The Connected Learning Community
Technology Roadmap

Introduction

Chapter 5 Planning the Technology System:

OVERVIEW

This chapter presents the advantages of networks in educational settings and introduces the basic elements of a technology system and network terminology and configurations.

The Building Blocks

In your technology planning journey, you are the architect of the territory you're about to traverse. And your technology system, when completed, will resemble a city or state or country—any area of organized human activity. The components are as follows:

- **Personal computers,** scattered throughout the system and organized into networks, are like houses or housing developments in various communities.
- **Servers,** much like the business districts and public utilities of any town, provide basic services. These services include communications (electronic-mail or voice-mail servers), databases, productivity software tools, software libraries (CD-ROM servers), remote administration and asset management tools, and so on.
- **Local area networks (LANs),** the high-speed communication systems connecting servers, personal computers, and peripherals, are like the streets within each community.
- **Wide area networks (WANs),** collections of LANs linked by high-speed modem connections, are the state or interstate highway systems that link the communities into a productive whole.

Assembling the system will require informed decisions about the following:

- **Communications infrastructure**—the "backbone" of your network, including the cables and wiring that connect the network's various parts. The infrastructure provides the *bandwidth*—or carrying capacity, such as that provided by a water main in a public water system—to carry multimedia to each computer on the network.
- **Hardware and software systems**—the tools that run and support the instructional, administrative, and productivity software: personal computers, servers, networking hardware, networking software, and workgroup software like electronic mail, scheduling, and connectivity to the information highway.
- **Productivity software**—tools that teachers and administrators use to simplify and manage tasks, and which students can use to research, write, analyze data, and present their work.
- **Specialized applications**—tools designed to meet specific needs, for example, supplementary curriculum applications like multimedia CD-ROMs; library automation; and administrative automation solutions for student records, accounting, and state reporting.

System components are described in more detail in following chapters as they relate to network and school administration and classroom use. Included are discussions of the choices you face, tips on integrating components into the education setting, and guidelines on costs and budgeting.
Network Basics

In the simplest terms, a computer network is a collection of computers that communicate with each other. Specifically, a network allows users to share three things: resources, files, and applications.

1. **Sharing resources.** A network allows users common access to any equipment (such as disk drives, printers, and CD-ROMs) regardless of the physical location of the equipment or the user.
2. **Sharing files.** On a network, files can be shared in three ways: 1) computer-to-computer transfers, 2) temporary storage, and 3) long-term group editing and archiving.
3. **Sharing applications.** One network copy of a software program (licensed for a specified number of users or desktops), such as a school's electronic card catalog, can be used by all the licensed users or computers on the network. That provides a potential cost and time savings compared to using a stand-alone copy at each computing location: For example, software licenses purchased for multiple users or desktops are typically much less expensive than the same number of individual copies of a program, and network versions of software can be centrally administered, making it easier to update and manage software configurations over time. Additionally, with network programs, students and staff can access the programs they need from any computer in the school.

Network Advantages

Local area networks within schools allow students to share their work with other students; teachers to access student work from anywhere within the school; and administrators and staff to share student records, memoranda, and other information. With a district network, those same capabilities can be expanded so that data sharing takes place *among* schools throughout the district. Once the district or school network connects to the Internet, the opportunities grow even larger.

Benefits of a local area network for administrators, students, and teachers include the following:

For administrators

- Central storage of administrative records, with access from anywhere on the network
- Decreased cost of record-keeping and management functions
- Easier update of software, backup of centrally stored data, and protection of data from accidental damage
- Cost savings from use of shared network resources such as disk drives and printers
- Easier and more effective internal and external communications
- Ability to offer new classes or to supplement current classes through video conferencing and Web sites
- Access from home during inclement weather and off-hours

For students

- Ability to share work with others around the world through Internet connectivity
- Remote access for homework help
- Ability to submit assignments while traveling or during illnesses
- Access to active information sources such as weather satellites, news bureaus, and working scientists
- Interactive and collaborative learning through access to multimedia, video conferencing, and e-mail
- Exposure to national and global perspectives
- Encouragement of verbal communication, writing skills, and articulation of ideas because of the text-based nature of networks

For teachers

- Ability to facilitate open-ended student learning using the Internet
- Access to informational postings and student data
- Access to the latest information and materials to update curricula and to keep teaching skills fresh
- Access to video conferencing for question-and-answer sessions between students and teachers or experts in different locations
- Ability to communicate with other teachers, parents, administrators, and curricula experts on a one-to-one basis by e-mail

Network Terminology

A **server** is the computer that contains the disk drives, CD-ROM drives, files, printer, and other resources to be shared among the network computers. The server acts as an information manager and as a centralized source of one or more services for network users, such as data or voice-mail applications, shared software, and other productivity tools. The options available are limited only by the hardware and software installed to provide these resources. In general, the server:

- Manages interactions between computers on the network.
- Manages interactions between networks (LAN to WAN to Internet).
- Allows multiple users to run programs that take more than one computer to use (e-mail, Web access, networked CD-ROMs).

A **client** (or workstation) is any computer on the network that is not a server. The client looks to the server to get part of its job done for its user, whether that be actual processing (as in the case of network computers or mainframe access terminals) or simply gaining access to a program executing on the server and delivering information across the network. Clients act as an access point for one or more users to share data, programs, and services.

Local area networks (LANs) are the high-speed communication systems that include personal computers, nodes, wires, and servers. LANs typically are systems in close proximity, usually within the same building. A LAN provides the capability to share programs, information, and resources such as disk drives, directories, and printers among personal computers. LANs are generally of two types:

1. A **server-based LAN**, also referred to as a client/server, typically consists of a single dedicated server that shares its resources with other computers (also called *nodes*) connected to the LAN. The other computers in the network are configured as workstations and may use only the shared resources of the server. When the server is dedicated in this fashion, its purpose is to serve the needs of the network; it does not typically serve a workstation role. Server-based LANs have high performance, allow for easy centralized administration of resources, and provide the most options for security and access control.
2. A **peer-to-peer LAN** allows every computer on the network to act as a non-dedicated server so that any one of them can share its resources with any other. Additionally, every computer can act as a workstation. Peer-to-peer networks allow the greatest flexibility for the location of information but make administration of data resources and access control more difficult. Constant signal traffic between all points in the network can also cause performance (speed) degradation in larger peer-to-peer configurations.

A **wide area network (WAN)** is a collection of LANs that is not geographically limited in size. WANs use high-speed modem connections via telephone lines to connect to LANs. The networks of computers that make up the Internet are connected to form a WAN.

Network Topologies

Topology is the way computers are linked together in a LAN. The three most common topologies are bus, star, and ring.

Bus network.

In this, the simplest type of LAN topology, coaxial Ethernet cable is strung as the "backbone," connecting all computers, printers, servers, and other hardware. The cable can be laid out on the floor, in the walls, in the ceiling, or in any combination of these, as long as it is one continuous line. A bus network is probably the simplest and least expensive to install because it uses a minimum amount of cabling. However, any failures in common cable will disable computers and other hardware along the line. Because such failures can be difficult to locate in a large bus network, this topology is no longer a popular one.

Star network.

In a star topology, the most common type used today, personal computers and other devices are connected to a central "hub," a hardware device with several ports, into which a network cable connection can be plugged. This arrangement limits possible disruption of the network: If a cable breaks, only one spoke of the network is disabled, making it easy to locate the problem. Each personal computer is a "point" on the star, radiating out from a hub that connects to the LAN. As the number of personal computers increases in a given location, you can connect clusters of them together and then connect each cluster to a hub.

Ring network.

In this topology, the computers are linked in a ring-like loop. As with bus networks, information is passed from computer to computer. By using "repeaters"—hardware used to boost the signal—a ring network can cover a much greater distance. The ring network is a compromise in cost between bus and star networks, although speed decreases as computers are added to the ring.

Which network topology is right for your school or district? The choice will be driven by any existing infrastructure and by performance. New installations should favor newer technologies, both for greater performance and reduced maintenance costs. Most new sites build in star and ring configurations to maximize performance and ease of maintenance. Segments of a star network (defined by centralized hubs) can be easily isolated for repair while not affecting other users on the network. Older bus technologies are at a disadvantage here. Bus topology is usually not a first choice, except for modest improvements to already existing bus configurations, because of reduced speed (compared to ring topology) and troubleshooting difficulties—one disabled node can easily affect the traffic on the entire network.

Now that you have a basic understanding of the various network terms and components, you are ready to move on to planning the actual infrastructure that will support your network.

Chapter 6 Planning the Infrastructure

OVERVIEW

The most visible part of a network—the servers and client computers—depend on a less-visible infrastructure to share data and to access the outside world. This chapter describes some of the key components of the network infrastructure and provides planning tips to help you build a system that meets your school or district's current and future needs.

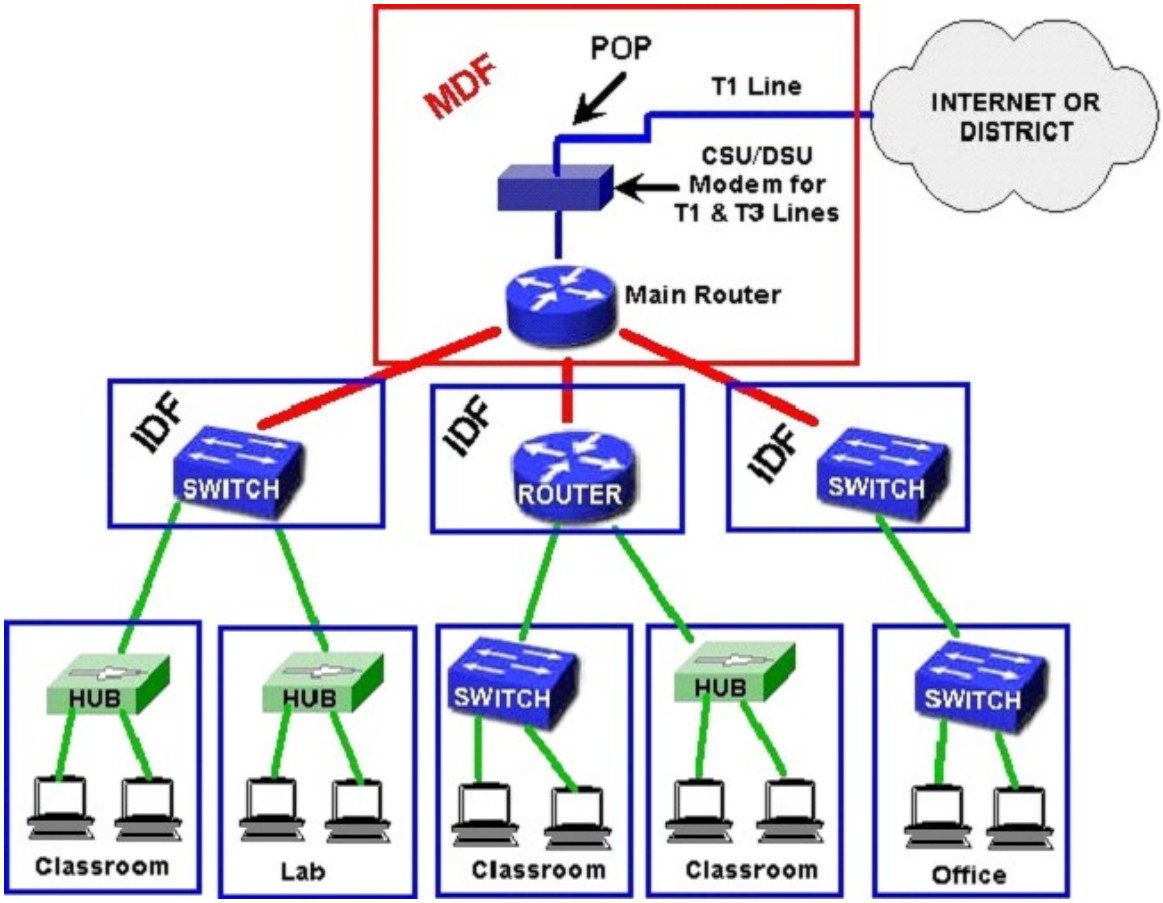
Your Network's Nervous System

It's easy to take for granted the hidden structures and processes that make networks work. All the services you use on the network depend on a hidden web of cables and hardware whose sole job is to move information from place to place. Like the nerve fibers that transmit messages to our muscles and initiate an action, your network's infrastructure turns a click of the mouse in your classroom into a multimedia show, an e-mail message, or access to data on a shared server.

Informed Decision Making

The ability to upgrade your school or district's network to embrace more services, more users, and more geographically distant segments will depend on some of the decisions you make when first planning and installing the network infrastructure. The tips in this chapter will help you plan an infrastructure that is right for both your current needs and future expansion, but they are just a starting point. Infrastructure choices determine the future of your network and are among the most expensive to change if a mistake is made. Careful planning depends on your ability to communicate your school or district's needs effectively to technology professionals, and on being an informed consumer in the network hardware marketplace.

When you consult with technology professionals in your school district or among your corporate partners, be familiar with both your needs and the relevant hardware necessary to make connections within your school, across your district, and to the Internet. Also be thoroughly familiar with any infrastructure already in place so that your technology consultant can make an informed decision about whether to expand an existing topology or consider an upgrade for the entire system.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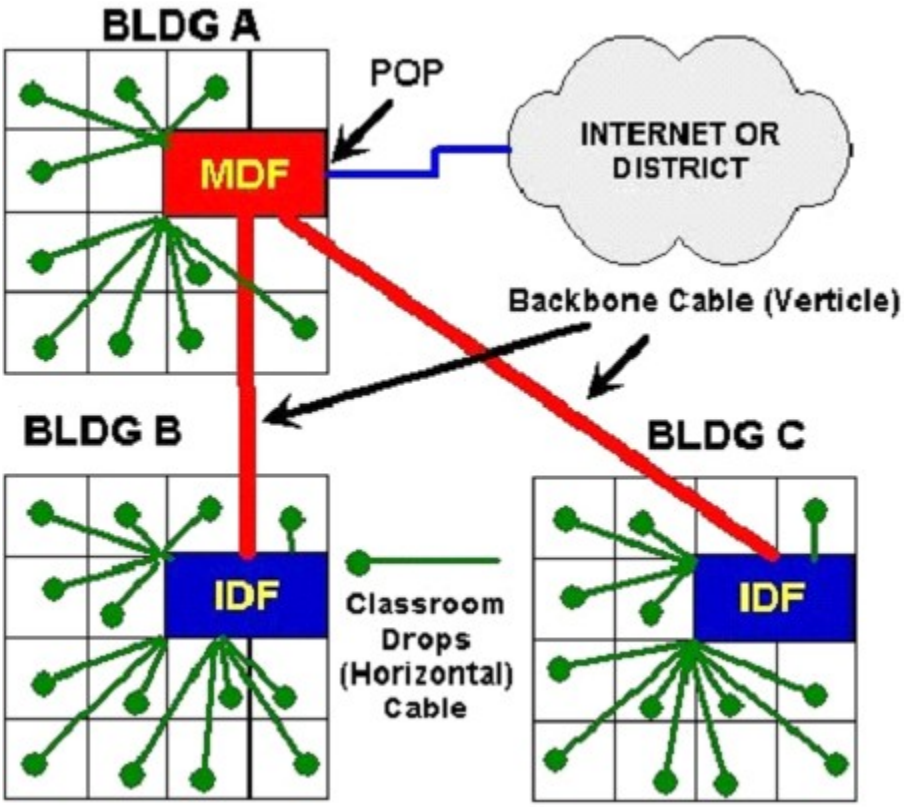

Connectivity Within Schools

Take a look at the diagram above, a "local map" of a basic district networking system. Each school is a virtual "town"—a Connected Learning Community. Exploring the Connected Learning Community begins by leaving the local hard disk drive; you can move from computer to computer or send electronic mail by sending signals down *cables*. As new services (like a CD-ROM server or centralized database) become popular and receive more users, classrooms or labs will need to centralize and route traffic to avoid a tangle of cables and crossed signals. *Hubs* are the link between key shared resources and the individual computers in the classroom, lab, or office. Good planning—in the Connected Learning Community sense—means understanding how to optimize the network and avoid bottlenecks and accidents. Let's take a look at the elements that carry the traffic for students and staff.

Cabling

Cables are the wires that connect individual computers, enabling them to transmit data from one point to another. These include not only the wire that runs from the interface card in a computer to wall- or floor-mounted network cable jacks, but also the wires between those jacks and the nearest hub. These wires may run under floors, behind walls, above ceilings, or all of the above. Remember: It is *always* cheaper to install an access point (jack and cable running within a wall to a specific room) for your computer networking cable during the *initial installation* than to add connections to an existing system later.

Cable types.

The most up-to-date information-highway building materials have high speed limits and can handle a significant traffic volume. The most capable cabling for local routes (from personal computers to hubs and on to the server) is *Category 5 twisted-pair* cabling, made up of four pairs of wires twisted about each other to eliminate electrical noise.

When purchasing this cable as part of your total infrastructure installation, look for certification (through a cable test report produced by the installer) that the cable has been tested to handle the highest possible transfer speeds (up to gigabit transfers). Most cabling should handle a minimum speed of 100 megabit data transfer. The installer should be able to test and certify the speed the cabling can truly handle.

To give you an idea of just how fast the transfer is, let's look at 100 megabit, a speed rapidly becoming the standard. At this cable speed, the network can move the entire contents of 100 floppy disks from one place to another every second! Gigabit speeds are 10 times faster, allowing the transfer of up to one gigabyte of data (the equivalent of an entire hard disk in 1996) every second.

The highway you build to connect segments of your network (such as between floors in a building or across a local campus) will likely be made up of *fiber optic* cable. Fiber optic connections are typically made between specialized types of hubs built to handle and relay traffic between segments of your network.

Unlike twisted-pair copper wire, which, like standard telephone wiring, conducts electronic signals, fiber optic cable transmits your school's data at very high speeds using pulses of light. Because of its price (about 10 times the installation cost of twisted-pair cabling), fiber optic cable is rarely used for connections directly to the desktop. However, its high transmission speed and very large traffic capacity make it ideal for moving multimedia and other large flows of data from one part of your network to another. Ask your network installation professionals about using fiber optic cable as a backbone for the key transfer points in your network.
Cable prices vary, but are usually presented in a proposal as a calculation of cost per foot, connections required, and the labor necessary to run the cable above ceilings, under floors, and behind walls in your unique environment.

Hubs

Once a cable has been connected to a computer's network interface card, where does the other end go? In most networks, the cable bundles coming from one or more classrooms and labs eventually wind up linked to a hub. Hubs are central points of connection in your network that manage traffic and pass data between servers, client computers, and peripherals such as shared printers. Hubs are the traffic managers on the information highway, ensuring that many requests for services coming from many computers are sent to the right place at the right time. Hubs can also boost signal strength and link segments of a widely dispersed network. As you can see in the district network map, hubs are the last local stop for data before it is passed to another device (such as a CSU/DSU, in the case of relaying data over analog leased lines) for transmission out of the local area network.

Purchasing Tips
When purchasing cables and hubs, keep in mind the following:

- *Buy for the future.* Plan to purchase the highest capacity, highest quality possible. As both software and hardware advance, the demands on your network for data transmission will grow dramatically. That "special of the week" offered by network installation vendors is often designed to clear older technologies from inventory to make room for state-of-the-art products. Look for manufacturers that offer flexibility (for example, 10/100 megabit switchable or upgradable hubs), and don't be reluctant to shop around. Your local telephone or cable provider may well be entering this market and looking for your business at an attractive price.
- *Build in flexibility.* Today's activity room may be tomorrow's classroom; yesterday's hall closet may end up containing the hubs for your network. Whether you plan on using classroom computer sites or centralized labs, run cable to every room that could

conceivably hold computers in the future. An investment in installing network connection points today is far less expensive than patching cable and ports into an existing network in the future. For hubs, choose a centralized location when building a wiring closet. Avoid locations that would be physically impossible to expand or very difficult to connect by cable to your servers.

- *Get more than one quote.* Hub and cable installation prices vary dramatically, based on both your needs and a vendor's resources. Ask for referrals from other schools or business technology professionals. Your local Microsoft Solution Provider can be a resource for determining your cabling and other network hardware needs.
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Bringing Your District Together

Once your local school is wired, you'll soon look toward tying your district's other schools into one integrated Connected Learning Community. Your local area network will need to have access to higher-capacity "highways" that can make sending e-mail, accessing administrative data, or browsing a Web page at a remote location as easy as accessing the server down the hall. Once those connections are built, each school LAN shown in the boxes at the bottom of the district network map can be integrated into the larger wide area network (WAN).

WAN Connectivity Infrastructure

Connecting distant points to a centralized network presents a different set of technical challenges than wiring a two- or four-building local campus. You'll need to invest in new hardware and software to provide access to data transmission lines, provide data relay to remote locations, and manage security for connections to the Internet.

Routers, relatives of hubs, provide traffic management and relay services between your network and the telephony network that will move data to and from other schools or the Internet. The latest routers provide high transmission capacities and feature hardware-level error checking, firewall services, data compression/encryption, and more. You will need one router, along with one or more channel service units/data service units (CSUs/DSUs).

The CSU/DSU manages how different kinds of data are interpreted and passed to the routers linking to the LAN. How many CSU/DSU units you will need depends on the type of high-speed connection lines available between the district LAN sites you want to link to a WAN.

In the sample district network map, a CSU/DSU is acting as a translator between each school's network and the higher-speed line available between sites. At the district level, a second CSU/DSU for each incoming school traffic stream stands ready to "decode" the highly compressed, high-speed signals coming over the T1 line and to relay that information to the district's router for relay to and from the Internet.

Leasing Lines

How are these high-speed connections between schools and district gateways to the Internet built? As mentioned, schools use existing parts of the telephony network to interconnect the individual networks that make up the WAN. Since most schools (or private companies, for that matter) do not have the resources to install and maintain their own private, high-capacity links for voice and data across a large geographic area, telephony service providers lease these links for an installation fee plus a monthly subscription. Choices are fairly limited, but somewhat sophisticated in how they can be configured to meet your needs. Your district or outside technology consultant can assist you with your decision. Some of the options include:

- *T1 line.* This entry-level WAN and Internet access link is the most common solution for data transmission. It is also one of the least expensive, since it can be used for both voice and data traffic. In fact, you can "discover" funds to allocate to T1 leasing by moving your regular telephone traffic from its current configuration over to the T1. In the sample school district

map, this link provides high-capacity data transfer (1.54 megabytes per second) between schools and the district.

- *T3 line.* The T3 is the same type of link at a significantly higher transfer rate (45 Mbps) and correspondingly higher cost. Districts with very high traffic loads coming from many locations may find this the most cost-effective solution in the long run, but will endure significantly higher start-up and leasing costs.
- *Fractional line.* If your school or district's budget is too tight to afford a T1 or T3 line, consider leasing a fractional line. Both T1 and T3 lines can be "split" among several customers, a way of "sharing the road" with other computer traffic headed to the same general area. Think of it as being allowed to drive in one or two lanes of a four-lane highway. Later, when your school or district's usage rates and budget expand, you can add "lanes" (capacity) to improve performance.

Accessing the Internet

Making the connection to the Internet requires the same hardware investment as connecting to the wide area network. The primary difference lies in where the data connection ends. In a WAN, a physical connection runs between each school in your district. To provide access to the Internet, one or more LANs must connect directly to an Internet service provider (ISP), typically via a fractional or dedicated T1 or T3 line.

Cost of Infrastructure

So how much will it cost to put all these technologies in place? Prices for installation and ongoing service vary dramatically by region, provider, and your school or district's unique needs and/or hardware configuration. Be sure to seek recommendations and benchmarking data from other school districts and businesses, and get multiple proposals before you invest.

The table that follows gives a general idea of the current cost of making the network connections illustrated. However, keep in mind that regional price variation and quickly changing technology make estimation difficult. Be sure to investigate government initiatives and corporate sponsorships for price reduction options that allow schools to access the Internet more easily. You can also contact your local Microsoft Solution Provider, telephone service (local and/or long distance), cable company, and Internet service providers for quotes on the cost of access and for information about the Universal Service Fund and other incentives that may be available in your area.

Infrastructure item/service	Approximate cost
Leased T1 (school to school or school to ISP)	$1,000 installation fee plus $300–$400 per month, depending on fractional capacity and traffic carried
Router and CSU/DSU	$2,500–$3,700 per location (required at each end of the connection, whether school or ISP)
Internet access	$1,500–$2,000/month for direct connection via leased line

Pre-purchase Considerations

Before you purchase your school or district's network equipment, be sure to consider the following:

- *Total cost of ownership (TCO).* It's easy to get caught up in the features of individual technologies and lose track of the need to purchase with an eye toward cost management. Look for equipment that offers remote administration tools and usage reports and that can be configured to take advantage of your cost/use data. As with your client and server

computers, investing in as few brands or types of expandable hardware as possible limits support costs and ensures you get the most for your computing dollar.

- *Physical space needs.* The number of routers, hubs, and cable can expand quickly as users and access are added to your network. Consider equipment security, temperature control, cable access, and floor space that will be needed to comfortably store and troubleshoot your equipment.
- *Usage policies*. You will need to establish usage policies—who has the right to use the computer system? when? under what conditions? how can unauthorized use be prevented?—before the system is installed. Having considered usage questions in advance, you'll have a preemptive answer to those people concerned about data security and system misuse.
- *Internet access policies.* Decisions about how to limit access to sites deemed inappropriate to educational settings need to be made early in the infrastructure planning process. Some ISPs offer screening or blocking services; other options include hardware and software tracking, and blocking of Internet content.
- *Support needs.* A technology program must have a provision for technical support. Some of the technologies involved in WAN and Internet connectivity can be provided by contracting with service providers. However, you will need a knowledgeable on-site resource to work with the infrastructure of your LANs. Invest in staff or training to ensure that, at the least, basic troubleshooting skills (such as use of a Fluke or other network diagnostic meter and cable repair/replacement) are available to keep your network in peak operating condition. A technology plan *must* include in its design provisions for continuous on-site technical assistance and user support.