Wireless Networking at Dartmouth College

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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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Preface

The EDUCAUSE Center for Applied Research (ECAR) produces research to promote effective decisions regarding the selection, development, deployment, management, socialization, and use of information technology (IT) in higher education. ECAR research includes research bulletins, short summary analyses of key IT issues; research studies, in-depth applied research on complex and consequential technologies and practices; and case studies designed to exemplify important themes, trends, and experiences in the management of IT investments and activities.

ECAR has investigated the state of wireless networking in higher education and has issued “Wireless Networking in Higher Education.” This research was undertaken in three phases:

- an online survey of 391 EDUCAUSE members 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, covering 17 selected institutions, with IT personnel and university members who are directly involved with the creation, operation, or use of wireless networks; and
- best practices cases studies with six higher education institutions about their wireless network implementations.

Between March and May 2002, ECAR and IDC began with a list of approximately 150 colleges and universities that had experience implementing wireless networks. From this list, 20 were interviewed extensively by telephone, and six were selected for either on-site visits or extensive telephone follow-up. On-site visits are rigorous and involve nearly two days of interviews and meetings with the widest variety of institutional representatives associated with—or affected by—the technologies or practices being investigated.

This case study was undertaken to draw on the direct experience of others to provide insights into what has—and, as appropriate, what hasn’t—worked in wireless implementations. It is assumed that readers of the case studies will also read the main report, which incorporates the findings of the case studies within the generalized context of the report.

ECAR wishes to thank the leadership of Dartmouth College for their time, assistance, and diligence in support of this research. We hope readers of this ECAR case study will learn from their experiences.
Introduction

Located in Hanover, New Hampshire, Dartmouth College is a private four-year college with an enrollment of 4,200 undergraduates in the liberal arts and 1,500 graduate students. With an annual budget of approximately $425 million (for fiscal year 2000), Dartmouth employs approximately 3,115 staff and 2,250 faculty. A member of the Ivy League, Dartmouth offers 16 graduate programs in the arts and sciences, as well as a medical school (Dartmouth Medical School), a professional school of engineering (Thayer School of Engineering), and a graduate school of management (Tuck School of Business). Dartmouth College is also intimately associated with the Dartmouth Hitchcock Medical Center, of which the College and the Medical School are members. In terms of information technology, the two environments are close peers, sharing various services, although DHMC maintains separate networking.

Consistent with its size, Dartmouth maintains a highly centralized IT organization, known as Peter Kiewit Computing Services. In addition, there are smaller IT organizations affiliated with each of the three professional schools. With a staff of approximately 150, Computing Services consists of:

- Academic Computing
- Administrative Computing
- Computing Support
- Technical Services

Academic Computing focuses on providing services to the student and faculty population. It includes three subgroups. The Academic Consulting Services group provides general consulting assistance to faculty and staff. The Research Computing group supports and develops computing applications and information resources with a primary focus on supporting research. The Curricular Computing group assists the Dartmouth faculty in the use of information technology for research and instruction.

The focal point of support for most institutional administrative systems, Administrative Computing provides systems needs analysis, design, development or procurement, operations, and maintenance; data administration; information systems and capacity planning; system security; and consulting on system use. This division forms close partnerships with institutional efforts to improve the effectiveness and efficiencies of local or campus-wide administrative processes.

Computing Support includes Computer Sales, Service, and Support and Communications and Telephone Services.

Technical Services develops and supports Dartmouth’s technical infrastructure for data networking and computing. The Technical Services division supports the school’s Ethernet backbone and servers, connection of the backbone to the Internet, and network applications.

The core of Dartmouth’s computing infrastructure is an Ethernet backbone employing Nortel routers that links all 161 of the school’s buildings. Dartmouth supports approximately 20 public computing clusters across the campus, the largest of which are located in the Kiewit Computation Center and the Baker-Berry Library. The school also provides extensive computing facilities for faculty, graduate students, and researchers, including several multiprocessor Unix and Linux servers for computational, statistical, and visualization applications.

Drivers of Dartmouth’s Wireless Deployment

Dartmouth’s wireless initiative began early in the fall of 2000 with a series of small department-level pilot programs in the Engineering and Computer Science departments as well as parts of the student union and library. While Computing Services had some involvement in the wireless initiative,
it was by and large a decentralized effort, enabled by the departments’ willingness to take ownership in the early stages. This meant not only installation, maintenance, and management of the 20 to 30 access points (APs) that were initially deployed, but also providing early funding from department budgets.

Since Dartmouth’s wireless initiative started out as a “bottom up” deployment, many factors are cited as drivers. However, the one basic driver common to all was the increasing rate of laptop computer ownership in both the student and faculty populations. For instance, from 1999 to 2001, the laptop share of computers purchased by students through the campus computer store rose from 27 percent to 45 percent to 70 percent. (At present, approximately 40 percent of undergraduate students own a laptop.) Coupled with the fact that all laptops sold in 2001 were factory-equipped with wireless cards, a consensus began to emerge that wireless computing was becoming a viable option on campus.

Within Dartmouth’s Thayer School of Engineering, the deployment of wireless was seen as a low-cost means of expanding computing resources for its 400 undergraduate and 150 graduate students. As enrollment in the school grew, the School of Engineering could not accommodate—for reasons related to both cost and physical space—the demand for more workstations. The logic of providing wireless access in Engineering was further buttressed by the fact that students in technical disciplines are more likely to use laptops and thus would be well positioned to take advantage of it.

Dartmouth’s pilot deployments were judged a clear success by virtue of their popularity with students and faculty. Determined to build on this success, staff from Computing Services began discussions with the Deputy Provost for Academic Affairs about making wireless ubiquitous across the campus. According to Larry Levine, Director of Computing, the core value proposition for wireless was its ability to enable networking for everybody, everywhere. “We made the case that wireless would produce abundant benefits to the overall academic process,” said Levine. “For faculty, we saw clear value for both teaching and research.” Under Levine’s vision, the role of Dartmouth’s IT organization was to work with faculty to facilitate innovation, but leave it to faculty to drive innovation.

While presenting the benefits of wireless in the lofty terms of the overall computing and communications environment, Computing Services also sought to provide practical demonstrations. In this way, key Dartmouth decision makers (principally the provost) could see the value of wireless in action. In addition, alumni from various IT sectors who serve as advisors to Dartmouth’s IT environment strongly endorsed the notion of a wireless campus.

In October 2000, the provost gave the green light to expanding the initiative under the condition that most of the deployment be completed by spring of 2001. Underlying this speedy timetable was the idea that the sooner a leading-edge wireless environment was established, the sooner Dartmouth’s students and faculty would begin deriving benefits. This, in turn, would provide Dartmouth an opportunity to showcase these benefits to the broader academic community. Indeed, the increasing press coverage and buzz created by the issue of campus wireless were factors in Dartmouth’s decision to move ahead aggressively.

**Wireless Deployment Issues**

In planning for its wireless expansion, Levine’s team consulted with schools (for example, Carnegie Mellon University) that already had advanced wireless implementations, with the aim of sharing best prac-
practices and lessons learned. The most valuable feedback related to network topology, especially the placement and configuration of wireless APs. Of particular interest were issues surrounding “edge effects”—specifically, understanding how wireless networks behaved at the boundaries of coverage areas between access points. The issue of edge effects was most relevant to how wireless end-user devices “reassociate” (hand-off) from one AP to another. One of the key lessons in this area, noted Levine, is the importance of calibrating the transmission power of APs in order to limit instability between “subnets” or coverage zones. “A message that came through loud and clear was that AP placement is more of an art than a science,” said Levine. “We learned that when it comes to signal power, less can be more—which wasn’t intuitive to us at first.”

In the weeks leading up to the roll-out, Computing Services took a hands-on approach to AP placement, with teams fanning out across the campus to identify the best locations. These teams—composed of staff and students using laptops, APs, and walkie-talkies—employed a trial-and-error method that involved measuring signal strengths under different placement options.

Technology and Standards Selection

Another key lesson Dartmouth learned from peer institutions was that wireless standards had not fully evolved. For Dartmouth’s planners this implied that, for the immediate future, a single-vendor solution made the most sense. At the outset of the project, Dartmouth had short-listed Lucent, Cisco, and 3Com. Although Lucent’s WaveLAN AP was used in the initial trial, Lucent was dropped from consideration due largely to delays in delivering its next-generation wireless local-area network (WLAN) products. Cisco, on the other hand, was viewed favorably by virtue of its recent acquisition of Aironet (a WLAN vendor) and was seen as a more stable player. The most important factor working in Cisco’s favor was its willingness to underwrite a major share of Dartmouth’s infrastructure costs through donations and deep discounts. The influence of a large contingent of Dartmouth alumni within Cisco also played a major role in the deal.

On the standards front, Levine saw IEEE 802.11b as the most practical near-term option. “802.11b was the most well-understood, most prevalent technology at the time we deployed wireless,” noted Levine. “We found it to be a robust and easy-to-deploy technology, with good end-user experiences.”

While currently examining the next generation of standards, Dartmouth has voiced early support for deploying 802.11g (versus 802.11a) by virtue of its support for 802.11b. The major issue driving the move to the next standard will be increased user demands for higher bandwidth and collaboration.

Funding Wireless

Dartmouth’s wireless expansion was originally projected to cost approximately $400,000, with funds provided by the provost and donations from Cisco. Going forward, Dartmouth has rolled the cost of maintaining the wireless network into its general IT budgeting practices. Under these practices, Dartmouth’s five major budget centers (consisting of its three professional schools, the Office of Residential Life, and all other areas) are charged on a cost-per-port basis. Wireless costs, which include added support costs, are embedded in these cost-per-port estimates.

Profile of Dartmouth’s Wireless Deployment

Dartmouth’s wireless network provides 100 percent coverage through a network of 476 Cisco Aironet APs. These include a mix of APs powered over the network (through injectors) and separately powered units. Dartmouth’s wireless network extends
over 161 buildings and all major outdoor areas and off-campus facilities (the stadium, boathouse, and facilities). Dartmouth’s APs operate chiefly under an omnidirectional antenna scheme and are arrayed in a micro-cell pattern to enable frequency reuse and to mitigate range-related problems. Each access point connects directly to a local building’s wired subnet rather than into a campus-wide wireless virtual LAN (VLAN). This was necessary due to the current architecture of the campus backbone, and may change when the campus wired network is upgraded during the coming year. The wireless network delivers 11 Mbps coverage.

While its network is effectively fully deployed, Dartmouth’s wireless strategy is far from static. Computing Services constantly modifies the network to maximize performance by either adjusting transmitter signal strengths or moving APs. While Computing Services monitors the operational status of the wireless network remotely, most feedback comes from students and faculty.

Applications Supported
By and large, Dartmouth’s wireless applications mirror those used on the wired network. Among general-purpose applications, messaging, Web browsing, and productivity applications constitute the most widely used applications. Within the Thayer School of Engineering, key applications supported (both wired and wireless) include computer-aided design (CAD) applications such as ProENGINEER and MathLab. Likewise, at the Tuck School of Business, students use wireless to access e-mail, the Web, and a comprehensive array of intranet services.

Wireless Security Profile
At present, Dartmouth’s wireless network security is token at best. To access the wireless network, a user needs to enter a non-user-specific service set identifier (SSID). Levine sees the present weak security regime as a temporary—yet necessary—fact of life in what is now the “early phase” of Dartmouth’s wireless history. “We didn’t want a solution where everyone has to register a MAC [media access control] address, mostly because the MAC address can change frequently,” explained Levine. “Ultimately we’re moving toward using our LDAP [lightweight directory access protocol] name directory for sign on, but a cross-vendor standard does not exist for that right now.” Levine does not see unauthorized access as a problem right now, although Dartmouth will nonetheless move swiftly toward required login and other security measures.

Dartmouth does not plan to deploy a campus-wide virtual private network (VPN) because of the difficulties and complexities of providing client software for all clients. In the area of encryption, wired equivalent privacy (WEP) is enabled and optional on the wireless network. Dartmouth chose to make it available because it was supported by the access points, yet chose to make it optional because it was not supported by all wireless cards.

Wireless Usage Patterns
At present, wireless use on campus falls under two broadly defined categories: general-purpose access (the vast majority) and targeted, customized wireless applications. Based on incidence of use, the most common usage of wireless is for student-to-student and student-to-professor e-mail, principally through Dartmouth’s BlitzMail messaging platform (discussed below). This is followed closely by Web browsing, including the use of the Web to conduct library-based research. Some other general observations about wireless usage on the Dartmouth campus, drawn from a March 2002 study, follow:
Roaming is limited, with most users limiting their activities to a few key sites in their daily routine.

Overall, residential activity dominates, with most usage coming from residence hall rooms, even though all residence halls are also wired.

Residential and social-space use is heavier in the evening hours, academic and administrative usage is highest during the day, and library-based use is spread more evenly.

Most sessions are short (with a median of 16 minutes), probably reflecting students checking e-mail at periodic intervals.

Buildings with large lecture halls and the Baker-Berry Library have the most concentrated activity, implying the need to configure APs accordingly.

The next two sections profile two of the more prominent department-specific wireless applications deployed at Dartmouth, one fostering engagement and the other, collaboration.

**Increasing Engagement through Wireless**

One of the earliest and most innovative uses of wireless at Dartmouth involved PDAs, enabling all students to simultaneously respond to a professor’s question. Under the application, which was developed by G. Christian Jernstedt, professor of psychological and brain sciences, students can direct their answers to a Jernstedt question onto a large screen. The application also enables Jernstedt to continually ask students questions during class and have every student answer every question (with anonymity where appropriate).

Jernstedt sees the main benefit of his application as a marked increase in students’ level of engagement in the classroom experience. “Research shows that in traditional lecture environments, students are very often not actively engaged, since taking notes amounts to passively receiving and storing information,” said Jernstedt. “This approach provides students with truly interactive experience, thus increasing the overall quality of the time spent in the classroom.”

Jernstedt’s wireless application was derived from an older wired system that had proven unmanageable due to the need to string wires in the classroom. The emergence of suitable wireless technology allowed Jernstedt to get around these issues. A grant from Handspring, which donated 80 Visor PDAs for the class, helped him make it happen.

Jernstedt noted that while wireless in the classroom can lead to distraction in classes with low levels of engagement, the converse holds true in classes with good engagement. “When the class is taught in an engaging manner, the issue of wireless distraction is a non-issue,” stated Jernstedt. “Wireless tends to amplify the existing climate of learning in a particular classroom—not change its direction.”

**Fueling Team-based Collaboration**

Dartmouth’s Thayer School of Thayer School of Engineering, an early pioneer, has woven wireless tightly into its curriculum. Some of the more common applications include using PDAs to download course-related materials and lecture notes, and to view relevant Web content (such as the latest semiconductor technology from IBM). Engineering has deployed wireless to make the learning process more compelling.

Ted Cooley, Director of Computing for the Thayer School of Engineering, also sees an ideal platform for supporting research. “Wireless enables students to work more productively in a laboratory setting because it leverages the inherent collaborative strengths of wireless and the teamwork ori-
presentation that tends to prevail in a research environment," said Cooley. "Students can input data as they generate it, download data to the laptop, crunch numbers, and write their laboratory report in real time. That's a real improvement in efficiency."

Cooley also pointed to the more general benefits of wireless in the classroom—most notably the efficiency with which professors can deliver data to students. "Wireless benefits the teaching process because it allows students to focus less on transcribing lecture content and more on learning through compelling presentation," explained Cooley. "But to capitalize on wireless's capabilities, instructors will need to change their teaching styles—enabling more flexibility and fluidity in the student-teacher exchange."

Examples cited by Cooley include the downloading of class notes, so students can go along with—and make annotations to—a presentation as a professor delivers it.

Some key observations on the impact of wireless messaging follow:

- **Scheduling.** Wireless messaging allows students to better “fine tune” their schedules because it enables a much shorter planning horizon. This affects both the academic sphere (for example, how study groups congregate and interact) and the social sphere. One serendipitous finding was that intensive wireless messaging users often elected to keep their planning horizons short (hours) and avoid excessive longer-term scheduling commitments. This is seen as a reflection of the greater flexibility afforded by wireless messaging. Some other common scheduling-related messaging practices include sending “persistent” e-mail to oneself and receiving event notifications via BlitzMail.

- **Collaboration.** Wireless messaging has made it easier for work groups to collaborate on projects. Message threads are seen as a useful way of tracking the history, direction, and flow of a subject matter discussion.

- **More intensive, but less intrusive, messaging.** Wireless messaging leads to more intensive (that is, frequent) messaging than would occur using cell phones (the equivalent channel for ubiquitous messaging). In short, students feel unconstrained in sending frequent (or recurrent) e-mails without inducing “message fatigue.”

- **RSVP.** The pervasiveness of messaging has given rise to a “messaging etiquette” on the Dartmouth campus, the most important element of which is a prompt response to messages. In addition to messaging, wireless has also led to an increase in students’ mobility as they conduct nonmessaging wireless applications. While the ability to do remote

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**Gauging the Impact of Wireless**

While still a relatively new phenomenon, wireless has already had a marked impact on communication, learning, and teaching practices across the university. Of these three domains, communications practices—student-to-student and student-to-professor—has undergone the most significant evolution since the introduction of wireless. Not surprisingly, the frequency and ease with which messages can be checked and sent enabled (and catalyzed) this evolution.

Discussing their use of wireless on campus, Dartmouth undergraduate students saw messaging (via the BlitzMail system) as having the most pervasive impact on their academic and social lives. The common theme cutting across the different uses of wireless messaging is an increase in control of their social and academic agendas.
work is more a function of portable computing capability (like having a laptop), the wireless component provides students with the all-important ability to stay “plugged in.” Among students interviewed, one of the key values of wireless computing is the ability to perform work in a common-area setting, such as the Green or in social and dining spaces. In the words of one student, wireless computing breaks the trade-off between having to get work done and being around peers. “With a wireless laptop, students can now work in a social setting, which is seen as very desirable,” said the student. “Overall, it’s a better experience because there’s more freedom and happiness in the work process.” Ironically, students working in social settings point to the need for music to drown out background or crowd noise—a need satisfied by downloading streaming music via their wireless laptop.

Wireless is also seen as a powerful tool in library research, with the “killer app” being research in the stacks and accessing of digital media (such as netLibrary, which lets students obtain digital versions of certain books). Under one of the more collaborative scenarios, students can find research materials via the Web, mark it, and forward it either to themselves or to others on their research team.

Wireless has also radically changed the way students communicate with their professors by making such communication virtually 24 × 7. For students, the key benefit has been increased accessibility and faster problem solving, as well as a more convenient and efficient way to schedule time with professors. For faculty, the key benefits are two-fold. First, wireless messaging improves management because instructors can bulk mail answers to a class as a whole, share question threads, and so forth. Second, instructors have more flexibility as to where or when they answer students questions (in the office, at home, in class, or while traveling).

Professor Cooley sees the use of wireless messaging as a variant on the customer relationship management (CRM) model. “Like CRM, messaging allows me to address more routine queries as they come in so that I can focus on more involved inquiries or problems during office hours,” said Cooley. “Overall, it makes my office hours more valuable and manageable.”

The second key benefit for faculty has been the feedback that wireless inquiries provide. Professors can infer from the content of messages which areas or subjects need clarification. More broadly, professors can use this feedback as a way to reshape their teaching curriculum.

Lessons Learned
Many of Dartmouth’s lessons learned relate to technology or deployment issues. Among the more practical observations is the need to more accurately account for electrical and wiring costs in the development of the wireless infrastructure. Dartmouth far outspent its original budget ($400,000) largely because wiring costs (the need to prepare sites for APs) far exceeded original expectations. However, more than 100 APs were donated by Dartmouth alumni at Cisco and by the Dartmouth Alumni Association of Silicon Valley, which greatly helped in keeping the project a financial success.

Ted Cooley sees a broader lesson learned during Dartmouth’s wireless initiative as the need to acknowledge the subsidiary role of wireless vis-à-vis the wired network. “It’s important in the design stage to realize that wireless should not be considered a replacement for the wired network,” said Cooley.
“In our case, it’s truly a supplemental network—with bandwidth capabilities being the major factor.”

On the usage front, a key lesson learned is that students often choose wireless network access even when wired network ports are available. Stan Pyc, IT Director for the Tuck School of Business, pointed out that even though Tuck’s facilities are some of the most heavily wired on campus, MBA students find the wireless network very convenient. “All Tuck students are required to own a notebook computer, and the wireless network enables them to move from room to room very easily without regard for the availability of wired network ports. It’s amazing to observe just how popular the wireless network has become in such a short period of time,” observed Pyc. “All of the students arriving next fall will have notebook computers with wireless networking, so we expect usage to double.” Pyc sees the main challenge arising from this projected increase as the management of expectations regarding network performance.

The Future of Wireless at Dartmouth

With its infrastructure roll-out practically complete, Dartmouth plans to focus on the continuing task of optimizing coverage—adding, adjusting, and reconfiguring APs as needed. Consistent with its long-held policy, Computing Services will continue to work with Dartmouth’s academic departments to facilitate their plans for using wireless to enhance teaching practices.

The two biggest items on Dartmouth’s wireless agenda—likely to take place over the next 12 to 18 months—will be a move toward a more robust security framework and a migration to the next-generation WLAN standard (most likely 802.11g). The latter anticipates the significant growth in higher bandwidth activities, such as streaming video, that is likely to characterize Dartmouth’s wireless network.