected to change, as first-year students in fall 2001 are the first class that is required to use laptops in the business program."

John Bielec, chief information officer, Drexel University, described faculty members' adoption of laptops: "Drexel replaces one-third of the faculty's computers every year. Previously, about 80–90 percent of faculty requested desktops. This year, however, laptops represented 50–60 percent of the upgrades."

An IT representative at the Van Pelt Library at the University of Pennsylvania stated, "One reason we offer wireless access at the library is because students requested it; they're installing wireless cards in their laptops and wanted to use them in the library."

One professor estimated that about 80 percent of his college's students own computers, and most students who buy PCs when they come to campus now buy laptops. Another university pegs student laptop ownership at 25 percent.

Yet not everyone can afford or wants a laptop. Joel Smith, vice provost and chief information officer, Carnegie Mellon University, questioned his philosophy of science students about their wireless usage. "Only one person in my class of 20 students used the wireless network. The reason for the lack of use is laptop nonownership. And the laptop nonowners were not inclined to purchase a laptop for three reasons: One, the screen size. Two, they want to 'monkey around' with their computers; it's hard to install a new video card or different sound card in a laptop. Three, desktops are cheaper."

But some worry about the lack of equal access to laptops and the impact on nonusers' educational experiences. Some institutions interviewed offer laptop checkout programs, either for individual use or for an entire classroom.

Library checkout programs for individual students seem particularly popular. "Education seems to be a lot more collaborative, and folks are sitting with their laptops, working on group projects," stated David Atkins, assistant professor, Hodges Library, The University of Tennessee. "Now students who don't have a laptop can check one out and join right in." Indeed, in the first weeks of operation, the library posted 450 laptop turnovers. Drexel University's library reports about 3,000 laptop checkouts per month.

For classroom or lab applications, institutions maintain carts of laptops that faculty members reserve in advance. This offers advantages and disadvantages. During class, all students have equal access to the equipment and laptops. But faculty members distribute and collect the laptops before and after each class, a task that eats away at instructional time.

Other institutions take a more proactive stance by mandating laptops for some or all of their students. (See Figure 5-2.) Typically, students in a specific college or department—not the entire student body—must own laptops. Only 6 percent of institutions require notebooks for all students; most of these are small (less than 5,000 FTE) and/or privately controlled institutions.

Institutions implement a mandatory laptop policy to maintain their reputation, enhance their program, and/or prepare their students for postgraduate employment. Ira Winston, computer and information, School of Engineering, University of Pennsylvania, stated, "We wanted to be able to say that we had a wireless network. Our usage is not
that heavy, but we really do have to have a wireless network if our school is to be considered leading edge.” Gregory Strong, director of technology, Florida State University, School of Law, believes a mandatory laptop requirement helps the school in several ways. “The College of Law and the MBA program in the College of Business wanted to deploy a laptop/wireless initiative. Both programs indicated this was becoming the norm for teaching in their respective disciplines to benefit students and faculty. And wireless is one of the reasons that our law school was named the 13th ‘most high-tech’ law school in the country by The National Jurist magazine. The days of the legal pads and the Dictaphone are over. Some schools are having a hard time moving forward, and the high-tech experience helps students to get jobs afterwards.”

A notebook requirement drives wireless usage. (See Figure 5-3.) More than half of the online survey respondents with a mandatory notebook policy require wireless access also. This is logical, because wireless access enables students to use their notebooks more frequently, generating a higher return on the mandatory investment in their laptops.

**Wireless Access Devices**

Unsurprisingly, almost all online survey respondents identified laptop computers as a means to access the wireless network. (See Table 5-1.) Yet IT administrators and wireless users are also interested in PDA usage in the wireless environment. “We are intrigued by the use of PDAs in the classroom, and we feel there is potential [for] better integration of the lab work with the classroom, for example,” stated Joel Smith of Carnegie Mellon University. And while laptops exemplify mobile computing today, they are still rather heavy and cumbersome for true portability. Many envision a future in which students will pull a PDA out of their pocket—not a laptop from their backpack—to access the network, especially as more wireless networks expand outdoors. It’s easier to use a PDA than a laptop while strolling across campus.
Wireless Networking in Higher Education

Figure 5-3. Institutions with a Mandatory Notebook Policy and a Wireless Access Requirement*

Table 5-1. Devices for Accessing Wireless Networks, by Carnegie Classification*

<table>
<thead>
<tr>
<th>Device</th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master's (N=75)</th>
<th>Bachelor's (N=62)</th>
<th>Associate's (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
<td>Add in 24 Months</td>
<td>Now</td>
</tr>
<tr>
<td>Laptop Computers</td>
<td>94%</td>
<td>10%</td>
<td>98%</td>
<td>11%</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>9%</td>
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<td>11%</td>
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<td>93%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14%</td>
</tr>
<tr>
<td>Desktop Computers</td>
<td>46%</td>
<td>14%</td>
<td>41%</td>
<td>9%</td>
<td>43%</td>
</tr>
<tr>
<td></td>
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<td>19%</td>
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<td>45%</td>
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<td>11%</td>
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<tr>
<td>PDAs</td>
<td>39%</td>
<td>27%</td>
<td>53%</td>
<td>38%</td>
<td>40%</td>
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<tr>
<td></td>
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<td>25%</td>
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<tr>
<td>Handheld Devices</td>
<td>9%</td>
<td>22%</td>
<td>16%</td>
<td>25%</td>
<td>8%</td>
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<tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21%</td>
</tr>
<tr>
<td>Cellular Phones</td>
<td>4%</td>
<td>15%</td>
<td>5%</td>
<td>23%</td>
<td>3%</td>
</tr>
<tr>
<td></td>
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<td>15%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>18%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.

* Current and planned use. Equipment type most often mentioned by respondents is highlighted.
In fact, PDA usage could be higher, but some institutions do not currently support common PDA operating systems such as Windows CE or Palm OS on their wireless networks because they present new support and technical problems. They are not as stable as laptops, and they operate different applications and plug-ins. Small screens are another barrier. Scrolling around on Web pages makes surfing the Internet very tedious, thus limiting the PDA’s appeal in the classroom.

An IT representative at the Van Pelt Library, University of Pennsylvania, summarized his vision: “I see a move toward handheld devices/PDAs. I really think wireless will take off with portable devices similar to Palm and CE devices but [with] a slightly larger tablet [and] a 10- or 12-inch screen. I am not sure what the input device will be, [perhaps] a touch screen or trackball. But I think that is where the future lies for wireless, because these tablets will be very thin, with a large screen, and [they will be] light—less than one pound.”

**Wireless Cards**

Just under half of online survey respondents maintain a standard for wireless cards, yet actual operating experience seems to encourage standardization. Just over half of the respondents who currently operate a wireless network have a standard, while only 28 percent of those piloting a wireless network do. One reason to standardize wireless cards is to minimize support. F. Meena Lakhavani, director of user services, Carnegie Mellon University, explained, “People bought different kinds of cards, and they were incompatible with the network. Finally, we decided to standardize on these configurations.”

Interestingly, 87 percent of the respondents who plan to implement a network will

<table>
<thead>
<tr>
<th>Table 5-2. Method of Wireless Card Acquisition, by Carnegie Classification*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
</tr>
<tr>
<td>Purchased on Their Own</td>
</tr>
<tr>
<td>Either on Own or from Institution</td>
</tr>
<tr>
<td>Purchased from Institution</td>
</tr>
<tr>
<td>Given at No Charge/Included in Tuition</td>
</tr>
<tr>
<td>Purchased from Specific College/Dept</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>None</td>
</tr>
</tbody>
</table>

* The methods most often mentioned by respondents are highlighted. Base: Current/piloting wireless network operators.
standardize on a wireless card. Table 5-2 shows the current methods for obtaining wireless cards. As Figure 5-4 illustrates, Cisco is the leading brand (31 percent) among respondents with a standard; Orinoco, Lucent, and Avaya follow.

As Table 5-2 illustrates, most institutions let students choose their own wireless cards. Doctoral universities and large institutions are the most likely to offer a choice of self-purchase or procurement from the institution. To encourage adoption, some institutions subsidize wireless card prices—for example, with vendor discounts or student technology fee subsidization.

Figure 5-4. Wireless Card Standards in Use*

* Base: Current/piloting wireless network operators requiring a standard (N = 141).
Installing Wireless Networks

Wireless network installation entails more than placing random access points throughout a building; the network is actually an intricate web of transmission points specifically placed to ensure the most effective transmission pattern. As a result, network design relies almost as much on intuition as on proven design techniques.

Planning/Implementation Participants

IT departments initiate many wireless networks, but frequently they work in tandem with specific colleges and departments to address their individual research and academic requirements. (See Table 6-1.) This is especially true as an institution’s full-time equivalence (FTE) grows. Dan Shapiro, director of information services and chief information officer, School of Dental Medicine, University of Pennsylvania, explained, “The school wanted better network access for students’ research and clinical activities. The university’s central IT department is working with us to help bring this about.”

Smaller institutions may rely on the IT

Table 6-1. Academic Groups Initiating Wireless Network, by FTE Size*

<table>
<thead>
<tr>
<th>Users</th>
<th>Total (N=329)</th>
<th>FTE: 1–4,999 (N=170)</th>
<th>FTE: 5,000–9,999 (N=53)</th>
<th>FTE: 10,000–19,999 (N=52)</th>
<th>FTE: 20,000+ (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Department</td>
<td>89%</td>
<td>87%</td>
<td>89%</td>
<td>96%</td>
<td>86%</td>
</tr>
<tr>
<td>Specific College/Department</td>
<td>24%</td>
<td>15%</td>
<td>23%</td>
<td>44%</td>
<td>52%</td>
</tr>
<tr>
<td>Library</td>
<td>20%</td>
<td>14%</td>
<td>23%</td>
<td>35%</td>
<td>24%</td>
</tr>
<tr>
<td>Faculty</td>
<td>19%</td>
<td>19%</td>
<td>17%</td>
<td>25%</td>
<td>19%</td>
</tr>
<tr>
<td>Administration</td>
<td>15%</td>
<td>14%</td>
<td>21%</td>
<td>10%</td>
<td>24%</td>
</tr>
<tr>
<td>Students</td>
<td>6%</td>
<td>5%</td>
<td>4%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>Research Centers</td>
<td>4%</td>
<td>2%</td>
<td>4%</td>
<td>8%</td>
<td>10%</td>
</tr>
</tbody>
</table>

* As reported by current/planned wireless network operators. Academic departments most often mentioned by respondents are highlighted.
department as a more centralized resource. Larry Levine, director of computing, Dartmouth College, stated, “The wireless idea came from the department/faculty level. The central IT organization picked up the ball, making the necessary arrangements. The user believes that the IT organization is eager to hear of ideas that they can support. The faculty sees this as the major benefit.” Richard Parker, CIO and director of computing and information services, Harvey Mudd College, concurred: “IT plans, maintains, and updates the wireless network. If an academic department would like to expand or enhance coverage for some of their space, we discuss their needs with them and move in recommended directions as the budget permits.”

The IT department continues its involvement throughout the implementation process, partly to ensure interoperability around the campus. As Table 6-2 illustrates, IT departments are almost always highly involved in planning and implementing wireless networks. Again, specific departments and colleges are more likely to be involved at doctorate institutions, reflecting their larger scope. David Ferriero, vice provost and university librarian, Duke University, said, “The planning is coordinated between the enterprise IT group and various groups and departments on campus. Departments are consulted to determine coverage needs.”

### Table 6-2. Academic Groups Involved in Implementation Process, by Carnegie Classification*

<table>
<thead>
<tr>
<th>Group Involved</th>
<th>Total (N=329)</th>
<th>Doctoral (N=67)</th>
<th>Master’s (N=80)</th>
<th>Bachelor’s (N=71)</th>
<th>Associate’s (N=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT</td>
<td>98%</td>
<td>99%</td>
<td>95%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Administration</td>
<td>43%</td>
<td>34%</td>
<td>49%</td>
<td>35%</td>
<td>59%</td>
</tr>
<tr>
<td>Library</td>
<td>53%</td>
<td>58%</td>
<td>53%</td>
<td>61%</td>
<td>41%</td>
</tr>
<tr>
<td>Research Center</td>
<td>10%</td>
<td>25%</td>
<td>6%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Specific College or Dept.</td>
<td>43%</td>
<td>67%</td>
<td>46%</td>
<td>24%</td>
<td>41%</td>
</tr>
<tr>
<td>Faculty</td>
<td>40%</td>
<td>46%</td>
<td>38%</td>
<td>31%</td>
<td>47%</td>
</tr>
<tr>
<td>Students</td>
<td>19%</td>
<td>22%</td>
<td>18%</td>
<td>21%</td>
<td>6%</td>
</tr>
<tr>
<td>IT Manufacturers</td>
<td>18%</td>
<td>19%</td>
<td>16%</td>
<td>13%</td>
<td>19%</td>
</tr>
<tr>
<td>Communications Provider</td>
<td>17%</td>
<td>15%</td>
<td>21%</td>
<td>17%</td>
<td>9%</td>
</tr>
<tr>
<td>System Vendor</td>
<td>25%</td>
<td>25%</td>
<td>31%</td>
<td>27%</td>
<td>19%</td>
</tr>
</tbody>
</table>

* As reported by current/planned wireless network operators. The non-IT academic department most often mentioned by respondents is highlighted.
Yet their large scope enables doctoral institutions to achieve economies of scale. Their median cost per user is far lower than that of other institution types.

**Source of Funding**

As Table 6-4 illustrates, the IT departments of approximately 60 percent of online survey respondent institutions fund the wireless network implementation. Sometimes IT departments will fund the original design and installation of the wireless network to seed its adoption. Making the resource available for free encourages academic colleges, schools, and departments to experiment with wireless technology with little financial investment. “They will come, but we have to make it reasonable pricewise for users to

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**Table 6-3. Planning and Implementation Characteristics of Respondents, by Carnegie Classification***

<table>
<thead>
<tr>
<th></th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master’s (N=75)</th>
<th>Bachelor’s (N=62)</th>
<th>Associate’s (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Planning Time (Months)</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Median Implementation Time (Months)</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Median Amount Spent or Budgeted</td>
<td>$50,000</td>
<td>$80,000</td>
<td>$50,000</td>
<td>$20,000</td>
<td>$30,000</td>
</tr>
<tr>
<td>Median Number of Students/Faculty That Wireless Network Serves</td>
<td>1,000</td>
<td>3,000</td>
<td>1,000</td>
<td>610</td>
<td>500</td>
</tr>
<tr>
<td>Median Cost/User</td>
<td>$50.00</td>
<td>$26.67</td>
<td>$50.00</td>
<td>$32.79</td>
<td>$60.00</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.

**Table 6-4. Wireless Network Implementation Funding Source, by Carnegie Classification***

<table>
<thead>
<tr>
<th>Source of Implementation Funding</th>
<th>Total (N=329)</th>
<th>Doctoral (N=67)</th>
<th>Master’s (N=80)</th>
<th>Bachelor’s (N=71)</th>
<th>Associate’s (N=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall IT Budget</td>
<td>57.0%</td>
<td>45.2%</td>
<td>55.5%</td>
<td>67.7%</td>
<td>52.5%</td>
</tr>
<tr>
<td>Specific Department</td>
<td>11.9%</td>
<td>19.3%</td>
<td>10.0%</td>
<td>4.6%</td>
<td>9.7%</td>
</tr>
<tr>
<td>Specific Academic or Research Grant</td>
<td>9.3%</td>
<td>4.8%</td>
<td>9.3%</td>
<td>12.3%</td>
<td>13.6%</td>
</tr>
<tr>
<td>IT Supplier Donation</td>
<td>1.9%</td>
<td>3.3%</td>
<td>0.7%</td>
<td>0.5%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Student Usage Fees</td>
<td>7.5%</td>
<td>11.8%</td>
<td>10.7%</td>
<td>3.8%</td>
<td>7.3%</td>
</tr>
<tr>
<td>Other</td>
<td>11.4%</td>
<td>15.6%</td>
<td>13.3%</td>
<td>9.5%</td>
<td>14.8%</td>
</tr>
</tbody>
</table>

* Mean percentage as reported by current/planned wireless network operators. The non-IT source most often mentioned by respondents is highlighted.
Wireless Networking in Higher Education

So we subsidized wireless in the beginning by funding the infrastructure and by providing the loaner equipment in the library,” explained Ken Blackney, core technology infrastructure director, Drexel University.

But as wireless becomes operational, the IT department continues to fund its operations at many institutions. (See Table 6-5.) In the long term, this may raise issues, as institutions struggle to create a cost-recovery model. “We had a difficult time putting our hands around it, because how do you bill for it? How can you manage who’s using it?” explained Judy Huddleston, director, IT infrastructures administrative services, The University of Tennessee. Joel Smith, chief information officer, Carnegie Mellon University, advised institutions to “think through the costs before you start, because you are really building a parallel network. Your wired network is not disappearing, so you are making a significant add-on. You’ve built an entire new infrastructure that requires refreshing, and it has a technological improvement cycle. That means you really have to build a cost-recovery model.”

Installation Issues

Installing a wireless network is not as easy as one, two, three. “We put a fair amount of effort up front in the designs to create as stable a network as possible to avoid paying on the back end with the support,” stated Chuck Bartel, director of operations and project director of Wireless Andrew, Carnegie Mellon University. “Institutions may try a quick and easy design by throwing some access points here or there, but they’ll spend significant time after the fact troubleshooting problems.”

Many online survey respondents planned extensively; over half (57 percent) conducted a radio frequency (RF) site study. Doctoral and master’s institutions are much more likely to have done so, perhaps indicating the more complex nature of their networking environment and/or greater IT resources. The split is fairly even between those using internal resources (31 percent) and those using external resources (26 percent) to conduct the study.

Of those doing the study internally, roughly one-third possessed the expertise

<table>
<thead>
<tr>
<th>Source of Implementation Funding</th>
<th>Total (N=329)</th>
<th>Doctoral (N=67)</th>
<th>Master’s (N=80)</th>
<th>Bachelor’s (N=71)</th>
<th>Associate’s (N=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall IT Budget</td>
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<td>81.0%</td>
<td>99.0%</td>
<td>84.0%</td>
</tr>
<tr>
<td>Specific Department</td>
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<td>5.0%</td>
<td>1.0%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Specific Academic or Research Grant</td>
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<td>39.0%</td>
<td>19.0%</td>
<td>3.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>IT Supplier Donation</td>
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<td>13.0%</td>
<td>4.0%</td>
<td>3.0%</td>
<td>13.0%</td>
</tr>
<tr>
<td>Student Usage Fees</td>
<td>4.0%</td>
<td>6.0%</td>
<td>4.0%</td>
<td>3.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Department/School Usage Metric</td>
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<td>3.0%</td>
<td>4.0%</td>
<td>1.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Other</td>
<td>11.0%</td>
<td>13.0%</td>
<td>20.0%</td>
<td>8.0%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

* Base: Current/planned wireless network operators. The non-IT source most often mentioned by respondents is highlighted.
already. (See Figure 6-1.) Most (93 percent) of those using an external contractor to conduct the site study said the contractor had a good track record. Almost all (95 percent) were satisfied with the external contractor’s service.

Institutions used different methods for selecting their wireless equipment vendors. Some preferred to use vendors from previous applications. Greg Schaffer, director of network services, Middle Tennessee State University, explained, “We went with a vendor who handles our wired network components, for compatibility, familiarity with company and personnel, and functionality.”

Others compared vendors. Barry Walsh, director, Indiana University, stated, “We tested three vendors’ access points and PC cards and determined that interoperability was as promised. We picked one vendor based on minor preferences for its management application.” Dewitt Latimer, executive director, IT infrastructure, The University of Tennessee, said, “We created a list of [five] criteria for vendor selection: security, upgradability to [IEEE] 802.11a, 54-megabit-per-second spec, cost of ownership over three years, and willingness of the company to work with UT as far as a partnership.”

Fewer than one-third of the respondents installed a specific antenna scheme to maximize coverage and capacity. Doctoral and 20,000-plus FTE institutions (more than 40 percent in both cases) were much more likely to do so, again perhaps indicating the more complex nature and greater scope of their wireless networks. Those that implemented an antenna scheme used a variety of methods. Individual responses follow:

- Used varied antenna types and radio power, including Aeronet 350s, which have two coax antenna connections. Under continual adjustment.
- Chose various schemes, depending on the coverage requirements and expected density of wireless users.
- Involved internal RF experts, but largely determined the scheme and placement empirically.
- Selected antennae to match the size and shape of the area. For several outside locations, used directional high-gain antennae.
- Used a combination of technologies, based on the situation, most notably deployment of radiating coax cable.
- Installed low-gain (2 dbm) dual-diversity antennae for small, isolated areas, medium-gain (6 dbm) omnidirectional antennae with overlapping cells to provide wide-area coverage inside buildings, and high-gain omnidirectional (8 dbm) antennae for outside coverage.

* Figure 6-1. Expertise for Conducting RF Site Study*
Selected various antennae as required to improve coverage, mostly by trial and error.

Used a variety of antenna configurations to give maximum coverage.

Deployed access points with standard antenna configurations to deliver overlapping coverage areas, added additional access points in locations with larger numbers of users.

Chose overlapping zones with omnidirectional antennae tuned to specific fields.

Two institutions provided examples of the multidimensional aspects of wireless network installation.

Richard Parker, Harvey Mudd College, described his installation process: “Harvey Mudd has relatively new buildings (for example, no 4-foot-thick walls, few solid interior concrete walls) that are not spaced particularly close together. This simplifies things. In general, given the wireless standard, we planned coverage for each building, tested it for the initial targeted areas, and made adjustments in the antenna placement (or, occasionally, [antenna] type) as necessary. By planning for the whole building, [issues of] range, coverage, and spectrum allocation were relatively straightforward to address. Coverage for nearby outdoor spaces was planned in conjunction with the building.”

Mark Cain, executive director, information services and support, Mt. St. Joseph College, explained, “We followed vendor recommendations. You have 11 channels available, but effectively can use only three, because you have to have three- to four-channel separation between nearby access points. Then you have to think three-dimensionally. Range, coverage, and spectrum use are probably best managed with the right kind of antenna. In a classroom, you need to be able to provide a lot of bandwidth for a large number of simultaneous users, but if you put an access point in every class without the proper antenna, you’ll have signal interference.”

AC circuits power the access points for 62 percent of online respondents; the other 38 percent use power over the Ethernet cable. Older wireless network installations may rely on AC power because power via the Ethernet is a relatively recent design option. And when refreshing access points, institutions may switch to power over Ethernet because it eliminates one power outlet drop, saving considerable installation expense. Before he decided to use power over the Ethernet directly, Ken Blackney, Drexel University, was “getting estimates of $1,100 per outlet for electricity.”

### Wireless Standards

Table 6-6 illustrates online survey respondents’ current and future technology standards plans. IEEE 802.11b/Wi-Fi is the dominant technology today, but fewer respondents plan to continue supporting it 24 months from now, as more institutions switch to 802.11a. Support for 802.11b/Wi-Fi varies by Carnegie classification because the subsequent equipment investment may deter smaller institutions from switching.

“802.11b equipment is getting really inexpensive. There are still many situations where the convenience of wireless connectivity makes the lower bandwidth of 11.b not an issue. We will continue to deploy it as the application makes sense,” said KC Hundere, director of network services, Glendale Community College.

Other institutions are debating the pros and cons of an 802.11a upgrade. Deke Kassabian, senior technology director, University of Pennsylvania, is concerned with faster transmission and an uncrowded spectrum. “We are interested in 802.11a, partly in order to gain higher throughput,” he
### Table 6-6. Current and Projected Support for Various Wireless Standards, by Carnegie Classification*

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Doctoral</th>
<th>Master’s</th>
<th>Bachelor’s</th>
<th>Associate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(N=299)</td>
<td>(N=64)</td>
<td>(N=75)</td>
<td>(N=62)</td>
<td>(N=28)</td>
</tr>
<tr>
<td>Nine Months</td>
<td></td>
<td>Add in 24 Months</td>
<td></td>
<td>Add in 24 Months</td>
<td></td>
</tr>
<tr>
<td>Add in 24 Months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>802.11b/Wi-Fi</td>
<td>90%</td>
<td>67%</td>
<td>91%</td>
<td>89%</td>
<td>90%</td>
</tr>
<tr>
<td>802.11a</td>
<td>13%</td>
<td>53%</td>
<td>13%</td>
<td>11%</td>
<td>15%</td>
</tr>
<tr>
<td>802.11g</td>
<td>4%</td>
<td>25%</td>
<td>2%</td>
<td>3%</td>
<td>6%</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>3%</td>
<td>18%</td>
<td>2%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Broadband</td>
<td>1%</td>
<td>6%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.

explained, “but mostly to get out of the crowded 2.4-GHz spectrum.” This is a special concern to avoid interference with Bluetooth-enabled devices.

Lack of 802.11a/802.11b compatibility is another issue. Greg Schaffer of Middle Tennessee State University explained, “We’ve deployed access points that can handle both 802.11b and 802.11a clients simultaneously for future needs, but [we] only offer 802.11b connectivity now. With the dual capability, we’ll be able to offer 802.11a service without alienating our 802.11b customer base. We’re also considering using 802.11a to connect remote access points that cannot be connected to the wired network directly.”

Standards turbulence is a concern for Jack McCredie, CIO and associate vice chancellor, information systems and technology, University of California, Berkeley. He said, “We will deploy 802.11a when we feel it has matured enough to be reliable and the costs are such that we can reasonably replace the equipment on a standard three- or four-year life cycle.”

McCredie’s concerns are justified because the IEEE standards committee is about to approve the 802.11g standard, adding to the standards confusion. This standard addresses incompatibility issues by functioning like a step-down modem, transmitting at both the 2.4-GHz and 5-GHz levels. Chuck Bartel of Carnegie Mellon University believes that 802.11g products will not reach the market until late 2002 at the earliest. When they do, he predicts that “many institutions will operate bimodal networks, supporting both 802.11a and 802.11b. When 802.11g arrives in the marketplace, they will replace their 802.11b cards with 802.11g cards because the 802.11g card can step down to 802.11b mode.”

Most IT administrators believe the wireless network has minimal impact on network traffic in general. Few cite any impact at all. Mark Cain of Mt. St. Joseph College explained, “There is an increase in traffic, but the wired network is far faster than the wireless, so it doesn’t even breathe hard.”
Security is a universal issue among online survey respondents and IT administrators. Russell Yount, manager of network development, Carnegie Mellon University, summarized the concerns: “The air is a shared medium, and you cannot accurately predict where someone will receive us. We can’t trust any physical limitations and differences; it depends on too many variables: receivers, cards, antennae, and location. Propagation is totally unpredictable, so that means you need encryption if you want privacy.” Most institutions take a proactive stance, but the lack of effective tools can impede their efforts.

Luckily, no institution in the follow-up interviews or cases reported any major security breaches in their wireless network—yet. Larry Conrad, assistant vice president and CIO, Florida State University–Tallahassee, summarized the view of most institutions: “Student privacy, identity theft, and fraud concerns are potential problems. [We have had] no special problems as yet; however, we see a significant exposure for abuse and misuse.”

**Security Methods Used**

Table 7-1 summarizes respondents’ encryption and authentication methods. Network complexity and resources seem to affect the type of security methods institutions use. Doctoral institutions, with their more complex networks, greater research activities, and larger student populations, tend to take more aggressive security steps.

Largely because of dissatisfaction with the wired equivalency privacy (WEP) standard in general, a high percentage of doctoral institutions use non-WEP solutions. IT administrators complain about WEP’s security flaws and lack of scalability. As a result, many institutions—larger ones in particular—turn to other solutions. For example, 25 percent use virtual private networks (VPNs), and 13 percent use third-party solutions. Interestingly, almost 30 percent of baccalaureate institutions use no encryption or authentication methods at all.

Deke Kassabian, senior technology director, University of Pennsylvania, explained, “We recognized weaknesses in WEP from the very start. We don’t see the point in using WEP, not only because it’s weak in its current form, but because higher-layer security may be more appropriate and may apply well in both wired [and] wireless environments.” Others, too, like a more centralized security solution. Barry Walsh, director, Indiana University, stated, “We will deploy with a VPN. We foresee future security problems unless we holistically and centrally manage at the very least the security servers. As well, this is
another reason for our desire to launch a more comprehensive wireless environment that is centrally managed."

Location plays a role in security concerns. Potential unauthorized access is a concern in cities, where every car on the street poses a potential sniffing threat. According to Deke Kassabian, "The potential for unauthorized access to wireless networks, especially in a large urban campus, is very high." Isolation in the countryside changes the situation. Jeffrey Rehbach, special projects for library and information services, Middlebury College, stated, "Security is not an issue at present because of limited deployment. In a remote rural location, security is not as high a priority as in urban environments, but we anticipate there could be snooping and attempts at interception."

Some institutions base their wireless security strategies on the premise that the network is never secure. Russell Yount of Carnegie Mellon University explained, "We have the advantage in that we have never trusted the physical network. So we've always used Kerberos; we've always assumed that people can sniff the network.... We educate students from the start, don’t trust it—even the wired network. If you need privacy, you need to encrypt. It is a very big education factor because most people believe the network is secure." Greg Schaffer, director of network services, Middle Tennessee State University, agreed: "WEP isn’t too secure, and anyone with the same WEP key can sniff traffic, so we encourage SSL/SSH [Secure Sockets Layer/Secured Shell] use and ‘safe surfing.’"

Many believe that WEP’s four-key encryption strategy is impractical for any large-scale wireless implementation. "You have to broadcast all the keys out to the network's

<table>
<thead>
<tr>
<th>Encryption/Authentication</th>
<th>Total (N=299)</th>
<th>Doctoral (N=64)</th>
<th>Master’s (N=75)</th>
<th>Bachelor’s (N=62)</th>
<th>Associate’s (N=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>128-Bit WEP</td>
<td>33%</td>
<td>28%</td>
<td>36%</td>
<td>31%</td>
<td>46%</td>
</tr>
<tr>
<td>40-Bit WEP</td>
<td>17%</td>
<td>9%</td>
<td>21%</td>
<td>21%</td>
<td>18%</td>
</tr>
<tr>
<td>Firewall</td>
<td>24%</td>
<td>23%</td>
<td>27%</td>
<td>15%</td>
<td>46%</td>
</tr>
<tr>
<td>RADIUS</td>
<td>18%</td>
<td>30%</td>
<td>19%</td>
<td>10%</td>
<td>14%</td>
</tr>
<tr>
<td>IP VPNs</td>
<td>14%</td>
<td>25%</td>
<td>12%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Wireless Vendor-Supplied Solution</td>
<td>9%</td>
<td>8%</td>
<td>8%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Extensible Authentication Protocol</td>
<td>5%</td>
<td>6%</td>
<td>4%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Third Party Hardware/Software Security Solution</td>
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<td>13%</td>
<td>4%</td>
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<tr>
<td>Kerberos</td>
<td>3%</td>
<td>8%</td>
<td>3%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>None</td>
<td>18%</td>
<td>14%</td>
<td>16%</td>
<td>29%</td>
<td>14%</td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators.
A few thousand users. It doesn’t really give you a lot of security,” explained Yount. “Even if WEP’s security was good, you’d want to change the keys very frequently to maintain the security. There is no updating strategy or methodology built into it.” Philippe Hanset, IT infrastructure, The University of Tennessee, concurs: “We started WEP key management ... only IT or department IT administrators could enter the WEP keys into the users’ laptops. It became unmanageable. And it didn’t make any sense to implement it because anyone on the network with the four keys could sniff anyone else on the network with the four keys.” Many online survey respondents agree; fewer than one-quarter change their WEP encryption keys regularly. (See Figure 7-1.)

Just over half of survey respondents enforce application encryption/authentication, with slightly more than one-third (35 percent) using Web-based SSL, 13 percent using SSH, and 3 percent some other method. Forty-nine percent do not enforce application encryption/authentication.

At least one institution believes security is a more fundamental issue than transmission method. “In cases where encryption is called for, it doesn’t matter whether the data is transmitted over wired or wireless networks,” explained Deke Kassabian. “Both network types may be vulnerable to sniffing. This is why network layer or application layer end-to-end encryption is more generally useful than a data-link-layer encryption like WEP. You can tap in through either transmission method.”

Wireless network users were either relatively unconcerned about security issues or felt it was central IT’s domain. Brian D. Voss, associate vice president for telecommunications, Indiana University, explained, “There are no security problems. Central IT determines security guidelines. For example, you don’t want to put in a wireless port so anyone can just walk in and get access to the university network. We have controls such that if a person comes into one of these ports, they feed into a virtual private network address space and they have to authenticate. Departments gain from central IT’s lessons; most are very appreciative and cooperative.”

![Figure 7-1. Network Operators That Change Encryption Keys Periodically, by Carnegie Classification*](chart.png)

* Base: Current/piloting wireless network operators.
Support

Many IT administrators view their wireless network as parallel or subservient to their wired infrastructure. As a result, most IT departments use the same support structure and tools for both. Occasionally, the IT department will designate one person on its staff to handle support issues. Yet wireless network support is not without issues. Some institutions report user confusion over driver downloads, and some standardize on particular wireless network cards to minimize support issues. (See Figure 5-4.)

Many institutions offer neither special support help desks nor formal training programs for wireless users. In fact, 93 percent of respondents use the same help desk for wired and wireless networks, while only 3 percent have special wireless help desks. A few (4 percent) have other options. As Mark Cain, executive director, information services and support, College of Mount St. Joseph, explained, “There is no formal training program specifically for the wireless network. Since it’s a ubiquitous cloud, students use it without thinking about it. That’s the whole point.” Other institutions may fold wireless usage tips into general computer orientation sessions for new students and/or post information and procedures on their Web sites.
Most survey respondents, IT administrators, and wireless users report overall satisfaction with their wireless networks. Many track satisfaction qualitatively through user feedback, though some institutions do incorporate quantitative tools as well.

Jack McCredie, CIO and associate vice chancellor, information systems and technology, University of California, Berkeley, stated, “We track the wireless network quantitatively by the number of access points deployed (and requested) and the number of users of them, and [we check] qualitatively by feedback via the campuswide task force.”

Mark Cain, executive director, information services and support, College of Mount St. Joseph, explained, “We track it qualitatively, primarily. We do student surveys to find dead spots and satisfaction. However, by using the wireless network administration tools, we get quantitative readouts of performance, which help us spot problem areas.”

Richard Parker, CIO and director of computing and information services, Harvey Mudd College, stated, “The number of happy users is the best gauge. Since we require registration for some wireless access, we can watch the increase in total number of users. We also monitor traffic and watch its increase.”

### Challenges and Disadvantages

As Figure 8-1 illustrates, almost 70 percent of survey respondents identified security issues as a key challenge. Unsurprisingly, Carnegie classification and FTE size affect the response. Security issues gain importance as institution size and complexity grow. Ninety percent of 20,000-plus FTE institutions and 88 percent of doctoral institutions identified security as a concern, but only half of associate’s institutions and 60 percent of 1–4,999 FTE institutions did so.

Many IT administrators cited cost management as a disadvantage because, as David G. Brown, vice president and dean of the International Center for Computer Enhanced Learning, Wake Forrest University, succinctly explained, “Cost is a problem because it’s a double system.” John E. Bucher, director of computing services, Oberlin College, elaborated: “It adds costs to network infrastructure.” Larry Conrad, assistant vice president and CIO, Florida State University–Tallahassee, further explained, “It is duplicative of existing wired plant investment,
adding management and support load.”

Users cited class distraction as a potential challenge. Dr. Brian D. Voss, associate vice president for telecommunications, Indiana University, explained, “Anecdotally, there have been some faculty that are resistant to the idea of having connected machines in conference rooms and classrooms. Students have yet another thing to distract them; [they worry] that these devices are taking away from the students the ability to concentrate.”

From a technology perspective, users listed the laptops’ limited battery power and the network’s limited bandwidth as disadvantages. An instructor at Middle Tennessee State University elaborated: “There is a bandwidth issue. When the number of users increases during the day—when people read their e-mail in the a.m. or look at the Web at lunch—there is a slowdown in network performance. And I have noticed slowdowns during windy weather. And when the nearby tree blossoms, the leaves affect transmission. I suggested putting the antenna on a pole on top of the trailer so it’s higher than the tree.”

**Unforeseen Problems**

Dan Shapiro, director of information services and CIO, School of Dental Medicine, University of Pennsylvania, stated, “At first the wireless network was unstable. For about four or five months, it was up and down all the time, and people did not want to use it because it was so unstable. Eventually, the network operations group from Penn’s Central IT Department was able to adjust the access points to resolve the problem. Since that time, the wireless connectivity has been much more reliable.”

Pam Nelson, instructor in geology, Maricopa Community College, encountered a problem during her night class, when there was limited support to assist her. “Once, the electrical power to the building spiked, crashing the access point. It was hard to locate someone who knew the access point’s location. And then we had to go up into the ceiling and reset it.”

David Dunne, adjunct professor of marketing, Joseph L. Rotman School of Management, University of Toronto, worries about online testing: “If a professor holds an open book exam, then students access

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* Figure 8-1. Security Tops the List of Wireless Operators’ Key Challenges*

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* Base: Current/piloting wireless network operators (N = 299).
their laptops for their notes. What prevents the students from communicating their notes to each other during the exam? If the students have laptops with external cards, professors can instruct the students to pull out the cards and place them on their desks. Now more laptops have internally installed cards, so what can we do now to prevent this?

Dr. Elizabeth Bookser Barkley, professor, Humanities Department, College of Mount St. Joseph, wondered about equipment disparity among students: “Students who are not full-time traditional students are not required to buy laptops as part of course requirements. This means wireless could exclude evening and weekend students. This category of student introduces complexities as to how to equip them with laptops (such as loaners).”

Lessons Learned

Both IT administrators and users offer lessons in several areas. Some emphasize the importance of planning and the need to concentrate on good, basic service initially.

Ira Winston, computer and information, University of Pennsylvania School of Engineering, advised, “We spent a lot of time making sure we had really good coverage, mapping out the area. You should just really do a selected deployment at first. Focus on the places or space where it was difficult to do computing (network access) before.”

Barry Walsh, director, Indiana University, agreed. “Focusing on security and policy and standards first has been a benefit of our approach. I think any institution needs to address these issues before launching a wireless network.”

KC Hundere, director of network services, Glendale Community College, said, “Don’t do anything exotic. We are using it the way it was designed. We don’t use technology just for the wow factor. Faculty and staff sometimes want a technology just because they’ve read about it or someone else has it. Make sure the application makes sense, otherwise it could get really expensive real fast.”

Finding a good outside partner is important if institutions lack in-house expertise.

Mark Cain, College of Mount St. Joseph, outlined several activities. “One: Work very hard to find a good business partner, someone who has solid experience in doing this. We have already had to redo our residence hall once. Use a vendor, unless you have considerable in-house expertise in wireless networking (unlikely). This is still more of an art than a science, so you should make certain the vendor has experience, especially with wireless networks in higher education environments. Two: Get your vendor to create a careful, written plan. (Visio drawings are good.) Three: Be prepared to ask lots of questions … try to poke holes in the plan. Questions should be like this: Will we have enough bandwidth in this classroom, that classroom? Won’t we get frequency interference this way? Wouldn’t this work better?”

And finally, institutions should strive for campus-wide access.

David G. Brown, Wake Forest University, believes, “Wireless will not become the primary network until 100 percent of the campus is covered… until it can accommodate almost all network uses. The educational gains from wireless do not yet justify the added cost and the compromises that must be made in terms of speed and versatility.”

Larry Levine, director of computing, Dartmouth College, noted, “What worked well was to jump in, decide to spend the money, bring it up ASAP, not worry about security, subsidized cost of client cards. PR it a lot, etc., … get it going. People like it, find it worthwhile.”
Satisfaction and Benefits

Most online survey respondents expressed satisfaction with their wireless networks. (See Figure 8-2.) Wireless communication has met or exceeded the expectations of nearly 90 percent of the respondents who have implemented it.

Most IT administrators and users expressed satisfaction also.

Brian Voss, Indiana University, believes, “Benefits are really defined as user satisfaction and, as such, are nebulous. The benefit is to increase the way technology can affect teaching, learning, research, and service missions of the university. It's not a question of metrics, it's more a question of providing an environment.”

Mark Cain, College of Mount St. Joseph, stated, “The students love it, the faculty love it. It is already enabling/creating new forms of learning and collaboration.”

Richard Parker, Harvey Mudd College, explained, “It has exceeded our expectations. We found more uses than we had anticipated. And the requests for additional areas of coverage were rewards in themselves.”

Most institutions cited convenience as a benefit. Parker explained, “Sometimes the issue of convenience determines whether someone will try to incorporate technology into their teaching or not. Faculty's being able to use their computer, configured how they want it, in a classroom is very appealing. Students' being able to access the Web at any time from anywhere, without planning for it, is a big plus.”

Others believe wireless technology enhances productivity. Larry Levine of Dartmouth College listed several benefits: “Definitely productivity, lower cost, service, convenience, efficiency. We receive glowing reviews—it's a robust technology and people use and like it.”

Some users believe wireless enhances the classroom experience.

Dr. Elizabeth Bookser Barkley, College of Mount St. Joseph, said, “Another benefit for the students who collaborate is that wire-

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Figure 8-2. Results vs. Expectations for Wireless Networks, by Carnegie Classification*

<table>
<thead>
<tr>
<th>Classification</th>
<th>Exceeded</th>
<th>Met</th>
<th>Fell Short</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associate's</td>
<td>7%</td>
<td>86%</td>
<td>4%</td>
</tr>
<tr>
<td>(N=28)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor's</td>
<td>8%</td>
<td>77%</td>
<td>11%</td>
</tr>
<tr>
<td>(N=62)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Master's</td>
<td>23%</td>
<td>67%</td>
<td>7%</td>
</tr>
<tr>
<td>(N=75)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctoral</td>
<td>14%</td>
<td>73%</td>
<td>6%</td>
</tr>
<tr>
<td>(N=64)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>14%</td>
<td>74%</td>
<td>7%</td>
</tr>
<tr>
<td>(N=299)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Base: Current/piloting wireless network operators (N = 299).
less creates a less formal environment for interaction. The mobility is also a major benefit of the wireless function, as is the ability to print out using networked printers in the area of the department.”

Gregg Humphrey, director of elementary education, Middlebury College, stated, “These students are working professionals and are able to get more done in the course of their seminar time. This is important because they are looking for practical, efficiency-enhancing results.”

Chris Jernstedt, professor of psychological and brain sciences, Dartmouth College, said, “Research shows that in traditional lecture environments, students are not actively engaged most of the time. Taking notes is not particularly active; it is passively receiving and storing information. This has almost none of the characteristics of active learning. Wireless is not making things get done faster, but better. It makes people [focus more] on thinking and less on the clerical and logistical, which are deemed less relevant to the overall mission of the enterprise.”

**Future Plans**

Most IT administrators plan to maintain both their wired and wireless networks in tandem. Richard Parker of Harvey Mudd College explained, “They are complementary. We use wireless as an additional way of accessing the network, broadly defined. We have not used wireless for building-to-building connectivity, except in very limited areas where bandwidth needs were not great.”

Many IT administrators also want to continue wireless network expansion throughout their institutions, using it as a means to provide ubiquitous computing. Bandwidth is another issue; institutions want to provide better service so that users can utilize the wireless network for data-intensive applications like video.

And unsurprisingly, many plan to monitor IEEE 802.11a and security developments for future implementation. Users plan to continue fostering wireless networking’s adoption in the classroom by promoting its capabilities to faculty members and students and by enhancing applications.

PDAs and handheld devices intrigue both IT administrators and users. (See Table 5-1.) Barry Walsh of Indiana University stated, “PDA usage seems to be a key item for future consideration. This is a two-edged challenge, dealing not only with access but also with processing of application screen images to fit the variety of PDA-sized screens.” Jeffrey Rehbach, special projects manager for library and information services, Middlebury College, expects that “wireless will mimic the wired network environment, potentially serving a mix of laptop and PDA equipment.”
Further analysis of the online survey results identified numerous characteristics and trends by institution type. This chapter profiles the wireless networking deployment and usage characteristics of higher education institutions by Carnegie classification, institution profile, and full-time enrollment.

Carnegie Classification
The wireless networking activities of institutions in different Carnegie classifications vary considerably. Table 9-1 presents a snapshot view of wireless characteristics by institution type, followed by a profile of each institution type.

Doctoral
Given their extensive academic and research programs, the broad use of wireless networks at doctoral institutions isn’t surprising. Many doctoral institutions use wireless networks to connect their vast infrastructures and campuses.

Factors Driving Wireless
Wireless implementations serve a marketing role as well as a functional role within doctoral institutions. Like other institution types, doctoral institutions rated improved network access at any time for students (54 percent) and faculty (46 percent) as important reasons to implement a wireless network. Unlike other institutions, more than 40 percent of doctoral institutions identified wireless technology’s contribution to their being perceived as leading-edge institutions as an important implementation factor.

Year of Implementation
Doctoral institutions had the highest percentage of survey respondents (37 percent) that implemented their first wireless network before 2000.

Scope of Wireless Networks
Almost 60 percent of doctoral respondents claim to operate at least three wireless networks at their institutions. More than 60 percent state that their wireless networks serve a specific building, and almost three-quarters said their wireless networks offer outdoor use.

Nevertheless, expansion plans are commonplace. More than half of the doctoral institutions without a campus-wide wireless network plan to expand to campus-wide coverage. And while the mean percentage of geographic area covered by wireless networking is 26.6 percent, doctoral institutions plan to increase this to 50.6 percent in the next 24 months.
Table 9-1. Wireless Characteristics, by Carnegie Classification

<table>
<thead>
<tr>
<th>Item</th>
<th>Doctoral</th>
<th>Master’s</th>
<th>Baccalaureate</th>
<th>Associate’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implemented</td>
<td>75%</td>
<td>59%</td>
<td>45%</td>
<td>43%</td>
</tr>
<tr>
<td>Pre-2000 Adoption</td>
<td>37%</td>
<td>26%</td>
<td>15%</td>
<td>18%</td>
</tr>
<tr>
<td>Multiple WLANs</td>
<td>70%</td>
<td>43%</td>
<td>39%</td>
<td>59%</td>
</tr>
<tr>
<td>Campus-wide</td>
<td>23%</td>
<td>25%</td>
<td>15%</td>
<td>21%</td>
</tr>
<tr>
<td>Outdoor</td>
<td>72%</td>
<td>47%</td>
<td>58%</td>
<td>46%</td>
</tr>
<tr>
<td>Median Geographic Coverage Percentage</td>
<td>15%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>User Mix</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergrad: 78% Faculty: 86% Admin: 77% Grad/Res: 80%</td>
<td>Undergrad: 84% Faculty: 75% Admin: 55% Grad/Res: 45%</td>
<td>Undergrad: 77% Faculty: 58% Admin: 42% Grad/Res: 18%</td>
<td>Undergrad: 61% Faculty: 54% Admin: 36% Grad/Res: 4%</td>
<td></td>
</tr>
<tr>
<td>Highest Identified Department Usage</td>
<td>Business: 55% Computer Science: 47% Engineering: 47%</td>
<td>Computer Science: 36% Business: 33% Physical Science: 32%</td>
<td>Physical Science: 34% Computer Science: 32% Social Science: 31%</td>
<td>Physical Science: 36% Lang/Arts/History: 25% Computer Science: 18%</td>
</tr>
<tr>
<td>Equipment Mix</td>
<td>Laptops: 98% PDAs: 53% Desktops: 41%</td>
<td>Laptops: 96% Desktops: 43% PDAs: 40%</td>
<td>Laptops: 95% Desktops: 45% PDAs: 24%</td>
<td>Laptops: 93% Desktops: 61% PDAs: 21%</td>
</tr>
<tr>
<td>Planned 802.11a Adoption</td>
<td>70%</td>
<td>56%</td>
<td>42%</td>
<td>32%</td>
</tr>
<tr>
<td>WEP Usage</td>
<td>34%</td>
<td>51%</td>
<td>45%</td>
<td>61%</td>
</tr>
<tr>
<td>IP VPN Usage</td>
<td>25%</td>
<td>12%</td>
<td>10%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Buildings with Wireless Access

Wireless use at doctoral institutions covers a wide variety of buildings, users, and equipment. Many institutions of all types reported significant wireless access in libraries and classrooms, but more doctoral institutions reported wireless access in administration (36 percent) and research centers (27 percent).

Users

Students, of course, use the wireless network, but doctoral institutions reported a high incidence of use by faculty (86 percent), administration (77 percent), and graduate students/researchers (80 percent).

Equipment Used

Doctoral institutions reported higher usage of PDAs (53 percent), handheld devices (16 percent), and cell phones (5 percent) than other institutions.

Installation Issues

The organization of doctoral institutions is complex, and their wireless implementations reflect this complexity. Besides IT, many parties, including specific colleges or depart-


ments (48 percent), are involved in planning and implementation. After planning, wireless network implementation takes longer than at other institution types—5.7 months on average.

Doctoral institutions spent or budgeted more than other institution types: an average of $332,935. Almost 20 percent of the funding originated from a specific department, a far higher percentage than at other institution types.

Standards
Doctoral institutions’ early adoption of wireless networking and their extensive resources may allow them to adopt emerging technology more quickly than other institution types. This class was the most likely to adopt emerging IEEE 802.11a (70 percent), 802.11g (31 percent), and Bluetooth (22 percent) standards over the coming 24 months.

Security
Doctoral institutions are less likely to use wired equivalency privacy, or WEP, (34 percent) but more likely to use advanced solutions such as RADIUS (30 percent), IP VPN (25 percent), and Kerberos (8 percent). This class reported the highest percentage of network operators (36 percent) replacing WEP with extensible authentication protocol (EAP) 802.1x draft.

Master’s
Respondents at master’s institutions displayed a mixture of traditional and innovative characteristics. Wireless technology is less entrenched in master’s institutions than in doctoral institutions, but its adoption surpasses that at baccalaureate institutions.

Factors Driving Wireless
User need drove master’s institutions to implement wireless networks. The most important factors, according to respondents, were improved access for students (50 percent) and faculty (46 percent), and the capability to meet future computing needs (46 percent).

Year of Implementation
Many master’s institutions are just implementing their first wireless network; 40 percent of respondents launched their initial wireless installation in 2001.

Multiple Initiatives
Almost 60 percent of master’s institutions reported one wireless network in operation.

Scope of Wireless Networks
Three-quarters of wireless networks at master’s institutions are restricted to specific buildings or a specific location. Just half of master’s institutions reported their wireless networks are not campus-wide, though many (52 percent) do plan to expand to campus-wide coverage. Outdoor use is available at 47 percent of respondent campuses in this class.

Master’s respondents hope to double the mean percentage of campus geographic area covered from 27.6 percent to 56.6 percent in the next 24 months.

Buildings with Wireless Access
While wireless is still a relatively new phenomenon at master’s institutions, 20 percent of respondents reported wireless availability in dormitories—the highest response for any Carnegie class. Wireless access is available also in classrooms (51 percent) and libraries (59 percent).

Master’s institutions generated the lowest response for wireless access in administrative buildings (28 percent), and nearly 44 percent of respondents are uncertain about connecting them to their wireless networks.
Users
Master’s institutions reported the highest incidence of undergraduates (84 percent) using their wireless networks. Other parties—faculty (75 percent), administration (55 percent), and graduate students/researchers (45 percent)—access the wireless networks too, but to a lesser degree than at doctoral institutions.

Departmental Use
Computer science (36 percent), physical science (32 percent), and business (33 percent) are the departments or colleges that most often use wireless.

Equipment Used
Many respondents already connect laptops (96 percent) and desktop computers (43 percent) to their wireless network. Some respondents (24 percent) plan to add handheld devices/scanners in the next 24 months, and 19 percent are planning to add desktop computers.

Installation Issues
The mean amount spent/budgeted for wireless networking at master’s institutions was $82,968, and implementation took just 3.9 months.

Standards
While many master’s institutions (65 percent) plan to support 802.11b in the next 24 months, 56 percent of respondents plan to incorporate 802.11a, 24 percent 802.11g, and 16 percent Bluetooth.

Security
More than half of the master’s institutions use WEP, and 27 percent use firewalls.

Satisfaction
Master’s institutions are satisfied with their wireless networks; 23 percent of respondents stated that wireless exceeded their expectations—the highest response for any Carnegie class.

Baccalaureate
Wireless networks are relatively new at baccalaureate institutions. As a result, it seems that many are still seeding the technology, focusing on library implementations and gearing usage toward students.

Importance in IT Strategy
More than one-quarter of baccalaureate respondents believe the wireless network has a low priority in the overall IT strategy.

Factors Driving Wireless
Improved network access for students (56 percent), student and teacher access during class time (44 percent), and improved faculty access (38 percent) were the top three reasons baccalaureate schools gave for implementing their wireless networks.

Year of Implementation
Wireless networks are a relatively new capability for many baccalaureate institutions. More than half of the respondents initiated their first wireless local area network in 2000.

Multiple Initiatives
Like master’s institutions, many baccalaureate institutions maintain limited wireless network operations; 61 percent of respondents use a single wireless network.

Scope of Wireless Network
Fifty-six percent of baccalaureate institutions said their wireless network is confined to specific buildings, and fewer than half (47 percent) plan to expand to campus-wide coverage.

Almost 60 percent of baccalaureate institutions’ wireless networks offer outdoor
use, covering, on average, 24.6 percent of the campus’ geographic area. Baccalaureate institutions plan to increase campus geographic coverage, on average, to 46.4 percent in the next 24 months.

**Buildings with Wireless Access**

The library is the center of the baccalaureates’ wireless network; just over 60 percent offer wireless access. And 61 percent of baccalaureate institutions reported their libraries are involved in the planning/implementation process—a higher response than at doctoral and master’s institutions.

A smaller percentage of baccalaureate institutions provide wireless access to administration buildings (27 percent), classrooms (45 percent), and dormitories (16 percent) than doctoral or master’s institutions.

**Users**

Undergraduates are the primary wireless users; just over three-quarters of baccalaureate respondents identified undergraduates as wireless users. A far smaller percentage of faculty (58 percent), administrative personnel (42 percent), and graduate students/researchers (18 percent) access the wireless network in baccalaureate institutions.

Baccalaureate institutions believe their wireless network will serve only 1,518 students and faculty members, the smallest average number of users among all Carnegie institution classifications.

**Departmental Use**

A wider range of departments use wireless networks at baccalaureate institutions. Physical science (36 percent) and computer science (32 percent) generated the highest response rates for departmental access, and language/arts/history (27 percent) and social sciences (31 percent) generated higher response rates than their counterparts at doctoral and master’s institutions.

**Equipment Used**

While laptops predominate (95 percent), a slightly higher percentage of baccalaureate institutions reported connecting desktops to their wireless networks (45 percent).

Portable device usage—PDAs (24 percent), handheld devices (5 percent), and cellular phones (5 percent)—is lower than at doctoral and master’s institutions. Almost one-third of baccalaureate institutions, however, are interested in adding PDA access to their wireless networks within 24 months.

**Installation Issues**

More than 90 percent of baccalaureate respondents identified the IT department as the primary group to initiate wireless implementation. Other groups—a specific college/department (17 percent), library (18 percent), faculty (11 percent)—were less often involved in the process than at doctoral and master’s institutions.

The mean expenditure/budgeted amount for baccalaureate institutions was $43,588.

**Standards**

While more than three-quarters plan to support 802.11b/Wi-Fi standards in the coming 24 months, fewer baccalaureate respondents plan to support 802.11a (42 percent), 802.11g (19 percent), and Bluetooth (15 percent) than doctoral and master’s respondents.

**Security**

Security is not as important to these institutions. Fewer baccalaureate respondents (53 percent) cited security as a key challenge when implementing a wireless network—a far lower response than for doctoral and master’s institutions.

As a result, fewer baccalaureate institutions support wireless encryption or authentication. Almost 30 percent of baccalaureate respondents reported using no encryption or authentication.
Only 45 percent support WEP standards, 15 percent use firewalls, 10 percent use RADIUS, and 10 percent employ IP VPNs. These institutions, however, are slightly more inclined to use vendor-supplied solutions (11 percent).

There is less interest in replacing WEP with 802.1x draft (29 percent). Sixty-five percent do not use any levels of application encryption/authentication enforcement.

**Satisfaction**

Interestingly, baccalaureate institutions have the highest percentage of respondents (11 percent) that felt their wireless network fell short of expectations and the lowest percentage (8 percent) that felt it exceeded expectations.

**Associate’s**

Most wireless networks in associate’s institutions seem to be applications-oriented. While many associate’s institutions implemented their initial wireless network less than a year ago, a significant number use multiple implementations. The research suggests that wireless’ targeted application is inexpensive network access for classrooms, the most likely buildings to have wireless access. Associate’s institutions reported a relatively high percentage of desktop users, and fewer associate’s institutions plan campus-wide networks.

**Importance in IT Strategy**

Almost one-quarter of associate’s respondents claim that the wireless network has a low priority in terms of overall strategy.

**Factors Driving Wireless**

Current student needs (47 percent), student and teacher access during class (58 percent), and the ability to meet future computing needs (49 percent) were the initial factors driving implementation.

**Year of Implementation**

More than 40 percent implemented their initial network in 2001.

**Multiple Initiatives**

Despite the late start, almost 60 percent of associate’s respondents reported at least two wireless networks in operation.

**Scope of Wireless Network**

Almost 80 percent of associate’s institutions reported that their wireless networks are limited to specific buildings or locations. Only 40 percent of those associate’s institutions with limited networks plan to expand their coverage campus-wide, and only 46 percent of respondents reported current outdoor use. As a result, associate’s institutions reported that their wireless networks cover an average of 15.2 percent of the campus’ geographic area. Respondents plan to increase coverage to an average of 54.6 percent of their geographic area in 24 months.

**Buildings with Wireless Access**

Wireless access is concentrated in classrooms, which were most often cited (39 percent) as the facility with wireless capability. Wireless access is less common in other buildings. Associate’s institutions have the lowest response rate for wireless capability in the library—less than 30 percent. Although 43 percent of respondents plan to add wireless accessibility to the library, nearly 30 percent were uncertain.

Few administration buildings (29 percent) are equipped for the wireless network, and only 4 percent of respondents have connected dorms to their wireless networks. Ninety-three percent could not state definite expansion plans.

**Users**

Undergraduates (61 percent) and faculty (54 percent) make up the largest user groups.
for wireless networks. Interestingly, one-quarter of respondents identified “other” users.

**Departmental Use**

Physical sciences (36 percent) and language/arts/history (25 percent) generated the highest response for department use. More than 43 percent identified other departments that use wireless.

**Equipment Used**

While 93 percent of associate's institutions indicated laptop usage on their wireless networks, more than 60 percent identified desktop computers—the highest percentage for desktops. There was far less interest in utilizing portable devices: PDAs (21 percent), handheld devices (4 percent), and cellular phones (4 percent).

**Installation Issues**

Limited scope translates into fast setup time. Associate's institutions implemented their wireless networks in a mean time of 2.1 months.

**Standards**

Associate's institutions like to use established technology; 93 percent currently support 802.11b. Fewer associate's institutions are interested in supporting 802.11a (32 percent) and 802.11g (14 percent) than other Carnegie classifications.

**Security**

Associate's institutions generated the highest response for WEP use (61 percent) and firewalls (46 percent). Yet more than one-third enforce changing encryption keys on a periodic basis. Only 18 percent plan to replace WEP with new standards.

**Institution Control**

Table 9-2 illustrates the differences between privately and publicly controlled institutions.

**Private Institutions**

Many private institutions strive for ubiquitous wireless access. While many reported operating one network, a significant percentage offer a campus-wide implementation with access in student dorms as well as in the library and classrooms. This translates into a higher mean expenditure than that of other institution types. Private institutions are also less concerned about security; many offer only basic security options or no options as all.

**Importance in IT Strategy**

Wireless networking is considered an important IT initiative. Almost 20 percent of private institutions reported that wireless network implementation has a high priority over other IT initiatives.

**Factors Driving Wireless**

The three most important factors that drove implementation are improved access for students (57 percent) and faculty (47 percent), and greater student and teacher access during class (47 percent).

Almost one-quarter of private institutions—the largest proportion of any institution category—rated competitive pressures from other institutions as an important factor driving implementation.

**Year of Implementation**

Wireless networking is a fairly recent addition to most private institutions; more than 80 percent of respondents reported their initial wireless implementation occurred in either 2000 or 2001.
Multiple Initiatives
Almost 60 percent of private institution respondents reported operating only one wireless network.

Scope of Wireless Network
A significant percentage of private institutions’ wireless networks have a wide scope. Twenty-eight percent reported a campus-wide implementation—the highest percentage of respondents for any institution classification. More than half of those institutions without campus-wide access plan to expand their wireless networks throughout the institution.

Fifty-six percent of private institutions reported an outdoor implementation. Compared with public universities, private institutions cover a larger geographic area—on average about 34 percent of the campus.

Buildings with Wireless Access
Almost two-thirds of private institutions reported wireless access in their libraries, 51 percent reported wireless access in their classrooms, and 22 percent provide wireless access in their research centers. Administrative applications are less common; only 29
percent of administrative buildings have wireless access.

Dormitories are also a priority; 22 percent reported wireless access to their dormitories, the highest respondent percentage for any institution classification.

**Users**

Private institutions reported a mean of 26.3 percent of students with access to their wireless networks—almost twice the percentage of their public institution counterparts.

As at other institutions, undergraduates are the predominate users; 82 percent of respondents reported undergraduate usage. Compared with public institutions, other college constituents are less likely to use the wireless network.

**Departmental Use**

A wide variety of departments use the wireless network: computer science (42 percent), physical sciences (38 percent), business (30 percent), language/history (28 percent), and social sciences (31 percent).

**Equipment Used**

Ninety-five percent of respondents indicated that laptop computers access the wireless network. Almost 30 percent plan to add PDA access within 24 months.

**Installation Issues**

Almost one-quarter of private institutions reported that students were at least moderately involved in the wireless planning/implementation process—the highest percentage of all institution classifications.

Private institutions spent on average more than $136,000 on their implementation, compared with an average of $126,000 for public colleges and universities.

**Security**

Fewer private (63 percent) than public institutions perceive security as a problem, and their actions reflect this attitude. Almost one-quarter reported no encryption or authentication enforcement, and almost 60 percent do not use application encryption or authentication enforcement.

Compared with their public counterparts, a slightly larger proportion will use WEP (48 percent) and firewalls (24 percent), but private institutions are less likely to use RADIUS and IP VPNs.

**Public Institutions**

Wireless network implementations reflect public institutions' comprehensive nature. Many operate several wireless networks on campus, and many different members of the academic community not only use the networks but also are involved in their planning.

**Importance in IT Strategy**

Seventy percent of public institutions believe wireless is important, but other initiatives have higher priority.

**Factors Driving Wireless**

Forty-four percent of public institutions stated that their ability to meet future computing needs was an important factor in the implementation decision. Forty-five percent identified improved student access to the network as an important implementation factor.

**Year of Implementation**

Almost 30 percent of public institutions reported implementing their first wireless network before 2000.

**Multiple Initiatives**

Almost two-thirds of public institution respondents operate multiple wireless networks, and 40 percent reported three or more in operation.

**Scope of Wireless Network**

Given the large campus size of many public institutions, it isn’t surprising that their
wireless access is more limited than that of their private institution counterparts. Public institutions, on average, reported wireless access on less than 20 percent of their total geographic area. Only 17 percent reported campus-wide implementations.

Substantial expansion is planned. Public institutions want to increase access to an average of 50 percent of their geographic area in the next 24 months. More than half of public institutions with specific implementation plans look to expand campus-wide. About half reported current outdoor use, but an additional 24 percent plan to add outdoor access.

**Buildings with Wireless Access**

More than one-third of public institutions reported wireless access in administration buildings; 49 percent reported access in libraries, and 43 percent in classrooms.

**Users**

Fewer public (73 percent) than private institutions identified undergraduates as wireless network users, but a higher percentage of faculty (74 percent), administrative personnel (53 percent), and graduate students/researchers (47 percent) have access.

**Departmental Use**

Computer science (34 percent), business (32 percent), and physical science (29 percent) are the departments most often using the wireless network. The “other” category also generated significant response (43 percent).

**Equipment Used**

Users access the wireless network with laptops (93 percent), desktop PCs (46 percent), and PDAs (42 percent).

**Installation Issues**

Their larger scale translates into a slightly longer average planning time (4.79 months) and execution period (4.86 months) for public institutions.

Interestingly, public institutions reported spending less on average ($126,028) than private institutions, despite planning to serve more than twice as many students (an average of 5,761).

Interest in wireless technology is dispersed throughout public institutions. They reported a slightly higher frequency of non-IT groups involved in the wireless network initiation process than did private institutions. Twenty-two percent cited involvement by specific colleges/departments, 21 percent by the library, and 23 percent by faculty. Interestingly, far fewer public institutions (2 percent) indicated that students were involved in the process.

**Standards**

Most public institutions expect to support 802.11b (69 percent) and 802.11a (50 percent). Expected support for 802.11g is 26 percent and for Bluetooth 22 percent. A few public institutions indicated plans to support broadband (7 percent) and GPRS/2.5G (3 percent).

**Security**

A higher percentage of public institutions regard security as a key challenge, and their activities support this view.

Public institutions are less reliant on WEP for encryption. While 44 percent do use WEP, 22 percent reported using RADIUS, 17 percent IP VPNs, 11 percent vendor-supplied solutions, and 3 percent EAP. Almost 60 percent enforce application encryption or authentication.
Enrollment
As Table 9-3 illustrates, wireless networking characteristics can vary considerably with enrollment size. The following profiles expand upon these differences.

FTE 1–4,999
Institutions with 1–4,999 FTE are small, and their wireless networks reflect this. They operate only one wireless network, which is frequently limited to specific buildings, and few identified campus-wide expansion plans.

Table 9-3. Wireless Networking Characteristics by Enrollment Size

<table>
<thead>
<tr>
<th>Item</th>
<th>FTE: 1–4,999</th>
<th>FTE: 5,000–9,999</th>
<th>FTE: 10,000–19,999</th>
<th>FTE: 20,000+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implemented</td>
<td>55%</td>
<td>68%</td>
<td>64%</td>
<td>65%</td>
</tr>
<tr>
<td>Pre-2000 Adoption</td>
<td>14%</td>
<td>44%</td>
<td>26%</td>
<td>40%</td>
</tr>
<tr>
<td>Multiple WLANs</td>
<td>42%</td>
<td>55%</td>
<td>65%</td>
<td>81%</td>
</tr>
<tr>
<td>Campus-wide</td>
<td>22%</td>
<td>28%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Outdoor</td>
<td>50%</td>
<td>52%</td>
<td>69%</td>
<td>70%</td>
</tr>
<tr>
<td>Median Geographic Coverage Percentage</td>
<td>13%</td>
<td>15%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>User Mix</td>
<td>Undergrad: 77% Faculty: 65% Admin: 45% Grad/Res: 27%</td>
<td>Undergrad: 78% Faculty: 80% Admin: 52% Grad/Res: 56%</td>
<td>Undergrad: 76% Faculty: 73% Admin: 69% Grad/Res: 53%</td>
<td>Undergrad: 75% Faculty: 90% Admin: 85% Grad/Res: 95%</td>
</tr>
<tr>
<td>Highest Identified Department Usage</td>
<td>Computer Science: 32% Physical Sciences: 30% Lang/Arts/History: 21% Social Sciences: 21%</td>
<td>Business: 44% Computer Science: 40% Physical Science: 32%</td>
<td>Business: 49% Computer Science: 44% Physical Science: 42%</td>
<td>Engineering: 75% Business: 60% Computer Science: 55%</td>
</tr>
<tr>
<td>Equipment Mix</td>
<td>Laptops: 92% Desktops: 47% PDAs: 27%</td>
<td>Laptops: 96% Desktops: 48% PDAs: 44%</td>
<td>Laptops: 100% PDAs: 44% Desktops: 31%</td>
<td>Laptops: 95% PDAs: 65% Desktops: 40%</td>
</tr>
<tr>
<td>Planned 802.11a Adoption</td>
<td>45%</td>
<td>60%</td>
<td>62%</td>
<td>75%</td>
</tr>
<tr>
<td>WEP Usage</td>
<td>53%</td>
<td>36%</td>
<td>38%</td>
<td>45%</td>
</tr>
<tr>
<td>IP VPN Usage</td>
<td>7%</td>
<td>20%</td>
<td>20%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Importance in IT Strategy
More 1–4,999 FTE institutions (26 percent) reported that wireless networking has a lower IT priority than institutions with a larger FTE.

Factors Driving Wireless
Students drive wireless network usage; 51 percent of 1–4,999 FTE institutions considered improved student access to networks to be an important reason for implementing their wireless network. Student and
teacher access during class generated the second highest response (49 percent).

**Year of Implementation**
Many 1–4,999 FTE institutions reported that wireless networking is a recent phenomenon. Almost 40 percent launched their initial implementation in 2001, and another 45 percent implemented their first wireless network in 2000.

**Multiple Initiatives**
Almost 60 percent reported only one wireless network in operation, the highest response for all institutions by FTE category.

**Scope of Wireless Network**
Because of their smaller geographic area, many 1–4,999 FTE institutions’ wireless networks are small in scope. A typical wireless network in these institutions took only 3.5 months on average to implement, the shortest average time for any FTE category. Moreover, 1–4,999 FTE institutions spent less for implementation—an average of $66,221.

Just over half reported that their wireless network is limited to specific buildings. Almost 60 percent of 1–4,999 FTE institutions that do not offer campus-wide access do not plan to do so.

Only half of 1–4,999 FTE institution respondents—fewer than any other FTE category—reported outdoor use. However, these respondents reported the highest mean percentage of geographic area (55 percent) to be covered by wireless networking in the coming 24 months.

**Buildings with Wireless Access**
Wireless networks serve many types of buildings at 1–4,999 FTE institutions. Wireless capability was reported in administrative buildings (31 percent), the library (54 percent), and classrooms (44 percent). These institutions reported the highest incidence of wireless access in dormitories (17 percent).

**Departmental Use**
More than 40 percent reported that “other” departments access their wireless network, the highest percentage by FTE institution size. Computer science (32 percent) and physical science (30 percent) generated the highest response for identifiable department usage.

**Equipment Used**
Laptop computers (92 percent) and desktop computers (47 percent) are the most popular devices used on wireless networks at 1–4,999 FTE institutions.

Respondents reported the lowest incidence of network use with other portable devices: PDAs (27 percent), handheld devices (6 percent), and cellular phones (3 percent). Compared with other FTE categories, 1–4,999 FTE institutions aren’t especially interested in adding these devices to their network over the next 24 months. Respondents reported the lowest level of interest (47 percent) in adding any devices to their wireless network.

**Standards**
Many 1–4,999 FTE institutions (89 percent) currently support 802.11b/Wi-Fi standards, but far fewer respondents in this category are interested in supporting 802.11a (45 percent), 802.11g (19 percent), and Bluetooth (12 percent) in the next 24 months.

**Security**
Fewer 1–4,999 FTE institutions (60 percent) identified security as a key wireless networking challenge, and their actions support this claim. Almost one-quarter reported using no encryption or authentication tools; more than one-half do not use any application encryption or authentication tools.

Institutions in this category are more likely to rely on WEP encryption; 53 percent of respondents report using WEP.
Fewer respondents in this category reported the adoption of other encryption and authentication tools. Only 24 percent use firewalls, 10 percent use RADIUS, and 7 percent use IP VPNs. A smaller percentage of 1–4,999 FTE institutions plan to replace WEP with 802.1x than institutions in other FTE categories.

**FTE 5,000–9,999**

Many institutions in this category exhibit a commitment to wireless technology, perhaps for research purposes. A significant percentage identified wireless networking as an important IT strategy for their institution. Many implemented their first wireless network before 2000. Faculty members are just as likely as students to use the wireless network. Security is a high priority; many 5,000–9,999 FTE institutions eschew WEP for more sophisticated solutions.

**Importance in IT Strategy**

Almost 20 percent of 5,000–9,999 FTE institutions (the highest percentage by FTE category) reported that wireless network implementation is a high priority over other IT initiatives at their institutions.

**Factors Driving Wireless**

The ability to meet future computing needs was cited by 48 percent of these institutions as an important reason for implementing wireless networking. In addition, improved student access (50 percent) and faculty access (41 percent) were identified as important implementation factors.

**Year of Implementation**

Many respondents exhibited an early commitment to the technology. Forty-four percent implemented their first wireless network before 2000; 12 percent reported their implementation occurred in 1997 or earlier.

**Multiple Initiatives**

Fifty-five percent of 5,000–9,999 FTE institutions have at least two wireless networks in operation.

**Scope of Wireless Network**

Just over half of these institutions reported that their wireless networks are limited to specific buildings. More than half with limited implementations plan to expand to campus-wide networks. And more than 80 percent of respondents reported their wireless networks either currently offer outdoor access (52 percent) or will in the future (30 percent).

**Buildings with Wireless Access**

Fifty-four percent of 5,000–9,999 FTE institutions provide wireless access to their libraries, and 48 percent provide it to classrooms. Only 12 percent provide wireless access in their dorms, the lowest percentage for all FTE categories.

**Users**

Interestingly, a higher percentage of 5,000–9,999 FTE institutions reported greater faculty access (80 percent) than student access (78 percent) to their wireless networks.

**Departmental Use**

A significant percentage of 5,000–9,999 FTE institution respondents reported that “other” departments use their wireless networks. Respondents most frequently identified business (44 percent) and computer science (40 percent) departments as wireless network users.
**Equipment Used**

While many 5,000–9,999 FTE institution respondents reported wireless network access by laptops (96 percent), desktop computer access (48 percent) generated the highest response for any FTE institution category. Significant use of PDAs (44 percent), handheld devices (10 percent), and cellular phones (8 percent) was also reported.

**Standards**

Eighty-six percent of respondents support 802.11b/Wi-Fi standards. Current support by 5,000–9,999 FTE institutions is 20 percent for 802.11a, 6 percent for Bluetooth, and 2 percent for broadband. Sixty percent, 32 percent, and 24 percent, respectively, plan to support these standards in 24 months.

**Security**

While 20 percent of 5,000–9,999 FTE institutions reported no encryption or authentication enforcement, many currently use advanced solutions. WEP support is less common (36 percent) than in any other FTE category. Rather, 5,000–9,999 FTE institutions are using firewalls (26 percent), RADIUS (24 percent), and IP VPNs (20 percent). Eight percent reported using a third-party hardware/software solution, the highest percentage for any FTE category.

Almost 30 percent of respondents enforce regular changing of encryption keys—the highest percentage by FTE category.

**Satisfaction**

These institutions have the highest percentage of respondents reporting that wireless networking has exceeded their expectations (26 percent).

**FTE 10,000–19,999**

Despite the relatively recent adoption of wireless networking by 10,000–19,999 FTE institutions, many have worked to spread the technology throughout their institutions. Many operate multiple wireless networks to serve classrooms, libraries, or administration buildings. And different constituencies are involved in initiation, planning, and use of the wireless networks.

**Factors Driving Wireless**

Attitude may be the primary motivator. The implementation decision factor that generated the highest response—more than in any other FTE category—was wireless’ ability to bolster the perception that the institution is on the leading edge.

Cost issues were not a factor. Only 5 percent of respondents mentioned installation or operational savings compared with wired networks as an important decision factor, the lowest response by FTE category.

**Year of Implementation**

Almost three-quarters of 10,000–19,999 FTE respondents initiated their first wireless network in 2000 (38 percent) or 2001 (36 percent).

**Multiple Initiatives**

Almost two-thirds of these institutions reported more than one wireless network in operation; 52 percent reported three or more wireless networks.

**Network Scope**

Two-thirds of 10,000–19,999 FTE institutions reported their wireless networks are limited to specific buildings. Fifty-six percent not offering campus-wide wireless networks plan to do so in the future.

As campuses grow larger, it becomes harder to offer a campus-wide implementation; only 20 percent in this category have campus-wide wireless networks. These institutions reported an average of only 17.7 percent of their campus currently accessible to the wireless network. Coverage will increase to an average of 45 percent of campus area in 24 months. Sixty-nine percent offer outdoor access.
Buildings with Wireless Access

Thirty-three percent of 10,000–19,999 FTE institutions currently have their administrative buildings accessible to wireless networking, and 31 percent are planning such access.

Libraries are a priority for institutions in this category. Respondents reported that 71 percent currently have library access to a wireless network, and another 27 percent plan to implement wireless in their libraries within 24 months.

Almost 60 percent of respondents have classroom accessibility; another 33 percent plan to offer it within two years. Institutions in the 10,000–19,999 FTE category also reported the highest percentage of respondents who either have (16 percent) or plan to have (31 percent) their dormitories connected to the wireless networks.

Users

Many groups at 10,000–19,999 FTE institutions use the wireless network. Respondents reported undergraduate usage (76 percent), faculty usage (73 percent), administrative usage (69 percent), and graduate student/research usage (53 percent).

Departmental Use

Numerous departments use the wireless network. Forty-nine percent of respondents reported usage by the business department, 44 percent by computer sciences, and 42 percent by the physical sciences.

Equipment Used

Interestingly, 10,000–19,999 FTE institutions were the only respondents reporting 100 percent on laptop computer access. Conversely, desktop access generated the lowest response by FTE category, with only 31 percent reporting desktop PC access. PDAs (44 percent) and handheld devices (13 percent) are relatively popular too.

Installation Issues

Many groups at 10,000–19,999 FTE institutions initiated, planned, and now use their wireless networks. Most respondents (96 percent) reported involvement not only by IT departments in the initiation of wireless networks, but also by specific colleges/departments (76 percent), the library (35 percent), faculty (25 percent), and students (6 percent). This is more diverse involvement than reported by other FTE categories.

Respondents from 10,000–19,999 FTE institutions also reported that many groups were involved in planning: IT departments (100 percent), libraries (73 percent), research centers (15 percent), specific colleges (69 percent), faculty (46 percent), and students (17 percent).

Such widespread involvement lengthens the planning cycle. These institutions reported that it took 7.3 months on average to plan their wireless network implementation.

Standards

Almost 96 percent of 10,000–19,999 FTE institutions reported current support for 802.11b/Wi-Fi, the highest response by FTE category. Moreover, they are interested in supporting new standards in the future; only 9 percent of respondents didn’t know their future standards support plan.

A high percentage of respondents plan to embrace all types of new standards and technologies, not just the popular standards such as 802.11a (62 percent), 802.11g (29 percent), and Bluetooth (24 percent).

A small percentage of 10,000–19,999 FTE institution respondents plan to support broadband (9 percent), GPRS/2.5G (4 percent), UMTS/3G Cellular (2 percent), and HOMERF (2 percent).

Security

Wireless network security gains importance as enrollment grows. Eighty percent of respondents identified security as a key
challenge when implementing a wireless network.

Only 9 percent of respondents reported using no encryption or authentication security measures, and only 38 percent reported no application encryption or authentication enforcement, the lowest response by FTE category.

A significant percentage of respondents in this category use non-WEP solutions. Thirty-eight percent reported WEP support, but 24 percent use firewalls, 38 percent use RADIUS, and 20 percent use IP VPNs.

**Challenges**

Despite aggressive implementation by 10,000–19,999 FTE institutions, there may be a hint of problems on the horizon. Twenty percent believe that wireless technology was more costly than expected—the highest response by FTE category.

**Satisfaction**

While 76 percent did say wireless networking met their expectations, 9 percent felt that it fell short—again, the highest response for all FTE categories.

**FTE 20,000-Plus**

Large institutions typically use wireless networking as a network access tool throughout their operations. They are early adopters, and many operate multiple networks in libraries, classrooms, research centers, and administration buildings. They serve a broad user base: students were less often cited as users than faculty, research staff, and administration. Because the networks are pervasive, planning is more complex and involves more departments. In addition, security measures are more sophisticated.

**Importance in IT Strategy**

Almost 90 percent of 20,000-plus FTE institutions believe that wireless networking is an important IT priority, but other initiatives have higher priority.

**Factors Driving Wireless**

Network accessibility is driving wireless usage. Two-thirds of respondents identified improved student network access and 62 percent identified improved faculty access as important factors behind their wireless technology implementation.

**Year of Implementation**

Many 20,000-plus FTE institutions are early adopters of wireless networking. Only 15 percent of respondents initiated their first wireless network in 2001; 40 percent implemented their first wireless network in 1998 or 1999.

**Multiple Initiatives**

More than 80 percent of 20,000-plus FTE institutions reported that they operate at least two wireless networks, and 76 percent operate three or more.

**Scope of Wireless Network**

Only 10 percent reported campus-wide implementations, and the current average coverage by wireless networking is 13.8 percent of geographic campus area, the lowest percentage by FTE category. This isn’t surprising, given the large geographic area these campuses encompass. Yet 61 percent of 20,000-plus FTE institutions that offer limited wireless networks plan to expand campus-wide—more than any other FTE category.

Seventy percent of respondents reported current outdoor access. This category has the fewest respondents (15 percent) reporting no plans for outdoor wireless access.

**Buildings with Wireless Access**

With the exception of dormitories, 20,000-plus FTE respondents reported the
highest percentage of either current or planned wireless network access in the various campus buildings: administrative buildings, 45 percent current, 40 percent planned; libraries, 50 percent current, 40 percent planned; classrooms, 40 percent current, 50 percent planned; and research centers, 20 percent current, 50 percent planned.

**Users**

This FTE category cited undergraduate students least often as wireless network users (75 percent). Members of the academic community cited more frequently as users were faculty (90 percent), administration (85 percent), and graduate students/researchers (95 percent).

**Departmental Use**

Three-quarters of respondents identified the engineering department, 60 percent identified business, and 55 percent identified computer science as departments currently using wireless networking. As evidence of their graduate school activity, 35 percent of respondents identified law schools and 20 percent identified medical schools as users.

**Equipment Used**

While 95 percent of 20,000-plus FTE institutions reported wireless access by laptops, PDAs (65 percent) and handheld devices (15 percent) were mentioned more often than by any other FTE category. Many of the large institutions want to add more devices in the next 24 months, again generating a higher response rate by FTE category for all products: PDAs (40 percent), handheld devices (40 percent), cell phones (40 percent), desktops (25 percent), and mobile laptops (15 percent).

**Installation Issues**

Respondents from 20,000-plus FTE institutions reported the longest average implementation time—5.9 months—and the largest average amount spent or budgeted—$346,154.

Unsurprisingly, more than half of the respondents reported that a specific college or department was involved in the initiation of wireless networking at the university. Almost one-quarter identified involvement by administration—the highest response by FTE category.

**Standards**

Eighty-five percent of respondents currently support 802.11b/Wi-Fi, and more 20,000-plus FTE institutions plan to adopt new standards in the next 24 months than institutions of any other size. Seventy-five percent of respondents want to adopt 802.11a, 30 percent expressed interest in 802.11g, and 30 percent will support Bluetooth. Interestingly, no institution in this category expressed interest in supporting broadband technology.

**Security**

Ninety percent of 20,000-plus FTE institutions identified security as a key wireless networking challenge, and institutions of this size use a variety of encryption and authentication tools.

Institutions in this category report the highest usage rate for the various security methods: 45 percent use WEP, 30 percent use RADIUS, 40 percent use IP VPNs, 15 percent use third-party hardware/software, 15 percent use KERBEROS, 10 percent use the Advanced Encryption Standard, and 10 percent use EAP. Almost 45 percent of respondents plan to replace WEP with 802.1x.
Conclusions

On the basis of the online survey results, numerous IT and user interviews, and case study discussions, EDUCAUSE and IDC conclude that wireless networking is becoming an integral component of IT infrastructure for institutions of higher education. Half of all higher education institutions operate at least a limited wireless network, and most others—all but 8 percent—are planning for wireless. Most institutions that have implemented wireless networks are expanding them.

As wireless networking gains popularity on campuses, several key trends have emerged. Wireless is a supplemental, not substitutional, network for the wired infrastructure at higher education institutions. It provides an additional means for students, faculty, and staff to access the institution’s network. Its convenience, more than its capability, drives its adoption. In fact, wireless is bringing network access to more places—libraries, classrooms, common areas, and hard-to-wire locations—but users must be careful how they use it. Limited bandwidth means that data-intensive applications or simultaneous access by too many users may severely degrade wireless network performance. As a result, the wired infrastructure will continue to be the primary campus network. Institutions plan to implement new technologies (IEEE 802.11a, 802.11g) that will expand bandwidth to provide better performance and help meet the demands of a growing number of users.

Wireless is one of the most successful IT implementations. More than 90 percent of higher education institutions surveyed reported that their wireless networks met or exceeded expectations. Students and faculty incorporate wireless access into their day-to-day activities on campus for both academic and personal endeavors—conducting online research and checking e-mail, for example. The institutional staff, in many cases, is not as involved because many work from an assigned workplace that already contains a data port for wired network access. The key challenge for wireless is the classroom application—training faculty to adapt their pedagogy and instructing them to incorporate online teaching elements so that they can realize the full potential of wireless technology.

Conversations with IT administrators and users consistently illustrated the ease and enthusiasm with which students adopt wireless technology. The technology fulfills students’ expectations for instant information. A stroll around the case study campuses found
students huddled around wireless laptops, collaborating on projects. Some institutions seed wireless adoption through the library, implementing initial pilots and/or establishing laptop checkout programs for students.

While desktops are still the primary computing device in higher education, anecdotal evidence suggests that laptops are gaining popularity among both students and faculty. Laptops are the primary device used to access the wireless network. Some administrators, however, are looking beyond the laptop to the widespread use of lighter and less expensive PDAs and handheld PCs to expand the uses and adoption of wireless networking on campus.

Some administrators worry that the lack of universal student access to laptops may promote different educational experiences for those who can and do access the wireless network and those who cannot or do not. For example, how do laptop haves and have-nots collaborate on common projects? Institutions have addressed this in several ways:

◆ laptop checkout programs for students at libraries or student common areas,
◆ carts of laptops that faculty reserve in advance for classroom or lab applications, and
◆ mandatory laptop requirements for students in academic programs, particularly professional graduate programs in business, law, engineering, and medicine.

Wireless also has raised support issues for both students and faculty. IT departments must deploy extra resources to handle the surge in user help requests (installing drivers, for example) when the wireless network initially goes online. More daunting are the support issues that institutions face as faculty adapt course curriculums to facilitate online teaching elements and learn to operate the new classroom technology confidently. Some institutions have created specific programs and departments to address this issue.

Wireless is viewed by some institutions as a competitive differentiator. As prospective students’ technology demands become more sophisticated, wireless is becoming increasingly a “checklist” item. This is especially true in professional schools—business, law, medicine, and engineering—where wireless-equipped laptop computers are increasingly mandatory. Wireless not only facilitates the academic process but also enhances students’ preparation for their postgraduate careers.

Examining the survey results reveals that research universities led the wireless adoption curve. Many implemented their first wireless network more than three years ago, most likely using pilot implementations to test the technology’s capabilities, then expanding to other parts of the academic community. In the past two years, master’s and baccalaureate institutions have broadly adopted wireless. Associate’s institutions have begun to implement wireless too, although adoption lags in this segment.

Cost is a double-edged sword. Installation costs typically are relatively low: The reported median amount spent or budgeted is $50,000, and the median cost per student is only $50. Many institutions, employing the qualitative measure of positive user feedback, feel their return on investment is successful. Maintaining the networks over the long term, however, can be a challenge, because a wireless network represents a parallel infrastructure to support. While this enables IT departments to piggyback on current staff for operation, maintenance, and support functions, most are planning to implement new technologies, which will require some capital funding. Unfortunately, most IT departments have no long-term
funding strategies or cost recovery plans for their wireless networks, and many institutions are grappling with this issue.

Wireless installation is a challenging, complex process because there are so many variables—building architecture, construction material, room design, and room capacity—that impact access point and antenna placement. Many institutions implement a pilot application initially to learn about wireless technology characteristics. Others hire value-added resellers to assist in the process. And because it is easy for individual departments and colleges to install their own wireless networks, many institutions centralize wireless planning, operation, and policy within their IT departments to avoid interference and incompatibility problems.

Security presents a dilemma. Wireless technology’s radio transmission medium expands network access for authorized users throughout the campus, but it also creates the potential for security breaches and poaching of institutional resources by unauthorized users. Fortunately, no institution reported any significant problems—yet. Still, no easy solution exists today for the potential problems. Some institutions, especially doctoral ones and those with large enrollments, regard wired equivalency privacy (WEP) as ineffective and nonscalable. Instead, they turn to solutions like virtual private networks (VPNs), but this is costly and inefficient. Some institutions stress user education, outlining the potential security risks that wireless networking poses to users. A relatively large number of institutions (particularly AA and BA) have no encryption/authentication tools in place. Effective and efficient solutions (Advanced Encryption Standard use in VPNs, IEEE 802.1x/EAP) are coming, but they are a year or two away.

Different institution types exhibit different intentions about adopting newer wireless technologies. Perhaps because they have greater experience or financial resources, many research universities plan to adopt IEEE 802.11a in the next two years; other segments appear to be more reticent or divided over standards.
Appendix 1
Participants in the Follow-up, In-Depth Qualitative Interviews

**Carnegie Mellon University**
Chuck Bartel, Director of Operations and Project Director of Wireless Andrew
Doug Blair, Services Development Group Leader and Project Leader–Handheld Andrew
Tracy Furthy, Former Vice Provost and Chief Information Officer, currently Chief Information Officer, Duke University
Lawrence Gallagher, Manager of Data Communications
Alex Hills, Distinguished Service Professor of Engineering and Public Policy
F. Meena Lakhavani, Director of User Services
Brad Myers, Senior Research Scientist, Human-Computer Interaction Institution
Indira Nair, Vice Provost for Education
Mark Poepping, Technical Director
Daniel Sieworek, Director, Human-Computer Interaction Institute
Asim Smailagic, Senior Research Faculty, Institute for Complex Engineering Systems
Joel Smith, Vice Provost and Chief Information Officer
Pomona Valero, User Services Department
David Yaron, Associate Professor, Chemistry
Russell Yount, Manager of Network Development

**College of Mount St. Joseph**
Elizabeth Bookser Barkley, Professor, Humanities Department
Mark Cain, Executive Director, Information Services and Support

**Dartmouth College**
Ted Cooley, Director of Computing for the Thayer School of Engineering
Christian Jernstede, Professor of Psychological and Brain Sciences
Lawrence Levine, Director of Computing

**Drexel University**
John Bielec, Vice President for Information Resources and Technology
Janice Biros, Associate Vice President–Office of Information Resources and Technology
Ken Blackney, Core Technologies Infrastructure
Nira Herrmann, Professor and Department Head–Department of Mathematics and Computer Sciences
Frank Kelley, Professor
Jamie Ly, Student
Constantine Papadakis, President of Drexel University
Mitch Peabody, Student
Ed Gomes, Senior Manager, IT

**Edison Community College**
Brad Reed, Instructor of Interactive Media, Internet Technologies, and Technical Communications

**Florida State University**
Larry Conrad, Assistant Vice President and CIO
Greg Strong, Director of Technology, School of Law

**Glendale Community College**
KC Hundere, Director of Network Services
Pam Nelson, Instructor in Geology

**Harvey Mudd College**
Richard Parker, CIO/Director of Computing and Information Services

**Edison Community College**
Dennis Myers, Vice President for Information Technology Services

**Indiana University**
Barry Walsh, Director
Brad Wheeler, Associate Dean
Brian Voss, Associate Vice President for Telecommunications

**MCP Hahnemann University**
Charles Puglia, Professor
Arnold Smolen, Associate Dean

**Middle Tennessee State University**
Al Camp. Lab Administration and Technician, Continuing Studies Computer Lab
Gregory Schaffer, Director of Network Services

**Middlebury College**
Gregg Humphrey, Director of Elementary Education
Jeff Rehbach, Special Projects Manager for Library and Information Services

**Oberlin College**
John Bucher, Director of Computing Services
Gary Kornblith, Professor of History

**Rockland Community College**
Harry Nelson, Director, Instructional Technology Center

**Salt Lake Community College**
Lynn Cundiff, President
John Laplante, Director of IT

**University of California, Berkeley**
Zane Cooper, Chief Technology Officer and Director
Jack McCredie, Associate Vice Chancellor and CIO

**University of California, San Diego**
Elazar Harel, Chief Information Officer
Greg Hidley, Director, School of Engineering Computing
University of Pennsylvania
Roy Heinz, IT Administrator, Van Pelt Library
Deke Kassabian, Senior Technology Director
Daniel Shapiro, Director of Information Services and Chief Information Officer, School of Dental Medicine
Ira Winston, Computer and Information, School of Engineering

University of Tennessee
David Atkins, Assistant Professor, Hodges Library
Elizabeth Aversa, Professor and Director, School of Information Sciences
A.J. Baker, Professor, Engineering Department; Director, Computational Fluid Dynamics Laboratory
Kathleen Bennet, Web Instructional Technologist, Innovative Technology Center
Peggy Beauvois, Associate Professor, Modern Foreign Languages and Literatures
Lori Brewer, Student, SGA Technical Services Committee
Michael Burke, Instructional Technologist, Innovative Technology Center
Dwayne Burnell, Student, MBA Program
Shawn Collins, Technology Coordinator and Budget Officer
Shawn Colter, Program Coordinator, Innovative Technology Center
Loren Crabtree, Provost
Sarah Gardial, Dean, Full-Time MBA Program and Professor of Marketing
Philippe Hanset, IT Infrastructure Department
Wes Hines, Professor, College of Engineering
Judy Huddleston, Director–IT Infrastructures Administrative Services
Ashley Jarrell, Client Services–Customer Technology Support
Matthew Johnson, Student, Chairman–SGA Technical Services Committee
Dewitt Latimer, Executive Director, IT Infrastructure
Julie Little, Director, Educational Technologies and Innovative Technology Center
Dwayne McKay, Vice President for Research and Information Technology
Marla Peterson, Professor, Counseling–Deafness and Human Services
Stan Pinkleton, Director OIT Customer Service
Predrag Radulovic, IT Infrastructure Department
Raj Raman, Associate Professor, Biosystems Engineering and Environmental Science
Timothy Rogers, Vice Provost, Student Affairs
Amadou Sall, Instructor, African American Studies
Michael Stahl, Professor of Management and Director, Physicians MBA Program, College of Business Administration
Ramsey Valentine, Director of Technology, College of Business Administration
Fred Weber, Associate Professor, Department of Chemical Engineering
Luther Wilheim, Professor and Interim Associate Dean, College of Engineering
Eric Williams, Student, MBA Program
Maryann Woodside, Professor, Counseling–Deafness and Human Services
Dolly Young, Associate Professor, Modern Foreign Languages and Literature
University of Toronto
Jack Gorrie, Provost’s Adviser on Information Technology
David Dunne, Adjunct Professor of Marketing, Joseph L. Rotman School of Management

University of Wisconsin, Madison
Joseph Brown, Chief Information Officer

Kathi Dwelle and Rusty Smith, Director, DoIT Communications, Organizational and Student Initiatives

Wake Forest
David G. Brown, Vice President and Dean of the International Center for Computer Enhanced Learning
Appendix 2
Respondents to Online Survey

Acadia University
Adirondack Community College
Albertson College of Idaho
Algonquin College
Amherst College
Aquinas College
Arizona State University
Arizona State University East
Arizona State University West
Athabasca University
Auburn University at Montgomery
Austin Community College
Azusa Pacific University
Baker University
Baldwin-Wallace College
Ball State University
Barnard College
Bellarmine University
Bentley College
Berea College
Berklee College of Music
Biola University
Boise State University
Bradley University
Briar Cliff University
Bridgewater State College
Broome Community College
Brown University
Bryant College
Bryn Mawr College
Buffalo State College
Caldwell College
California Institute of Technology
California Polytechnic State University–San Luis Obispo
California State Polytechnic University–Pomona
California State University–Bakersfield
California State University–Fresno
California State University–Hayward
California State University–Northridge
California State University–San Marcos
Calvin College
Canisius College
Capilano College
Carlos Albizu University Miami Campus
Carnegie Mellon University
Carroll College
Case Western Reserve University

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Cedar Valley College
Cedarville University
Central Carolina Technical College
Central College
Centre College
Chadron State College
Chandler-Gilbert Community College
Chattanooga State Technical Community College
Choate Rosemary Hall
City Colleges of Chicago Olive-Harvey College
City Colleges of Chicago Richard J. Daley College
City University of New York
Clackamas Community College
Clark Atlanta University
Clark State Community College
Clarke College
Clayton College and State University
Clemson University
Cleveland Institute of Art
Colby-Sawyer College
Colgate University
College Misericordia
College of Mount St. Joseph
College of New Rochelle
College of the Holy Cross
Collin County Community College District
Colorado State University
Columbia University
Columbus State University
Community Colleges of Colorado
Corcoran College of Art and Design
Cornell University
Crown College
Cuyahoga Community College
CyberMark
Dakota Wesleyan University
Dallas Baptist University
Dallas County Community College District
Daniel Webster College
Dartmouth College
DePauw University
Dickinson State University
Drexel University
Duke University
Earlham College
East Carolina University
Eastern Michigan University
Eastern Oregon University
Ecole des Hautes Etudes Commerciales
Edison Community College
Elmhurst College
Emory University
Episcopal High School
Estrella Mountain Community College
Fairfield University
Fashion Institute of Technology
Flathead Valley Community College
Fontbonne College
Fort Lewis College
Franklin and Marshall College
Franklin W. Olin College of Engineering
GateWay Community College
Genesee Community College
Georgetown University
Georgia College and State University
Georgia Perimeter College
Georgia State University
Glendale Community College
Goucher College
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Murray State University
New Mexico Institute of Mining and Technology
Nipissing University
North Carolina School of the Arts
North Park University
Northeastern Ohio Universities College of Medicine
Northeastern University
Northern Illinois University
Northern Michigan University
Northfield Mount Hermon School
Northwest Missouri State University
Northwest Nazarene University
Northwestern College
Nova Southeastern University
Oberlin College
Occidental College
Ohio Dominican College
Oklahoma Baptist University
Oklahoma Christian University
Oklahoma State University
Ottawa University
Otterbein College
Our Lady of the Lake University
Pace University
Pacific Lutheran University
Phillips Academy
Phillips Exeter Academy
Phoenix College
Pima County Community College District
Pitzer College
Point Loma Nazarene University
Point Park College
Portland State University
Prairie Bible Institute
Presbyterian College
Princeton University
Queens College/CUNY
Queensborough Community College/CUNY
Radford University
Raritan Valley Community College
Reed College
Rensselaer at Hartford
Rhode Island School of Design
Rhodes College
Rockland Community College
Rust College
Rutgers, The State University of New Jersey New Brunswick
Ryerson Polytechnic University
Sacred Heart University
Saint Joseph College
San Diego Miramar College
San Diego State University
San Jacinto College North
San Jose State University
San Juan College
Santa Barbara City College
Santa Fe Community College
School of the Art Institute of Chicago
Shepherd College
SIAST
Siena Heights University
Sierra Nevada College
Skidmore College
South Dakota State Board of Regents
System Office
Southern Illinois University Edwardsville
Southern Methodist University
Southern Polytechnic State University
Southwestern University
Spelman College
St. John Fisher College
St. John’s University/College of Saint Benedict
St. Lawrence University
St. Mary’s College of Maryland
Stony Brook University
SUNY College of Optometry
SUNY College of Technology at Cobleskill
SUNY Empire State College
SUNY Maritime College
Sweet Briar College
Texas A&M University–Corpus Christi
Texas Christian University
Texas State Technical College–Waco
Texas Tech University
The College of New Jersey
The College of Saint Scholastica
The Evergreen State College
The George Washington University
The Ohio State University Mansfield Campus
The Pennsylvania State University
The Sage Colleges
The University of South Dakota
The University of Toledo
Thomas Jefferson University
Tufts University
Tulane University
Tyler Junior College
Union College
United States Air Force Academy
United States Coast Guard Academy
United States Naval Academy
Universite de Montreal
University College of the Cariboo
University of Alabama in Huntsville
University of Alaska Statewide System
University of Alberta
University of British Columbia
University of Calgary
University of California, Berkeley
University of California, Irvine
University of California, Merced
University of California, Santa Barbara
University of Central Florida
University of Central Oklahoma
University of Chicago
University of Cincinnati
University of Colorado at Boulder
University of Detroit Mercy
University of Findlay
University of Georgia
University of Hawaii System
University of Houston–Downtown
University of Iowa
University of Kansas
University of Kansas Medical Center
University of Manitoba
University of Maryland, Baltimore
University of Maryland, Baltimore County
University of Massachusetts President’s Office
University of Massachusetts Worcester
University of Miami
University of Minnesota–Duluth
University of Missouri System
University of Missouri–Columbia
University of Missouri–Kansas City
University of Missouri–Rolla
University of Montevallo
University of Nebraska at Kearney
University of New Brunswick
University of New Hampshire
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University of North Dakota
University of North Texas HSC at Fort Worth
University of Northern Iowa
University of Northwestern Ohio
University of Notre Dame
University of Oklahoma
University of Oklahoma Health Sciences Center
University of Oregon
University of Pittsburgh/Titusville
University of Portland
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Utah State University
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Weber State University
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Western Illinois University
Western Kentucky University
Western Maryland College
Westmont College
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William Woods University
Winston-Salem State University
Wofford College
Worcester Polytechnic Institute
Xavier University
Xavier University of Louisiana
Yale University