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ABSTRACT

This paper considers a basic question that many schools districts face in attempting to develop affordable, expandable district-wide computer networks that are resistant to obsolescence: Should these wide area networks (WANs) employ wireless technology, stick to venerable hard-wired solutions, or combine both. This publication explores the wireless option to WAN connectivity in educational facilities, examines its advantages and various limitations, and considers interface, security, and reliability issues. The paper also examines the aspects of a school district that make it a good candidate for utilizing wireless technology in creating a WAN. Final comments discuss ways to perform a building site survey before deciding to install a wireless WAN, and WAN infrastructure requirements and installation costs. (GR)

Wireless Wide Area Networks for School Districts

National Clearinghouse for Educational Facilities

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Network connectivity issues daunt school districts around the country. Schools need affordable, expandable computer networks that are resistant to obsolescence. But should these networks employ wireless technology, stick to venerable hard-wired solutions, or combine both?

A wide area network (WAN) is a communications network utilizing devices such as telephone lines, satellite dishes, antennas, and microwaves to span a larger geographic area than can be covered by a local area network (LAN). Typically, a WAN consists of two or more LANs. A metropolitan area network, or MAN, is a term sometimes used to describe a system that falls somewhere between a WAN and LAN and combines some of the features of both.

If cost were no issue, schools would build their WANs using fiber optic cable, which is capable of transmitting data at a billion or more bits per second (1 Gb/s). Fiber cable provides the fastest, most reliable, and secure way to transmit computer data. But it is often an expensive approach.

To connect their buildings when the Internet was in its infancy, school districts used basic telephone lines costing about $30 per building per month and offering modest speeds of up to 56 kb/s. Communications between buildings were usually limited to electronic text transmissions of administrative data, not graphics. The relatively low-speed connection was not a major issue, and the connection between computers in limited areas, such as offices and computer labs, was generally provided by LANs.

As demand for network access grew following the rapid deployment of educational technologies and Internet access in classrooms, so too did the need for higher capacity and transmission speed, known as *bandwidth*. Consequently, schools installed services such as ISDN (Integrated Services Digital Network) at 128 kb/s and T1 leased lines at 1.5 Mb/s. These have been expensive options, with a T1 line, for example, costing upwards of $300 per month per building and as much as $2,000 per month for service to remote locations. And, because these lines had to be shared by many users with an attendant reduction in speed for each additional person using the system, speeds at the desktop could be anything but impressive.

Today, with computers in nearly every classroom, Internet access for every computer, and computer labs placing more demands on network resources than ever before, inter-building connectivity has become a hot issue, with schools scrambling for all the bandwidth they can get. But when examining such expensive options as T3 lines that offer speeds of up to 45 Mb/s and dedicated fiber connections costing thousands of dollars per month to lease, many school districts have been seriously viewing the wireless option. Its numerous advantages include high bandwidth, zero ongoing connection costs, reasonable periodic maintenance costs, no trenching, no line leasing, and no need to obtain easements to traverse public rights-of-way.

The Wireless WAN

Wireless WANs are hardly new. They have been utilized since the mid 1980s when microwave transmissions were beamed about by complex and powerful transmitting units that required Federal Communications Commission (FCC) licenses and radios and antennas costing $40,000 to $50,000. Today, wireless systems can deliver up to 100 Mb/s speeds at 40 miles' distance, and speeds are increasing.

Wireless systems gained a foothold for widespread use with the adoption of a standard, IEEE 802.11, in 1997 by the Institute of Electrical and Electronics Engineers that established clear guidelines that helped wireless vendors begin to produce standardized, interoperable products. IEEE 802.11 established 1 Mb/s and 2 Mb/s wireless data transmission rates, but these speeds were inadequate for most business requirements, and wireless LAN and WAN systems were slow to be adopted.

Glossary of Terms

LAN. Local area network. A communications network of computers or other electronic equipment in a local area such as a school or office.

MAN. Metropolitan area network. A communications network designed for a city or town that is larger than a local area network but smaller than a wide area network.

WAN. Wide area network. A communications network utilizing devices such as telephone lines, satellite dishes, antennas, and microwaves to span a larger geographic area than can be covered by a local area network.

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kb/s. Kilobits (one thousand bits) per second.

Mb/s. Megabits (one million bits) per second; one thousand times faster than a kb/s.

Gb/s. Gigabits (one billion bits) per second; one million times faster than a kb/s.

Access point. An antenna that transmits and receives signals over the airwaves and thereby serves as the interface between the wired network and wireless LAN adapters (see definition for wireless network adapters) installed in laptop computers or other wireless devices.

Backbone. The principal or main transmission line in a network that carries data gathered from smaller wires or cables that interconnect with it.

Bandwidth. The amount of data that can pass along a communications channel in a given time period.

Bit. A unit of information that has the value 0 or 1; short for binary digit.

Byte. A unit of information comprising eight bits, generally used to signify a letter of the alphabet.

Encryption. Use of code to obscure communications. The numbers, such as 128- or 40-bit encryption, refer to the size of the key used to encrypt the message. Encryption with a 128-bit key would require 309,485,009,821,345,068,724,781,056 times more computer power to decipher than encryption with a 40-bit key.

Ethernet. A popular apparatus for enabling communications between two or more computers over a communications cable. Ethernet supports data transfer rates of 10 Mb/s. Fast Ethernet, a newer version, supports transfer rates of 100 Mb/s. Evolving 10 Gigabit Ethernet systems support transfer rates of 10,000 Mb/s. Faster systems are being developed.

Fiber optic cable. A thin strand of very pure glass covered in plastic developed to supercede the use of copper cable for transmitting great quantities of information encoded as pulses of laser light.

Firewall. A security plan intended to prevent unauthorized users from accessing a computer network.

Hard-wired. To connect (computer components, for example) by electrical wires or cables.

IEEE. Institute of Electrical and Electronic Engineers, an international standards organization.

Interoperability. The harmonious working together of different types of computer hardware and software.

Virtual private network. A private network that uses the Internet to connect remote sites or users and that utilizes advanced security techniques to create secure communications.

Wireless network. The extension of a LAN or WAN without wires so that devices equipped with wireless network adapters can communicate with the wired network via the airwaves (also see access point)

Wireless network adapters. Electronic circuit boards that install in a variety of computers, from desktops to handhelds, and are intended, in wireless networks, to give users of laptop computers, notebook computers, and handheld devices the ability to move freely within a campus or building environment while maintaining uninterrupted connection to a network and the Internet.

The 1997 technology also was hampered by high costs, with wireless network adapters typically costing $400—twice what they cost in 2001. The earlier products also provided little security, permitting nearly anyone to tap into a private wireless network.

Recognizing the critical need for faster data transmission and improved security, IEEE ratified what it called the 802.11b *high rate* standard, which permits transmissions at 5.5 and 11 Mb/s. The revised standard fostered explosive growth in wireless LANs in the business community and, more recently, in schools because it promised wireless transmission speeds rivaling the wired Ethernet. In practice, however, IEEE 802.11b only permitted a data transmission rate of about 7 Mb/s—still impressive, but insufficient to transfer data from, for instance, a digital video disk or a video file.

IEEE has recently approved the 802.11g standard, which permits transmission rates of 54 Mb/s and makes wireless wide area networks more viable than ever. This standard is backwardly compatible with the existing 802.11b standard, and it will usher in many new products that harness the increased speed.

For schools, the primary advantage of IEEE 802.11b and subsequent standards is fast communication between buildings with no recurring costs other than periodic maintenance expenses. That means installation costs can be amortized within a year or two in most cases by eliminating fees to telephone companies.

Wireless installations enjoy another advantage over cable in that they represent a one-time capital cost that can benefit a school district for many years. This scenario is far more likely to attract grant money than the situation where a school is making recurring payments to a service provider—typically the telephone company—for leased lines.

Line of Sight Limitation

A major limitation of wireless WANs is that they require a clear line of sight between the transmitters and receivers that provide the communications link between buildings. While installations exist where signals can traverse short distances through such obstructions as heavy foliage, in general wireless transmitters and receivers must be located so that no obstructions exist between them.

What does this mean for a school district that has several buildings but none offering obstruction-free signal paths? The problem is not insurmountable. Moderate obstructions often can be overcome by using transmitting towers. In some cases, school districts have employed existing structures, such as light poles, to surmount problematic transmission conditions caused by obstructions between buildings.

Interference, Security, and Reliability

If other cost-effective, high speed wireless products operating on the licensed 5 GHz frequency band become available, schools will be able to transmit data more securely over their wireless WANs. Experts are debating the value of the 5 GHz products for building-to-building connectivity. Of note are concerns over licensing issues and the shorter transmission distances possible on this frequency compared to the two lower frequencies—900 MHz and 2.4 GHz—presently authorized by the FCC for unlicensed microwave transmission. Most wireless WANs operate on the 2.4 GHz band.

While unlicensed use frees a school district from the red tape of government approvals, it also opens up the possibility of interference caused by others using the same, free, unlicensed frequency. To solve this problem, wireless equipment manufacturers such as Lucent Technologies, Cisco Systems, Inc., 3Com Corp., and Symbol Technologies, Inc. rely on the IEEE 802.11 family of standards, which include communications protocols that let users on a particular wireless system communicate freely while blocking unauthorized users. This eliminates most interference problems.

But there is still the security issue to consider. Present wireless WAN security technology offers two levels of encryption: 40 bit and 128 bit. Typically, 40-bit encryption should be sufficient to prevent unauthorized entry. For greater security, experts recommend 128-bit encryption.

Encrypting signals that traverse the wireless link itself is just one of several layers of security that a school should provide for its computer networks. Other appropriate security methods such as password authentication, firewalls, and virtual private network solutions can greatly reduce security risks for users and for LAN-based resources networked over a wireless WAN.

Wireless systems sometimes can be considered more reliable than leased lines because all the wireless equipment belongs to the owner and remains on the owner's property. Leased lines may experience problems caused by power failures or other interruptions, including unscheduled repairs and maintenance by utility companies. Microwave transmissions can travel up to 25 miles without significant signal degradation and can withstand most weather conditions, including wind, rain, and snow, although they are susceptible to heavy fog. But severe wind might dislodge an antenna, and caked ice and snow can degrade signals. Antennas must also be protected by lightning arrestors to avoid severe damage and consequent loss of service.

Though areas that experience severe weather may be unsuitable for wireless connectivity, weather is generally not a significant factor. An installation at the Bronx Zoo in New York City survived the relatively harsh winter of 2000 without fault. Arizona's Vail School District connects 15 buildings wirelessly, and the district's technology director Billy Martin said the system withstands the Southwest's infamous desert storms without a problem.

The Wireless WAN—Is It For You?

School districts with multiple buildings within a few miles of each other but located outside of dense urban environments are good candidates for wireless WANs. Unless special arrangements are made with local utilities or other institutions to provide connectivity via fiber, no other system delivers the high bandwidth connectivity between buildings that wireless offers.

Other factors to consider beyond building proximity are terrain and visual obstructions. Wireless works best when terrain is relatively flat. Hills and valleys may destroy clear lines of sight between buildings. Such was the case at Saugus Union School District in Santa Clarita, California, which considered and rejected a wireless solution, despite the recurring fees it had to pay Pacific Bell. In the words of James Klein, the school district's director of information services, "We would have preferred to avoid recurring costs altogether by using wireless links for the wide area network; however, this solution would have required clear line of sight between the radios, which was not possible in the canyon where our school district is located."

Wireless WAN solutions can work in concert with wired network backbones. These hybrid solutions may take many forms and provide satisfactory performance, giving schools the benefits of a wired network backbone and the flexibility of wireless connectivity. For example, a school district may choose a wireless system to connect buildings up to 25 miles apart that have a clear line of sight and use leased or fiber lines to connect buildings that don't.

The thousands of mobile classrooms and temporary buildings in this country offer a strong case for wireless building-to-building connectivity. Many of these facilities lack network capability, and school districts are loath to spend money to install network cabling in such temporary structures. Moreover, burying cable between structures and main buildings is often too impractical or too costly.

This was the case with the Wake County school system in North Carolina's Research Triangle Park region, which decided to wirelessly connect its mobile classrooms to its district network. "Our first initiative was to provide connectivity to our mobile classrooms, which number about 525 here," said Vass Johnson, director of networking. "We already have a fiber network throughout the district, but every year the facilities department must relocate a host of mobile units to meet changing needs at many of the schools. We were constantly reinstalling the fiber connections to keep the desktops and laptops in these classrooms connected with the campus LAN. With wireless, there's no need because the mobile classrooms are always connected. We save a lot of money by not having to make these adjustments every year."

Planning the System—Performing the Site Survey

Making a final determination about wireless requires a site survey of all buildings involved. If line-of-sight issues arise, a relay station or antenna can provide a third point for a line of sight between two buildings with a blocked signal path. Surveys also can determine likely antenna placement locations and they can provide installation cost estimates.

A school district in North Plainfield, New Jersey, illustrates how a school system with six school buildings and one administrative building can first consider and then make the actual transition to a wireless WAN. The seven buildings had been connected to their district network (centered in the high school) by leased ISDN lines operating at 128 kb/s. Director of technology Ron Fisher realized that the proximity of these buildings to each other (within a 1.5-mile radius) made them good candidates for wireless connectivity. Accordingly, the school district authorized a site survey of all seven buildings.

During the survey, workers installed one omni-directional antenna about 20 feet above the high school's roof and attempted to make contact with directional antennas located at each of the six satellite locations. Initially, they established 11 Mb/s connections with four buildings. The line of sight to the East End school, located in a valley, however, was blocked, and the high school's antenna could establish a maximum connection of only 5.5 Mb/s with the district administrative office because of its distance from the high school and its relatively low profile.

Nevertheless, the school's technical consultants recommended that the high school remain the central point for communications with the other buildings, since the line-of-sight problem could likely be solved by placing the antenna on a chimney on the high school. Failing this option, the project could be implemented in two phases. Phase one would connect the first five buildings and phase two would connect the Somerset and East End schools once renovation work was completed at Somerset school. At that time, a relay antenna located at Somerset would be used to establish a line-of-sight connection with East End and the high school, thereby providing a bridge to the two buildings having obstructions between them.

Infrastructure Requirements

The hardware required to install a wireless WAN is simple. It consists of access points, which provide access for all users to the wireless network, antennas with mounting hardware and lightning arrestors, rooftop antenna towers of varying heights as needed, cabling required to connect antennas to the LAN, and access to standard electrical outlets for each access point.

In each building, the wireless network terminates at an access point that connects to a local hub or switch and serves as a bridge to the wired LAN. Access points must be located as close as possible to the building antenna (less than 25 feet is preferred to avoid loss of bandwidth) and must be protected from the elements.

Installation Costs

Installation costs per location will vary depending upon the height of antenna towers and the extent of cabling required. In general, materials, equipment, and installation costs will likely range from $4,000 to $10,000 per building. Where towers are needed, add $2,000 to $10,000 per tower.

These one-time costs permit buildings to be connected at up to 54 Mb/s. Compare this to the telephone company's charge of $3,500 per year for a 1.5 Mb/s T1 connection. While good wireless WAN installations rarely require continuous adjustment and maintenance, it is advisable to set aside about 15 percent of the initial installation cost for annual maintenance.

Simple, Fast, Affordable Alternative

The promise of connected schools remains just a promise unless school districts find ways to efficiently bring to all students and staff the electronic resources available on the district-wide network and Internet. It is incumbent upon each school district to evaluate the feasibility of wireless networks as part of its overall plan to implement educational technology within its schools.

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Additional Information

See the NCEF resource lists on *Technology Integration* and *Wired and Wireless Networks* at *http://www.edfacilities.org/rl/*

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