Wireless LANs in Higher Education

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Abstract

This paper gives an overview of the development of wireless technology and identifies a number of higher education institutions that have used, or are in the process of developing wireless LANs. Some suggestions are offered as to how to address the problems and challenges that exist for the implementation of wireless LANs on campus. Most institutions of higher education are not considered leading-edge telecommunication organizations due to their lack of funding, especially when compared to their commercial counterparts. True, there are some major universities that are research oriented and are blessed with adequate funding for research from grants and substantial endowments, but most campuses are just now becoming completely wired and have started to fully use applications like e-mail, distance learning, and Web-based classroom management. The idea of taking these newly established wired networks and replacing them with wireless capability makes no sense. However, the idea of extending wireless capability to classrooms and labs that have not been previously connected has a great deal of merit.

Keywords: Communication, wireless LANs, higher education, VLA

It seems that every few years an information technology revolution occurs on campus. We had the initial IT revolution in the 1970's when administrative offices, like the accounts receivable office and the registrar's office started using mainframe computers, and we started to see classes in computer programming. In the 1980s we had the introduction of the personal computer and the start of on-line processing. Classes would have assignments that required students to go to the computer lab, where they could stand in line in order to use a computer to do their class reports on a word processor. In the 1990s laptop computers could be seen on campus and students communicated with their instructors and each other using e-mail and bulletin board systems and on-line chat. The Internet and World Wide Web became the standard method for beginning research. Now that we are in the 21st Century, or 3rd Millennium, we find that we are no longer required to use wires in order to communicate with each other or via the Web. Wireless communication has started to be used on campus and it is becoming an important facet of information sharing and instruction as more professors start using computers for their classroom activities and research endeavors.

We have used radios to communicate over long distances for many years, but it wasn't until the last few years that society started using wireless communication for access to the Web and other computer networks. Wireless communications use the Wireless Application Protocol (WAP), which is a universal open standard developed by the WAP forum and governs wireless communication. The programming used for WAP is based on the www-programming model. The model has three components: the client, the gateway, and the original server. HTTP is used between the gateway and the original server to transfer the content of the message, and the gateway acts as a proxy server for the wireless domain.

Another component of the WAP is the wireless markup language (WML). WML documents are subdivided into small well-defined units of user interaction known as *cards*. The users navigate by moving from card to card. The communications protocol stack of WAP has six layers—application, session, transaction, security, transport, and network—which can adapt to the standard Web protocols (Stallings, 2001).

The organization that developed WAP, the WAP Forum, was founded by an industry group in June of 1997 with the goals of bringing Internet content and advanced data services to wireless phones and other wireless terminals, to create a global wireless protocol across all wireless network technologies, to enable the creation of applications and content that reach across wide ranges of wireless bearer networks and device types, and to use and expand existing standards and technologies wherever possible. The purpose of the WAP Forum is not to develop products, but rather create a license-free standards environment for the entire industry to use to assist in the development of products to be used in a wireless setting. The forum identifies new areas of technologies whose standards do not exist or exist and need modification for wireless use. It is estimated that by 2004 the number of wireless subscribers will break the one billion mark (www.wapforum.org). Of course, most of these users will be using cell phones and PDA types of devices; nevertheless, the increase in the use of wireless communication on campus is obvious.

The area of wireless communication growth on campus, outside the student use of cell phones, is the Wireless LAN (WLAN). WLANs offer flexibility that cannot be found in traditional wired alternatives. They work best in situations where wiring costs are prohibitive, or where wiring is impractical, such as in older buildings or historical structures where rewiring is prohibited. (Littman, 1998).

The development of a standard to use for WLAN took seven years and was approved by IEEE Standards Activity Board as 802.11. The standard covers just about everything from wire augmentation and ad hoc networking to factory automation. 802.11 defines the physical (PHY) and the medium-access-layer (MAC) protocols. MAC works seamlessly with the Ethernet local area network standard. The PHY specification includes three transmission options. One is for infrared, which at present has few suppliers. The other two are RF based options and include direct-sequence spread spectrum (DSSS) and frequency hopping spread spectrum. The options cover a range of price performance requirements. Because of the existence of the standard, the mass-market production of components should help drive down the prices for WLAN. Some popular products available today for WLANs are IEEE 802.11 compliant PC card radio modules for original manufacturer equipment (OEM). The OEM PC cards are designed for easy integration by systems designers and developers and can even be installed in standard notebook and mobile computers. 11 Mbps WLAN technology operates in the unlicensed 2.4 Ghz band and promises a performance level comparable to an industry standard 10 Mbps Ethernet system with expectations that WLAN technology will soon be adopted by end-users as either a mainstream enhancement to wired networks or as a standalone network solution (Schneiderman, 1999).

WLAN technology has been enhanced by the widespread application and use of IEEE-802.11b wireless Ethernet standard, which uses DSSS methods in the 2.4-GHz ISM band with a data rate of 11Mbps. Inexpensive network interface cards (NICs), compatible with PCMIA ports for notebooks as well as ISA, PCI, and USB ports for desktops, have been introduced by many companies. The low cost of these NICs, virtually all of which are interoperable with one another, are making wireless connectivity an alternative to direct cable connections. The Wireless Ethernet Compatibility Alliance (WECA) promotes interoperability of 802.11b products and sponsors a formal testing and certification program. A major contributor to WLAN product availability is Lucent Technology. In addition to making chip sets for 802.11b NICs, Lucent's ORiNOCO Division also produces the infrastructure systems that connect to any 10Base-T Ethernet LAN. The division recently announced its AP-500 Access Point bridge, which allows wireless access within a building or small campus. With an external antenna the communication range can be extended. It is expected, that as the 2.4-GHz band gets saturated with more 802.11b NICs, Bluetooth-enabled products, and the many cordless phones that use this band, WLANs will probably migrate to the 5-Ghz band (Frenzel, 2000).

A number of universities have introduced WLANS on their campuses including: Carnegie Mellon, the University of Southern Mississippi and SUNY Morrisville (Olsen, 2000).

Higher frequencies seem to be the future for wireless communication. The upper frequency limits for wireless communication has been almost doubling every 10 years and the higher frequencies will continue to become more attractive as RF devices become more affordable and offer higher quality with denser base station deployments, and as the demand for wide bandwidth circuits and frequency reuse increases (Vanderau, 1998).
Bluetooth, a protocol form transmitting short-range radio signals to link electronic devices to the Web, which supports devices like: cellular phones, mobile computers, and portable devices like the palm pilot, still has some compatibility problems with WLANs, due to frequency interference problems, but these problems are expected to be solved soon. The problem is being addressed on a number of levels: the geometry or the distance between devices, the applications, packet size, packet length, operating rules and channel widths within the 2.4-GHz band, and the characteristics of DSSS, which is used in WLANS and the characteristics of frequency hopping spread spectrum (FHSS), which is used in Bluetooth. A current opinion is that the problem will be solved by the ability of Bluetooth to hop around the frequency to avoid the interference (Heftman, 2000).

In addition to the frequency-sharing problem, WLANs are slower than their wired counterparts, although the use of the MAC protocol can make for the efficient use of the available capacity. WLANs may need to support hundreds of nodes across multiple cells, and, in most cases, the WLAN will be connected to the backbone of a LAN for most purposes. This is accomplished by the use of control modules that can communicate across both types of LANs. In some cases, there also may be the need to facilitate the use of mobile computing in order to support ad hoc wireless standards. The typical service area of a WLAN is 100 to 300 meters in diameter.

It would seem that WLAN and teaching would go hand in hand. There are many advantages to using wireless technology for teaching, especially on older campuses, or in situations where no wired facilities currently exist. WLANs are currently being used successfully in a number of colleges and universities, but bandwidth is a major concern. On campuses engaged in collaborative research, real-time wireless collaboration has not achieved the level of use that many professors and information technology professionals expect. Another problem with wireless communication is that tracking the information on the network is not as easy as when the information is communicated from a fixed node. Broad range security is still not possible in a wireless environment unless a total encryption scheme is used, which adds a great deal of overhead to the network. Another concern is how a university implementing a WLAN will manage it.

The US Federal Communications Commission's E911 regulation requires that wireless network operators must pass a caller's phone number cell site, and cell sector location to a public safety answering point if personal wireless connectivity is used to call 911. This can help universities that are associated with a medical school or hospital.

Universities should engage in strategic evaluation of how they plan to handle computing enterprise wide for the next five years. The University of Wisconsin is working on a project called Project 1.6- Wireless, for example. In this approach the University is planning to move from a port based MAC authentication to a plan to eliminate the plug and proceed to a wireless campus. The plan encompasses a two to five year timeframe at a cost of approximately $1,500 per classroom and $600 per computer (www.educause.edu/etcom/reports/wireless.doc).

Implementing a successful wireless network depends on a number of factors such as: user interface, network log-on rate, response time, throughput, reliable data delivery, and perhaps most of all the amount of technical support available. Questions that need to be answered include: Which applications require wireless communication? What type of hardware would best serve the architecture? What software would work best? Is the wireless component to be restricted just to campus utilization? What type of connectivity is most appropriate? Are FCC licenses required? What are the traffic access patterns? Can the network management and routing system provide quality of service guarantees? What about unauthorized access and how will it be handled? What procedures can facilitate integration of fixed land based and wireless networks? Will there be a combination of wired and wireless systems? (Littman, 1998).

Perhaps the leader in using wireless communication in higher education is Carnegie Mellon University. They built the first and most extensive wireless computer network in the world and are about to update it. They are in the process of replacing "Wireless Andrew", a network that allowed anyone with a specially equipped laptop to link to the university's main computer. The old system covered seven buildings and part of the exterior of the campus, while the new one will cover the entire 103-acre campus, as well as a number of important off-campus buildings. The name Andrew comes from the university's two most important benefactors, Andrew Carnegie and Andrew Mellon. Lucent Technologies, the university's partner in the project will contribute $800,000 worth of equipment to rebuild the network, and Carnegie Mellon will spend $75,000 to rewire the system and replace the existing components. Each antenna-equipped network access point is hooked to the wired network of the university, and acts as a gateway for as many as 30 wireless laptops. When a user moves across campus he or she will move from one access point to another. There are 100 access points covering seven buildings. Most of them are indoors but a few are on rooftop antennas, which can reach across the main outside area of the campus.

The CMU system is rather slow compared to Ethernet LAN speeds with a data transfer rate of 2 Mbps, but it is still faster than a standard 28.8 modem link. The latest transmitters and receivers run at 2.4 Ghz as opposed to the 900 Mhz, because of all the interference at the lower frequency from cell phone and other electronic devices. CMU is engaged in $20 million in sponsored research into mobile and wearable computers, so it appears that technological development will continue in the wireless field (Houser, 2000).

Another school that is leading the charge in wireless computing is the School of Public Health at Johns Hopkins University. Between 1996 and 1999 the school has revamped their information technology infrastructure. In 1995-96 they modified their entire network. They replaced an aging IBM mainframe with a Digital 8200 AlphaServer, which was used as the primary e-mail server and as an application server for SAS, SPSS, and S+ applications, which was offered to all students and faculty. Each computer became part of a 10 MB Ethernet network with fiber connecting hubs and providing high-speed access to the rest of the university network in 1997 the computer labs were upgraded to be state-of-the-art computers running Windows NT and Macintosh OS.

Because of the age of the buildings and the limited space on the Johns Hopkins campus, creating new computer labs was not feasible. So laptop computers are used extensively on their campus. They experimented with wireless computing to address the laptop integration problem in 1997. By using a small PC card and a base unit the size of a Cracker Jack box, provided by Texas Instruments, Johns Hopkins was able to run performance tests. They used a pilot group of 40 students to further test the system, and after a test period of six weeks, where Internet access, downloading and everyday business was carried out, the system was declared viable. The pilot test was carried out with the assistance of Netwave Inc. (McKenzie, 1999).

An obvious advantage of wireless networks is that students can connect to the network from anyplace on campus. Drexel University is attempting to become the first to establish a fully wireless campus. The idea is to have a laptop become like a cell phone. Drexel first ventured into the wireless arena when they provided wireless connections in their library, where they offered students laptop computers with wireless adapters that could be checked out. The program proved so popular that the university started offering wireless computing in other buildings. There are 150 "access points", transmitters that are fixed to walls inside buildings, and about 20 antennas outside, that cover the campus in a single network, which allows users to roam across access zones. Drexel estimates that they will spend approximately $650,000 on the wireless additions, but they have spent $5 million on the wired network it is hooked up to. They use 128-bit encrypted radio frequencies for security, and the students, who were already required to purchase laptop computers, were also required to purchase a $175 wireless adapter for their computers. The residence halls will not have wireless capability because the students already have plug in capability there, but other universities, like Wake Forest University, found that students preferred the wireless connections even in their rooms, because they did not want to fool with the wiring (Carlson, 2000).

When WLANs were first introduced, they were supposed to be an alternative to wired networks. It was thought that the rewiring and relocation problems caused by the constant reorganization of businesses could be alleviated by the introduction of wireless networks. The pulling of wires, or the tearing out of ductwork would no longer be necessary. Phones, computers and people could be moved from place to place without having to be concerned or wait for rewiring to take place. It was believed that the wireless networks would over time pay for themselves. It is true that most universities and businesses do not have to be concerned with the rewiring process once they choose a wireless network, but most organizations have approached wireless communications differently. They tend to leave the wired networks in place and just to add a wireless component to the network as an enhancement to the existing structure. Information technology (IT) professionals are also finding that separate buildings on campus that operate on a single network can be connected most cost-effectively by using a wireless bridge or router.

The idea of a WLAN was initially greeted with a warm welcome, but the cost of installing one was a prohibitive factor. After the introduction of IEEE guidelines, new products were introduced and the price curve began to take effect, causing prices to drop and making the installation of WLANs more affordable and competitive with wired alternatives.

The convergence of telecommunications and computer industries continues. The dividing line between them has blurred so much that it is difficult to identify what is a computer and what is a telecommunication device. The Telecommunications Act of 1996 further stimulated this convergence. It opened the door for many different kinds of wireless communication devices that could be hooked up to wireless networks, while bypassing the myriad of local telecommunication regulations that stymied the growth of these networks.

Although more applicable for business, the concept of a wireless virtual LAN may also have a significant impact on college and university campuses. Recent research has been carried out on virtual LANs (VLAN), and how to bypass some of the problems that occur when using a VLAN in a asynchronous transfer mode (ATM) environment. When using ATM there have been problems in trying to connect to wireless mobile end-systems. A VLAN is a logical subgroup within a LAN that is created via switches and software, as opposed to manually moving the wiring from one network device to another. For example if a network administrator needed to create a sub-network of devices located at physically different places, it could be done without rewiring or relocating personnel, by the use of a VLAN (White, 2001).

In order to handle the mobility problem, a virtual path could be established within the ATM network. Another approach would be to allow switching capability at the base station. In order to accomplish this buffering of the ATM, cells would have to take place during the switching process. For efficiency purposes, the two functions should be combined. For example, since the mobile location function has to be added for wireless processing, this function can be combined with Internet Protocol Address Resolution Protocol (IP-ARP), LAN Emulation Address Resolution Protocol (LE-ARP) and connection setup within the same phase of the operation (LIU, 1998).

To assist with these problems, a new protocol has been developed to function within the ATM adaptation layer. This protocol is known as, ATM adaptation layer for improving TCP performance over wireless ATM networks (AAL-T). Since wireless connections are characterized by higher error rates and burstier error patterns, it is not well suited for transmission over ATM. The function of this protocol is to push error control to the AAL layer, which will allow the Transmission Control Protocol (TCP) to be responsible for only congestion control. AAL-T is based on an Automatic Repeat Request (ARQ) mechanism that supports quality-critical TCP traffic over wireless ATM networks (Akyildiz, 2000).

A university that did not have plans for a totally wireless campus, one that was just interested in setting up wireless computer labs in classroom buildings, for example, would not have any need for the mobility protocols previously discussed, but institutions, like Carnegie Mellon and Drexel, that are planning for extensive use of wireless facilities on their campuses, could certainly make good use of this protocol.

CONCLUSIONS

Most institutions of higher education are not considered leading-edge telecommunication organizations, due to their lack of funding, especially when compared to their commercial counterparts. True, there are some major universities that are research oriented and are blessed with adequate funding for research from grants and substantial endowments, but most campuses are just now becoming completely wired and have started to fully use applications like e-mail, distance learning, and Web-based classroom management.

The idea of taking these newly established wired networks and replacing them with wireless capability makes no sense. However, the idea of extending wireless capability to classrooms and labs that have not been previously connected has a great deal of merit.

From an instructor's prospective, there are situations when wireless capability would enhance educational opportunity. A personal example is appropriate. The Computer Information Systems Department at our university has a number of off-campus sites where the department's classes are taught. The classroom and labs used at these off-campus sites belong to other institutions, primarily community colleges. The classes are, for the most part, hands-on classes in information technology topics, such as e-commerce, client/server processing, and a number of computer languages. In order to successfully teach these classes, it is necessary for the students to have access to certain types of software. Many times these software products are not available at the off-campus site and to install them at the site usually causes problems with the licensing of the software and the network regulations at the host site. It would be easier for the instructor of the class to carry notebook computers to the site or to store the notebooks at the site and then to establish a WLAN in the classroom for the students to use while the class is in session. It would certainly be worthwhile for a college of university to look into wireless networks and applications for certain areas of their campus, especially if their students were already required to purchase laptop computers. It would seem that a wireless network would be a logical progression.

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