

**Design and
Implementation of a
Wide Area Network:
Technological and
Managerial Issues**

Rohit Rampal

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Rohit Rampal
Portland State University, USA

EXECUTIVE SUMMARY

This case deals with the experience of a school district in the design and implementation of a wide area network. The problems faced by the school district that made the WAN a necessity are enumerated. The choice of hardware and the software is explained within the context of the needs of the school district. Finally the benefits accruing to the school district are identified, and the cost of the overall system is determined.

BACKGROUND

The organization is a reasonably small school district with about 2,700 students, in a town named X that is comprised of four villages (A, B, C and D). There are five schools in the district, the Board of Education that oversees those schools, and the Bus Garage. The buildings that house these seven entities are spread over the four villages, and the distance between locations is more than ten miles in some cases. While the school district is not exceedingly wealthy, it does have access to state and federal grants for bringing schools online. What isn't covered by the grants has been funded out of the municipal budget, with virtually no opposition from the Board of Finance, setting a stage whereby the town maintains an aggressive approach to deploying technology in its schools.

SETTING THE STAGE

The Town of X needed to connect the computers and systems at the seven locations in order to share information and resources. The district is spread out over the four villages that make up the town (A, B, C and D) and its seven locations within that area are separated by as much as ten miles. The faculty, staff and students within the school district needed the ability to communicate with each other and with the rest of the world via electronic mail. Accessing information via the World Wide Web was needed to keep up with the changing world, both for the faculty and the students. They needed to share files without printing and distributing hard copies. There was a distinct need for getting access to the Internet into the classroom. The schools in the school district had computer labs,

and computer-based education was a priority, but the computers could not connect to the Internet. The students, teachers and administrators in the school district needed to run collaboration applications like groupware and various administrative applications that required connectivity to a central database. Given the geographical distances involved, a wide area network seemed to be a good solution, that would take care of most of the needs of the school district.

An example of this need for connectivity and bandwidth is the Phoenix database, a school administration package used in the school district for town X and many other districts. Phoenix is a large and complex database written for Microsoft Access 2.0. It is clunky and painful to deploy in many respects, and it does not run on the newer versions of Access. So Access 2.0 must be installed for the database to run, but package serves its purpose and is popular. Phoenix has modules for maintaining student records (attendance, grades, discipline, etc.), class and bus schedules, payroll for faculty and staff, cost accounting and a number of other functions needed to run a school district. The ability to run this software product across a network is indispensable in this environment, as it allows each school to handle its own administrative tasks independently. In order to enable the proper running of the Phoenix software over the network, a good bandwidth is a requirement.

When the project was envisioned, direct fiber over the distances involved was not a viable option (the distances between two consecutive schools could run to more than ten miles). A wide area network, using some form of leased transmission lines was considered the most efficient way to connect the school district and create a cohesive enterprise. Such an enterprise could communicate efficiently and act in concert, providing connectivity and services to the faculty, staff, students and even the citizens of the Town X school district.

CASE DESCRIPTION

A Look at the Network

The Town X wide area network is described from two perspectives. The first perspective gives an overview of the network and the services that it delivers. This view primarily describes the software. The second perspective explains how these services are delivered. This perspective provides a discussion of the hardware and the network protocols used in the wide area network deployed.

Network Services

Just as a desktop computer requires an operating system (OS) to run, a network needs a network operating system (NOS). For the town X school district, the NOS chosen was Microsoft's Windows NT Server 4.0. There were a number of reasons for choosing Windows NT 4.0, but the overriding reason was the fact that the network administrator was familiar with the software. The NOS resides on a single computer known as a Primary Domain Controller (PDC). The school district network is configured as a single NT domain network—that is, a user needs to log on only once to the network in order to reach all resources he/she is allowed access to. The NT Server OS can also be configured to run as a stand-alone server to host other services on the network. There may be a number of such servers in a domain. In the case of the Town X school district WAS, there are two other NT servers that serve as hosts for additional services.

The Role of Domain Controller(s)

While the PDC, of which there can be only one, hosts the Security Accounts Management (SAM) Database, it is the Backup Domain Controllers (BDC) who maintain a copy of this SAM Database and actually perform the authentication of logins to the Domain. So when a user turns on a client machine and enters a user name and password, the "request" is directed not to the PDC but to a BDC, provided there is BDC present. For the Town X school district, each location has a BDC. At login the user name is compared against the SAM Database, and those privileges and accesses

that were assigned to that user's group or groups are granted to that user. (A user may belong to one or more groups). Some of the pre-defined groups in the NT domain include "domain users", "administrators", "print operators" or any of a wide variety of others. In a LAN running Windows NT, normally access is granted by group membership and not on an individual basis. This practice makes management of the domain a lot easier. In addition a user may be assigned a home directory on the server, access to which is normally restricted to the user only.

The process of creating accounts in the NT domain occurs on the PDC and then is copied to the BDCs by replication. The BDC also mirrors most of the other functions of the PDC, so that in the event the PDC fails, a BDC must be "promoted" to PDC status until the primary machine is fixed or replaced. This redundancy enables fault tolerance and is an essential part of smooth network operation.

Internet and Proxy Service

At the Town X High School, the BDC also hosts two other critical packages, namely Microsoft's Internet Information Server (IIS) and the Proxy Server. This IIS connects both to the Internet and to the internal network. It also hosts the Web site for the Town X school district. In order to limit the number of IP addresses needed, the network in the Town X school system uses private IP addresses. What that means is that these internal IP numbers cannot be routed to the Internet. So the IIS server needs to have two network cards, one with a private address to connect to the internal network, and one with a public address to connect to the Internet. In case the IIS server had only the public IP address, the way for the computers on the internal network to reach the Internet server would have been to go out to the Internet via the proxy server and reach it via the public IP address.

Proxy service allows the administration and monitoring of Internet usage as well as logging of inbound and outbound traffic. Also, more importantly the Proxy server allows the filtering out of objectionable materials from the office or academic environment. The school district was so concerned with this issue of restricting access to objectionable material that they augmented the filtering function by the addition of a third-party product called Web Sense. Web Sense is a subscriber service that downloads, on a daily basis, an updated list of URLs from which the objectionable materials issue. Web Sense then works closely with Proxy Server to block access to these URLs.

Once the Proxy Server has been installed on the network, the client machines are configured to "point" at it for their access to the Internet. The server caches a configurable amount of content (100 MB – 200 MB is common) as it is accessed from the Web and compares its cached material to the remote material periodically, keeping it updated. This way the frequently accessed material is kept readily available locally, speeding up Internet access for the user, and freeing up bandwidth for other more desirable uses.

DHCP and WINS

The Town X school district network uses DHCP and WINS to locate computers on the network. Dynamic Host Configuration Protocol (DHCP) is a dynamic TCP/IP addressing method that assigns each machine a TCP/IP address when it gets on to the network. Windows Internet Name Server (WINS) provides a NetBIOS host name address resolution for WINS clients. WINS increases network efficiency by reducing the number of network broadcasts needed to resolve a NetBIOS host name to an IP address. A NetBIOS name is a unique computer name that is entered in the identification tab in the network control panel of a computer. This is the name of the computer that would show up in the Network Neighborhood. Names are generally mnemonic, and so identify either the primary user of that computer (smith, librarian) or the location of the computer (Library12, Lab3), etc. On a TCP/IP network, however, the DHCP server assigns an IP address (which is a number) to the computers. A WINS server maintains a database that is updated periodically which matches the NetBIOS name with the IP address for each computer on the network.

Mail Services

The e-mail service in the Town X domain is provided by a dual-server MS Exchange 5.5 approach, while the e-mail client software used is MS Outlook 98, a 32-bit Windows application.

The two-server configuration was chosen to enable greater security by separating student and administrative accounts while providing fault-tolerance through information store replication. So in case one e-mail server goes down, the second can take over till such time the first server comes back up.

The protocols standardized for the students, teachers and administrators to send and receive electronic mail are SMTP and POP3 respectively. SMTP is the de-facto standard for sending mail, while POP3 was chosen as the e-mail client protocol as it limits the amount of incoming mail that stays on the e-mail server. One of the reasons for choosing MS Exchange as the e-mail server was the ease of use and management tools available. As with other Microsoft products (like MS Proxy Server) which are part of Microsoft's Back Office suite of products, MS Exchange provides a number of tools for tracking usage and monitoring performance. Since e-mail tends to become indispensable in an enterprise, keeping it online requires proper allocation of resources, and monitoring is critical to this process.

Server and Desktop Management

The network management software chosen for the Town X school district was the MS Systems Management Server (SMS), yet another member of the Back Office family. The software is powerful enough that with the client portion of the software installed on the workstations, the network administrators can remotely control and manage desktops and servers as well as troubleshoot. SMS can be used to inventory and collect data, distribute software and upgrades, and monitor server and network traffic, all from remote management stations.

Desktop Configuration

A conscious decision was made to configure each desktop in the domain in a standard fashion to present a consistent look and feel throughout. A standard computer has the MS Office Professional suite, a World Wide Web browser and MS Outlook 98 for e-mail and group scheduling tools. Other software as needed for the individual users is installed on a case-by-case basis.

All the network clients are configured to use DHCP and WINS servers as well as MS Proxy server. Finally each machine is configured to log on to the NT domain and access appropriate logon scripts, user profiles, home directories if applicable, shared applications and other network resources.

THE DESIGN OF THE WIDE AREA NETWORK

The Town X domain involves servers and desktop computers spread over seven buildings at five sites within the town. The Board of Education (BOE) and Town X High School, which are adjacent to each other, are connected by a fiber optic backbone allowing transfer of data at 100 Mbps. The Main Distribution Frame (MDF) at Town X High School is the network core. The remaining sites are connected by means of a wide area network implemented over frame relay connections at T-1 speed (1.54 Mbps). Another frame relay connection at T-1 speed links the network to a local Internet Service Provider (ISP) which then links it to the Internet.

Frame Relay vs. Point-to-Point

A considerable amount of thinking went into the decision to use Frame Relay as the connection technology for this WAN. Traditionally, WANs were created using point-to-point technologies. The difference between Frame Relay and point-to-point is that point-to-point is implemented over a dedicated copper line from one site to a phone company digital switch and from that switch to a second

site. In order to connect the entire Town X school district network in this fashion, each site on the network would need to have five such connections, one to each of the other sites. Since point-to-point connections are leased on a per-mile monthly fee (about \$40 per mile in this case), the costs add up pretty quickly.

Frame relay, on the other hand, requires only one connection per site. That connection is leased at a set fee and goes to what is called a “frame relay cloud,” a group of digital switches which on request forms a connection to another such cloud where the object of that request (the machine that is being accessed by your network) is connected. So the T-1 speed in the case of the Town X school district WAN is actually “burstable to T-1” speed. If there are simultaneous connections to more than one other site on the school district network, the bandwidth is then split among them. In spite of that, frame relay was found to be the more cost-effective and efficient way to connect at the time the network was designed. This was true even when compared to some of the lower cost technologies like ISDN or modems. The problem with ISDN or simple modem technologies was that neither of these was sufficiently robust to carry the kind of traffic generated by the school district. At one time in the past, the school district network was actually connected by 56kbs frame relay, but the administrative database program, Phoenix, which is extensively used, required a much higher bandwidth so the connection was increased to a T-1.

The Main Distribution Frames

At the heart of each of the Town X school district WAN’s school is an MDF built around 3Com’s Corebuilder 3500 Layer 3 switch. The “Layer 3” refers to the fact that the Corebuilder provides for not only 100 Mbps port switching but also routing at “wire speed.” (The backplane of the Corebuilder routes packets as quickly as the network electronics can deliver them. Cisco’s router did not have this capacity; as it could only route at the speed of its processor). The Corebuilder design is also fully scalable by means of plug-in “blades,” each with fiber or Ethernet ports. So this design also allows for expandability using technology not even available yet.

The servers at each site connect to the network through the TX (Ethernet) blades, while the Ethernet Switches, both at the MDF and the various IDFs (intermediate distribution frames), connect by fiber to the fiber blades.

An added feature of the 3Com Layer 3 product is that its routing capacity allows for the creation of Virtual LANs (VLANs), by segmentation of a LAN into IP subnets. Since routing is a managed activity, this feature is used to provide extra security on the network by blocking traffic (via a process known as “packet filtering”), between the student and administrative subnets. For each LAN, three VLANs were set up so that students and administrators could be denied access to each other’s areas, without denying them access to common resources such as the servers themselves. In the absence of Layer 3 switching this packet filtering can also be done at the routers, but would slow down the network.

Switched Port Hubs

The Town X school district network computers connect to their respective distribution frames (DFs) via 3Com’s Superstack 3300 24-port Ethernet Switch. In the High School alone, there are 15 of these. (Appendix A has full details on hardware, software, labor and costs for the entire project). The reason switched hubs were chosen for this implementation is the speed. One advantage of using switched port hubs is that the bandwidth is not shared, unlike in ordinary hubs. A second advantage of a switched port hub is that packets are delivered to the port the destination computer is attached to, instead of being broadcast to every computer connected to the hub.

Connecting to the WAN

The Town X High School LAN connects to the WAN through a Cisco 2500 Router and a Motorola CSU/DSU. A router passes data packets from one IP subnet to another, and the CSU/DSU

acts somewhat like a modem. It translates frame relay protocol from the telco loop (telephone company line) into TCP/IP (Transmission Control Protocol/Internet Protocol). In this case there are two connections through the router to two separate CSU/DSUs. One connection comes from the Internet server and routes a genuine Internet IP address to the ISP. Another comes from the TX blade on the Corebuilder and routes a private or internal IP address to the other LANs in the Domain. There it is picked up by the LAN's respective CSU/DSUs and routed to their respective Corebuilders. There too the IP addresses are private and are not routed to the outside world.

TCP/IP Addressing in the Town X Domain

The IP addresses of machines directly connected to the Internet never start with a 10 as that number is reserved for private networks. All the machines at the Middle school have an IP address starting with 10.0.10. At the High School and BOE the addresses are 192.168.*.*. These are also IP addresses reserved for private networks. At the Mem school they are 10.0.9.*, and so on.

The routers meanwhile have addresses of 10.0.11.*, 10.0.8.* and so on. They use a convention where the .1 is on the WAN side and the .2 is on the LAN side. It helps the network engineers to keep track when they are configuring the network.

The only actual real-world IP address in the whole domain is the one that gets routed from the IIS server to the ISP. The ISP has actually given the Town X school district network a quarter of a class C address: in this case the IP addresses 209.R.S.128 through 209.R.S.191 with the .128 and .191 being the network and broadcast addresses respectively. The number of IP addresses available to the school district was not sufficient, thereby making the use of private IP addresses for computers on the internal networks a necessity.

Problems in Implementation

Problems in the implementation of an IT solution can come in many forms, all the way from technical/technological, to financial and political.

The wide area network was designed and implemented for the school district of a small town. The cost of networking the individual locations averaged about 125,000 (for a total cost of about 750,000). While the WAN had a fixed initial cost, it had a recurring monthly cost. The WAN cabling was done by the local telephone company who brought the frame relay connections to the individual locations at a cost of \$1,200 each. There was also a monthly line charge of \$400 per location. As we said, Town X has six such connections. For a small municipality that was a considerable financial burden.

One of the things that helped in Town X was a program of state-sponsored infrastructure grants, a program established specifically for the purpose of bringing schools online. There was also federal grant money available for these purposes. The Town X school district spent a lot of time and effort to make sure that they made a very good case for getting the state and federal funds. Approximately 90 percent of the cost of implementing the WAN was covered by the State and Federal grants. What wasn't covered by grants was funded out of the municipal budget, with virtually no opposition even from the Board of Finance. Even though the remaining 10 percent of the cost was a significant amount of money for a small town, the Board of Education kept the Board of Finance involved and informed at all points in time. So in spite of the ever-present danger of financial problems, the WAN implementation managed to get through the implementation stage without any major hiccups. This was primarily due to a lot of work up front by the BOE members who made sure that everyone on the town council was committed to the project.

The WAN project was overseen by an implementation team, which included a representative from the Board of Finance, the district technology coordinator and a Superintendent's representative, who was also the grant writer for the Board of Education. These three spent a lot of time with representatives of the contractor to set up the implementation plan. Good planning ensured that the

contractor was aware of the school schedules, and had the appropriate resources available when needed during the implementation. The implementation team, along with representatives from contractor, both administrative and technical, met regularly to coordinate their efforts and keep the project on track. The meetings were more frequent during those phases of the implementation when there was a lot of activity, and less frequent during the slower phases. The meetings helped ensure that all the parties involved were aware of the situation at all points in time, and any deviations from the plan were discussed and then agreed upon. This approach worked quite well and the project was completed pretty much on its schedule, roughly two months for the cabling of the various locations and configuring the network electronics. Most of the work was done in the summer or after school hours with the school custodians providing the cabling and technicians access to the buildings, often until 11:00 at night. On the administrative side the major headaches were in the accounting and coordinating of the grant and municipal funding and the allocation of costs to each budget as appropriate. The contractor had prior experience working with school districts, and on projects based on similar state and federal grants. So the contractor's representatives were able to provide inputs into the process that helped properly administer the grants.

There was one unexpected snag when asbestos was discovered in one of the wings of the High School. The work at the High School had to be halted while the asbestos was removed. However, due to the existence of a comprehensive implementation plan, resources could be shifted to other school sites while the asbestos abatement took place. The fact that the affected area in the High School didn't include any of the wiring closets helped, as it did not impede the phased completion of the project significantly.

Benefits to the District

Some of the benefits in this case are immediately apparent. Running administrative applications like Phoenix from a central location is not just a convenience. It represents significant savings in man-hours, and therefore money, to the town. The fact that each school can now provide inputs into the scheduling system, maintain student records and other administrative tasks, without having to send over hard copies of data to the BOE, is a significant improvement in efficiency. Packet filtering at the routers and Layer 3 switches restricts access to the administrative side of the network while allowing for the use of less sensitive services by others, thereby increasing the overall utility of the project.

Another part of this benefit is centralized Internet access. Having this access through a central point gives the network administrator the ability to establish an Internet use policy and enforce it without having to do so on a location-by-location basis. As mentioned before, a third-party product called Web Sense is used to implement URL filtering of potentially offensive materials (the use of this filtering is a politically charged issue, but it is common in a number of school districts).

The use of the Internet in the classroom is becoming more prevalent. The students and teachers use the Internet to research current topics, and get access to information that was not readily available before the WAN was set up.

With Internet access the district is beginning to make many services available to the citizens in the community at large. School schedules, lunch menus and library card catalogues are all posted for access through the Internet. Students and faculty can retrieve their internal and/or external email, through the Web, whether on or off site. Eventually other services, such as distance learning, may be implemented in Town X.

CURRENT CHALLENGES / PROBLEMS FACING THE ORGANIZATION

The Town X school district is considering expanding the scope of the wide area network. One of the locations in the school district, the Bus Garage, was not connected to the WAN due to lack of planned funding. This has resulted in perpetuating some of the inefficiencies that the WAN was

supposed to eliminate. Since the garage is not networked, the bus availability and the bus schedules have to be transported manually from the garage to the BOE offices and back.

A number of classrooms in the schools are still not connected to the network. So it generates a feeling of inequity among the teachers and students who are assigned the non-networked classrooms.

While the connectivity is good in most locations, the high school seems to hog most of the available bandwidth on the WAN. The ability to access information from the Internet seems to slow down during the time the High School is in session. There seem to be some problems with the filtering service, as there are cases of objectionable material being found on some of the computers in the high school labs. Some of the lab computers have been used to serve up copyrighted material, while others run bandwidth-intensive applications that bog down the network.

ACKNOWLEDGMENT

This case was researched on site in Town X and through many hours of conversation with the Senior Systems Engineer with the contractor and the designer of this particular network.

FURTHER READING

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BIOGRAPHICAL SKETCH

Rohit Rampal is Assistant Professor of Management Information Systems at the School of Business Administration, Portland State University, OR. He received his Ph.D. from Oklahoma State University. He has previously worked in the College of Business Administration, at the University of Rhode Island. His areas of research include telecommunications, information systems in manufacturing, virtual enterprises, forecasting, and neural networks. He has previously published in the International Journal of Production Research, and the Encyclopedia of Library and Information Science.

APPENDIX A: PROJECT COSTS

High School and Board Of Education (BOE)

Cabling	Qty	Each	Total	Purpose
Classroom Drops (4 data/1 voice)	64	450	28800	Connect classrooms to each other and the internet
Office Drops (2 data/1 voice)	30	400	12000	Connect offices to each other and the internet
6 strand fiber between MDF and 5 IDF's	5	5200	26000	Connect all wings of the school together
<i>Cabling Total</i>			66800	

Network Electronics	Qty	Each	Total	
3-Com Superstack 3300 24-port Ethernet Switch	15	2,20	33000	Connect servers to classrooms and offices
3-Com Corebuilder 3500 Layer3 Switch	3	8000	24000	Layer3 switch to connect fiber and add network security
3-Com Corebuilder 3500 6 Port Fiber Blade	7	4800	33600	Connect all wings to servers
3-Com Corebuilder 3500 6 Port TX Blade	6	3000	18000	Connect all servers to the network
<i>Network Electronics Total</i>			108600	

Additional Network Hardware

4 foot Category 5 patch cables	316	3	948	Patch rooms to network electronics
15 foot Category 5 line cord	316	4	1264	Patch computers to network
APC 1000 Net UPS Rack Mount	6	829	4974	Protect servers from faulty power and power outages
Fiber Patch Cables	36	62	2232	Connect fiber to network electronics
<i>Additional Network Hardware Total</i>			9418	

Network Servers

	Qty	Each	Total	
LAN & WAN File Servers	2	8500	17000	NT server/primary DNS, mail server, backup domain/web server
Built-IN POP & SMTP Mail				
Built-IN DNS service				
Built-IN WWW server				
Built-IN Appleshare File & Print Services				

Network Software

	Qty	Each	Total	
MS BackOffice	3	1400	4200	Server operating system - NT, Mail, Web, Management
Windows Backoffice Client License	300	60	18000	License for clients to access servers
<i>Network Software Total</i>			22200	

Labor - Hardware & Software Installation, Training & Preparation

	Qty	Each	Total	
Cabling	Included			
Network hardware & hub installation	30	100	3000	Installation and configuration
Network server install & configuration	60	100	6000	Installation and configuration
Desktop configuration	316	75	23700	Installation and configuration
Training	40	75	3000	Administration of network
<i>Total - Labor</i>			35700	
High School and BOE Total			259718	

APPENDIX A CONTINUED**Middle School**

Cabling	Qty	Each	Total	Purpose
Classroom Drops (2 data)	68	\$200	\$13,600	Connect classrooms to each other and the internet

Cabling Total \$13,600

Network Electronics	Qty	Each	Total	
3-Com Superstack 3300 24-port Ethernet Switch	6	1,450	\$8,700	Connect servers to classrooms and offices
3-Com Corebuilder 3500 Layer3 Switch	1	\$8,000	\$8,000	Layer3 switch to connect fiber and add network security
3-Com Corebuilder 3500 6 Port TX Blade	2	\$4,800	\$9,600	Connect all servers to the network
<i>Network Electronics Total</i>			\$26,300	

Additional Network Hardware

4 foot Category 5 patch cables	136	\$3	\$408	Patch rooms to network electronics
15 foot Category 5 line cord	136	\$4	\$544	Patch computers to network
APC 1000 Net UPS Rack Mount	3	\$829	\$2,487	Protect servers from faulty power and power outages

Additional Network Hardware Total \$3,439

Network Servers	Qty	Each	Total	
LAN & WAN File Server Built-IN POP & SMTP Mail Built-IN DNS service Built-IN WWW server Built-IN Appleshare File & Print Srvices	3	\$8,500	\$25,500	

Network Software	Qty	Each	Total	
MS BackOffice	3	\$1,400	\$4,200	Server operating system - NT, Mail, Web, Management
Windows Backoffice Client License	136	60	\$8,160	License for clients to access servers
<i>Network Software Total</i>			\$12,360	

Labor - Hardware & Software Installation, Training & Preparation

Cabling	Included			
	10	\$100	\$1,000	Installation and configuration
Network server install & configuration	60	\$100	\$6,000	Installation and configuration
Desktop configuration	136	\$75	\$10,200	Installation and configuration
Training	30	\$75	\$2,250	Administration of network
<i>Total - Labor</i>			\$19,450	

Middle School Total **\$100,649**

APPENDIX A CONTINUED**Mem School**

Cabling	Qty	Each	Total	Purpose
Classroom Drops (4 data/1 voice)	27	\$450	\$12,150	Connect classrooms to each other and the internet
Office Drops (2 data/1 voice)	15	\$400	\$6,000	Connect offices to each other and the internet
6 strand fiber between MDF and 2 IDF's	2	\$5,200	\$10,400	Connect all wings of the school together
<i>Cabling Total</i>			\$28,550	

Network Electronics

	Qty	Each	Total	
3-Com Superstack 3300 24-port Ethernet Switch	5	2,200	\$11,000	Connect servers to classrooms and offices
3-Com Corebuilder 3500 Layer3 Switch	1	\$8,000	\$8,000	Layer3 switch to connect fiber and add network security
3-Com Corebuilder 3500 6 Port Fiber Blade	1	\$4,800	\$4,800	Connect all wings to servers
3-Com Corebuilder 3500 6 Port TX Blade	1	\$3,000	\$3,000	Connect all servers to the network
<i>Network Electronics Total</i>			\$26,800	

Additional Network Hardware

4 foot Category 5 patch cables	138	\$3	\$414	Patch rooms to network electronics
15 foot Category 5 line cord	138	\$4	\$552	Patch computers to network
APC 1000 Net UPS Rack Mount	3	\$829	\$2,487	Protect servers from faulty power and power outages
Fiber Patch Cables	4	\$62	\$248	Connect fiber to network electronics
<i>Additional Network Hardware Total</i>			\$3,701	

Network Servers

	Qty	Each	Total	
LAN & WAN File Servers	3	\$8,500	\$25,500	NT server/primary DNS, mail server, backup domain/web server
Built-IN POP & SMTP Mail				
Built-IN DNS service				
Built-IN WWW server				
Built-IN Appleshare File & Print Services				

Network Software

	Qty	Each	Total	
MS BackOffice	3	\$1,400	\$4,200	Server operating system - NT, Mail, Web, Management
Windows Backoffice Client License	108	60	\$6,480	License for clients to access servers
<i>Network Software Total</i>			\$10,680	

Labor - Hardware & Software Installation, Training & Preparation

	Included			
Cabling	Included			
Network hardware & hub installation	20	\$100	\$2,000	Installation and configuration
Network server install & configuration	60	\$100	\$6,000	Installation and configuration
Desktop configuration	138	\$75	\$10,350	Installation and configuration
Training	40	\$75	\$3,000	Administration of network
<i>Total - Labor</i>			\$21,350	

Mem School Total**\$116,581****Cen School**

APPENDIX A CONTINUED

Cen School

Cabling	Qty	Each	Total	Purpose
Classroom Drops (4 data/1 voice)	34	\$450	\$15,300	Connect classrooms to each other and the internet
Office Drops (2 data/1 voice)	15	\$400	\$6,000	Connect offices to each other and the internet
6 strand fiber between MDF and 2 IDF's	2	\$5,200	\$10,400	Connect all wings of the school together
<i>Cabling Total</i>			\$31,700	

Network Electronics

	Qty	Each	Total	
3-Com Superstack 3300 24-port Ethernet Switch	7	2,200	\$15,400	Connect servers to classrooms and offices
3-Com Corebuilder 3500 Layer3 Switch	1	\$8,000	\$8,000	Layer3 switch to connect fiber and add network security
3-Com Corebuilder 3500 6 Port Fiber Blade	2	\$4,800	\$9,600	Connect all wings to servers
3-Com Corebuilder 3500 6 Port TX Blade	2	\$3,000	<u>\$6,000</u>	Connect all servers to the network
<i>Network Electronics Total</i>			\$39,000	

Additional Network Hardware

4 foot Category 5 patch cables	166	\$3	\$498	Patch rooms to network electronics
15 foot Category 5 line cord	166	\$4	\$664	Patch computers to network
APC 1000 Net UPS Rack Mount	3	\$829	\$2,487	Protect servers from faulty power and power outages
Fiber Patch Cables	4	\$62	<u>\$248</u>	Connect fiber to network electronics
<i>Additional Network Hardware Total</i>			\$3,897	

Network Servers

	Qty	Each	Total	
LAN & WAN File Servers	3	\$8,500	\$25,500	NT server/primary DNS, mail server, backup domain/web server
Built-IN POP & SMTP Mail				
Built-IN DNS service				
Built-IN WWW server				
Built-IN Appleshare File & Print Services				

Network Software

	Qty	Each	Total	
MS BackOffice	3	\$1,400	\$4,200	Server operating system - NT, Mail, Web, Management
Windows Backoffice Client License	136	60	<u>\$8,160</u>	License for clients to access servers
<i>Network Software Total</i>			\$12,360	

Labor - Hardware & Software Installation, Training & Preparation

Cabling	Included			
Network hardware & hub installation	20	\$100	\$2,000	Installation and configuration
Network server install & configuration	60	\$100	\$6,000	Installation and configuration
Desktop configuration	166	\$75	\$12,450	Installation and configuration
Training	40	\$75	<u>\$3,000</u>	Administration of network
<i>Total - Labor</i>			\$23,450	

Cen School Total

\$135,907

APPENDIX A CONTINUED

Cen School

Cabling	Qty	Each	Total	Purpose
Classroom Drops (4 data/1 voice)	34	\$450	\$15,300	Connect classrooms to each other and the internet
Office Drops (2 data/1 voice)	15	\$400	\$6,000	Connect offices to each other and the internet
6 strand fiber between MDF and 2 IDF's	2	\$5,200	\$10,400	Connect all wings of the school together
<i>Cabling Total</i>			\$31,700	

Network Electronics	Qty	Each	Total	
3-Com Superstack 3300 24-port Ethernet Switch	7	2,200	\$15,400	Connect servers to classrooms and offices
3-Com Corebuilder 3500 Layer3 Switch	1	\$8,000	\$8,000	Layer3 switch to connect fiber and add network security
3-Com Corebuilder 3500 6 Port Fiber Blade	2	\$4,800	\$9,600	Connect all wings to servers
3-Com Corebuilder 3500 6 Port TX Blade	2	\$3,000	\$6,000	Connect all servers to the network
<i>Network Electronics Total</i>			\$39,000	

Additional Network Hardware

4 foot Category 5 patch cables	166	\$3	\$498	Patch rooms to network electronics
15 foot Category 5 line cord	166	\$4	\$664	Patch computers to network
APC 1000 Net UPS Rack Mount	3	\$829	\$2,487	Protect servers from faulty power and power outages
Fiber Patch Cables	4	\$62	\$248	Connect fiber to network electronics
<i>Additional Network Hardware Total</i>			\$3,897	

Network Servers	Qty	Each	Total	
LAN & WAN File Servers	3	\$8,500	\$25,500	NT server/primary DNS, mail server, backup domain/web server
Built-IN POP & SMTP Mail				
Built-IN DNS service				
Built-IN WWW server				
Built-IN Appleshare File & Print Services				

Network Software	Qty	Each	Total	
MS BackOffice	3	\$1,400	\$4,200	Server operating system - NT, Mail, Web, Management
Windows Backoffice Client License	136	60	\$8,160	License for clients to access servers
<i>Network Software Total</i>			\$12,360	

Labor - Hardware & Software Installation, Training & Preparation

Cabling	Included			
Network hardware & hub installation	20	\$100	\$2,000	Installation and configuration
Network server install & configuration	60	\$100	\$6,000	Installation and configuration
Desktop configuration	166	\$75	\$12,450	Installation and configuration
Training	40	\$75	\$3,000	Administration of network
<i>Total - Labor</i>			\$23,450	
Cen School Total			\$135,907	