NETWORK DESIGN

Best Practices
For Alberta School Jurisdictions

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The primary intended audience for this framework is:

Administrators	✓
Counsellors	
General Audience	
Information Technologists	✓
Parents	
Students	
Teachers	✓

PREFACE

This report has two different target audiences: school principals and technology co-ordinators. Since these two audiences often have very different levels of knowledge and understanding, this report will be too technical for some and not technical enough for others. Nonetheless, I hope all readers will learn from it, and be in a better position to make informed decisions about issues that have an impact on network performance and design.

Tools cited in this report are those available in the author's school jurisdiction and those that are inexpensive for the end user. The scope of this report does not include a review of software products. Therefore, ***the mention of any particular commercial product in this report is not intended as an endorsement.***

-- Ralph Schienbein

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PLANNING CONSIDERATIONS

What does a jurisdiction network person, in-school computer person, school principal or jurisdiction decision maker need to know about network design, network performance, and end-to-end performance?

Take a "standards" approach to computing.

➢ *Adopt the computer industry standards that will be used for all local area network (LAN) and wide area network (WAN) designs.*

- Use the EIA 568A standard.
- Use TCP/IP as the standard. Begin to migrate away from other schemes.
- Establish 10/100 Mbps as standard for all wiring, network devices, and NICs. Test all cables to 100 MBps.
- Establish "switched to the desktop" as the standard for all sites.
- Build a physically secure wiring closet with room to expand and sufficient cooling to remove heat.
- Make use of "intelligent" network devices (SNMP and/or RMON) that can be remotely monitored.

Be prepared for rapid change.

➢ *Recognize that multimedia will become increasingly important and pervasive in education.*

- When computers are being purchased, **require benchmark results**.
- Contain complexity by reducing the number of types of computers and versions of software at a site. Change whole schools or departments at the same time.
- Plan for large increases in internal and external network traffic. Not only will e-mail increase in size and amount, but audio and video will also become more pervasive.
- Buy technology that will preserve long-term flexibility.
- Plan for your WAN connections to change in capacity and/or number of access points. Do not expect that slower speeds can be maintained for years to come.
- Monitor Internet traffic.

Build the internal infrastructure with the "enterprise" in mind.

- *Develop a network that is both functional and scalable. "Functional" refers to acceptable latency for the task and "scalable" refers to the ease of increasing bandwidth on the WAN as well as reconnecting within the LAN.*

  - Act locally but think jurisdiction or enterprise-wide. Decisions about networks, computers, and software should not reside exclusively at the school level.
  - Understand that, in a jurisdiction environment, all school Internet traffic and external e-mail has an impact on all other users in the jurisdiction.
  - Become "student-centric" and "network-centric" at the same time. Doing so will ensure that you begin to examine home-to-school network traffic, school-to-school traffic, home to other levels of educational institutions' traffic, and so on.
  - Record all IP addresses and MAC (Ethernet) addresses at the time a computer is received.
  - Maintain a wiring diagram for your facility so others can determine where the cables run.
  - Physically separate administrative and student traffic. Make use of filters and other network techniques to provide security.
  - Do not re-invent the wheel. Consult with other users around the province about the kinds of software being used before establishing a direction. Join and participate in Alberta Education's listserver <edc-techplangroup@gov.ab.ca>.

Adopt an end-to-end point of view.

- *Examine the network from the users' point of view. Performance is an end-to-end decision made up of the local computers, local area network, and wide area network connection.*

  - Determine the computers and appropriate subsystems required (disk, graphics, memory, network cards) for the tasks to be carried out.
  - Choose network devices that ensure security of data.
  - Choose servers for bandwidth conservation (cache servers), file servers, mail servers, domain servers, etc. that are appropriate for the architecture of the school.

Make use of available tools to monitor the network.

➢ *Use various emerging tools to assist in monitoring both the LAN and WAN. At this time there is no single tool available to analyze all aspects of the problem.*

- Determine what network management software is required for the jurisdiction; e.g., HP OpenView.
- Select performance monitoring tools; e.g., Performance Monitor, NetMedic.
- Require vendors to submit benchmark results for computers being purchased.

Recognize that the network will become more essential and complex.

➢ *Try walking into a staff room after the mail server has gone down and lost mail, or after someone has entered payroll data over a WAN link that is too slow. How quickly and silently services move from being "interesting and nice" to being essential.*

- Plan to hire the specialists in technology that will be required to manage the many new services available to schools—domain controllers, file servers, cache servers, firewalls, filtering software, software distribution schema, e-mail, etc.
- Plan to acquire more robust hardware and software as internal and external services begin to move from "nice to have" to mission critical." Redundancy and fault tolerant services will devolve to the site level.
- Do not leave out backups of key files "because we can not afford it." Consider what it means to a school/department to lose their data via hardware failure, vandalism, fire, etc.

Practice "safe software."

➢ *Help educators (who tend to be a very trusting group and therefore often share software, hardware, and passwords) to understand how such an environment is susceptible to illegal copies, viruses, and misuse.*

- Use filtering software to control web content access.
- Use a firewall software package to protect the site or jurisdiction from the outside.
- Ensure that all staff use proper password techniques.
- Remind educators who tend to be "loose" that illegal software use is a crime.
- Begin the move to "zero administration" of software. By examining the long-term costs for software, including installation of updates, one can better justify allocation of costs for other things beyond initial costs.

Actively address funding issues.

➢ *Consider establishing explicit funding for jurisdiction LAN/WAN support.*

If the author could make only one recommendation, it would be for a change in funding to support jurisdiction-wide networks. It is impossible to continue to build networks in school jurisdictions as “add-on work” and “add-on expenses” without designated funds to support this reality. Trained network professionals are very expensive and difficult to obtain, and the problem gets more difficult as the distance increases from major urban areas.

Site-based decision making has many merits. However, building a jurisdiction-wide network while funding goes to schools and implementing a cap on central costs encourages a “Balkanization” of networks, equipment, and standards. Educators need to be free to integrate technology into the curriculum, not kept busy trying to keep various generations of hardware and software operational. Often site-based decisions will be made for the benefit of a school and not necessarily with other schools in mind.

Smaller schools have difficulty implementing servers and WAN connections capable of giving equitable access since their student-based revenues are insufficient. They can not generate the funds required to properly acquire, implement, and maintain the infrastructure.

Also, rural schools often can not obtain sufficient bandwidth for the size of the school, and the costs for services vary greatly across the province. There is no equity on a per student basis across all schools in the province.

- Schools require resources to support increasingly complex and "mission-critical" systems.
- Supporting an end-to-end network is initially capital intensive and operating intensive.
- The current funding framework, which limits the expenses in central services, limits a jurisdiction’s ability to provide central network and computer support.
- Network staff are expensive to acquire and difficult to retain. Funding for this is required. In addition to new money, changes should be made to the amounts of funds that can be spent in central services—the logical place for school network support.
- Think “equity” for student access across the jurisdiction. Equity means equal opportunity for a student regardless of school size or location. It will be much more expensive for smaller and/or rural schools to provide WAN bandwidth than it will be for schools accessing urban networks.
- Schools and jurisdictions should continue to co-operate with other jurisdictions around the province to obtain better software prices.

POLICY ISSUES FOR SCHOOLS AND SCHOOL JURISDICTIONS

- When staff and students use software that is not essential to their programs and/or do an inordinate amount of downloading during peak hours, they overload the networks and create problems for other users. Decisions about using one source in a computer lab or having each student connected individually have an impact as well. For example, using the Internet as a "noon-hour supervisor" can create an overload.

- School jurisdictions continue to struggle with the challenge of providing equitable access to technology. (There are variations among large, small, rural, and urban schools.)

- School jurisdictions can avoid re-inventing the wheel and save money by sharing information and resources with each other and consulting with Alberta Education. For example, there may be opportunities for joint purchasing.

- Security is a major concern: the educator's tendency to have a "trusting" attitude can be a major problem in this context.

- Limiting the Internet sites that students are allowed to visit presents a challenge as well. Schools have to avoid censoring students' pursuit of information but at the same time act *in loco parentis*.

- Technology continues to change rapidly. Also, the cost of owning technology (networks, hardware, software, etc.) extends beyond the initial purchase: support and maintenance are a part of the cost as well. Therefore, school jurisdictions will benefit greatly from long-term planning.

INTRODUCTION

PERFORMANCE IS AN END-TO-END ISSUE

"My computer is slow" and "The network is slow" are typical statements users make to computer and network support staff. What they mean is they are trying to do something and it is either taking a long time to do it (for any variety of reasons) or it is abnormal.

The rapid evolution of the Internet has made computing *network centric* instead of *computer centric*. Historically, people have concentrated almost exclusively on computer clock speed as the measure for performance. It has been said, "When a personal computer is put on a network, the personal is removed."

All parts of a network have an impact on someone at a computer working in a network environment. An end-to-end enterprise view of performance and capacity is required. This includes the computer itself (CPU, memory, disk, network interface, graphics, etc.), the local area network (LAN), components within the LAN such as servers, the wide area network (WAN), etc. Each of these can be characterized and/or measured with a variety of tools and metrics.

This report will:

- Describe a model that can be used to project WAN connection speeds based on user traffic.
- Describe end-to-end performance issues.
- Characterize and identify tools for on-line analysis.
- Describe how network traffic has an impact on network design as well as computer architectures.
- Provide basic metrics where available.
- Identify industry trends.

PURPOSE AND OBJECTIVES

Network design is viewed as layers—cabling, network, computers, and a WAN (Figure 1). Each school/department site can be viewed as having these different layers. While this paper does not go into answering the question, "How do you wire a school?" it will examine subsections of the topology that have to do with end-to-end performance and capacity planning. (See Calgary Public Schools web site <http://www.cbe.ab.ca> for more details on wiring). This paper assumes active star topology, Category 5 wiring, Ethernet (running 10 Mbps but tested to 100 Mbps), and intelligent devices.

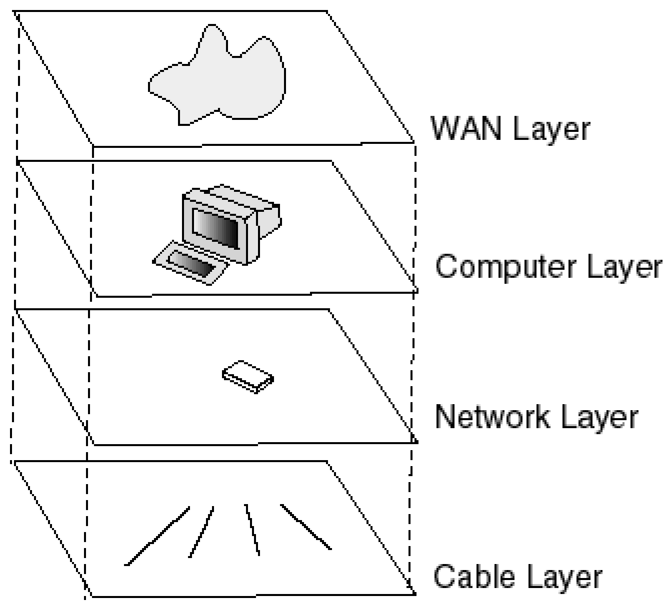

FIGURE 1: LAYERED VIEW OF NETWORK DESIGN

One of the general design principles for schools is "scalable and flexible." Adding a computer lab with thirty computers has a significant impact on the traffic flow in a school network. *Scalable* means that the network can be easily modified to meet changes (increases or decreases) in network traffic. The addition of electronic media such as an encyclopedia in the library also introduces significant traffic to a specific area of the school, as would a Career and Technology Studies (CTS) lab. The use of audio such as RealAudio creates a significant increase in traffic, as does two-way video via technologies such as CUSeeMe. The "killer application," from a capacity planning point of view, is the delivery of video in real time.

A school topology must be *flexible* enough to be reconfigured as the types of network traffic change. It also must withstand designing around specific staff who may move to other parts of the building or to another location and are replaced by staff who produce significantly different LAN/WAN traffic patterns.

The overall network traffic in schools is dynamic at any given moment. Traffic will change from year to year as well as during various times of the year. Newer multimedia technologies will use more bandwidth. The normal practice of secure wiring closets in each location is a given. Within this closet it is relatively easy to change a server from 10 Mbps to 100 Mbps and 1000 Mbps when required (Figure 2).

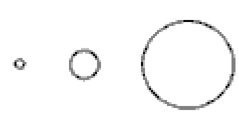

FIGURE 2: RELATIVE "PIPESIZES": 10, 100, 1000 Mbps

Tip

Design the network with 10/100 Mbps to the desktop, 10/100 Mbps for segments running servers, and 1000 Mbps for large schools for a backbone segment(s). If the topology is planned this way, downstream costs can be reduced or minimized.

END-TO-END PERFORMANCE

Assume a user who is browsing a site on the web notices that it takes a long time for the desired page to come up on the screen. Often the user attributes this lack of performance to either the computer (or more likely) the Internet service provider (ISP). The route to the desired server is illustrated in a highly stylized form in Figure 3.

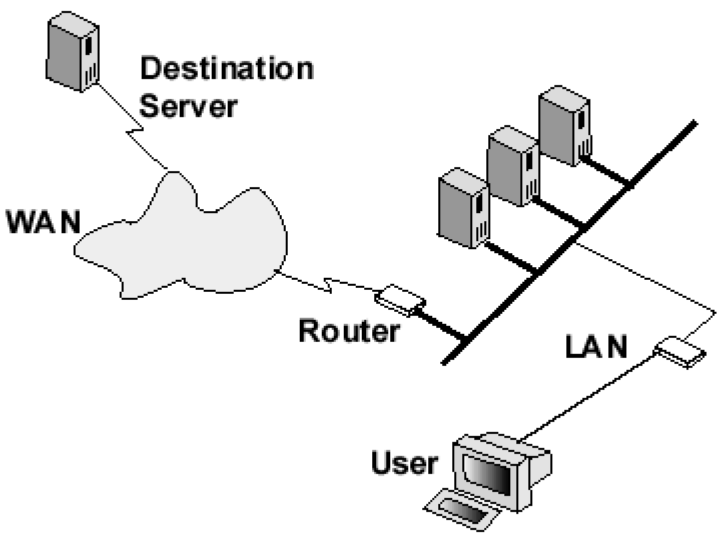

FIGURE 3: END USER ACCESSING A SERVER THROUGH A LAN AND WAN

In a typical session on the Internet, the server-client path may be quite complex and vary from one web site to another. This complexity is not noticed by the user, who usually observes only changes in performance. The end-to-end connection is illustrated in a different form in Figure 4. While there may be relatively fast (Ethernet or 10 Mbps) connections from the user computer, there may be any other number of network segment speeds between the user and the server. In this case the slowest segment is 56 Kbps.

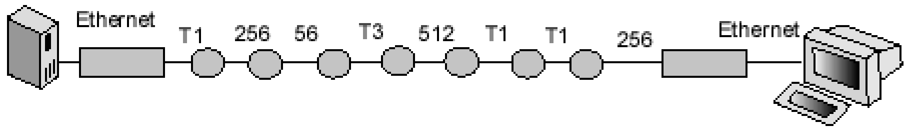

FIGURE 4: END-TO-END BLOCK BROWSER DIAGRAM

Initial analysis of the network may indicate that the slowest link (56 Kbps) is the source of the slow performance. In reality, it could be an overcommitted fast link like the T1, a busy web server, or momentary high use on the local hub the user is attached to.

Keys to understanding network performance include taking both an end-to-end view and a *user* point of view. For the purposes of this study, the destination site is Alberta Education's web site <http://ednet.edc.gov.ab.ca> which is accessible from all schools in the province.

The connection between Elk Island Public Schools (EIPS) and Alberta Education, a distance of approximately twenty-five kilometres, is accomplished through nineteen segments ("hops"): Sherwood Park, Toronto, Calgary, Edmonton, and then the server (Figure 5). The number of hops may vary with each trace. Each hop exhibits different latency (delay measured in milliseconds) to the browser session. Notice that three hops have relatively large delays—hop 13 (Toronto to Calgary) at 781 milliseconds, hop 11 at 581 milliseconds, and hop 18 at 581 milliseconds. In this example, any slowness perceived by the user is not within the district but rather at the ISP and within the target network. This does **not** give information about which devices are giving the latency or if the specific times were a result of momentary congestion.

```
C:\WINNT\system32\CMD.EXE
  2    <10 ms    <10 ms     10 ms   FIREWALL
  3    <10 ms     10 ms    <10 ms   142.60.100.125
  4      *        30 ms     40 ms   198.53.110.33
  5     30 ms    310 ms    201 ms   198.53.246.1
  6     90 ms    230 ms    491 ms   somerouter.iSTAR.net [198.53.254.177]
  7     50 ms    140 ms     90 ms   somerouter.iSTAR.net [198.53.254.149]
  8    751 ms    200 ms    131 ms   core2.Toronto.iSTAR.net [198.53.254.145]
  9    391 ms    390 ms    100 ms   border1.canix.iSTAR.net [198.53.254.10]
 10    581 ms    160 ms    180 ms   198.133.49.2
 11    360 ms    391 ms    581 ms   h4.bb1.tor2.h4.bb1.tor1.uunet.ca [205.150.242.65
]
 12    891 ms    401 ms    160 ms   h5.bb1.tor1.h5.bb1.cal1.uunet.ca [205.150.132.65
]
 13    631 ms    841 ms    781 ms   frcal01-f8-1-0.cal.sfl.net [205.150.143.18]
 14    280 ms    110 ms    110 ms   fredm01-atm0-0-0.edm.sfl.net [204.209.214.6]
 15    230 ms    130 ms    161 ms   142.229.63.65
 16    170 ms    311 ms    140 ms   198.161.6.9
 17    170 ms    160 ms    131 ms   devcis01.pwss.gov.ab.ca [142.229.61.14]
 18    220 ms    571 ms    581 ms   199.214.48.130
 19    300 ms    201 ms      *      ednet.edc.gov.ab.ca [142.229.18.199]
 20    151 ms    150 ms    130 ms   ednet.edc.gov.ab.ca [142.229.18.199]

Trace complete.

C:\WINNT\system32>
```

FIGURE 5: TRACE ROUTE FROM USER TO ALBERTA EDUCATION

Tool

Trace route (tracert) is a DOS command available under NT. There are UNIX equivalents.

WAN CONNECTION

Since WAN connections are a purchased service, it is important to buy enough bandwidth to meet the needs of the school/jurisdiction. This leads to the questions, "How much bandwidth is enough?" and "How can bandwidth be determined?" Three models were developed to answer these questions.

Again, there are design issues to keep in mind. If the school is large and bandwidth may grow over the next few years, it would be unwise to size WAN routers and WAN capital purchases that do not allow for bandwidth upgrade. For example, a user may change from a 56 Kbps to ISDN to fractional T1 to Ethernet in a relatively short number of years (particularly in urban areas). This is a *flexibility* issue as well as one of planning for change.

Tip

Assume the WAN connection will have a shorter replacement time than other layers of the network.

BANDWIDTH MODEL

Almost every school in Alberta is connected to the Internet by one of these means:

- analog to 56 Kbps
- centrex 56 Kbps
- ISDN 128 Kbps
- fractional T1 256 or 512 Kbps
- T1 1.54 Mbps
- Ethernet 10 Mbps

Some Alberta schools have used satellite (400 Kbps downlink with land uplink), cable modems (to 20 Mbps downlink and around 768 Kbps uplink), wireless (2–3 Mbps), HDSL/xDSL (early 1998), and AGNpac (Government of Alberta—Public Works, Supply and Services).

Key Concepts

1 byte **(B)** = 8 bits **(b**). 128 Kbps is 128,000 bits per second.

1 **MB** = 1 megabyte. 1 **Mb** = 1 megabit.

The WAN connection size can have a dramatic impact on user response times. Table 1 illustrates various common WAN connection capabilities and the length of time required to download a file. This model was developed in Microsoft Excel and can be utilized to estimate bandwidth requirements. This model, used in conjunction with traffic analysis, can be used to estimate WAN capacity.

	Bandwidth	**64 byte**	**pps**	**1518 + 64**	**Max**		**100 KB**
Type	**Kbps**	**pps**	**at 80%**	**pps**	**Bytes per second**	**Kbps**	**# sec**
Centrex	**56**	109	88	3.5	**7000**	7.0	14.286
ISDN	**128**	250	200	8.1	**16,000**	16.0	6.250
256	**256**	500	400	16.2	**32,000**	32.0	3.125
512	**512**	1000	800	32.4	**64,000**	64.0	1.563
T1	**1540**	3008	2406	97.3	**192,500**	192.5	0.519
Ethernet	**10,000**	19,531	15,625	632.1	**1,250,000**	1250.0	0.080

TABLE 1: WAN CONNECTION SPEEDS

Types of WAN connections appear in Column 1, and their bandwidth capacity (in Kbps) is in Column 2. If all network traffic over the WAN connection occurred in 64-byte packets (which it does not), the packet rates for these connections would be as shown in Column 3. ISPs and telcos sometimes refer to their services in either Kbps or pps. It is usually the network running with 64-byte packets. Column 4 gives capacity at 80 per cent. Chronic utilization levels above 80 per cent usually indicate that capacity should be re-evaluated. Column 5, “1518 + 64,” gives the scenario if all packets downloaded were the maximum size of 1518 bytes with a 64-byte packet acknowledgement. There would be 3.5 pps over a centrex in this scenario and 97.3 pps over a T1.

Packets are largely meaningless when analyzing performance. *Bytes per second* is a better metric of bandwidth capacity. The maximum number of bytes of data that can pass through a centrex line per second is 7000. The maximum number of bytes per second over a 256-Kbps link is 32,000.

It will be demonstrated later that school traffic typically is between 9:00 a.m. and 3:30 p.m., or 6.5 hours. The overall capacity of a 256-Kbps connection for 6.5 hours would be 748.8 MB (6.5 hours X 3600 seconds / hour X 32,000 bytes per second). The 24-hour maximum capacity would be 2748 MB. The “off-hours” capacity, the difference between the theoretical maximum daily rate and the “prime daytime rate,” would be 1999.2 MB. This is the maximum amount of traffic that could be used to download curriculum materials, “whack” web pages, update CTS modules, update video content, and do all the other things that could be done in off-hours.

Knowing WAN link byte capacities permits the estimation of the amount of time to download files of various sizes. To download a file of 100 KB would require 14.286 seconds via a 56-Kbps line and 0.519 seconds via a T1. Note that this is simplified in that the model examines **total** traffic and not just a one-way transmission of a single 100-KB file.

Few schools have only one user. The bandwidth model may be extended to examine any different number of users (Table 2). If a lab of thirty computers are all downloading a 100-KB file, it will take 428.6 seconds on a centrex line and 15.6 seconds on a T1. With 428 seconds (more than seven minutes) required to download a single page, the class will not have time to do any useful work. A centrex line would be too slow for their needs.

	100 KB	**Users**	**Users**	**Users**	**Users**	**Users**	**Users**
	# sec	**10**	**20**	**30**	**40**	**50**	**60**
Centrex	14.286	142.9	285.7	**428.6**	571.4	714.3	857.1
ISDN	6.250	62.5	125.0	**187.5**	250.0	312.5	375.0
256	3.125	31.3	62.5	**93.8**	125.0	156.3	187.5
512	1.563	15.6	31.3	**46.9**	62.5	78.1	93.8
T1	0.519	5.2	10.4	**15.6**	20.8	26.0	31.2
Ethernet	0.080	0.8	1.6	**2.4**	3.2	4.0	4.8

TABLE 2: DOWNLOAD TIMES FOR VARIOUS NUMBERS OF USERS

The model (Tables 1 and 2) will permit the estimation of times via various WAN connections to a variable number of end users. This model requires knowledge of how much data is to be downloaded. To illustrate how this table can be used in practical terms, examine the Alberta Education web site home page (Figure 6) <http://ednet.edc.gov.ab.ca>.

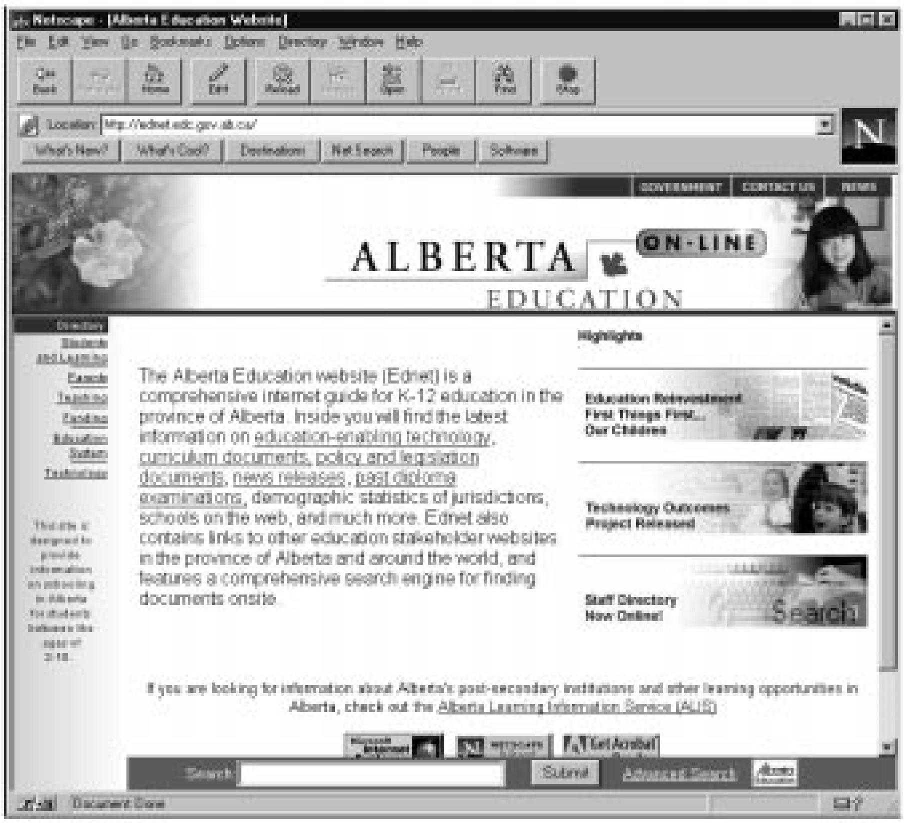

FIGURE 6: ALBERTA EDUCATION WEB SITE HOME PAGE

At the top of this home page is the picture of a child (Figure 7). This picture is a “gif file,” 22,798 bytes in size. Using the model developed in Table 1 and replacing the 100-KB file size with 23 KB, a single user would take approximately 3.3 seconds to download the image through a centrex line. It would take approximately 0.1 seconds to download the same file through a T1 (1.54 Mbps). It would take 98.6 seconds to download this single picture to thirty computers over centrex and 10.8 seconds over a T1.

FIGURE 7: ALBERTA EDUCATION HEADER

The model works for projecting bandwidth if the file size is known. This leads to the question, “How do you know how many bytes are downloaded?” Various tools can be used to quantify this question.

Metric Suggestion

A five-second response time can be considered the upper limit for a terminal user.

A twenty-second response time can be considered an upper limit for a browser on an “average” page.

WAN ANALYSIS

TOOLS

Given that a school or jurisdiction has a working bandwidth model, the next problem is to determine how much traffic will go to the WAN connection and therefore what WAN capacities are required. As indicated below, a number of tools with a wide range of costs can assist users in network analysis. At this time, no one tool can do all of the analysis that a user may wish to do. Some of these tools include:

- **Performance Monitor**. An inexpensive way to determine total bytes (if an NT workstation or NT server is available) is to use Performance Monitor built into NT. The network interface card (NIC) can be monitored for total traffic, disk utilization, and CPU utilization.
- **RMON2 Probes** (hardware and software). RMON is Remote MONitoring and is an industry standard. Elk Island Public Schools used probes from Technically Elite <http://www.tecelite.com>. RMON probes are useful in determining long-term traffic patterns as well as which computers are connecting with which other computers (Appendix F).
- **Network monitoring software**. HP OpenView provides real-time monitoring. Within these tools are traffic patterns (see Appendix D).
- **Query Router**. An inexpensive way of determining total bytes is to query the WAN router and examine byte counts. This is usually performed with vendor-specific software or some common tools such as telnet.
- **Low cost software.** NetMedic <http://www.vitalsigns.com> provides a series of tools to monitor ISP and server performance (see Appendix C).
- **Telco utilization reports**. Utilization of WAN connections can be obtained by the telephone provider (e.g., TELUS). See sample of traffic analysis in Appendix E.
- **Firewall traffic utilization** (Appendix G). If the school/district is using a firewall package, this software usually gives information that is useful for analysis.

Tip

Network monitoring such as HP OpenView or its equivalent encourages **proactive** management of the network. Instead of staff phoning and saying “I can not seem to run student records” or “I’m having a problem with the network,” alarm conditions can be set in the software to immediately notify users that a key device is not available. Network monitoring also helps to build a profile of problem devices and connections.

PACKET SIZE

Before examining output analysis from various tools, it is necessary to differentiate between traffic in bytes and *packets*. The *maximum* number of bytes (eight bits) per second for various WAN connections was given in Table 1. A 256-Kbps line has a *maximum* capacity of 32,000 bytes per second. Vendors and ISPs often talk in terms of *packets per second*. A brief introduction to packets is required to understand what this means.

Two assumptions used for this paper are Ethernet (within the building—ANSI 802.3) and the TCP/IP protocol (within the building and to the Internet). Data is moved from one computer to another in bundles called packets. The smallest Ethernet packet size allowed is 64 bytes and the largest allowed is 1518 bytes with various sizes between these two extremes. All data transmitted through an Ethernet are in packets.

Notes

- Only one packet can be on an Ethernet segment at a time.
- It takes 1.23 milliseconds to send a 1518-byte packet followed by a 9.6-microsecond pause (send-silence-send-silence-send etc.).
- When two adapters transmit at the same time, there is a collision. Both of them will "back away" and send later. Ethernet is a collision detect network. (Actually, it is "CSMA/CD," which is carrier sense multiple access with collision detection.)

This report will not go into the actual network conversations that take place when an Internet browser goes to a site like the Alberta Education web site home page. An analogy of the network conversation is as follows:

My browser: "Go to http://ednet.edc.gov.ab.ca"
Name Resolution
My computer: "What is the address for the site?"
Domain Name Server: "Its address is 142.229.18.199."
My computer: "Go to 142.229.18.199."
Local Router: "Where is 142.229.18.199?"
Various number of segments (hops) to arrive at ednet server
Elk Island Public Schools to Alberta Education is 19 hops with the current ISP provider
The ednet server synchronizes with my browser at this point.
Ednet server: "Here is the homepage."
Server: 1st packet
My Computer: "Got it"
Server: 2nd packet
My computer: "Got it."
This is repeated until the data has been transmitted. Each segment or hop is conducting the same process so there are many conversations going on.
Server: "Done."
Total packets = 234. Size = 99,128 bytes.

The Alberta Education web site home page is 61 KB. A total (send/receive) of 91,128 bytes of traffic are involved in downloading the home page (Figure 6). This was done in a total of 234 packets. The data path went through nineteen segments or hops (Figure 5). A parenthetic comment is in order here. Before optimizing the home page, 217,560 bytes of traffic were required to download the home page. This was done in a total (send/receive) of 417 packets. As more people develop web pages for central administration and schools, it is important to remember that there are many ways to reduce the amount of traffic required to access server pages. Any savings in size is repeated each time the page is accessed.

Servers will attempt to send the data in as large a packet as possible (usually 1518 bytes), and the response will be an acknowledgement (64 bytes). These packets are Ethernet packets and may be disassembled and re-assembled by the various devices on each hop or segment of the end-to-end pathway.

The *actual network* traffic travelling over the network is greater than just the number of bytes of the host page. This reality has to be taken into account when performance is being examined. *Each hop also can be a potential performance bottleneck!*

What do typical Internet (TCP/IP) packets look like? All data sent to and from a computer on an Ethernet segment follow highly structured standards (ANSI/IEEE 802.3) agreed to on a global basis. Both the IP address (derived from a domain name server and the PC) and the Ethernet address (a unique address built into each Ethernet adapter) are used to communicate.

The data is encapsulated within the packet and may be either a small or large portion of the packet. The smallest packet size is 64 bytes and the largest is 1518 bytes. Key pieces of an Ethernet packet are illustrated in Table 3. A detailed version of Table 3 in included in Appendix H, Figure 38.

Packet #1	
Packet Length:	146
Timestamp:	14:12:29.820935 02/04/1998
Ethernet Header	
Destination:	00:e0:b0:63:b3:eb
Source:	00:60:08:a3:11:bd
Source IP Address:	142.60.255.43
Dest. IP Address:	142.229.18.199
Data	

TABLE 3: ETHERNET PACKET

The length of the packet is 146 bytes, and the timestamp was 14:12:29 on February 4, 1998. Next are two physical addresses—the destination and the source. Physical addresses are unique to each Ethernet device. Every NIC, hub port, router port, etc. has a unique *hardware* address that is akin to a DNA sample or a retinal scan. It is an address in hex, where the first three pairs of numbers indicate the manufacturer of the Ethernet device. The *source* address above has a manufacturer 00:60:08, which is 3COM. The next three pairs of numbers are unique for that manufacturer: in this case, 63:b3:eb, which is a hex representation of a binary number (6 = 1010, 3 = 0011, b = 1011, 3 = 0011, e = 1110, b = 1011). Usually the *hardware* address and *source* addresses are the same.

Tips

- You can find your Ethernet address under NT by looking in the control panel in Networks under the adapter tab.
- Every school, jurisdiction, and department **should record** the TCP/IP address as well as the Ethernet address whenever a new computer is acquired or a new Ethernet connection is made to the network. These addresses are essential for network monitoring and troubleshooting.
- When a browser is in use, a time-out often occurs when a site is accessed that is not visited often (not in any cache table, etc.). The result is an error message that “A site was not found or did not have a DNS entry.” Resending the request usually allows a user to reach the destination.

The source and destination IP addresses are next. These numbers are assigned by someone within the school or jurisdiction. In this case the source address is 142.60.255.43 and the destination address is 142.229.18.199. Understanding the IP address is essential when working with security within a school. For example:

- It is desirable for remote users who dial in to have an easily identifiable address range. This makes it easier to track after-hours use, which is a very common opening for unauthorized access.
- If administration and staff are on a different “subnet” or address range, it is possible to control the flow of traffic within a school. This could permit a teacher to access a server on the “instructional side” of the school network but prevent student access to the administrative side of the network.
- IP addresses can be one of two types—static or dynamic. Static addresses are assigned to a particular computer and do not change. Dynamic addresses are assigned as needed and can change from one time to another. It is useful to assign a dynamic IP address for as long a period of time as possible for network troubleshooting or else have a log of which physical address an IP address was assigned to and for what period of time.

Security should always be a concern for every school. The packet analyzed was acquired by a class of software referred to as *packet capture* software. Packet capture software is designed to capture information on the network for analysis and trouble-shooting. It can be used to identify devices causing such problems as broadcasting too often on the network. It can be used to analyze what software is doing on the network.

In this report it was used to analyze traffic between a browser and an Internet host. It is a very powerful tool.

Being powerful, packet capture software also can be misused. It could be used by students to monitor a final exam being sent to a printer, to capture passwords going through the network in "clear text," and so on. It could also be used to monitor e-mail. Since this software captures packets in a passive fashion, it is impossible to detect from the network. This leads to the need to restrict the use of such software within jurisdictions to the individuals who are required to use it and to delineate the circumstances requiring its use.

When wiring a school or jurisdiction office, be careful to physically separate cable so that it is difficult to access the physical network connection of secure users (usually administration). These should be separated on different hubs or with switches that do not share traffic from users who may attempt to capture data. Students and staff can easily download trial versions of packet capture software (if the network allows this type of traffic) and the problem could be spread throughout a jurisdiction in a very short period of time.

Tip

Make a policy restricting the use of packet capture software.

EIPS WAN ANALYSIS—PACKET SIZE

EIPS currently has a 256-Kbps connection to its ISP. This Internet connection was monitored over a period of time. Using the model provided by Table 1, we know the maximum capacity of this link is 32,000 bytes per second. This traffic analysis was derived from the use of Size Trend (Figure 8), one of the elements of an RMON probe which permits longer-term analysis of traffic patterns.

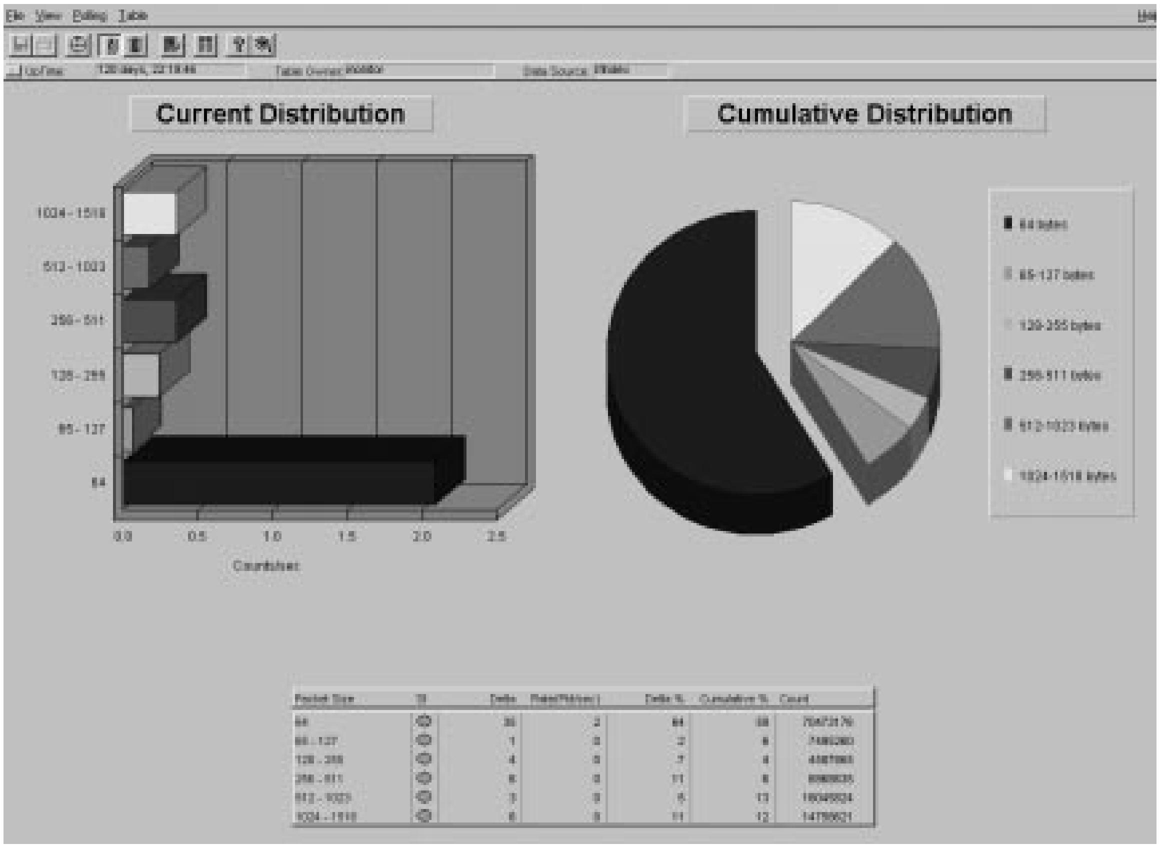

FIGURE 8: RMON PACKET SIZE TREND (15-SECOND SAMPLE, MARCH 6, 1998)

Size trend provides three pieces of information: packet size distribution in bar form for the sample (here fifteen seconds), a pie chart distribution of cumulative size distribution (here 120 days), and a table showing changes in sample distribution and cumulative packet counts. This cumulative count can be used to generalize traffic needs for the WAN. Note that while the count in Figure 8 was taken much later (March 6, 1998) than the data for the model in Table 4 (January 6, 1998), the percentage distribution is very similar. This means that the packet size distribution over this two-month period has been quite stable.

Notice in the RMON packet size trend (Figure 8 table at bottom) that the probe categorized the packet sizes into packet size groups and gave actual packet counts observed within each grouping. These groupings (64, 65–127, etc.) are standard RMON groupings. A packet that is 124 bytes long would be counted in the 65–127 grouping. Using this raw data from the observed counts in the probe would be very misleading.

Each data packet received on a network has to have a packet sent back to the sending computer acknowledging that it was received (an acknowledgement or ACK packet). The "observed" packet counts from the RMON probe are therefore corrected (Table 4) to determine the real distribution of packets. The observed packets by group (Columns 1–3) are obtained from the probe results. In this case there were 32,138,748 packets (Column 2) or 58 per cent (Column 3) packets of size 64 bytes, 3,710,830 (seven per cent) of size 64–127 bytes, etc. for a total number of packets of 55,328,321. Since every packet has an acknowledgement packet, one-half of the packets (27,664,161) must be these ACK packets and the other half data packets. Removing the ACK packets from the observed 64-byte packets yields the number of data packets of length 64 – 4,474,588 (32,138,748 – 27,664,161). The true distribution of packets (Columns 4–7) illustrate the **true** distribution of packet by groups (Column 7 bold). To summarize, the RMON probe gives true counts but these counts must be understood to examine true data distribution.

Column 1	Column 2	Col. 3	Column 4	Column 5	Column 6	Col. 7	Column 8	Column 9
256 Kbps	Observed				Total		**MAX 32 000**	
Packet Size	n	%	Data	Ack	packets	**%**	**Bps**	MAX pps
	61-day sample to January 6, 1998							
64	32,138,748	58%	4,474,588	4,474,588	8,949,175	**16%**	**5176**	40
65-127	3,710,830	7%	3,710,830	3,710,830	7,421,660	**13%**	**4292**	22
128-255	2,192,315	4%	2,192,315	2,192,315	4,384,630	**8%**	**2536**	8
256-511	3,145,617	6%	3,145,617	3,145,617	6,291,234	**11%**	**3639**	6
512-1023	7,422,880	13%	7,422,880	7,422,880	14,845,760	**27%**	**8586**	8
1024-1518	6,717,931	12%	6,717,931	6,717,931	13,435,862	**24%**	**7771**	5
	55,328,321		27,664,161	27,664,161	55,328,321		**32,000**	**90**
Total Bytes	22,502,503,034						**Max @64 + 64**	250
							Max @1518 + 64	20.2

TABLE 4: INTERNET PACKET ANALYSIS

Given this distribution (Column 7), it is possible to predict the number of bytes generated by each of these groups as well as the number of packets per second. For traffic of the EIPS profile the typical number of packets per second observed was 90 pps. From the bandwidth of 32,000 bytes per second, it is possible to estimate the maximum number of pps for the connection. If all packets were 64 bytes (+ 64 bytes ACK), the maximum number of packets would be 250 pps. If all packets were 1518 bytes (+ 64 bytes ACK), the maximum would be 20 pps.

It should be noted that packet traffic is dynamic and changes over time. The RMON probe illustrates this (Figure 9) showing the changing packet distribution over time.

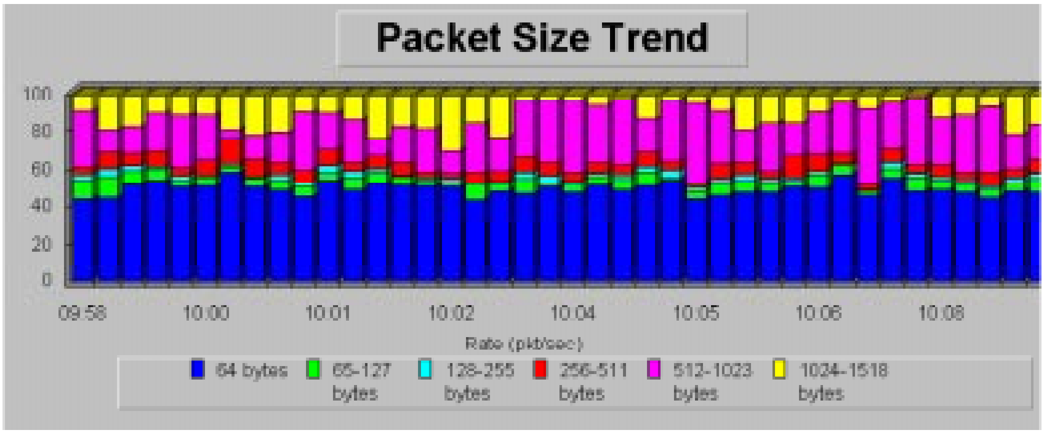

FIGURE 9: INTERNET PACKET SIZES

Tip

- The maximum bandwidth for any WAN connection (e.g., 256 Kbps = 32,000 bytes per second) will not change.
- Capacity quoted by ISPs in packets per second (pps) is not a meaningful metric for WAN connection speeds.

Findings

- Packets sent and received on a WAN tend to be symmetric, having similar counts. Total traffic sent and received measured in bytes is highly asymmetric, with many more bytes received than sent. While the ratio of received to sent will vary, it is in the order of between 8:1 and 10:1.
- Traffic measured in bytes from a user **to** a server will be less than **from** that server.
- Since most of the WAN traffic is K–12 student traffic, the packet size distribution (Column 7) may be generalized to other school jurisdictions.
- The packet size trend for Internet traffic (Figure 9) is **very different** from the trend over a typical Ethernet segment. You can not use the analysis of an Ethernet to project WAN traffic.
- Internet traffic has high use of larger packets due to the number and sizes of graphic elements.

EIPS WAN ANALYSIS—PERFORMANCE MONITOR

The use of an RMON probe was described and a model was developed to show packet size distribution. There are other ways of monitoring a network that involve less expensive tools. One of these tools is the Performance Monitor that comes as part of NT. Performance Monitor can be used to monitor various components within a computer and is useful in determining I/O bottlenecks, CPU performance problems, and so on. Usually this is done on key devices like cache servers, file servers, etc.
If the school is using an NT-based computer for a proxy server or the district is using NT for its firewall software, it is possible to use Performance Monitor to monitor the network interface card (NIC) and hence the bandwidth utilization. The EIPS firewall was analyzed in such a way (Figure 10).

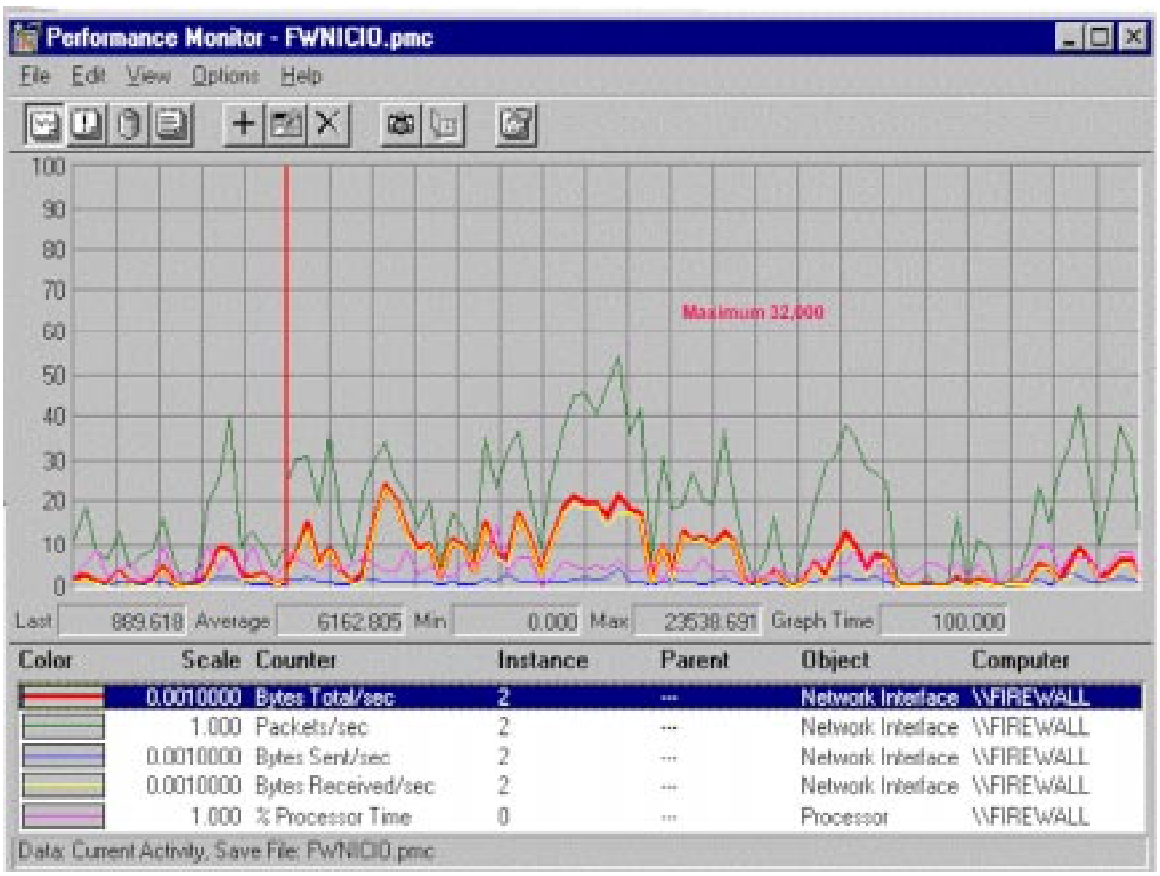

FIGURE 10: PERFORMANCE MONITOR OF 256 Kbps FROM ETHERNET

Performance Monitor can monitor approximately thirty objects, two of which are the network interface and processor. It gives four views—chart (used in Figure 10), alert, log, and report. Each object type contains counters or specific items that can be measured. In Figure 10, five counters were monitored—four on the NIC and the CPU. Which counters are to be monitored, as well as the colour and scale of the counters, is up to the user.

In this case the highlighted counter (Bytes Total/sec) is on the chart at 1/1000 (0.001) and is displayed in a heavy line. Count values for the selected counter appear below the chart. During the 100-second period of the chart, average traffic received was 6162 Bps with a maximum peak of 23,538 Bps and 889 Bps in the last second. Use of the chart gives a real-time look at a particular counter.

Monitoring the total bytes per second counter of the NIC connected to the WAN is an excellent method for determining when saturation is being reached. Alarms can be set for 80 per cent and 90 per cent utilization for monitoring peak utilization patterns. The data can also be logged over a longer period of time for more detailed analysis.

Tip

Increased bandwidth capacity is required when WAN traffic exceeds 80 per cent for sustained periods of time. This assumes that various bandwidth conservation techniques have been used.

The WAN is a shared resource. In EIPS, many schools are all sharing the available 256-Kbps (32,000 Bps) Internet connection. ***Every computer user on the WAN has an impact on every other one***. For this reason some jurisdictions choose to restrict what students can do. For example, they may choose not to allow files to be downloaded. Ignoring the security rationale for this, there is a good bandwidth reason why this may be a valid restriction.

FTP is a common protocol used to download files. A test was done on FTP on a quiet network (little or no WAN activity). The test involved downloading a version of proxy server, a task not uncommon for systems support personnel. Three views of this download were used (Figure 11). The location window (top right view) indicates a file size of 12,711 KB and gives the usual estimate of time remaining and amount completed.

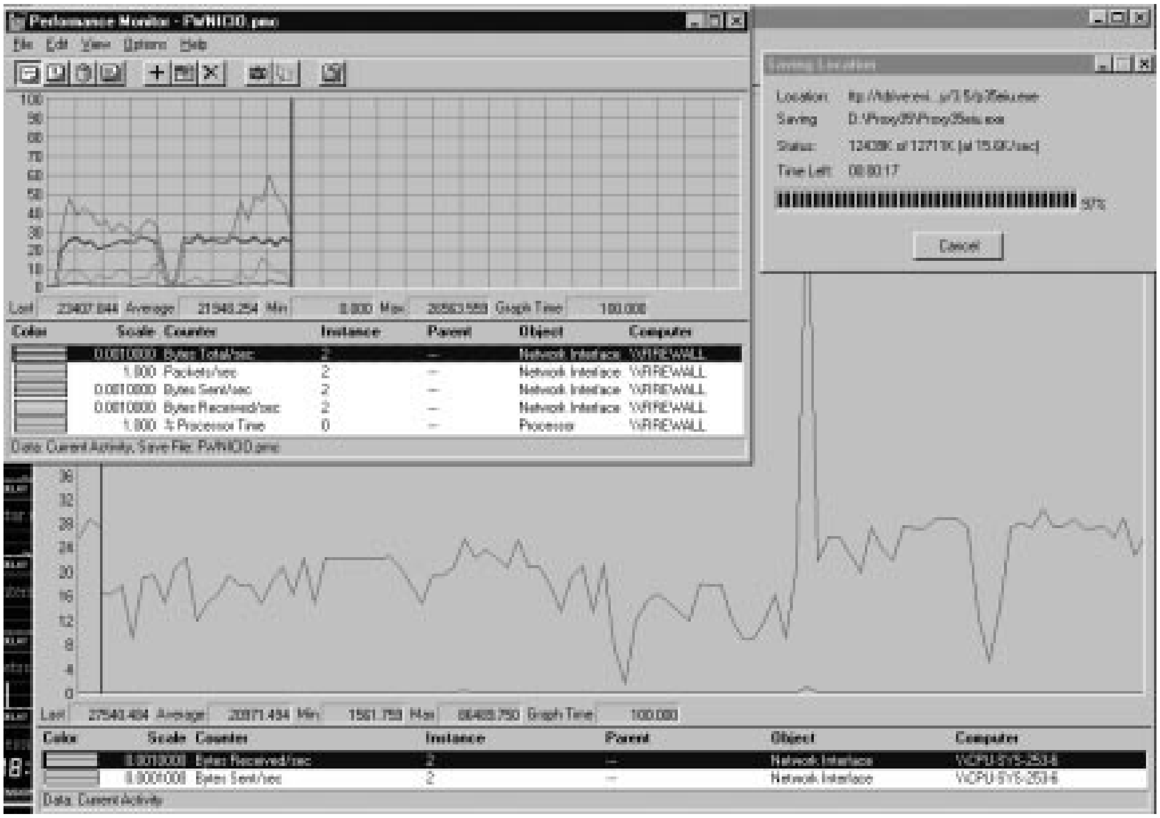

FIGURE 11: FTP ON WAN AND LOCAL NIC

Performance Monitor (large background view) was used to show what was happening at both the firewall and the local computer NIC. The average traffic *received* on the *local computer* was 20,971 Bps with very little traffic *sent* (small peak at bottom of chart just below large peak). The average *total* traffic on the *firewall* was 21,948 Bps. In other words, the FTP session took nearly 22,000 Bps of the 32,000 Bps maximum available. The likely reason that the FTP session did not take all of the bandwidth was due to latencies between the firewall and the destination host.

One user will take as much bandwidth as is available. This is true of all browsers and other users on the WAN. The difference between a browser user and an FTP user is a matter of scale. An FTP user typically utilizes high bandwidth for longer periods of time than a browser user.

WAN TRAFFIC—CONTENT

It is possible to analyze all traffic on the WAN. One of the useful features possible in a firewall package is the capture of accounting information. This information can be downloaded to other tools such as databases or spreadsheets for further analysis. The total traffic from selected dates was analyzed within EIPS. One date—January 15, 1998—was analyzed in detail for this study (this arbitrary date may or may not be representative).

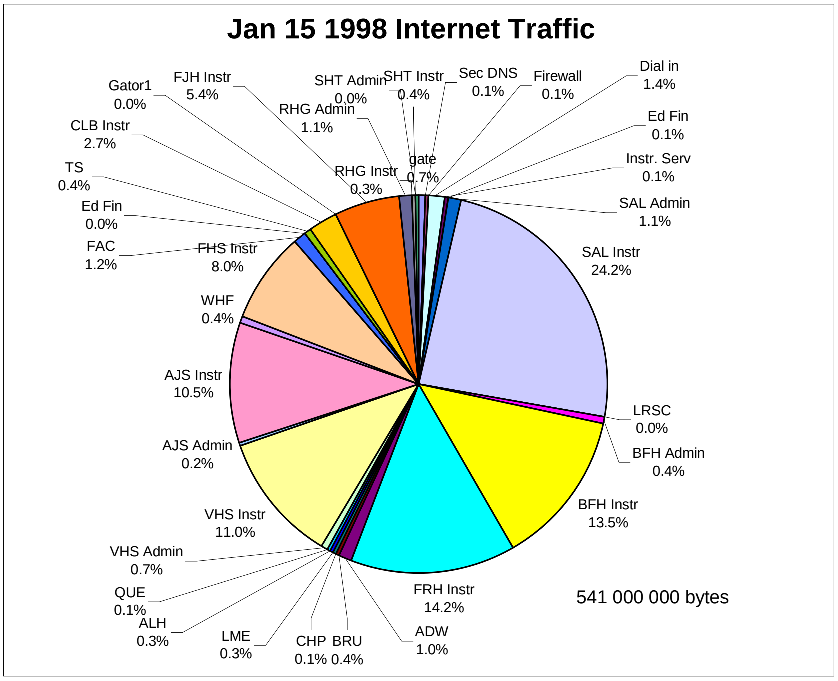

FIGURE 12: WAN TRAFFIC BY SITE

Total traffic for January 15 was approximately 541 MB. Of this traffic:

- a large senior high school (grades 10–12) accounted for 24.2 per cent
- a large junior high school (grades 7–9), 14.2 per cent
- another senior high school, 13.5 per cent
- a more distant high school (grades 7–12), 11 per cent.

Of interest here is not the total traffic but rather how the schools are connected. All of the senior high schools were properly wired during the summer of 1997, so their infrastructure was in place. The junior high school cited is largely wired, but not to the same extent as the high schools. Most of the other schools were not wired. In addition, most of the high traffic schools have good WAN speeds within the jurisdiction. The 24.2 per cent school is connected via fibre, the 14.2 per cent school by cable modem, the 13.5 per cent school by 2-Mbps wireless. The distant high school is currently connected by 56 Kbps but is in the process of converting to AGNpac.

Having the proper wiring infrastructure is essential to the use of the Internet. Equitable bandwidth from the school is essential.

All of the January 15, 1998 traffic was sorted in descending order of size (number of bytes). Sixty-one sessions (Appendix G) were greater than 500,000 bytes. The total traffic of these sixty-one sessions was 115,359,471 bytes (21.4 per cent of total) in 191,007 packets. This traffic occurred in seven services (Table 5). FTP accounted for 10.5 per cent of the traffic for sessions of 500,000 bytes or more, or 2.3 per cent of total traffic. (There could be more FTP traffic in other sessions for traffic less than 0.5 MB.) RealAudio accounted for approximately half of this amount at 5.8 per cent.

Sum of Bytes			
Service	**Bytes**	**Top**	**Total**
5000	1,362,983	1.2%	0.3%
666	19,255,018	16.7%	3.6%
6667	679,919	0.6%	0.1%
FTP	12,144,936	10.5%	2.3%
HTTP	72,510,046	62.8%	13.5%
pop-3	2,745,975	2.4%	0.5%
RealAudio	6,680,594	5.8%	1.2%
Grand Total	**115,379,471**		**21.4%**

TABLE 5: SUMMARY OF TRAFFIC BY SERVICE

Of the files over 0.5 MB that were downloaded, movies (".mov") made up 38.7 per cent of the traffic. Programs (".exe" and ".hqx") account for 6 per cent and 0.8 per cent of traffic. Examination of the destination files (see Appendix J, Figure 42) reveals that most of the movie files and sound files are entertainment-related. While it is understandable that students will want to go to these types of sites, it is difficult to justify from the perspective of total available bandwidth. While a particular school or teacher might not mind students going to these sites, bandwidth is limited and every connected user has an impact on every other user. A 5.8-MB movie file of *Scream2* has an impact on every class trying to do curriculum-related work.

Sum of Bytes			
Type	**Bytes**	**Top**	**Total**
	42,869,425	37.2%	8.0%
.au	8,143,345	7.1%	1.5%
.qt	577,645	0.5%	0.1%
AVI	1,974,036	1.7%	0.4%
exe	6,891,476	6.0%	1.3%
gif	1,184,388	1.0%	0.2%
hqx	922,878	0.8%	0.2%
jpg	524,459	0.5%	0.1%
mov	44,709,045	38.7%	8.3%
wav	6,857,769	5.9%	1.3%
zip	725,005	0.6%	0.1%
Grand Total	**115,379,471**		**21.4%**

TABLE 6: SUMMARY OF TRAFFIC BY FILE TYPE

The variety of possible solutions to issues raised here are beyond the scope of this report.

WAN EQUITY

Not all schools in the province or even within a jurisdiction have the same WAN options as others. Urban schools and large schools usually have more options that rural schools and small schools. It is possible to begin to quantify bandwidth requirements by school (Table 7). One common assumption is that the bandwidth requirements of students at different levels is different. For example, if it is assumed that a grades 7–12 school requires a bandwidth of of 56 Kbps per student, a school with 987 students would require 55,210 Kbps or 55.2 Mbps. Clearly, this model is too simplistic.

Grade Level	# Students	Kbps per student	Total Kbps
ECS	0		
1–3	0		
4–6	0		
7–9	476	56	26,656
10–12	510	56	28,560
Total	**987**		**55,210**

TABLE 7: SCHOOL BANDWIDTH PROJECTION

A model must be flexible enough to allow for altering bandwidth requirements. Some of the variables are:

- the number of stand-alone computers attached to the school LAN.

  LAN-connected, stand-alone computers are those computers in various rooms and locations that are capable of using the WAN. It is assumed that not all of these would be on the WAN at the same time (perhaps 20 per cent would be).

- the number of labs by type (15, 20, 25, 30, etc. computers) and, for each lab, whether or not the class will work on group or individual projects.

  During study periods, some computers would be doing word processing, some using the WAN, and so on.

- the number of computers in a library-type setting.
- the number of computers used by staff.
- the number of CTS or other high-bandwidth-use computers (video, real-time audio, distance education, etc.).

A school's bandwidth can be estimated (Table 8). This school has a population of 1068 and, in time, every student could have a computer. Since the maximum number of computers would be 1068, the network infrastructure has to be built accordingly. A ratio of 15:1 for the number of students per computer provides an estimate of eighty-three computers, while a 5:1 ratio yields 214 computers. It then requires the bandwidth to be estimated. All assumptions about bandwidth appear in italics.

School Population	1068
Number of computers @ 15:1	83
Number of computers @ 5:1	214
Maximum # student computers	1068
Student Stand-alone Computers	
Bandwidth—stand-alone Kbps per student	***56***
% stand-alone on WAN	***20%***
Stand-alone bandwidth @ 5:1 (Kbps)	2397
Labs	
Two labs of 30	60
Bandwidth—lab Kbps per student	***56***
Lab % of computers on WAN concurrently	***100%***
% lab bandwidth by cache server	***20%***
Lab bandwidth (Kbps)	2352
Staff	
Number of staff	90
Number of staff computers	30
% of staff on WAN	***50%***
Bandwidth—Kbps per staff	***56***
% bandwidth saved by cache	***35%***
Staff bandwidth (Kbps)	294
Net School Bandwidth Requirement (Kbps)	**5043**

TABLE 8: SCHOOL BANDWIDTH ESTIMATION

This model separates *assumptions* from easily derived metrics in order to examine their impact. If the established standard for the school is 56 Kbps per student and 20 per cent of the 214 stand-alone student computers are on the WAN concurrently, the bandwidth required for this portion of the school is 2397 Kbps (2.397 Mbps).

These are not the only computers in a school. Assume that there are two labs with thirty computers each (or one lab of thirty, another lab of fifteen, and fifteen in a library—sixty computers in definable groups). Again, assuming 56 Kbps per student on the WAN and 100 per cent of students on the WAN and 20 per cent of their traffic successfully cached in a cache server, the bandwidth impact of the labs would be 2352 Kbps (2.352 Mbps).

Staff (both teaching and support) also use computers. Assuming thirty staff computers with 50 per cent on the WAN concurrently and 35 per cent of their traffic cached in the cache server, the bandwidth requirements would be 294 Kbps (0.294 Mbps). The school total required would be 5043 Kbps (5.043 Mbps).

Few schools would pay for 5-Mbps WAN connections at current prices. The utility of a model is that various “what-if” scenarios may be run in order to examine and refine assumptions.

- Reducing the bandwidth standard to 28 Kbps (50 per cent reduction) or some other rate would decrease the requirements by 50 per cent (approximately 2.5 Mbps).
- Improving the cache server hit rates by tuning, utilizing larger drives, etc. would further reduce bandwidth.
- Scheduling classes in the labs so that only one of them is on the WAN at any time reduces the lab impact of the two labs by 50 per cent.
- Eliminating non-essential traffic would decrease requirements.
- Identifying high-use sites and mirroring them in the jurisdiction or school would reduce bandwidth requirements.

"What-if” analysis can be used to create a worst-case scenario. In this school, the worst case would be to have every staff member and student all using video at the same time. The LAN within the school must be designed to be worst-case ready. This will require secure wiring closets with 10/100-Mbps segments that are 1000 Mbps ready. The number of servers will continue to grow as the amount of electronic services and the complexity of the environment increase.

Most school staff have “a feel” for what is going on in the school and can identify WAN utilization somewhat intuitively. Given access to some of the tools identified in this report, it would be possible to monitor the total bytes, which IP addresses are generating traffic, which protocols are being used, and so on.

Enterprise Perspective

WAN bandwidth is dynamic in that instantaneous utilization varies from moment to moment. It also is a limiting resource; everyone has an impact on the performance of everyone else. In jurisdictions running a system WAN, every user in a school has an impact on every other user in the other schools. In site-based decision making, this level of integration is unusual.

Using the Internet as a “noon-hour supervisor” in one school impedes another school from doing curricular-related work.

Issues

- Equalizing the cost per Kbps among all schools, much like sparsity and distance.
- Measuring WAN capacity in Kbps per WAN user and not Kbps per school, which ignores the numbers of students and computers involved.

SHARED BANDWIDTH—THE CASE FOR A SWITCH

Many schools install “dumb hubs” in the network layer since the cost per port is lower than other alternatives. For example, an unmanaged hub sells for about $680 while the managed version sells for about $1100. A school/department that acquires the unmanaged hub will not be able to use network tools such as OpenView to monitor it.

Metric

Cost per port is useful for planning network costs; e.g., $75 per port or $X per port.

As LAN network traffic increases (and also as security becomes more of a concern) the use of hubs should be re-examined. Assume that a 24-port hub is in use. When a computer attached to one of the ports downloads a large file, every other computer attached to that hub also “sees” that traffic. Each computer’s network card is busy even though the individual computer is not downloading any data. When a user does create network traffic by browsing, etc., that network traffic competes with the other traffic on the hub.

Metric

A 10-Mbps Ethernet segment generally becomes “saturated” above 30 per cent or 3 Mbps.

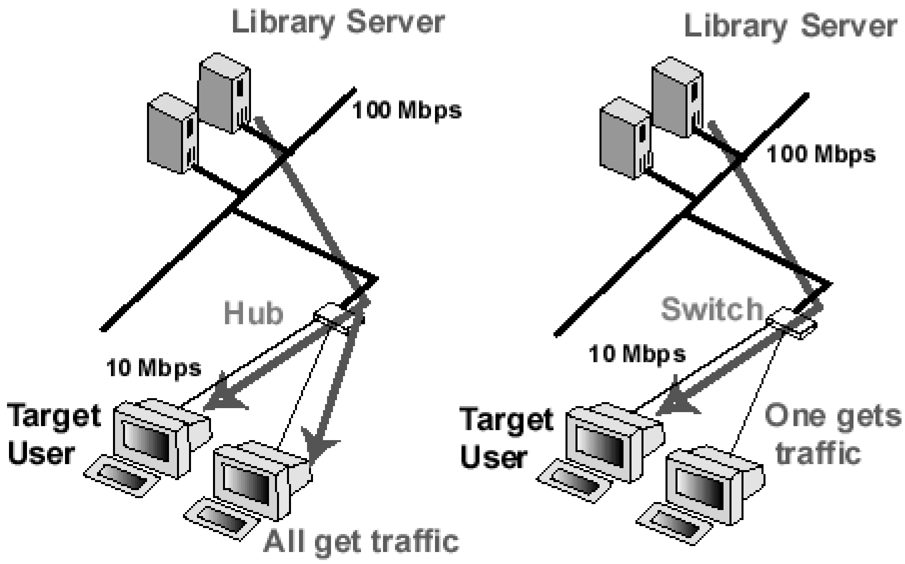

FIGURE 13: HUB VERSUS SWITCH

The use of a switch helps control *where* network traffic is transmitted. A proper switch will transmit the data only to the port requiring it, thus reducing the overall traffic to other computers on the segment (Figure 13). Note that even for small schools it is highly desirable to have a 100-Mbps segment since network traffic for on-line encyclopedias and multimedia will require this bandwidth. Large schools should be designed to move segments to 1000 Mbps when the need arises.

Design

Switched to the desktop. Just do it.

CACHE SERVER

One technique for removing traffic from the WAN connection is the use of a cache server. Cache servers are usually dedicated computers running software such as Netscape's Proxy Server or Microsoft's Proxy Server. Each time a user accesses a new page, the local copy of the browser copies the files to its hard disk. If this site is accessed again, a copy of the file is read from the local cache file and the traffic is not downloaded from the network (Figure 14).

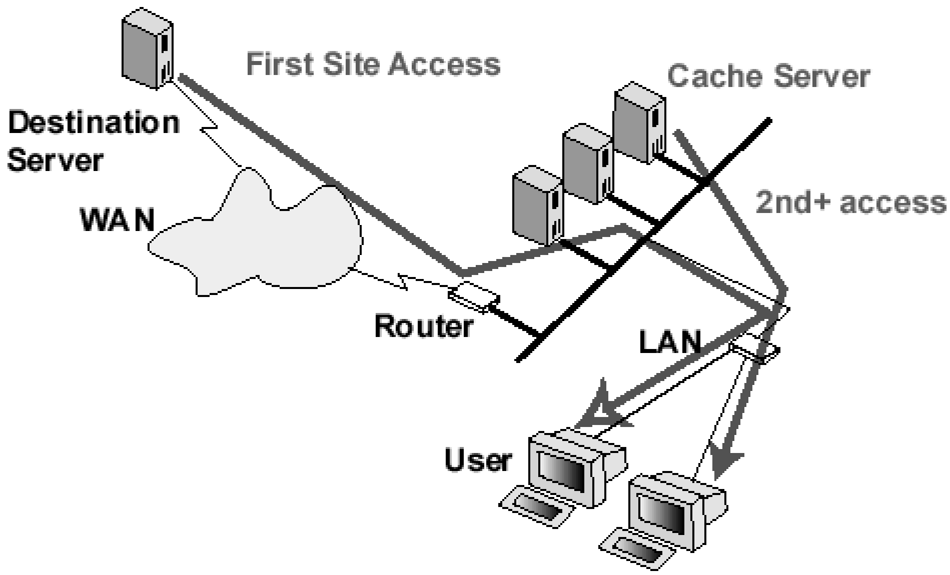

FIGURE 14: CACHE SERVER

If a cache server is installed on the network, each web page is copied to the cache server's hard disk. The first time a web site is accessed, the data is sent to the requesting computer and also is written to the hard disk drive on the cache server. Subsequent user requests to that web site will likely be served from the copy on the cache server and not from the host web site. A cache server has the potential of greatly reducing the overall WAN traffic.

To illustrate the potential impact of a cache server, assume the 100-KB file referred to in the model (Table 1) in a lab setting of thirty computers. The first user to access the web server will download 100 KB (ignore handshaking and other real network issues). This will be stored on both the user's browser cache as well as the cache server. If a second user in this lab accesses this site, the data will be downloaded from the cache server over a local Ethernet connection and **not** from the web server.

If each of the thirty computers access this same site (as would be the case in a teaching environment where a specific site is required), the total WAN traffic would be thirty times 100 KB (3000 KB) without a cache server and 100 KB with a cache server. This would represent a *best case* scenario.

If each user were doing independent work, the impact of the cache server would be reduced since these users tend to be going to different sites. In other words, the thirty times savings in WAN traffic would tend towards one time or no net WAN bandwidth saving. In reality, there is generally a 20 to 30 per cent cache hit rate in schools with a mix of labs and computers in other locations.

Overall network traffic may not seem to warrant a cache server, particularly in schools with small enrolments. (The cost per student for a small school to justify a cache server with UW disk drives is quite high.) However, there is another way of looking at cache servers: if the information has been cached, the latency for the student is much lower than waiting for it over a much slower WAN link.

Tips

- Cache servers are disk I/O-intensive. Ultra-wide SCSI (UW) disks are required for adequate performance. (The U2W drives that are beginning to be available should give better performance than UW.)
- Using two network interface cards (NIC) in a cache server helps segment the traffic. One NIC can connect to the LAN and the other to the WAN. This reduces unnecessary traffic to the WAN device (router, etc.).

Issue

Equity means that performance should be available equally to students in small and large schools. To provide network opportunities, schools may require cache servers and other network devices "beyond what the numbers warrant."

A question often asked: "Is a cache server worth the price? After all, they're expensive." There is no simple answer to this subjective question. A cache server could make the difference between a slow WAN connection being useful or too slow. The following snapshot of two cache servers illustrates actual student patterns. Table 9 lists the top destinations from two large senior high schools.

Site 1	#	%	Site 2	#	%
com	5377	57.9%	com	1405	53.1%
net	854	9.2%	net	247	9.3%
edu	642	6.9%	ca	238	9.0%
ca	578	6.2%	edu	231	8.7%
org	367	4.0%	org	126	4.8%
uk	237	2.6%	[Local Hos	66	2.5%
au	150	1.6%	uk	58	2.2%
de	93	1.0%	au	37	1.4%
se	80	0.9%	gov	30	1.1%
gov	70	0.8%	se	26	1.0%
nl	64	0.7%	de	25	0.9%
us	58	0.6%	us	22	0.8%
jp	51	0.5%	fr	18	0.7%

TABLE 9: CACHE SITE ANALYSIS

In both schools, the largest single destination is ".com"—commercial sites. This raises the further question as to which sites these are (Table 10).

School 1	n	%	School 2	n	%
www.geocities.com	1361	9.9%	www.geocities.com	1797	6.4%
members.aol.com	2684	1.9%	www.microsoft.com	436	1.6%
Images.yahoo.com	1373	1.0%	www.infoseek.com	395	1.4%
www.infoseek.com	1230	0.9%	www.burton.com	388	1.4%
members.tripod.com	1226	0.9%	images.yahoo.com	351	1.3%
home.netscape.com	1112	0.8%	home.netscape.com	305	1.1%
www.angelfire.com	1064	0.8%	Members.aol.com	259	0.9%
www.microsoft.com	798	0.6%	www.nhl.com	206	0.7%
www.excite.com	779	0.6%	www.disney.com	201	0.7%
ads.lycos.com	677	0.5%	www.g1d.com	194	0.7%
www.spe.sony.com	598	0.4%	www.excite.com	191	0.7%
www.fortunecity.com	458	0.3%	fvf.warzone.com	189	0.7%
www.windows95.com	454	0.3%	www.discoveralberta.com	184	0.7%

TABLE 10: ".COM" CACHE ANALYSIS

The largest single site in the ".com" group of sites is <www.geocities.com>. Like other large sites, this site has various categories. It would appear (from the network traffic point of view) that this site is being chosen over others for chat, e-mail, and free web pages.

If a jurisdiction has all of its schools connect to a jurisdiction-wide WAN connection, it is possible to have a jurisdiction or "head-end" cache server. This server will be queried for web pages before the network request goes out onto the Internet. The architecture of having a school cache server and a jurisdiction cache server is referred to as "cascading cache servers."

Tip

If WAN bandwidth is an issue, schools may wish to review what sites and types of activities are of educational merit.

MULTIPLE WAN CONNECTIONS

Most schools in the province are connected to the Internet via a single network access point. In August 1997, cable companies donated a cable modem to schools where the service was available. This event, which resulted in the potential for schools to have more than one WAN connection, raises some architecture design issues. If the school is part of a jurisdiction WAN with firewall and filtering at a central site, access to the Internet at the school level creates a security access point to the jurisdiction at many locations. This results in requirements for filtering, firewall, etc. at each site in addition to the central site.

Traditionally the solution would be to add a router at the site. A router is very good at keeping unwanted traffic out of the school, but it does little to filter for content or other types of tasks. With the prices of PCs falling rapidly, it is possible to use a proxy server-firewall-filter computer with two network interface cards (Figure 15).

Network World magazine reviewed a router (Cisco 2514) versus a PC (200 MHz Pentium with MS RRAS routing, 3Com 10/100 NIC) (January 12, 1998: <http://www/nwfusion.com>) and found that a Pentium 200 with 10/100 adapters could handle approximately twenty-five users per segment and up to 100 users overall before encouraging significant performance issues. Hardware-based routers like the 2514 were more appropriate for 50–75 users per segment or heavy load users.

PC and router costs are similar, depending on what is purchased for the PC. The PC gives better *flexibility,* in that more software such as filtering can be run and the computer can be moved to other locations in the school or jurisdiction when more capacity is required. A router performs that job well but is obsolete when it no longer meets the needs of the school.

A more thorough test of this architecture is being conducted at a school in the Elk Island Public Schools Regional Division.

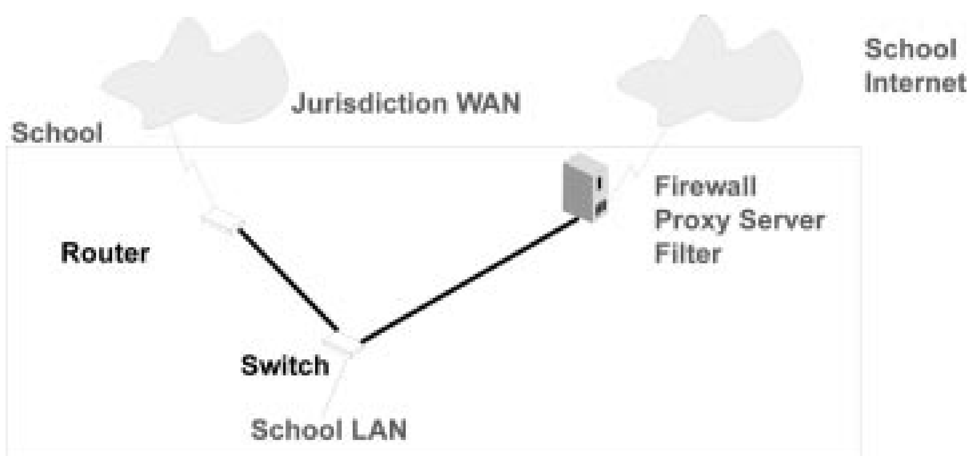

FIGURE 15: MULTIPLE WAN CONNECTIONS FROM A SCHOOL

SUBNETS AND FILTERS

Schools represent an interesting security challenge. In many schools, students know more about computers and networks than the teachers and staff. Students in senior grades also have access to packet analysis software, viruses, and all of the things that have the potential to make a school network vulnerable. Various mechanisms have been deployed to “lock up” the desktops. Recently there has been a move to Windows NT for student computers because of its ability to be tightly controlled.

One area of overall security that often is overlooked is subnets and filters. This area must be addressed very early in the design since any changes downstream are very time-consuming to implement. A number of early decisions can assist the school design.

What is the address:

- range of administrative computers
- range of instructional computers
- the mail server
- the school server
- the web server
- the primary domain controller (for NT schools)
- the remote access server (for dial in)
- the proxy/cache server
- video server
- library electronic resources server
- etc.

Before long, schools find they have a multiplicity of electronic services. In small schools many of these functions can occur on one server but in large schools they will quickly be on multiple computers. From a jurisdiction perspective there needs to be a similarity so that, when a device sets off an alarm in OpenView or its equivalent, the address will easily be identified (what type of device it is). These types of network services should have *static* addresses.

For purposes of discussion, assume that the school has a private B or C licence on their side of the firewall (x.x.125.0 and x.x.126.0 where 125 is administrative and 126 is instructional). The school wishes to have a mail server (x.x.126.z where 126 is instructional and z is the number for mail servers) that can be accessed by both students and staff. Placing it on the instructional side of the network will require access through a network device that lets staff through to the mail server but prevents students from going through the device to the administration side (Figure 16).

Interface	Proto	Port	Address	Mask	Action
Destination	TCP	25	x.x.125.0	255.255.255.0	Forward
Source		All	x.x.126.z	255.255.255.255	

TABLE 11: FILTER ADDRESS AND MASK

In the example shown in Table 11, the router would be given IP filter rules to allow TCP traffic for mail (SMTP is port 25) to go from the mail server (126.z) through. For most readers, *how* this works is not important, just that it can be done. ***This issue needs to be addressed early in the evolution of the school network.***

Figure 16 illustrates how a filter can allow administrative and instructional traffic to access a server while preventing an instructional computer from accessing the administrative network. The router permits the address range of the administrative subnet to go to the segment with the server. The same router drops the packets from the instructional computers so they are unable to get to the administrative segment. In order for this to continue to work, the system must prevent anyone from changing IP addresses on the instructional side to administrative ones.

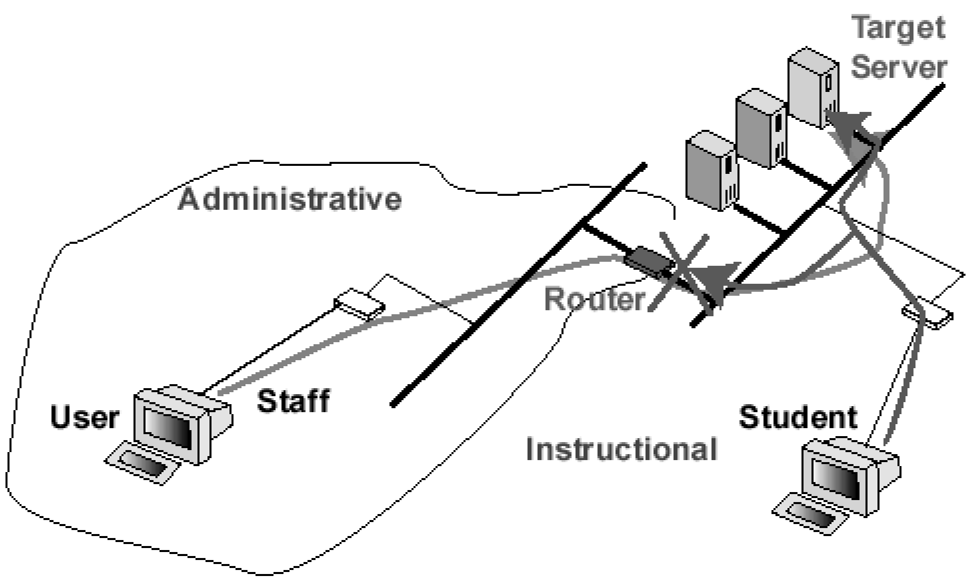

FIGURE 16: FILTER ON ADDRESS/PROTOCOL

Tips

- Administrative and instructional computers should have different IP addresses that can be filtered easily.
- Administrative and instructional computers should be attached to different physical hubs or switches.
- External access (e.g., from modems) should be controlled by an access server and should be easily identified by their IP addresses.
- Filters can be applied to IP addresses as well as protocols.
- Filter and allow only student IP addresses from instructional computers. This will prevent students from spoofing by changing their IP address to an administrator's address.
- Where possible, there should be "one computer for one service."

CASE ANALYSIS—LISTENING TO THE RADIO

Listening to a radio live (Figure 17) requires between 8 Kbps and 11 Kbps of bandwidth. It also requires a very good end-to-end connection since each network delay disrupts the audio noticeably. Notice this capacity may be determined by the use of the RealAudio window "Playing 8.0 Kbps," the NetMedic window (11 Kbps instantaneous in Speed Limit section at time of capture but averaging 8 Kbps), or 1251 Bps (1251 X 8 = 10,008 bits or 10 Kbps) average using Performance Monitor on the NIC.

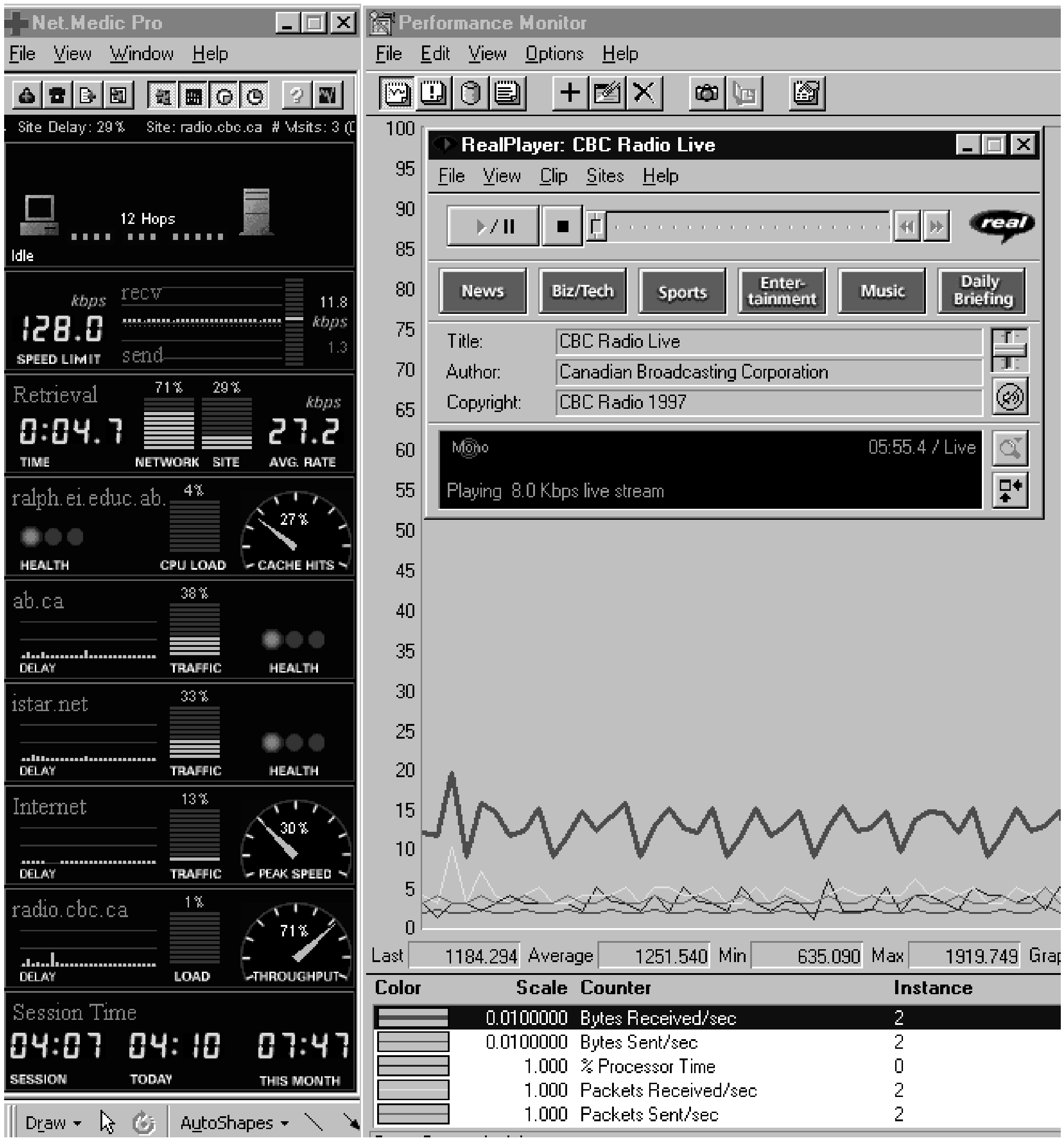

FIGURE 17: LIVE RADIO

The question may be asked, *"So what? Who cares if listening to audio takes eight Kbps?"* The answer relates to what a school may actually do in the future.

For example, consider a high school social studies teacher who wants to listen to a report on a key world event that is being broadcast on the Internet. If the teacher uses a single computer and speakers, the bandwidth to the school would be eight Kbps. If the teacher uses one computer per student, each student's bandwidth requirements are eight Kbps. A class of thirty would require 30 X 8 Kbps or 240 Kbps. Many schools do not have that bandwidth available. Trying to do this over a centrex line would result in lost data, broken speech, and an unsatisfactory instructional experience.

Knowing the general metric for RealAudio permits teachers to select alternative instructional strategies. One way around the bandwidth to the school would be similar to a cache server—creating an audio server (and using multicast). This would involve a computer that runs audio server software. The sound clip is downloaded to the server for subsequent use by students. Audio servers are very good at storing sound clips that are most often useful to auditory learners. Such a server is a network architecture design issue.

Useful Sites

RealAudio <http://www.realaudio.com/>

CU-SeeMe <http://www.wpine.com/>

PORNOGRAPHY, HACKERS, AND OTHER UNMENTIONABLES

Although most people recognize that many sites are inappropriate for student use, few schools and jurisdictions in Alberta are using filtering software. Some using the software may not have examined whether the software is *effective*. Many jurisdictions apparently do not want to be cyber-police and rely on signed “terms-of-use” agreements. This is one of the many new tasks that emerge in running a network, and often there is not sufficient staff to address all of them. Although the word “censorship” is often heard, materials available on the Internet may require some level of action *in loco parentis.*

Firewall-1 accounting logs indicate that students in unsupervised labs or using computers that a teacher/librarian can not see are accessing sites that many parents would not consider acceptable.

The major use of a firewall product such as Firewall-1 is to protect the internal network from outside attack. Many users throughout the world find, attack, and destroy the data, servers, and access to the Internet of individuals and institutions. Most schools operate in a trusting environment and are not used to having to protect themselves from such attack. Firewall-1 is a good product for providing a rules-based interface to firewall management.

Management of what internal users are permitted to do in such an environment is illustrated by a rule (Figure 18).

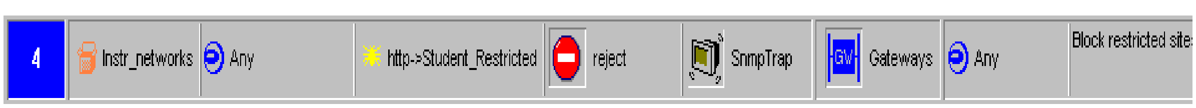

FIGURE 18: A FIREWALL-1 RULE

In this rule, a subset of users (all instructional networks) that attempt to access a restricted site (for example, those defined within SurfWatch or WebSense) will have their packets rejected. In addition to this, the management software monitoring the network (in our case, the OpenView console) will be notified by an SNMP alert that such an access has been attempted. It is possible to see network rule violations in real time.

To assist schools in reducing these situations, a screen (Figure 19) has been created that contains a loud siren noise. This web page is sent whenever the filter software encounters a site on the list of inappropriate sites. While it sometimes creates false alarms, such a technique reduces the number of in-school accesses. Note, however, that talented students can disable the sound before accessing sites.

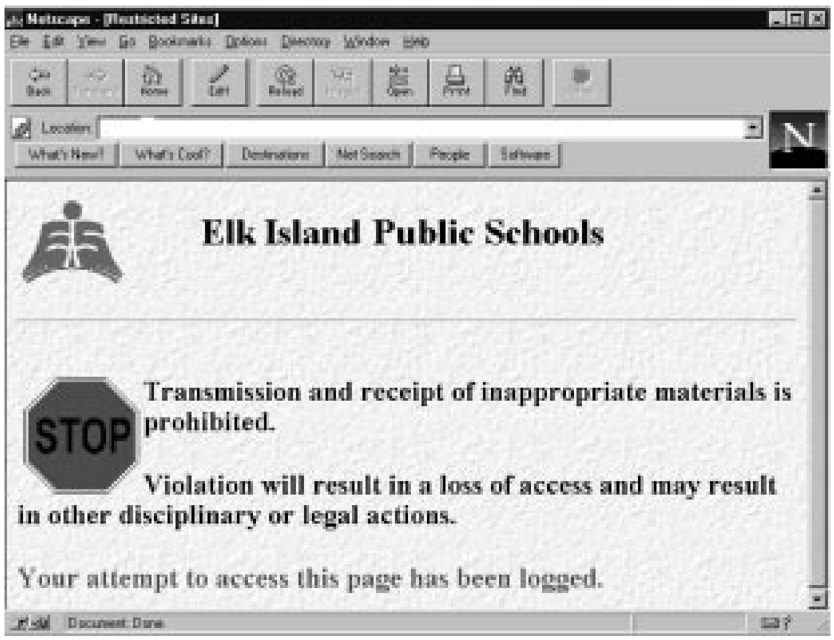

FIGURE 19: AUDIBLE ALERT

Suggested Strategy

Implement filtering and have staff check logs.

Useful Sites

WebSense <http://www.websense.com/>

Surfwatch <http://www1.surfwatch.com/home/>

DIAGRAMS AND DOCUMENTATION

One tool for recording IP addresses, MAC (Ethernet) addresses, and wiring diagrams is a visual database from Aperture. Starting off as a Macintosh application, it has moved to the Windows NT environment and also is integrated into OpenView.

Appendices H and I (Figures 38–40) include diagrams at the jurisdiction level down to individual computers with data records attached to them. Examination of the menu bar will illustrate that this is a combination drawing suite and database that can be navigated much like web pages with “hot spots.”

There are powerful and useful tools available to assist in the documentation process. All Elk Island Public Schools wiring tenders are first drawn with a tool and are given to potential contractors for a price quotation.

Useful Site

Aperture <http://www.aperture.com/>

WAN ANALYSIS SUMMARY

The model provided in this report illustrates a number of points. Network traffic occurs over Ethernet and Internet traffic utilizes the TCP/IP protocol. Different WAN connections have different capacities. A 56-Kbps connection has a maximum capacity of 7000 bytes per second while a T1 has a maximum capacity of 192,500 Bps. These are theoretical maximums; approximately 80 per cent of the capacity should be used to determine typical traffic.

There are different packet sizes on a network, and it takes different amounts of time to download files of various sizes. Many users have an impact on a WAN connection. Conservation of bandwidth can be achieved with cache servers, filters, etc., and WAN traffic can be split to multiple WAN connections.

Audio and video through a WAN connection can have a significant impact on network performance. Filtering of content addresses both bandwidth conservation issues and curriculum issues.

LAYERS AND COMPUTER PERFORMANCE

Poor browser performance also may be a result of the user's hardware and/or software.

A computer's many *integrated* subsystems all have a direct impact on performance. These subsystems include:

- central processing unit (CPU)
- disk (type, speed, controller)
- memory (amount and type)
- network interface card (speed)
- graphics (memory, resolution, graphics card)
- bus (type and speed)

It is possible to conclude (erroneously) that lack of performance with high CPU utilization is caused by a CPU that is too slow when the problem is insufficient memory. A lack of sufficient memory can cause excessive swapping with both the disk subsystem and CPU, with resulting high utilization. To draw an analogy, one has to diagnose the "cause of the headache," not treat the "headache."

This part of the report will attempt to serve two purposes—identifying problems and tools to assist in overall network performance from an end-user perspective, and education of the user to assist in better computer purchases.

For simplicity, illustrative tools will be drawn mostly from PCs but the general principles apply to all computers.

CENTRAL PROCESSING UNIT

The central processing unit (CPU) is the component that actually performs all the work. It performs "one task at a time" and is synchronized with the system clock. A clock speed of 166 MHz means that the clock is running at 166 million (mega) times per second. If the CPU performs one task for every clock cycle, then it can run 166 million instructions per second. If the clock is 333 MHz, it is running approximately twice as fast as the one running at 166 MHz.

The two most common computer families in schools are the PC and the Macintosh. Each CPU family has the instructions it can run built right into the silicon of the CPU. These instruction sets can not be modified. The Intel or PC family of computers include the 8088, 80286 (AT), 80386, 80486, Pentium, PentiumPro, Pentium II, etc. The Motorola family used in the Macintosh includes the 68000, 68020, 68030 (e.g., SE30), 68040, and the PowerPC 601, 603, and 604.

CPUs are "interrupt driven." They are halted every time there is a request to write or read to disk, update the screen, and so on. Newer architectures such as PCI 2.1 minimize the number of interrupts a computer receives and result in more efficient use of the CPU.

Computers need to get their information from memory. There is special memory for "often used" instructions called "cache memory." Cache memory has very short distances to transfer the data to the CPU and has wide data paths for doing so. L2 cache *significantly* affects the overall performance of a computer.

Tips

- Clock speed (measured in MHz) — Higher is better.
- L2 cache — Having it is better.

CPU METRICS

Measuring the performance of computers is becoming more of a science than it used to be. CPU clock speed is a significant factor when recalculating a spreadsheet, doing document spell checks, and anything that is "compute-intensive." Photograph and video editing are examples of highly CPU-intensive tasks.

Tasks such as typing, opening and closing files, e-mail, etc., tend to be affected more by the disk subsystem and memory than by CPU clock speed. Moving a window around on the screen is a highly CPU-intensive task (Figure 20), while surfing with a browser is not CPU-intensive.

Tip

On a Windows 95/NT computer, use the Task Manager to examine CPU utilization. This is an inexpensive way to see if the task is CPU-bound.

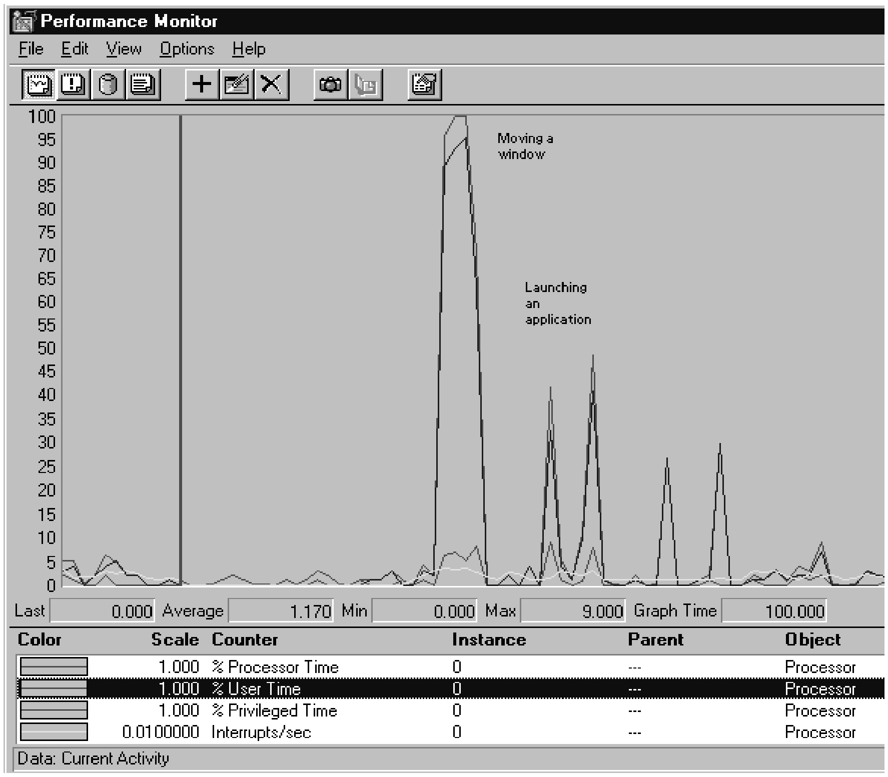

FIGURE 20: CPU UTILIZATION
MOVING A WINDOW AND LAUNCHING AN APPLICATION

The overall CPU processor time shows a rapid rise to 100 per cent utilization. (Note that the graph time window is 100 seconds.) Moving a window on the screen will consume all of the CPU (first spike in graph). The faster the CPU-graphics subsystems, the *smoother* the move will appear on the screen. Launching an application software package such as Word 97 will result in a momentary utilization of CPU, as indicated in the later spikes. Much of the application launch latency will be related to the disk and not the CPU. This example demonstrates the interconnectedness of the subsystems.

Four object counters were identified for the graph:

- per cent processor time. Total computing by all processors on system. When this counter consistently approaches 100 per cent, the system OS will suspend some tasks in order for others to run. This will create a processor bottleneck.
- per cent user time. Shows the total time spent on user or application processing and is one of the two components of total processor time. Applications that need to access hardware devices send the request to a privileged mode program. If this counter is high, then the application is the likely source of the bottleneck.
- per cent privileged time. Shows the privileged operations such as video, disk I/O, NIC I/O, etc. This can be used to identify which processes are causing the bottleneck.
- interrupts per second. The number of device interrupts.

Note that the scales, all of which can be modified, are not all the same.

Performance Monitor and Task Manager both allow the user to examine CPU utilization in "real time," while events are occurring. Two comparative tools are useful for measuring CPU performance—SPECmark and $CPUmark_{32}$. One metric used within PCs is $CPUmark_{32}$ developed by Ziff-Davis, part of the Ziff-Davis' WinBench® 98 Version 1.0 benchmarks suite. This metric, available in computer magazines, is highly useful when evaluating CPU performance.

For example:

- A Dell Dimension XPS D333 (a Pentium II running at 333 MHz) obtained a Ziff-Davis' WinBench® 98 Version 1.0 ZD $CPUmark_{32}$ score of **1600** (*PC Magazine*, February 24, 1998, p. 46).
- A Dell OptiPlex Gxa (a Pentium II running at 233 MHz) obtained a Ziff-Davis' WinBench® 98 Version 1.0 ZD $CPUmark_{32}$ score of **693** (*PC Magazine*, December 2, 1997, p. 185).

  Note: The above points are cited as magazine references instead of just $CPUmark_{32}$ results due to the constraints of the WinBench® 98 license agreement.

A different metric that crosses CPUs is required to measure performance of *dissimilar* computers. If a school or jurisdiction is evaluating a tender for a financial computer or student record computer and there are many vendors, such a metric could assist in "right sizing" the purchase. For example, a Digital computer with an Alpha CPU, an IBM RISC 6000, a Sun workstation, and a Pentium II-based PC could be compared.

One such metric is a SPECmark (Standard Performance Evaluation Corporation). A SPECmark is an audited benchmark that measures performance on various systems.

For example:

- a Dell Dimension XPS Pro200n
  - integer rating CINT95 = 8.20
  - floating point rating CFP95 = 6.21
- Motorola 604e SPECint95 = 7.41 (@200 MHz, 66 MHz Bus, L2—512 KB, 60 ns EDO)
- Motorola 603e SPECint95 = 4.4 (@200 MHz, 66 MHz Bus, L2—512 KB, 70 ns DRAM) and SPECint95 7.4 @300 MHz

Metric

A good metric for PC **CPU** performance is the $CPUmark_{32}$. A good metric for cross-platform servers is the SPECmark.

Common to all benchmarks is a detailed outline of precisely what hardware and software were used for the test. This is important since a different disk drive could substantially alter a computer's performance.

> ***Tip***
>
> When evaluating hardware, require the vendor to supply benchmark results. This will assist in evaluating not only relative performance but will ensure that all subsystems have been clearly identified.

STATE OF THE ART

Performance is much more important for servers than for most user computers. The PC environment is changing very rapidly. At the time of this writing, gigabit Ethernet adapters were becoming available and new bus speeds of 100 MHz were beginning to appear. The most dramatic improvement in PC architecture was the splitting of video (like the AGP graphics) and other subsystems to use less of the CPU than in earlier computers.

> ***PC Standards***
>
> The PC98 standard (<http://www.microsoft.com/hwdev/desguid/> and <http://developer.intel.com/design/pc98/>) outlines the changes from PC97 and also serves as a forum for the evolving PC99 standard.

Typical specifications for a high-end PC *at this time* include:

- 350–400 MHz Pentium II with 512K cache (BX chipset, new)
- ECC SDRAM memory
- 100 MHz bus (new)
- Ultra-Wide SCSI-3 hard disk drive (new)
- AGP video card with 8 MB video memory
- 10/100-Mbps NIC
- AWE 64-compliant sound with speakers

The current performance differences between a 300- and a 333-MHz computer likely will not be enough to warrant the price difference. According to benchmark tests, the CPUmark_{32} of a 333 MHz is between 800 and 850 while a 266 MHz obtains a score of approximately 700. This is because other subsystems are affecting the performance more than the CPU clock. Most users in education will not notice this difference.

Some significant changes occurred during 1998. With the arrival of the next generation of the Deschutes-based PCs, the clock rates go to around 400 MHz but the bus speeds increase to 100 MHz (from 66 MHz).

By mid-1998, Intel began to ship the replacement for the PentiumPro (Xeon), which has a full-speed backside bus, 100-MHz system bus, and 2-MB Level 2 cache. Late 1998 saw the 450 NX chipset with hot plug PCI. MMX-based Intel computers will not be a player.

The new G3 Macintosh is the first Macintosh to have some of the more common PC features (<http://til.info.apple.com/techinfo.nsf/artnum/n24396>). In addition to the faster clock (300 MHz), it has:

- a 1-MB backside L2 cache
- 150-MHz dedicated 64-bit backside bus
- integrated floating-point unit and 64K level 1 on-chip cache (32K data and 32K instruction)
- 66-MHz system bus
- 64 MB or 128 MB of SDRAM
- 64-bit memory bus
- 10/100 BaseT
- UW SCSI hard disk
- 128-bit 2D/3D graphics accelerator, 6 MB SGRAM
- three PCI expansion slots compatible with PCI 2.1-compliant cards
- two high-speed DMA serial (RS-232/RS-422) ports compatible

These significant hardware improvements for the typical Macintosh will result in noticeable improvements to the end user. Compare these specifications with the Model 6500 (603e at 250 or 275 MHz, 32K internal cache, 256 or 512K L2) with a *50 MHz* system bus or an older LC 630 (66 MHz) with a *33 MHz* bus at 32 bits.

There are no SPECmark ratings for Macintosh computers, and the MacBench ratings have no comparability to the WinBench numbers. Some Macintosh computers were rated in MIPS (millions of instructions per second) with an LC III rated at 6.3 MIPS and an LC 575 rated at 29 MIPS. MIPS is useful only when looking at the CPU performance.

Caveat Emptor. Not all CPU benchmarks will yield identical metrics. It is quite possible to use CPUmark_{32}, SPECfp95 and SPECint95, Norton Multimedia and SI32, and Intel's Media and get different results. You will have to dig deeper to examine what the benchmark is actually testing.

Tools		
Ziff-Davis	CPUmark_{32}	<http://www.zdbop.com>
SPEC	CPU95	<http://www.specbench.org>

Future trends:

- Slot 2-based Pentium II ("Marlinespike") with four dual in-line memory modules, the new 440GX chip set and up to 2 GB RAM
- Colfax-based notebook with Pentium II, 440BX chip set, Rambus support, 2X AGP, 100 MHz bus and IEEE 1394 (due second half of 1999)
- Merced ("Bigfoot") with two Merced processors, 4X AGP, modular I/O, 460GX chip set and Slot M interface (due fourth quarter, 1999)
- Katmai-based Pentium II to include 440JX ("Camino") (due second quarter, 1999)

MEMORY

Computers have many types of memory. The user is faced with EDO, SDRAM, ECC, VRAM, WRAM… and the list goes on. For the majority of end-user computers, whatever comes with the computer or whatever the motherboard is designed for is adequate. Macintosh users seldom have the opportunity to choose the type of memory they purchase whereas most PC purchases require input. In early 1998, SDRAM was the normal type of memory in microcomputers.

The *amount of memory* has a very large impact on a computer's performance. NT is particularly sensitive to memory: the difference in performance between 32 MB and 64 MB for a 200-MHz Pentium MMX is approximately 20 per cent and a 300-MHz Pentium II performs approximately 50 per cent better than 32 MB (*PC Magazine*, September 23, 1997).

NETWORK INTERFACE CARD

The network interface card (NIC) is the postal service that delivers mail from the "source" to the "destination." It never reads the "mail" but only delivers it. The network adapter is referred to as a "dumb" device because it never tries to read or make sense of any data in a packet. If it can not deliver the data, it will continue to retry until the software tells it to stop trying.

The NIC has a maximum rate at which it can send and receive data. While a 10-Mbps NIC has a rated capacity of 10 million bits per second, a NIC has a rating of approximately 7.4 Mbps *maximum* (approximately 74 per cent).

Metric

The maximum capacity of a 10-MBps NIC is approximately 7.4 MBps and the maximum for a 100-MBps NIC is approximately 56 MBps (under special circumstances this can be higher).

10BASE-T refers to 10 Mbps data rate, base band frequency, 100-metre lengths, and 100-ohm UTP cable with RJ-45 connectors.

Note: When multiple computers share a 10-Mbps Ethernet segment, the overall interactive traffic begins to degrade when total network traffic is above 3 Mbps; i.e. greater than 30 per cent.

Tip

Standardize on 10/100-Mbps NICs.

The NIC delivers the data. Its data transfer rate depends on other subsystems in the computer—bus speed, data path width, disk/memory subsystem, and IP stack. The NIC is attached to the computer through various means (on the motherboard, in a PCI slot, etc.). For discussion, assume that the NIC is in a PCI slot. The clock speed of the bus and the number of bits it can receive determine how fast the NIC can deliver the data to the computer. Recall that older Macintosh computers like the LC630 had a bus speed of 33 MHz. Most current computers have a bus speed of 66 MHz.

The second variable in performance (getting data into computer memory) is the data path (32 bit, 64 bit, etc.). A bus receiving data 64 bits at a time will have a two-fold performance advantage over a bus receiving data at 32 bits at the same clock speed. A user will notice both bus speed and width of the data path when receiving a page at a browser.

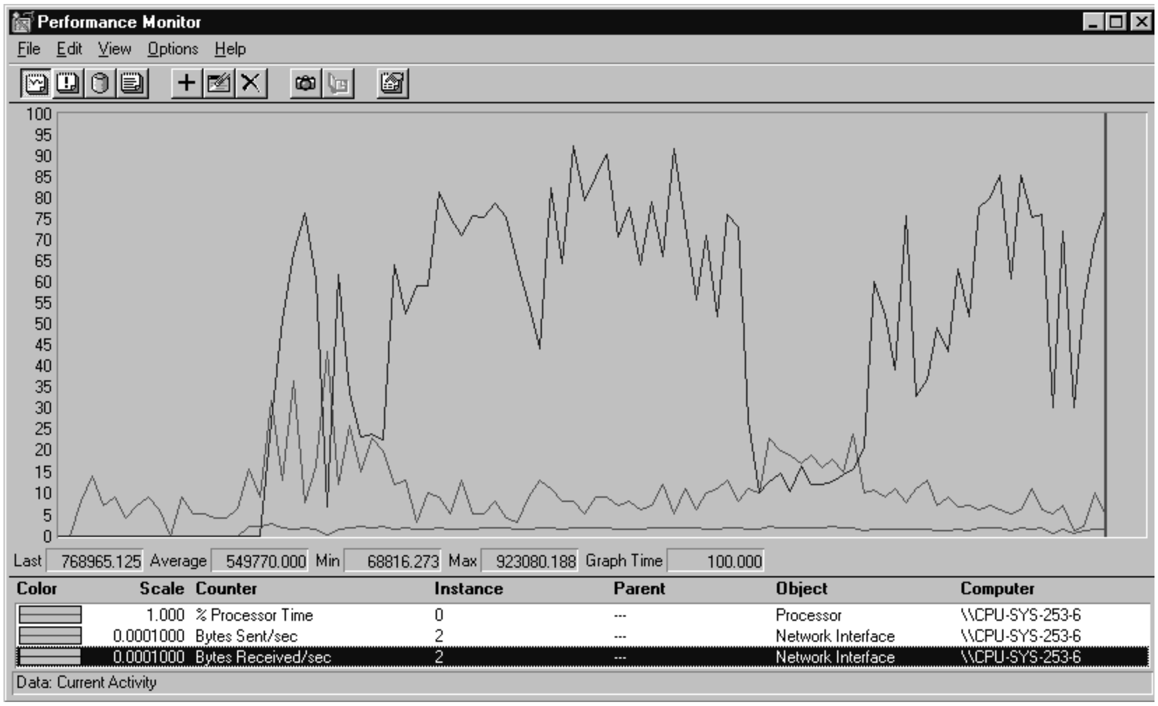

FIGURE 21: FILE TRANSFER THROUGH A NIC

Performance Monitor (NT) can be used to examine traffic to a NIC (Figure 21). In this case, 90 MB in 890 files of data were copied from a server to the local computer. The average for data received was 540,770 Bps (top line). The CPU was utilized at a peak of 45 per cent (centre line) and the average for bytes sent (mostly acknowledgements) was around 2 MBps (bottom line).

Examination of the bytes *received* (top line) indicates that the *rate* of a file transfer varies considerably. Many small files result in slower overall transfer rates while large file transfers will have a smoother graph.

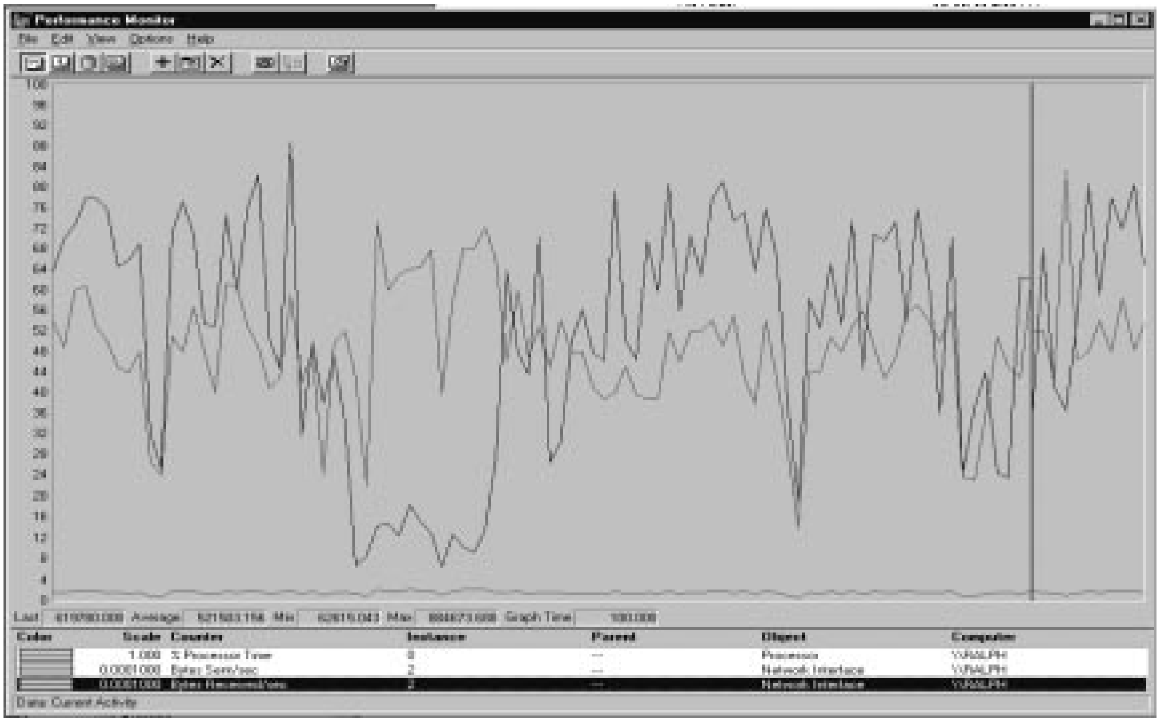

FIGURE 22: FILE TRANSFER THROUGH NIC—NON-UW

The transfer in Figure 21 was to a PCI-based UW SCSI disk drive. To illustrate the impact of the disk subsystem on NIC performance, the same 90 MB of data in 890 files was transferred to a computer that was identical in every respect except for the disk drive (Figure 22). The drive in the second test was to a PCI-based SCSI-2. Notice that CPU utilization was **significantly** higher (in the 50 per cent range). The CPU of a server with this drive subsystem would spend approximately half its time being interrupted and serving disk subsystem requests. It would likely peak for performance when there are very few additional tasks.

Tip

Servers with high I/O requirements require UW SCSI disk drives.

What is actually going on in the Ethernet cable can be examined with a probe. RMON probes give a different look at the network during the 90-MB file transfer. The packet size trend (Figure 23) illustrates that the network attempts to utilize the largest packets possible. Again, realize that each packet received has a 64-byte acknowledgement packet. It is clear that the majority of packets are large as a file is being transferred.

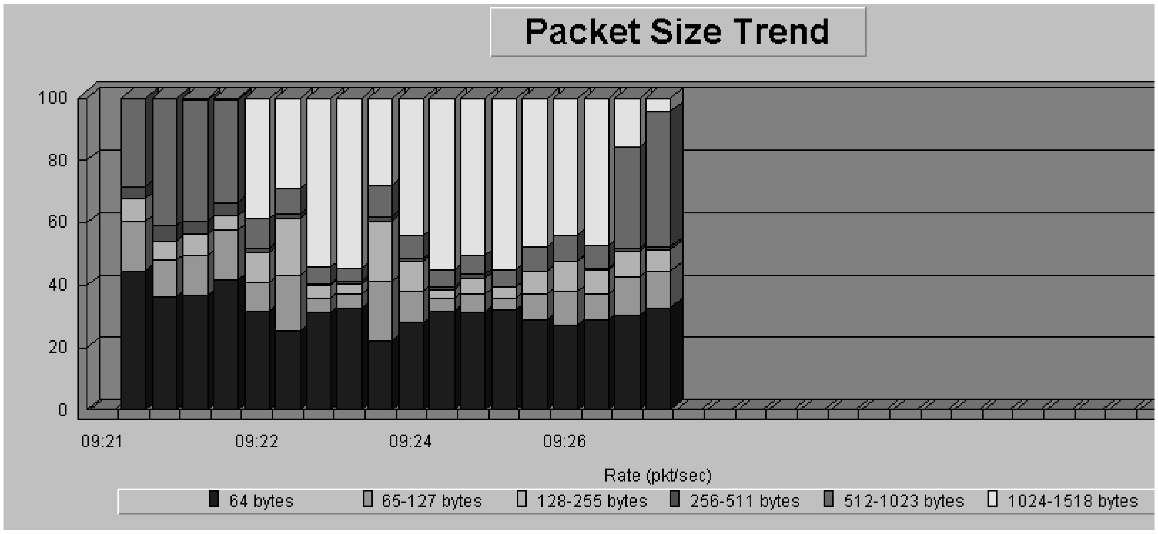

FIGURE 23: PACKET SIZE TREND

Figure 24 shows utilization and numbers of packets per second. Network utilization attained peaks of 50 per cent during the transfer, with packet rates peaking at approximately 700 pps. RMON gives users the ability to examine the same file transfer from different points of view.

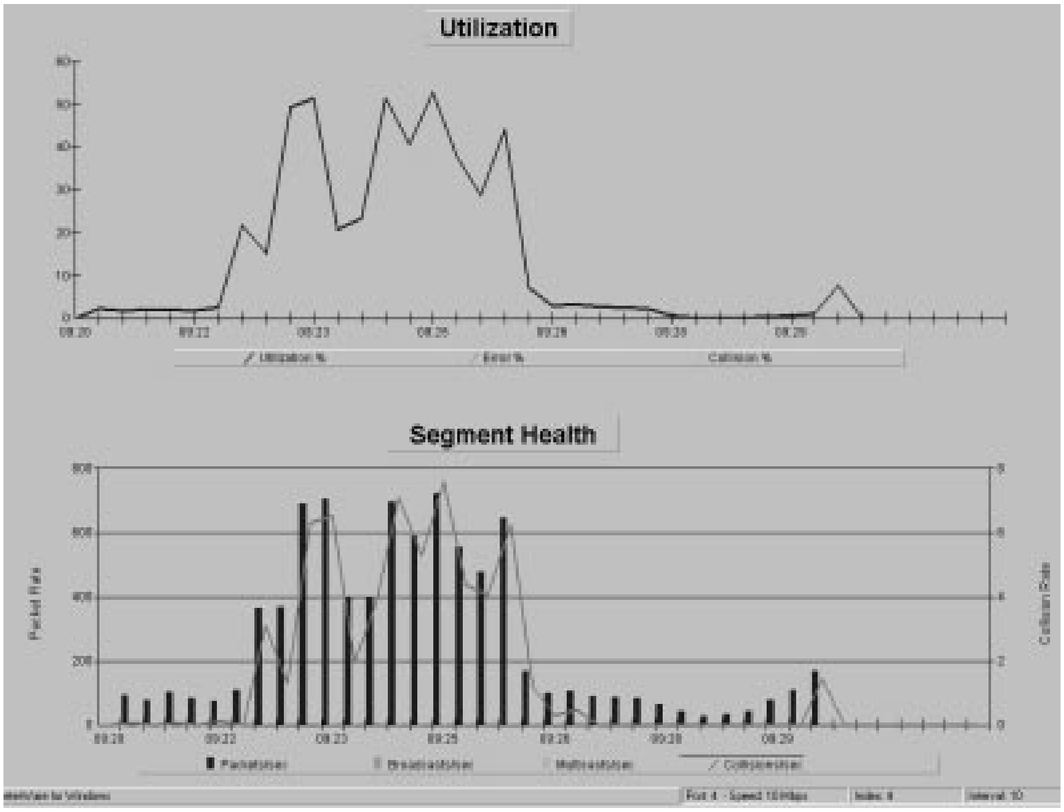

FIGURE 24: UTILIZATION AND PACKET RATE

A disk can have a great impact on the NIC performance during file transfers. To illustrate this in more detail, a single file of 11.4 MB was transferred four times. Performance Monitor was utilized to examine the NIC (Figure 25). The scales for each of the counters is different—there is a one thousand times difference between the bytes received and sent. This was done so that the lines could be visible on the graph. The packet per second scale is 0.01.

A single file has a “ramp-up” time of one to two seconds (the ascending curve), a relatively flat transfer rate of approximately eight seconds, and a “ramp-down” time of one to two seconds (the descending side of the curve). Each repetition yielded similar results. This example illustrates the actual transfer rates of the NIC-disk subsystem for a particular computer with a file size of 11.4 MB.

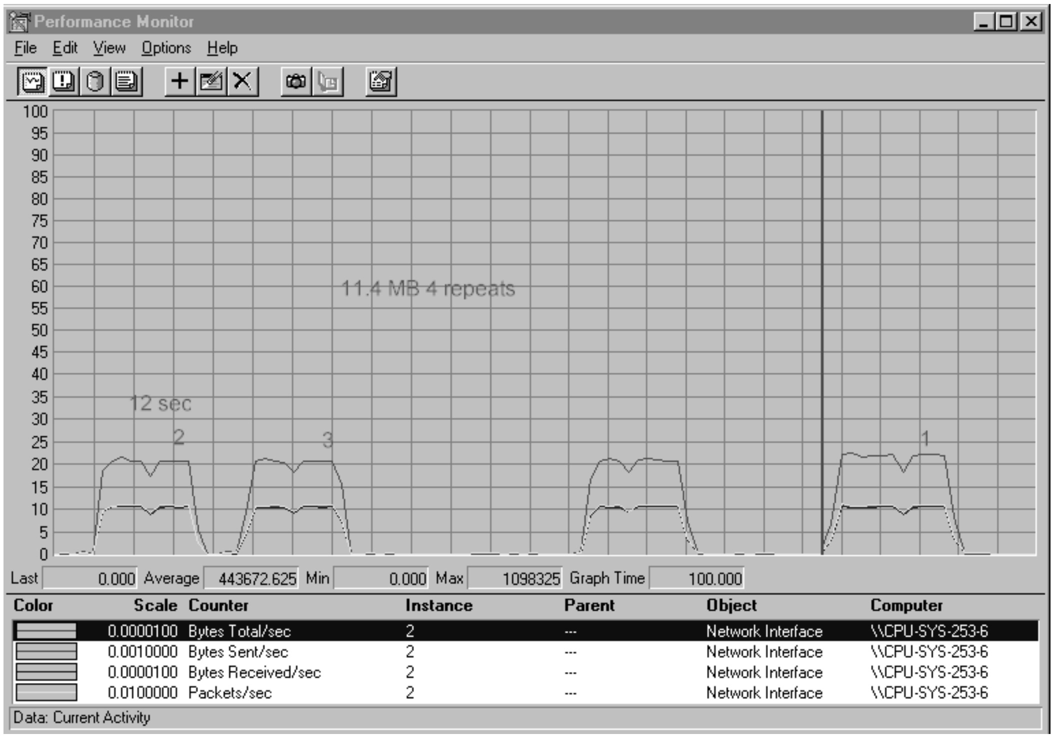

FIGURE 25: NIC-DISK TRANSFER RATES

GREENING

Although many students and staff are very ecologically aware, few seem to think of WAN bandwidth as a scarce resource. The following tips will help conserve bandwidth.

Tips

- Set "autoload images" off. Students like multimedia and visual presentation of information, but the pictures and animation require significant bandwidth due to their size. Not automatically loading these images will significantly reduce WAN traffic.
- Tune the cache on the local drive.
- Use a site-based cache server.
- Download web pages in non-peak hours and store them in the school.
- Minimize high bandwidth applications (real-time audio, two-way video, etc.). Use them only where they are needed.
- Limit the number of sessions per browser.
- Schedule WAN classes in the same way as the music room and gymnasiums.
- If more than one school is using the same ISP, get a jurisdiction-level cache server.

HARD DISK SUBSYSTEM

The hard disk plays a *significant* role in the performance of a computer. Every time a web page is accessed, a copy of the file is cached to the local hard disk. Again, many computer purchasers examine only the size of the disk drive (in GB) and seldom look at the components that actually make a difference in performance.

These components include:

- rotational speed (rpm)
- access time (milliseconds)
- seek time (milliseconds)
- transfer rates (MBps)
- mean time between failure (MTBF in hours)
- warranty

A 3-GB drive with a rotational speed of 5400 rpm (normal) will perform differently than the same-sized drive at 4500 rpm (low end) or 7200 rpm (high end). State of the art rotational speeds are 10,000 rpm.

Buying Tip

Typical consumer drives have rotational speeds of 5400 rpm. The minimum for servers should be 7200 rpm (and UW SCSI).

Average seek time is the average time the hard disk takes to move its read/write heads over the platters to a requested track. Seek times tend to decrease as disk capacity increases (about eight to ten milliseconds). *Average latency* specifies the time the drive takes to spin the platters until the appropriate portions of the track are spinning under the heads. *Average access time* is the **sum of** average seek time and average latency. It typically represents the amount of time it takes a hard disk to locate data.

Typical Drives

- Average seek times typically are about eight to 10 milliseconds.
- Average latency times are typically about 4.5 milliseconds for disks greater than one GB.
- Average access times are typically about eight to 12 milliseconds.

Tip

Computer magazines typically quote **access** times.

Transfer rates are the maximum rates at which the data can be transferred. *Internal transfer rate* is the speed at which the drive can take information off the disk and into internal buffers, and *external transfer rate* is the speed at which the data is actually transferred to the computer. The transfer rate (MBps) gives an indication of the performance of a drive. A 1-MB picture transferred at 16.6 MBps would take 0.06 seconds under the best conditions. Again, under "real conditions," these are maximums.

Disk drive performance is seldom an issue unless a school is considering servers or is a high-end user. Cache servers, library servers, etc., require a significant amount of disk I/O.

There are a number of disk drive performance metrics available (Table 12).

- Adaptec's ThreadMark 2.0 <http://www.adaptec.com>
- Ziff-Davis's SpeedRate <http://www.zdnet.com/zdhelp/dl> <help/speedrate/speedhelp.html>

SpeedRate gives three metrics—processor, disk, and graphics. A 120-MHz Compaq Deskpro (Column 2) yields a processor score of 357 while a Dell Pentium II 233 (Column 6) yields a score of 864 (2.4 times faster). The Compaq 120 had a mechanically slow drive and yielded a disk score of ninety. This metric confirmed a suspicion that there was a slow drive in the computer that warranted further investigation. As it turned out, this particular batch of computers had slow drives (about 4500 rpm). The result was tightening of specifications for computer purchases.

Often, more than one tool is required to uncover drive-related performance problems. Adaptec's ThreadMark exercises disk drives with various-sized I/O loads and monitors CPU utilization at the same time. Two identical Pentium II 266s were tested, one with an EIDE drive (Column 7) and one with UW SCSI (Column 8). While their SpeedRate CPU metrics were not that dissimilar (233 and 254), the data transfer rates were substantially different (3.41 MBps and 5.92 MBps). The amount of time the CPU required for the tests was very different as well (70 per cent and 11 per cent). In other words, the EIDE-based computer spent 70 per cent of the CPU time servicing the disk I/O requests compared to 11 per cent for the UW. It is easy to see from this test why any server-based application requires a UW drive.

Column1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
	Pentium	**Pentium OD**	**Pentium Pro**	**Pentium Pro**	**Pentium II**	**Pentium II**	**Pentium II**
MHz	120	133	200	180	233	266	266
SpeedRate							
Processor	357	297	806	811	864	983	994
Disk	90	164	232	410	269	233	254
Graphics	332		418	277	537	951	1143
Threadmark 2.0							
Data Transfer Rate in MBps	1.93	3.23	2.51	5.22	5.20	3.41	5.92
Average CPU	37.05%	40.64%	55.18%	12.90%	10.16%	70.27%	11.34%

TABLE 12: DISK SPEED METRICS

Tips

- According to Microsoft (<www.microsoft.com/hwdev/devdes/idedma.htm>), typical computers use 40 per cent CPU doing hard-drive transfers in PIO mode and 25 per cent in DMA mode. There is a fix for Windows 95.
- UDMA drives promise burst speeds of 33 MBps. Only computers with the TX chipset or LX chipset from Intel can make use of the increased speed. The other chipsets will run in PIO Mode 4 (ATA-2). Win98 will support UDMA, and Windows NT Workstation will require an upgrade to ATAPI.SYS to utilize it.

The web provides extensive information about manufacturer and model numbers for disk drives (Table 13). Data on track/inch and other metrics are readily available at the various sites.

Manufacturer	Quantum	Western Digital	Quantum	Quantum	Seagate
Model	Bigfoot TX	AC22100	Atlas II	Viking II	Cheeta 9
Formatted Capacity (MB)	4018	2111.8	4550	9100	9100
Interface	Ultra DMA/33	EIDE	UltraSCSI-3	Ultra LVD	Ultra 2 SCSI
Seek Time (ms)					
• Average (read)	<12	<12	8	7.5	5.7
• Track-to-Track	2.5	3	1	0.9	0.8
• Full Stroke	24	22	<18	<=15	
Average Rotational Latency (ms)	7.5	5.76	4.17	4.17	2.9
Rotational Speed (rpm)	4000	5200	7200	7200	10,025
Maximum Areal Density (MB per square inch)			659	1340	
Buffer Size (KB)	128	128	512	512	1024
Internal Data Rate (MB/s)	142	53-104	121	98-170	122-177
Internal Formatted Transfer Rate (MB/s)					14.5-23
Transfer Rate - Host (MB/s)	33.3	33.3	40	80	80
MTBF (hours)		300,000			1,000,000
Warranty (years)		3	5		
Source	http://www.quantum.com/products/hdd/bigfoot_tx/q_big_sp.html	http://www.wdc.com/products/drives/drive-specs/AC22100.html	http://www.quantum.com/products/hdd/atlas_II/q_at_sp.html	http://www.quantum.com/products/hdd/viking_II/q_vkg2_ky.html	http://www.seagate.com/disc/cheetah/cheetah.shtml

TABLE 13: SAMPLE DISK DRIVE SPECIFICATIONS

The Ziff-Davis Winstone and WinBench benchmarks are for business and high-end users. Business Winstone98 uses nine applications—Netscape Navigator, Microsoft Word 97, PowerPoint 97, Excel 97, Access 97, Lotus 97, Corel WordPerfect 7, Quattro Pro 7, and CorelDRAW 7. These are the applications most likely to be found on a newer computer in K–12 education. The high end (NT only) uses include Adobe Photoshop 4.01, Premiere 4.2, Microsoft FrontPage97, Visual C++5.0, MicroStation 95, PV-Wave 6.1, and AVS/Express 3.1.

One of the WinStone categories, business task switching, tests how well a system performs when switching between applications such as Word and Excel.

The WinBench suite tests five major subsystems—processor/RAM, graphics, disk, CD-ROM, and full-motion video. The 3D suite tests performance and rendering quality for 3D graphics.

Tests were conducted on various computers. The results for the researcher's Pentium II (266) appear in Table 14. The drive tested was a Quantum XP39100W. The two major scores gave the overall transfer rate for the business test at 1360 KBps and a high-end transfer rate of 3380 KBps.

Benchmark	Result	Notes
WinBench 98/Business Disk WinMark 98 (thousand bytes/second)	1360	3,4,5
WinBench 98/High-End Disk WinMark 98 (thousand bytes/second)	3380	3,4,5
Benchmark	**Result**	**Notes**
WinBench 98/Disk Playback/Bus:Browsers (thousand bytes/second)	2110	
WinBench 98/Disk Playback/Bus:Overall (thousand bytes/second)	1360	3,4,5
WinBench 98/Disk Playback/Bus:Publishing (thousand bytes/second)	1580	
WinBench 98/Disk Playback/Bus:SS/Database (thousand bytes/second)	949	
WinBench 98/Disk Playback/Bus:Task Switching (thousand bytes/second)	1640	
WinBench 98/Disk Playback/Bus:WP (thousand bytes/second)	1620	
WinBench 98/Disk Playback/HE:AVS/Express 3.1 (thousand bytes/second)	2500	
WinBench 98/Disk Playback/HE:FrontPage 97 (thousand bytes/second)	2360	
WinBench 98/Disk Playback/HE:MicroStation 95 (thousand bytes/second)	6650	
WinBench 98/Disk Playback/HE:Overall (thousand bytes/second)	3380	3,4,5
WinBench 98/Disk Playback/HE:Photoshop 4.0 (thousand bytes/second)	2500	
WinBench 98/Disk Playback/HE:Premiere 4.2 (thousand bytes/second)	4400	
WinBench 98/Disk Playback/HE:PV-Wave 6.1 (thousand bytes/second)	2830	
WinBench 98/Disk Playback/HE:Visual C++ 5.0 (thousand bytes/second)	8510	
WinBench 98/Disk/Read CPU Utilization (per cent used)	5.9	3,4,5,10,11
WinBench 98/Disk/Read Random Access:Average Seek Time (milliseconds)	10.5	3,4,5
WinBench 98/Disk/Read Transfer Rate:Beginning (thousand bytes/second)	9630	3,4,5
WinBench 98/Disk/Read Transfer Rate:End (thousand bytes/second)	8920	

TABLE 14: WINBENCH98 DISK RESULTS

Notes:

3. The playback directory was c:\~wbdtmp.
4. Common test settings: Disk Drive = c:\ CDROM Drive = e:\ Report CPU Utilization = No.
5. The following Windows tasks were running during this test and could affect the test results: comsmd.exe, LexStart.Exe, mgactrl.exe, MGAHOOK.EXE, MGAQDESK.EXE, mgasc.exe, netMedic.exe, OSA.EXE, pstores.exe, REALPLAY.EXE, smartagt.exe, snmp.exe, syshook.exe.
10. The block size used was 32,768 bytes.
11. The transfer rate achieved was 9488 thousand bytes per second.

The overall score results are a composite of various subtests. Notice the bus browser gave a score of 2110; word processing, 1620; and video editing, 4400. These numbers indicate transfer rates for particular application software and can be matched to the applications required for the computer. Notice that the *overall* CPU was 5.9 per cent whereas the disk-intensive ThreadMark yielded 11 per cent.

Tip

Use benchmarks, and ask for them when dealing with vendors and colleagues. It forces people to quantify variables and moves computing capacity planning from a "black art" towards a science. Realize that some benchmarks that do not publish source code may be tailored to maximize features.

On a recent price list acquired for this report, five 4.5-GB UW SCSI drives were examined. The prices for these drives ranged from a low of $624 to a high of $959, for a difference of $335. All the drives were "4.5-GB UW" drives. Having more detailed specifications would permit the rational matching of disk drives to the purpose for which they are intended. ***"Let the buyer beware."***

Tip

The manufacturer and model number of a drive can be used to locate drive specifications on the manufacturer's web site. The most common drive sites are:

Seagate:	<http://www.seagate.com/>
Quantum:	<http://www.quantum.com/>
Western Digital:	<http://www.wdc.com/>
IBM:	<http://www.storage.ibm.com.:80/storage/hardsoft/diskdrdl.htm>

Drive technology continues to evolve. At the time of this writing, Ultra-2 SCSI drives were beginning to appear. (So were fibre channel, but this is not an issue for most school locations.) Ultra-2 SCSI or SCSI3 drives double the bus bandwidth from 40 MBps to 80 MBps and illustrate the move to more "intelligent" subsystems. As with graphics, the disk subsystem is moving towards reducing the load on the CPU and bus.

Those who need to buy "the newest and best" should look up the specifications and ask the vendor for the disk tests in the WinBench suite. Just because it is *possible* to deliver up to 80 MBps does not mean it will on the computer someone installs it on.

Tips

- Do not put a fast, state-of-the-art drive in a computer that has a slow controller or bus.
- 7200 and 10,000-rpm drives generate more heat. Ensure case ventilation.
- By installing drives with lower specifications, vendors can increase profit margins when only size is specified. Ask for model numbers and performance benchmarks.
- A sustained data rate of 3.5 MBps is adequate for many typical users.
- Multimedia requires a sustained data rate of greater than 5 MBps. The higher the better.
- An additional source of information on disk drives is advertisements in the back of computer magazines. Companies that specialize in selling disk drives will list the manufacturer, model, rotational speeds, and prices in $US.
- CD-ROM speeds require more than spin rate. Look at more detailed questions such as transfer rates.
- Performance is often reduced because the data on a disk drive becomes fragmented. The regular defragmentation of disk drives significantly changes their performance.

FireWire (IEEE 1394) has burst throughputs between 100 and 400 Mbps and will be used to directly move video from a digital video camera to a drive. This interface permits downloading of large amounts of digital video directly to the computer for editing. By eliminating data conversion, it permits "lossless" non-linear editing. There are shipping products with FireWire adapters, both in the video world and microcomputer world.

FIREWIRE VERSUS USB—TWO SEPARATE PURPOSES

	1394/FireWire	**USB**
Maximum Devices	62	127
Data Transfer Rate	200 Mbps (25 MB/s)	12 Mbps (1.5 MB/s)
Macintosh	Yes	No

The future 1394 will include 400 Mbps, 800 Mbps, and 1 Gbps whereas USB is not designed to change.

Peripherals of 1394 will be disk drives, DV camcorders, HDTV, set top boxes, high-resolution digital cameras, etc. Peripherals of USB will be keyboards, mice, monitors, joysticks, speakers, etc.

Tip

DV capture from a 1394-enabled camcorder to a computer requires a **sustained** data transfer rate of 3.6 MB per second or more. A hard disk that is not fast enough to capture data at this rate will drop frames. IDE drives are not fast enough so a SCSI drive will be required.

CASE ANALYSIS: CD SERVER ON HD

Grande Yellowhead Regional Division No. 35 has demonstrated the use of a “switched to the desktop” coupled with common CDs such as Encarta on a server with UW SCSI drives. Schools in the division have a cache server on site. Students can access information from the faster hard drives instead of the CD. This excellent design makes common services available throughout the school. In elementary settings, it also can significantly reduce the Internet traffic requirement since more of the data resides in the school.

GRAPHICS SUBSYSTEM

The graphics subsystem in computing is changing very quickly and will likely continue to do so. The graphic subsystem consists of the graphics card (may be a card in a slot or on the motherboard) and the monitor attached to the computer.

Most monitors have physical metrics which include screen size (15, 17, 19, 21 inches), pixel size (0.25–0.28 mm), refresh rates (60–100 Hz), etc. Schools purchasing computers need to ask questions about more than screen size. A 17-inch monitor that is specified to display a maximum of 1024 X 768 pixels is a different price than one that is specified to display 1280 X 1024. To be “flicker free,” the vertical refresh rate (the number of times per second the screen is redrawn) needs to be 85 Hz or better. Screens that deliver 1024 X 768 at 60 Hz will exhibit flicker and often cause eyestrain. Since the screen is the major component for the user, specify more than just screen size.

Tips

- While the monitor currently is attached via a special cable, new monitors (and speakers) will make use of the USB port coming with the newer motherboards. This is an important trend to keep in mind when purchasing equipment. Consider monitors that have a USB option.
- If the graphics card can display 1600 X 1200 and the monitor 1024 X 768, then all the user will ever see is 1024 X 768. Monitors of lower standards can be attached to higher-end graphics cards, but will be able to display only to their own specifications.
- USB has a burst throughput of 12 Mbps.
- Always specify requirements in size of screen, pixel depth, and refresh rates. For example, 17 inch—1024 X 768 at 24 bit and 85 Hz.
- Screen size is important. A 19-inch screen is not just two inches larger than a 17-inch screen. It has 28 per cent more viewing area.

Since graphics cards are changing rapidly, this report deals with only a subset of the issues. The amount of graphics memory can be derived easily (Table 15), depending on requirements. For flexibility, the graphics card should be able to add memory as requirements change.

Resolution	16 colour 4 bit MB	256 colour 8 bit MB	65,000 colour 16 bit MB	16.7 M 24 bit MB
640 X 480	0.5	0.5	1	2
800 X 600	0.5	1	2	2
1024 X 768	1	1	2	2
1280 X 1024	1	2	4	4
1600 X 1200	2	2	4	8
1800 X 1440	2	4	8	8

TABLE 15: GRAPHIC RAM REQUIREMENTS

Graphic performance, which is more difficult to quantify, is perhaps the most rapidly changing subsystem in a computer. Assuming a PCI bus card, the CPU must take its graphic output from memory and send it to the graphics card via the PCI bus. The graphics card then converts the digital information back to analog and sends this to the monitor, which in turn displays the information on the screen. Moving a window on the screen therefore becomes a CPU-intensive task.

In moving identical windows on a variety of computers—a Pentium II with a good graphics card, a PentiumPro, a Pentium with and without MMX, an older Macintosh like an LC575, and a new G3-based Macintosh—the impact of limiting factors of CPU clock speed, bus speed, bus data path, etc., will quickly become obvious.

New graphics cards are now on the market and new 3D graphics cards are becoming more common. A comparison of three graphics cards (Table 16) illustrates the increased complexity of graphics subsystems and the lack of easily obtained detailed information.

Graphics Cards	Millenium II	GLoria-L 3D	Fire GL 4000
Acceleration	2D GUI, 250 MHz RAMDAC	IBM RGB526DB 200 MHz	TI TVP3026 220 MHz
2D3D Controller			Evans and Sutherland 3DPro
VGA Controller			Cirrus 5446
Memory	WRAM	VRAM DRAM	3DRAM, CDRAM
Controller	MGA 2164W		
Bus Type	PCI		
RAMDAC MHz	250		
Maximum Memory MB	16		16
Memory Speed	50 ns	60 ns VRAM, 50ns DRAM (GLINT)	10 ns 3DRAM, 15 ns CDRAM (3DPro)
Data Path	64-bit	64-bit	64-bit
Controller Clock Speed MHz	66	50	70
Maximum Vertical Refresh Rate Hz	200	200	120
Maximum Horizontal Scan Rate KHz	114		
Maximum Pixel Rate MHz	250	200	200
Random 10-Pixel Solid Lines (K/s)	310	1250	6000
Filled 25-Pixel Triangles (K/s)	140	500	2000

TABLE 16: COMPARISON OF NEWER GRAPHICS CARDS

The WinBench98 suite attempts to quantify graphic performance and therefore give the user a few metrics to use instead of a longer list of detailed parameters. These include the WinBench98/Business Graphics WinMark98 and WinBench98/High-End Graphics WinMark98.

A recent significant development in graphics is the accelerated graphics port (AGP) first implemented with the Intel 440LX chipset. Recognizing that the PCI was getting congested by ever-increasing graphics traffic, Intel decided to move the graphics traffic to a dedicated point-to-point channel between the graphics controller and the system chip set. AGP frees up the PCI bus for other tasks such as I/O to the disk and network.

The 66-MHz PCI bus has a capacity of 133 MBps. AGP-2x will deliver 533 MBps and AGP-4x (1999) will deliver greater than one GBps. This greatly increased graphics transfer rate is starting to be matched by faster graphics engines on the AGP graphics cards.

For more information on AGP: <http://www.intel.com/technology/agp/>

One of the "hot" new graphics engines is the RIVA128 chip from nVidea rated at five giga floating points operations per second (GFLOPS) floating point setup engine and fifteen billion operations per second (BOPS) integer pixel engine. Another metric is five million triangles per second and 100 million pixels per second. There is not much point in having AGP without a faster graphics processor.

AGP will be supported in NT 5.0 and Windows98. It appears that there are no equivalent developments similar to AGP in the Macintosh environment.

In April 1998, computers with the Intel BX chipset began shipping. This chipset, which supports a bus speed of 100 MHz, will have a significant impact on performance, particularly for high traffic areas such as servers.

Tip

Most users will **not** require the capacity of AGP-type developments except for high-end applications or virtual reality (VRML). (VRML simulations will increasingly become available in education.) *Flexibility* is the issue for education users. If it is anticipated that applications such as VRML will be a reality in the life of the computer (three to seven years), then AGP may be worth looking at.

Useful Sites

Some common graphic sites:

Matrox	<http://www.matrox.com/>
S3	<http://www.s3.com/>
Cirrus Logic	<http://www.cirrus.com/>
ATI	<http://www.atitech.com/>
NVidea	<http://www.nvidia.com/products/frames_overview.html>

MOTHERBOARDS

The school micro is no longer a stand-alone entity. Since support is part of the long-term cost of ownership, the following specifications should be required in any new computer:

- *DMI 2.0 compliance*. "Compliant" is different from "compatible." DMI permits remote monitoring as well as inventory of system components.

- *32-bit service layer.* If a network management package (e.g., HP's OpenView) is to be managed remotely, there must be a 32-bit service layer that arbitrates access and manages the PC's MIF database (should come with DMI 2.0).
- *MIF browser.* A management information file browser allows queries for hardware and software information. Many MIF browsers are proprietary, but there are some emerging standards.
- *Wake on LAN.* A newly emerging capability will permit network administrators to remotely “power up” a computer and update files, monitor assets and inventory.

Alberta Education has asked jurisdictions for computer inventory reports in the past. Maintaining current inventory lists are a chronic problem since computers are moved, new ones acquired, different versions of software are installed, and so on. Couple this with recent changes to Canadian copyright law, and maintaining inventory becomes a significant management issue for schools and jurisdictions. "Wake on LAN" and DMI are some of the technologies that will ease the burden of keeping inventory by making it interactive.

Network Tool

LANDesk Management (LDMS) from Intel is one of an emerging set of tools for hardware/software metering, remote control, software distribution, and virus scanning. LANDesk, designed to run on NT Server, supports Windows 3.x, Windows 95, Windows NT, Macintosh, and OS/2 clients.

Software can be sent to client PCs via push (sends an update at log-on or at a scheduled time), forced push (user can not cancel update), and pull (user requests software from server). These features are useful when new versions of software (e.g., Excel) are to be installed. Automating this process will make support easier.

Providing cost justification for some of this newer technology becomes easier when the long-term cost of ownership is used. Assume it takes a technician one hour plus travel to install a software upgrade (for illustration, assume $30 per hour). Experience indicates that each software package is upgraded every one to two years (assume two years). If there are typically three to five applications running on each computer (assume five), there would be estimated costs of $150 per computer (five applications at $30 each) every two years, or $75 per year. If a computer is used for five years, the software update costs are $375. Ignoring personnel limitations (a significant issue for most school jurisdictions), any software package that would reduce costs by $375 per computer over five years would be a cost-effective solution.

Holistic Costs

"Long-term or total cost of ownership" is a key mindset for schools and jurisdictions that must be considered in planning for computer purchases. Unfortunately, capital purchases often are in decentralized school budgets and support costs in other budgets. This accounting reality inhibits true cost minimization.

LAYERS AND COMPUTER PERFORMANCE SUMMARY

For most computer purchases, lowest price and fastest clock are the major criteria. Computers are compared on the basis of little more than, "Both have 4.5-GB drives." Little thought is given to performance, transfer rates, and so on. Sometimes a faster CPU with a slower drive will actually perform at a lower level than one with a faster drive. A motherboard with the graphics chip attached will be more inexpensive than one with it on a card.

What is given up is *flexibility*. If a school purchases computers with graphics on the motherboard at 800 X 600 pixels or 1024 X 768 pixels, these can not be upgraded later to higher levels such as 1280 X 1024 when the school wants to have more on the screen. To illustrate this point, think about the new multimedia world that students are moving into with MPEG video and DVD. Since schools often have to keep computer equipment for many years, flexibility of upgrades should be an important criterion along with price and clock speed.

Forecast

Students will increasingly use multimedia—which impacts both graphics and disk subsystems—in the classroom.

Schools can use various tools and metrics to quantify CPU speeds, disk performance, network interface performance, and so on in order to quantify purchasing decisions, and provide networks that perform better and retain longer-term flexibility.

SUMMARY

In future, even a small school is likely to have many servers in a quite complex environment. However, many schools do not have the time, staff, or expertise to support the emerging technology. Site-based decision making often has resulted in decisions for technology and support decentralized to the school that will likely be inappropriate in the near-term future. While this approach gives schools flexibility, it often does not address equity and causes short-term technology decisions.

Suggested Strategies

- Network LANs and WAN should be the responsibility of the school jurisdiction.
- **All** computer and network purchases should be co-ordinated centrally within jurisdictions.

From a user's point of view, performance includes the various subsystems, LAN devices, and WAN connections. It is an end-to-end issue. For adequate long-term performance, the overall architecture must include all aspects of the network.

GLOSSARY OF TERMS

The source for this glossary is the site PCWebopedia <http://www.pcwebopedia.com>. Some of the entries have been adapted for the purpose of this document.

ACK Packet	Each time a data packet is received on the network an ***ack**nowledgment **packet*** is sent back to verify that the packet was received.
AGP	Short for ***A**ccelerated **G**raphics **P**ort*, a new interface specification developed by Intel Corporation. AGP is based on PCI, but is designed especially for the throughput demands of 3-D graphics. Various levels of data transfer rates are offered: **1X** is 266 MBps, **2X** is 533 MBps; and **4X** provides 1.07 GBps.
ANSI	Acronym for the ***A**merican **N**ational **S**tandards **I**nstitute*. Founded in 1918, ANSI is a voluntary organization composed of over 1300 members (including all the large computer companies) that creates standards for the computer industry.
ATA	Short for ***A**dvanced **T**echnology **A**ttachment,* a disk drive implementation that integrates the controller on the disk drive itself.
Average Access Time	The sum of the Average Seek Time and Average Latency. It typically represents the amount of time it takes for a drive to locate data.
Average Latency	The time the drive takes to spin the platters until the appropriate portions of the tracks are spinning under the heads.
Average Seek Time	The average time it takes for a drive's read/write head to move over the platters to a requested track. Seek times tend to decrease as disk capacity increases.
Backbone	Another term for bus, the main wire that connects nodes (computers or devices on a network). The term is often used to describe the main network connections composing the Internet.
Bandwidth	The amount of data that can be transmitted in a fixed amount of time. For digital devices, the bandwidth is usually expressed in bits per second (bps) or bytes per second (Bps). For analog devices, the bandwidth is expressed in cycles per second, or Hertz (Hz).
Bus	In networking, a bus is a central cable that connects all devices on a local area network. It also is called the backbone.
Cache	Pronounced *cash*, a special high-speed storage mechanism. It can be either a reserved section of main memory or an independent high-speed storage device.
Centrex	Short for central office exchange service, a new type of PBX service in which switching occurs at a local telephone station instead of at the company premises. Typically, the telephone company owns and manages all the communications equipment necessary to implement the PBX and then sells various services to the company.

Controller	A device that controls the transfer of data from a computer to a device and vice versa. For example, disk drives, display screens, keyboards, and printers all require controllers.
CPU	Short for ***C****entral* ***P****rocessing* ***U****nit.* The CPU is simply the brain of the computer.
CSMA/CD	Short for ***C****arrier* ***S****ense* ***M****ultiple* ***A****ccess/****C****ollision* ***D****etection*, a set of rules determining how network devices respond when two devices attempt to use a data channel simultaneously (called a collision). Standard Ethernet networks use CSMA/CD. This standard enables devices to detect a collision. After detecting a collision, a device waits a random delay time and then attempts to retransmit the message.
Data Transfer Rates	The speed with which data can be transmitted from one device to another. Data rates are often measured in megabits (million bits) or megabytes (million bytes) per second. These are usually abbreviated as Mbps and MBps, respectively.
DMA	Abbreviation of ***D****irect* ***M****emory* ***A****ccess*, a technique for transferring data from main memory to a device without passing it through the CPU. Computers that have DMA channels can transfer data to and from devices much more quickly than computers without a DMA channel can. This is useful for making quick backups and for real-time applications.
DNS	Short for ***D****omain* ***N****ame* ***S****ystem (or* ***S****ervice)*, an Internet service that translates domain names into IP addresses. Because domain names are alphabetic, they are easier to remember. The Internet however, is really based on IP addresses. Every time you use a domain name, therefore, a DNS service must translate the name into the corresponding IP address. For example, the domain name www.example.com might translate to 198.105.232.4.
Domain Name	A name that identifies one or more IP addresses. For example, the domain name *microsoft.com* represents about a dozen IP addresses.
DRAM	Pronounced *dee-ram,* DRAM stands for ***D****ynamic* ***RAM****,* a type of memory used in most personal computers.
DV	Short for ***D****igital* ***V****ideo*. Refers to the capturing, manipulation and storage of video in digital formats.
ECC	Short for ***E****rror-****C****orrecting* ***C****ode memory,* a type of memory that includes special circuitry for testing the accuracy of data as it passes in and out of memory.
EDO RAM	Short for ***E****xtended* ***D****ata* ***O****utput* ***DRAM****,* a type of DRAM that is faster than conventional DRAM.
EIA	Short for ***E****lectronic* ***I****ndustries* ***A****ssociation*. A trade association representing the U.S. high technology community. It began in 1924 as the Radio Manufacturers Association. The EIA sponsors a number of activities on behalf of its members, including conferences and trade shows.

EIDE	Short for ***E**nhanced* ***IDE**,* a newer version of the IDE mass storage device interface standard developed by Western Digital Corporation. EIDE is sometimes referred to as *Fast ATA* or *Fast IDE,* which is essentially the same standard, developed and promoted by Seagate Technologies. It also is sometimes called ATA-2.
Ethernet	A local area network (LAN) protocol developed by Xerox Corporation in co-operation with DEC (Digital Equipment Corporation) and Intel in 1976. It is one of the most widely implemented LAN standards. A newer version of Ethernet, called 100Base-T (or Fast Ethernet), supports data transfer rates of 100 Mbps (Megabits per second); and the newest version, Gigabit Ethernet supports data rates of one gigabit (1000 megabits) per second.
Filters (Packet Filtering)	Controlling access to a network by analyzing the incoming and outgoing packets and letting them pass or halting them based on the IP addresses of the source and destination. Packet filtering is one technique, among many, for implementing security firewalls.
Firewall	A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both. Firewalls frequently are used to prevent unauthorized Internet users from accessing private networks connected to the Internet, especially intranets. All messages entering or leaving the Intranet pass through the firewall, which examines each message and blocks those that do not meet the specified security criteria.
Firewire (IEEE 1394)	A new, very fast external bus standard that supports data transfer rates of up to 400 Mbps (400 million bits per second). 1394 is ideal for devices that need to transfer high levels of data in real time, such as video devices. The main difference between 1394 and USB (Universal Serial Bus) is that 1394 supports faster data transfer rates and is more expensive.
FTP	Abbreviation of ***F**ile* ***T**ransfer* ***P**rotocol*, the protocol used on the Internet for sending files.
Gbps	Short for ***G**iga**b**its* ***p**er* ***s**econd,* a data transfer speed measurement for high-speed networks such as Gigabit Ethernet. When used to describe data transfer rates, a gigabit equals 1,000,000,000 bits.
Handshaking	The establishment of a two-way communication process that ensures each packet is received.
Head	The mechanism that reads data from or writes data to a magnetic disk or tape. The head is sometimes called a *read/write head.* Double-sided floppy disk drives have two heads, one for each side of the disk. Hard disk drives have many heads, usually two for each platter.
HDTV	Short for ***H**igh-**D**efinition* ***T**ele**v**ision*, a new type of television that provides much better resolution than current televisions based on the NTSC (**N**ational **T**elevision **S**tandards **C**ommittee) standard. There are a number of competing HDTV standards, which is one reason that the new technology has not been widely implemented. All of the standards support a wider screen than NTSC and roughly twice the resolution.

Hubs A common connection point for devices in a network. Hubs are commonly used to connect segments of a LAN. A hub contains multiple ports. When a packet arrives at one port, it is copied to the other ports so that all segments of the LAN can see all packets.

Hz Short for ***H****ertz*. This number represents the number of cycles per second. It often is used to measure screen refreshes.

IDE Short for ***I****ntelligent* ***D****rive* ***E****lectronics* or ***I****ntegrated* ***D****rive* ***E****lectronics*, depending on whom you ask. An IDE interface is an interface for mass storage devices, in which the controller, a device that controls the transfer of data between one device and another, is integrated into the disk or CD-ROM drive.

IEEE Abbreviation of ***I****nstitute of* ***E****lectrical and* ***E****lectronics* ***E****ngineers*, pronounced I-triple-E. Founded in 1884, the IEEE is an organization composed of engineers, scientists, and students. The IEEE is best known for developing standards for the computer and electronics industry. In particular, the IEEE 802 standards for local area networks are widely followed.

IMAP Short for ***I****nternet* ***M****essage* ***A****ccess* ***P****rotocol,* a protocol for retrieving e-mail messages.

I/O Short for ***I****nput/****O****utput*, and pronounced *eye-oh.* I/O refers to any operation, program, or device whose purpose is to enter data into a computer or to extract data from a computer.

IP Abbreviation of ***I****nternet* ***P****rotocol,* pronounced as two separate letters. IP is something like the postal system. It allows you to address a package and drop it in the system, but there is no direct link between you and the recipient.

ISDN Abbreviation of ***I****ntegrated* ***S****ervices* ***D****igital* ***N****etwork*, an international communications standard for sending voice, video, and data over digital telephone lines. ISDN requires special metal wires and supports data transfer rates of 64 Kbps (64,000 bits per second). Most ISDN lines offered by telephone companies give you two lines at once, called B channels. You can use one line for voice and the other for data, or you can use both lines for data to give you data rates of 128 Kbps, twice the data rate provided by today's fastest modems.

ISA Short for ***I****ndustry* ***S****tandard* ***A****rchitecture*. The bus architecture used in the IBM PC/XT and PC/AT. It often is abbreviated as ISA (pronounced as separate letters or as eye-sa) bus. The AT version of the bus is called the AT bus and became a de facto industry standard.

ISP Short for ***I****nternet* ***S****ervice* ***P****rovider*, a company that provides access to the Internet. For a monthly fee, the service provider gives you a software package, username, password and access phone number. Equipped with a modem, you can then log on to the Internet and browse the World Wide Web and send and receive e-mail.

KB Short for ***K****ilo****B****yte*. When used to describe data storage, *KB* usually represents 1024 bytes. When used to describe data transfer rates, *KB* represents 1000 bytes.

Kbps Short for ***K****ilo****b****its* ***p****er* ***s****econd*, a measure of data transfer speed. Modems, for example, are rated in Kbps. Note that one Kbps is 1000 bits per second, whereas a KB (kilobyte) is 1024 bytes. Technically, kbps should be spelled with a lowercase k to indicate that it is decimal but almost everyone spells it with a capital K.

LAN Short for ***L****ocal* ***A****rea* ***N****etwork*. A computer network that spans a relatively small area. Most LANs are confined to a single building or group of buildings. Most LANs connect workstations and personal computers. Each node (individual computer) in a LAN has its own CPU with which it executes programs, but it also is able to access data and devices anywhere on the LAN. This means that many users can share expensive devices, such as laser printers, as well as data. Users also can use the LAN to communicate with each other, by sending e-mail or engaging in chat sessions.

Local Bus A data bus that connects directly, or almost directly, to the microprocessor. Although local buses can support only a few devices, they provide very fast throughput.

MAC Address Short for ***M****edia* ***A****ccess* ***C****ontrol address,* a hardware address that uniquely identifies each node of a network.

MB Short for **m**ega**b**yte (1,000,000 or 1,048,576 bytes, depending on the context).

Mbps/MBps See ***Data Transfer Rates***.

MHz Short for ***m****ega****h****ertz*. One MHz represents one million cycles per second.

MPEG Short for ***M****oving* ***P****icture* ***E****xperts* ***G****roup*, and pronounced *m-peg*, a working group of ISO. The term also refers to the family of digital video compression standards and file formats developed by the group. MPEG files can be decoded by special hardware or by software.

NIC Short for ***N****etwork* ***I****nterface* ***C****ard*. Often abbreviated as *NIC,* an expansion board you insert into a computer so the computer can be connected to a network. Most NICs are designed for a particular type of network, protocol, and media, although some can serve multiple networks.

NT Short for ***N****ew* ***T****echnology*. Usually used in referring to Windows NT, the most advanced version of Microsoft's Windows operating system.

Packet A piece of a message transmitted over a packet-switching network. See under packet switching. One of the key features of a packet is that it contains the destination address in addition to the data. In IP networks, packets are often called *datagrams.*

Packet Switching Refers to protocols in which messages are divided into packets before they are sent. Each packet is then transmitted individually and can even follow different routes to its destination. Once all the packets forming a message arrive at the destination, they are recompiled into the original message.

PBX Short for ***P****rivate* ***B****ranch e****X****change,* a private telephone network used within an enterprise. Users of the PBX share a certain number of *outside lines* for making telephone calls external to the PBX.

PCI Acronym for ***P****eripheral* ***C****omponent* ***I****nterconnect*, a local bus standard developed by Intel Corporation. Most modern PCs include a PCI bus in addition to a more general ISA expansion bus. Many analysts, however, believe that PCI will eventually supplant ISA entirely.

Performance Monitor Performance Monitor is provided with Windows NT and allows the monitoring of Network Interface Cards for total traffic, disk utilization, and CPU utilization.

Platter A round magnetic plate that constitutes part of a hard disk. Hard disks typically contain up to a dozen platters. Most platters require two read/write heads, one for each side.

POP Short for ***P****ost* ***O****ffice* ***P****rotocol,* a protocol used to retrieve e-mail from a mail server. Most e-mail applications (sometimes called an e-mail client) use the POP protocol, although some can use the newer IMAP.

Proxy A server that sits between a client application, such as a Web browser, and a web server. It intercepts all requests to the web servers to see if it can fulfill the requests itself. If not, it forwards the request to the real server.

RAM Short for ***R****andom* ***A****ccess* ***M****emory*. RAM is volatile, meaning that it loses its contents when the power is turned off.

Read/Write Head *See* ***Head***.

RealAudio The de facto standard for streaming audio data over the World Wide Web. RealAudio was developed by RealNetworks and supports FM-stereo-quality sound. To hear a Web page that includes a RealAudio sound file, you need a RealAudio player or plug-in, a program that is freely available from a number of places. It is included in current versions of both Netscape Navigator and Microsoft Internet Explorer.

RMON Short for ***R****emote* ***MON****itoring*, a network management protocol that allows network information to be gathered at a single workstation.

Router A device that connects two LANs. Routers are similar to bridges, but provide additional functionality, such as the ability to filter messages and forward them to different places based on various criteria.

RPM Short for ***R****otations* ***P****er* ***M****inute*. Used when referring to hard disk drive units or CD-ROM drives.

SCSI

Abbreviation of ***S**mall **C**omputer **S**ystem **I**nterface*. Pronounced *scuzzy*, SCSI is a parallel interface standard for attaching peripheral devices to computers such as disk drives and printers. SCSI interfaces provide for faster data transmission rates (up to 80 megabytes per second) than standard serial and parallel ports. Although SCSI is an ANSI standard, there are many variations of it, so two SCSI interfaces may be incompatible. For example, SCSI supports several types of connectors.

The following varieties of SCSI are currently implemented:

- SCSI-1: Uses an 8-bit bus, and supports data rates of 4 MBps.
- SCSI-2: Same as SCSI-1, but uses a 50-pin connector instead of a 25-pin connector, and supports multiple devices. This is what most people mean when they refer to plain SCSI.
- Wide SCSI: Uses a wider cable (168 cable lines to 68 pins) to support 16-bit transfers.
- Fast SCSI: Uses an 8-bit bus, but doubles the clock rate to support data rates of 10 MBps.
- Fast Wide SCSI: Uses a 16-bit bus and supports data rates of 20 MBps.
- Ultra SCSI: Uses an 8-bit bus, and supports data rates of 20 MBps.
- SCSI-3: Uses a 16-bit bus and supports data rates of 40 MBps. Also called Ultra Wide SCSI.
- Ultra2 SCSI: Uses an 8-bit bus and supports data rates of 40 MBps.
- Wide Ultra2 SCSI: Uses a 16-bit bus and supports data rates of 80 MBps.

SDRAM

Short for ***S**ynchronous **DRAM**,* a new type of DRAM that can run at much higher speed than conventional memory.

SMTP

Short for ***S**imple **M**ail **T**ransfer **P**rotocol,* a protocol for sending e-mail messages between servers. Most e-mail systems that send mail over the Internet use SMTP to send messages from one server to another; the messages can then be retrieved with an e-mail client using either POP or IMAP.

SNMP

Short for ***S**imple **N**etwork **M**anagement **P**rotocol*, a set of protocols for managing complex networks. The first versions of SNMP were developed in the early 1980s. SNMP works by sending messages, called protocol data units (PDUs), to different parts of a network. SNMP-compliant devices, called agents, store data about themselves in Management Information Bases and return this data to the SNMP requesters.

Subnet

A portion of a network that shares a common address component. On TCP/IP networks, subnets are defined as all devices whose IP addresses have the same prefix. For example, all devices with IP addresses that start with 100.100.100 would be part of the same subnet. Dividing a network into subnets is useful for both security and performance reasons.

Switches In networks, a device that filters and forwards packets between LAN segments. Switches operate at the data link layer (layer 2) of the OSI (**O**pen **S**ystem **I**nterconnection) Reference Model and therefore support any packet protocol. LANs that use switches to join segments are called switched LANs or, in the case of Ethernet networks, switched Ethernet LANs. See also Packet Switching.

T1 A dedicated phone connection supporting data rates of 1.544 Mbps. A T-1 line actually consists of 24 individual channels, each of which supports 64 Kbps. Each 64-Kbps channel can be configured to carry voice or data traffic. Most telephone companies allow you to buy some of these individual channels, known as fractional T-1 access.

TCP/IP Most networks combine ***IP*** with a higher-level protocol called ***T****ransport* ***C****ontrol* ***P****rotocol* (TCP). Different from just IP, TCP/IP establishes a connection between two hosts so that they can send messages back and forth for a period of time.

Track A ring on a disk where data can be written. A typical floppy disk has 80 (double-density) or 160 (high-density) tracks. For hard disks, each platter is divided into tracks, and a single-track location that cuts through all platters (and both sides of each platter) is called a cylinder. Hard disks have many thousands of cylinders. Each track is further divided into a number of sectors. The operating system and disk drive remember where information is stored by noting its track and sector numbers.

USB Short for ***U****niversal* ***S****erial* ***B****us*, a new external bus standard that supports data transfer rates of 12 Mbps (12 million bits per second). A single USB port can be used to connect up to 127 peripheral devices, such as mice, modems, and keyboards. USB also supports Plug-and-Play installation and hot plugging.

UTP Short for ***U****nshielded* ***T****wisted* ***P****air*, a popular type of cable that consists of two unshielded wires twisted around each other. Due to its low cost, UTP cabling is used extensively for local area networks (LANs) and telephone connections. UTP cabling does not offer as high bandwidth or as good protection from interference as co-axial or fiber optic cables, but it is less expensive and easier to work with.

VRAM Short for ***v****ideo* ***RAM***, and pronounced *vee-ram.* VRAM is special-purpose memory used by video adapters.

VRML Pronounced *ver-mal,* and short for ***V****irtual* ***R****eality* ***M****odeling* ***L****anguage,* VRML is a specification for displaying three-dimensional objects on the World Wide Web.

WAN Short for ***W****ide* ***A****rea* ***N****etwork*. A computer network that spans a relatively large geographical area. Typically, a WAN consists of two or more local area networks (LANs).

WRAM Short for ***W****indows* ***RAM****,* a type of RAM developed by Samsung Electronics that supports two ports. This enables a video adapter to fetch the contents of memory for display at the same time that new bytes are being put into memory.

xDSL Refers collectively to all types of ***D****igital* ***S****ubscriber* ***L****ines,* the two main categories being ADSL (asynchronous) and SDSL (synchronous). Two other types of xDSL technologies are **H**igh-data-rate **DSL** (HDSL) and **S**ingle-line **DSL** (SDSL also). xDSL is similar to ISDN in as much as both operate over existing copper telephone lines and both require short runs to a central telephone office (usually less than 20,000 feet). However, xDSL offers much higher speeds.

APPENDIX A
USEFUL LINKS

GENERAL

Alberta Education listserver <edc-techplangroup@gov.ab.ca>

Alberta Education web site <http://ednet.edc.gov.ab.ca>

Calgary Public School District Wiring Standards <http://www.cbe.ab.ca>

Technology Implementation Review: Grande Yellowhead Regional Division No. 35/Wolf Creek Regional Division No. 32 <http://ednet.edc.gov.ab.ca/technology/>

TECHNOLOGY

Adaptec's ThreadMark 2.0	<http://www.adaptec.com>
AGP	<http://www.intel.com/technology/agp/>
Aperture	<http://www.aperture.com/>
ATI	<http://www.atitech.com/>
Cirrus Logic	<http://www.cirrus.com/>
CU-SeeMe	<http://www.wpine.com/>
IBM	<http://www.storage.ibm.com.:80/storage/hardsoft/diskdrdl.htm>
Matrox	<http://www.matrox.com/>
NetMedic	<http://www.vitalsigns.com>
PC standards	<http://www.microsoft.com/hwdev/desguid/> and <http://developer.intel.com/design/pc98/>
Quantum	<http://www.quantum.com/>
RealAudio	<http://www.realaudio.com/>
RMON Technically Elite	<http://www.tecelite.com>
S3	<http://www.s3.com/>
Seagate	<http://www.seagate.com/>
SPEC CPU95	<http://www.specbench.org>
Surfwatch	<http://www1.surfwatch.com/home/>
WebSense	<http://www.websense.com/>
Western Digital	<http://www.wdc.com/>
Ziff-Davis CPUmark$_{32}$	<http://www.zdbop.com>

APPENDIX B
ALBERTA EDUCATION WEB SITE HOME PAGE

D:\WINNT\Profiles\Jim Ward\Desktop\homepage

File Edit View Help

homepage

Name	Size	Type	Modified	Attributes
6.jpg	5KB	Image Expert Picture	4/1/98 8:58 AM	A
acrobat.gif	1KB	GIF Image	4/1/98 9:01 AM	A
addupcomingevent.jpg	5KB	Image Expert Picture	4/1/98 9:01 AM	A
albertatext.gif	2KB	GIF Image	4/1/98 9:01 AM	A
bpfive.jpg	7KB	Image Expert Picture	4/1/98 9:01 AM	A
darkblueline.html	1KB	Internet Document ...	8/19/97 9:14 AM	A
default.asp	1KB	ASP File	11/6/97 4:03 PM	A
DIPLOMAEXAM.JPG	5KB	Image Expert Picture	4/1/98 8:38 AM	A
GRADIENTYELLOW.GIF	1KB	GIF Image	4/1/98 10:15 AM	A
homepage.asp	4KB	ASP File	4/1/98 10:20 AM	A
Lineblue.gif	1KB	GIF Image	3/31/98 9:10 AM	A
Rightbar.gif	23KB	GIF Image	4/1/98 8:57 AM	A
rndbutton.gif	1KB	GIF Image	4/1/98 9:01 AM	A
sections.asp	2KB	ASP File	10/10/97 7:47 AM	A
tabhighlights.gif	1KB	GIF Image	4/1/98 9:01 AM	A
titlebar.asp	1KB	ASP File	3/16/98 2:41 PM	A
Topie.jpg	9KB	Image Expert Picture	4/1/98 11:35 AM	A
WHITETOBLUE.GIF	1KB	GIF Image	4/1/98 10:18 AM	A

18 object(s) 61.3KB

FIGURE 26: ALBERTA EDUCATION WEB SITE HOME PAGE FILE SIZES

The Alberta Education web site has the following structure:

<http://ednet.edc.gov.ab.ca/>

- Frame: <http://ednet.edc.gov.ab.ca/titlebar.asp>
  Background Image: <http://ednet.edc.gov.ab.ca/graphics/titlebar/5.jpg>
  Image: <http://ednet.edc.gov.ab.ca/rightbar.gif>
- Frame: <http://ednet.edc.gov.ab.ca/darkblueline.html>
- Frame: <http://ednet.edc.gov.ab.ca/sections.asp>
  Background Image: <http://ednet.edc.gov.ab.ca/gradientyellow.gif>
  Image: <http://ednet.edc.gov.ab.ca/images/lineblue.gif>
  Image: <http://ednet.edc.gov.ab.ca/images/lineblue.gif>
  Image: <http://ednet.edc.gov.ab.ca/images/lineblue.gif>
  Image: <http://ednet.edc.gov.ab.ca/images/lineblue.gif>
  Image: <http://ednet.edc.gov.ab.ca/images/lineblue.gif>
- Frame: <http://ednet.edc.gov.ab.ca/homepage.asp>
  Image: <http://ednet.edc.gov.ab.ca/images/tabhighlights.gif>
  Image: <http://ednet.edc.gov.ab.ca/lineblue.gif>
  Image: <http://ednet.edc.gov.ab.ca/features/topie.jpg>
  Image: <http://ednet.edc.gov.ab.ca/features/bpfive.jpg>

Image: <http://ednet.edc.gov.ab.ca/features/addupcomingevent.jpg>
Image: <http://ednet.edc.gov.ab.ca/acrobat.gif>
Image: <http://ednet.edc.gov.ab.ca/graphics/rndbutton.gif>
Image: <http://ednet.edc.gov.ab.ca/graphics/rndbutton.gif>
Image: <http://ednet.edc.gov.ab.ca/graphics/rndbutton.gif>

- Frame: <http://ednet.edc.gov.ab.ca/search.html>

Background Image: <http://ednet.edc.gov.ab.ca/images/whitetoblue.gifForm 1:>
Action URL: <http://ednet.edc.gov.ab.ca/search/query.idq>
Encoding: application/x-www-form-urlencoded (default)
Method: Get
Image: <http://ednet.edc.gov.ab.ca/graphics/albertatext.gif>

APPENDIX C
NETMEDIC OUTPUT

FIGURE 27: NETMEDIC WEB PAGE

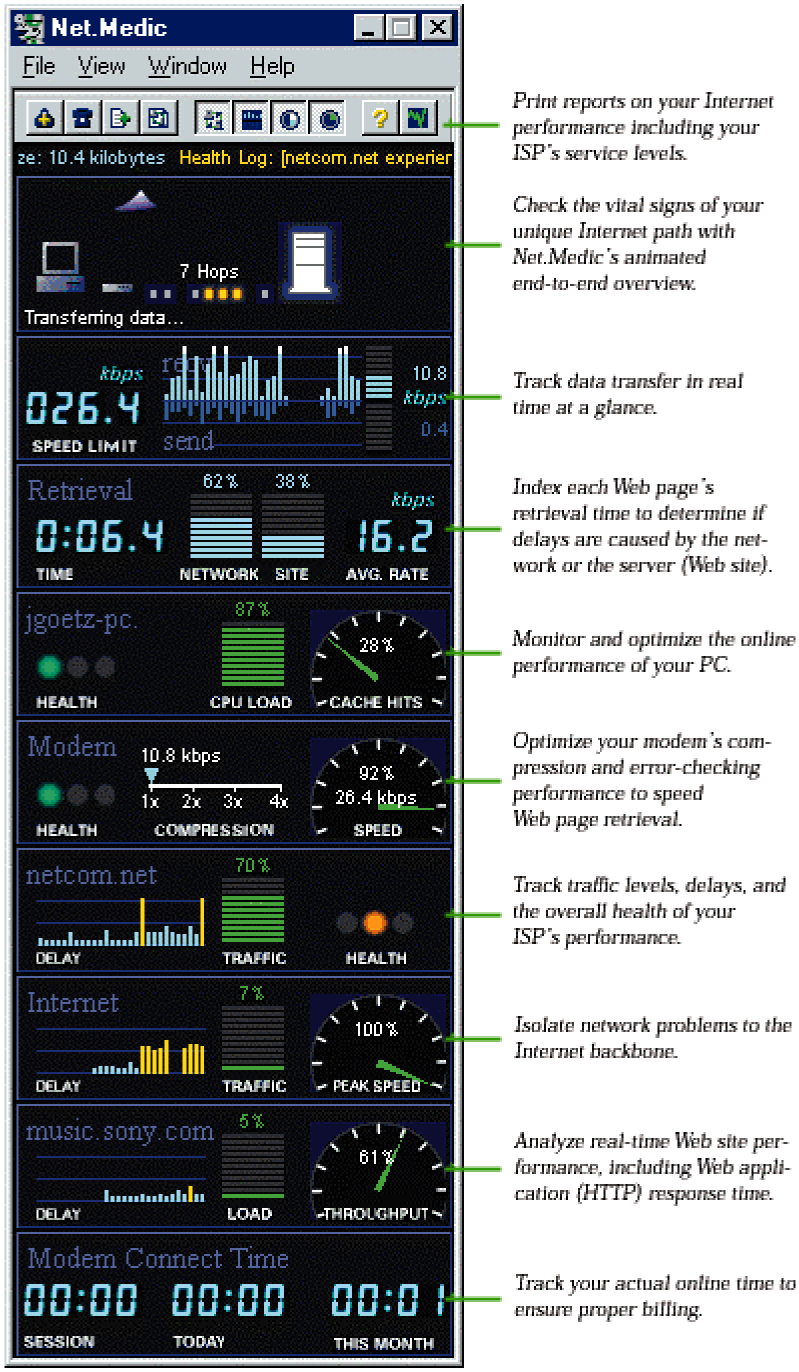

FIGURE 28: NETMEDIC PANEL

APPENDIX D
HP OPENVIEW

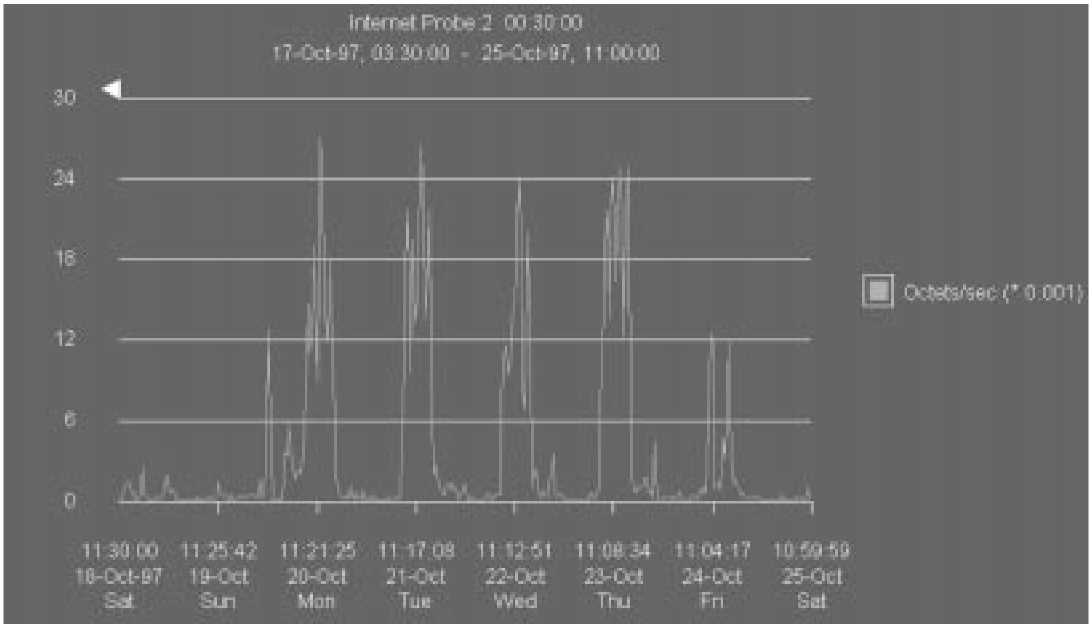

FIGURE 29: ELK ISLAND INTERNET TRAFFIC—1 WEEK

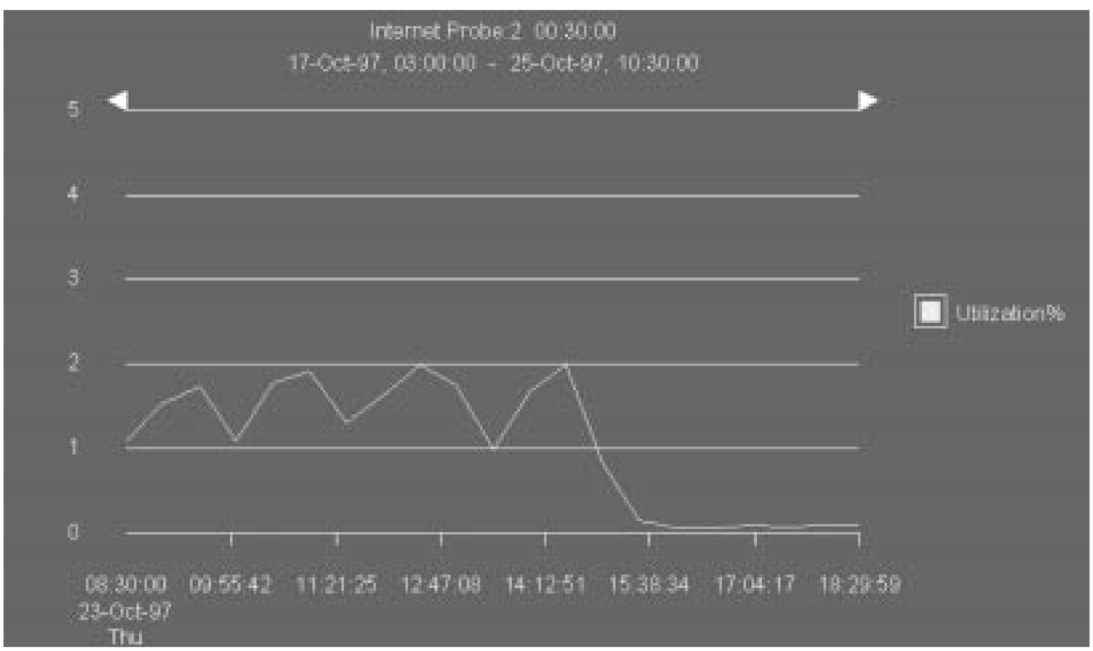

FIGURE 30: ELK ISLAND INTERNET TRAFFIC—1 DAY (EXPANDED FROM PREVIOUS)

APPENDIX E
AGNPAC ANALYSIS

UTILIZATION STATS FOR THE AGNpac FRAME RELAY CIRCUIT FOR THE SUMMITVIEW SCHOOL IN GRANDE CACHE (January 5 to January 8, 1998) (SPEED = 128 Kbps)

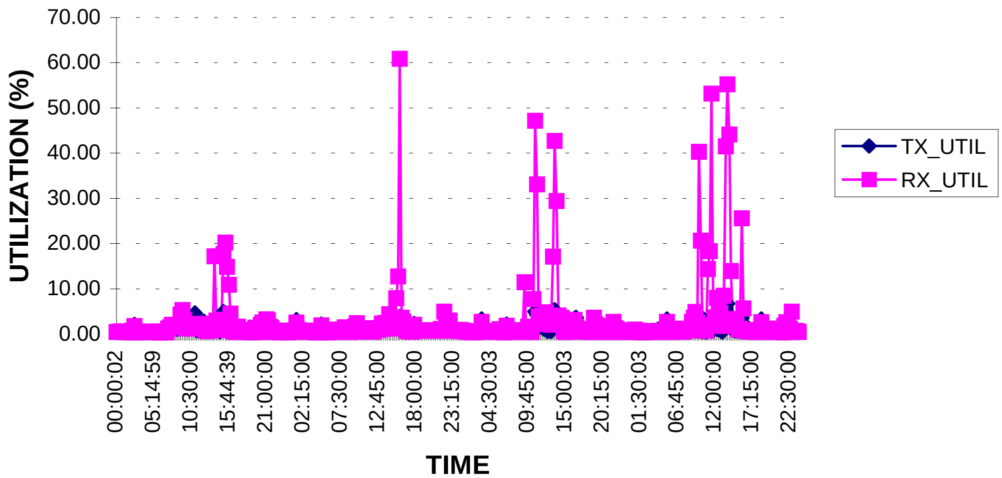

FIGURE 31: GRANDE CACHE FRAME RELAY CIRCUIT UTILIZATION

APPENDIX F
TECHNICALLY ELITE RMON PROBE MWARE SOFTWARE

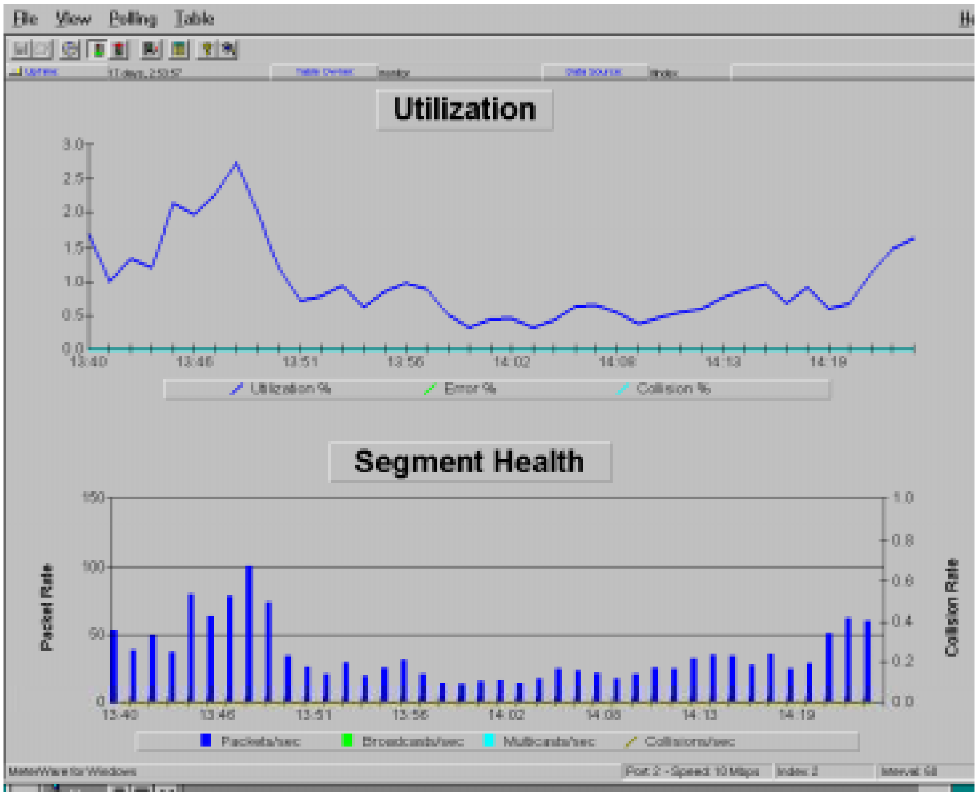

FIGURE 32: NETWORK UTILIZATION IN PPS AND PERCENTAGE

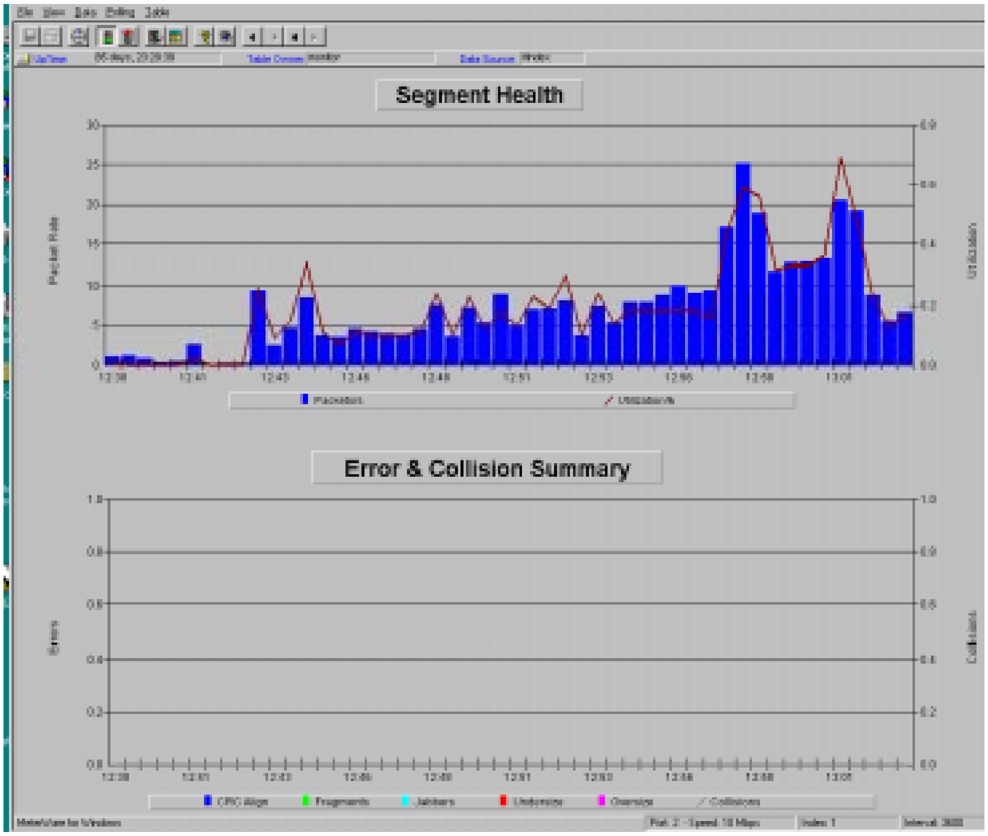

FIGURE 33: RMON HISTORY MIB

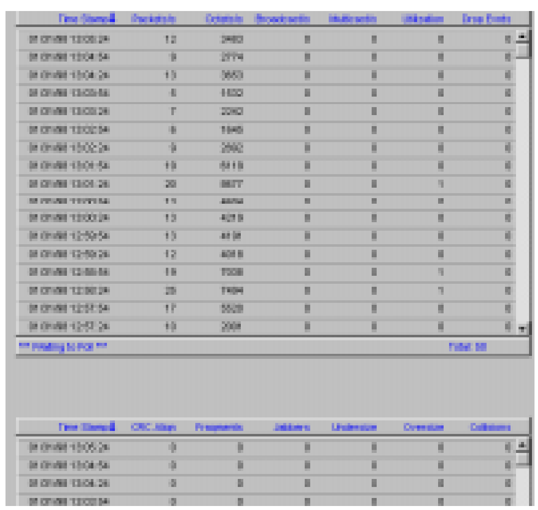

FIGURE 34: RMON HISTORY MIB—TABULAR FORM

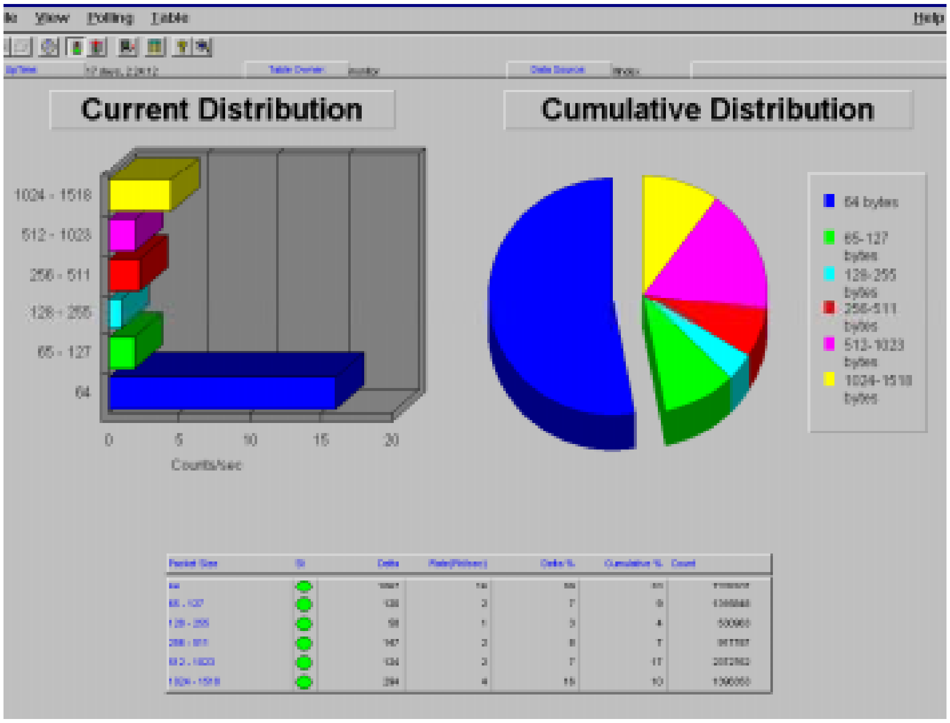

FIGURE 35: PACKET SIZE TRENDS AND CUMULATIVE STATISTICS

APPENDIX G
FIREWALL-1 ANALYSIS

Enabling Accounting summarizes all network sessions. This data can be downloaded via a text file to Access or Excel (depending upon size) for further analysis.

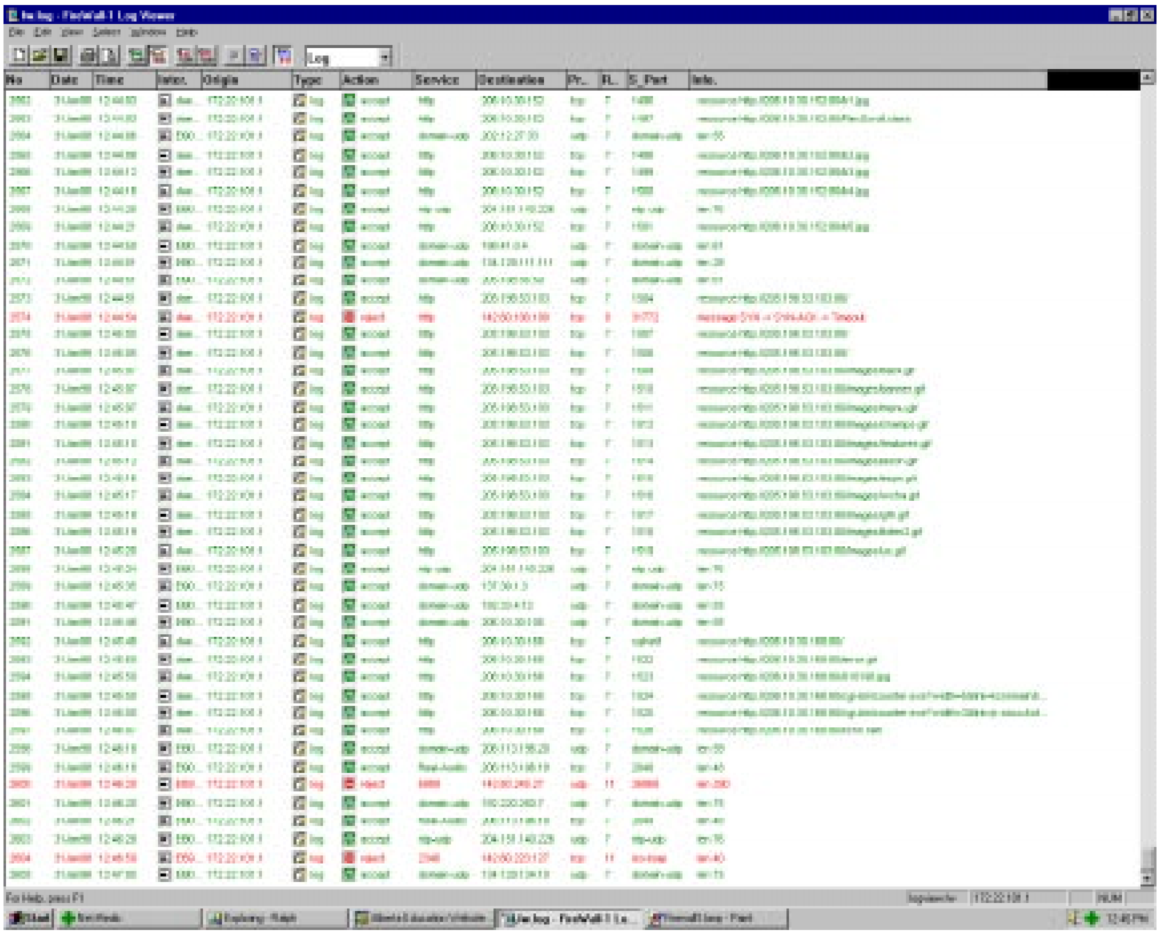

FIGURE 36: FIREWALL-1 LOG FILE (SOURCE IP SUPPRESSED)

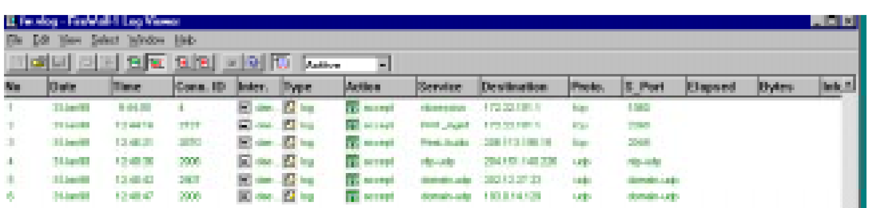

FIGURE 37: FIREWALL-1 ACTIVE SESSIONS (SOURCE IP SUPPRESSED)

Date	Time	Proto	Dst	Service	Source Port	Elapsed	Packets	Bytes	Resource
15Jan98	5:49:26 PM	tcp	128.171.184.253	666	1553	2:10:28	23395	19255018	
15Jan98	11:48:34 AM	tcp	206.251.6.117	FTP	3955	0:38:40	12868	7523148	
15Jan98	10:24:47 AM	tcp	207.240.151.14	HTTP	1072	1:03:45	9236	5768933	http://207.240.151.14:80/trailers/scream
15Jan98	3:43:40 PM	tcp	204.71.176.27	FTP	2048	0:20:32	7370	4621788	
15Jan98	4:27:42 PM	tcp	207.137.168.46	HTTP	1286	0:08:14	6353	3614410	http://207.137.168.46:80/z64/movies/zel
15Jan98	4:28:10 PM	tcp	207.137.168.46	HTTP	1287	0:08:31	6418	3604569	http://207.137.168.46:80/z64/movies/zel
15Jan98	1:52:52 PM	tcp	206.71.189.19	Real-Audio	1170	0:23:43	4695	3546466	
15Jan98	4:34:45 PM	tcp	207.137.168.46	HTTP	1290	0:04:51	5629	3412162	http://207.137.168.46:80/z64/movies/zel
15Jan98	4:29:44 PM	tcp	207.137.168.46	HTTP	1289	0:08:54	5901	3409744	http://207.137.168.46:80/z64/movies/zel

TABLE 17: FIREWALL-1 ACCESS ACCOUNTING DATABASE (SORTED DESCENDING ON BYTES) SOURCE IP SUPPRESSED

APPENDIX H
ETHERNET PACKET

```
Packet #1
   Flags:       0x00
   Status:      0x00
   Packet Length:146
   Timestamp:   14:12:29.820935  02/04/1998
Ethernet Header
   Destination:  00:e0:b0:63:b3:eb
   Source:       00:60:08:a3:11:bd
   Protocol Type:0x0800  IP
IP Header - Internet Protocol Datagram
   Version:              4
   Header Length:        5
   Precedence:           0
   Type of Service:      %000
   Unused:               %00
   Total Length:         128
   Identifier:           39509
   Fragmentation Flags:  %000
   Fragment Offset:      0
   Time To Live:         128
   IP Type:              0x01  ICMP
   Header Checksum:      0x7338
   Source IP Address:    142.60.253.6
   Dest. IP Address:     142.229.18.199
   No Internet Datagram Options
ICMP - Internet Control Messages Protocol
   ICMP Type:            8  Echo Request
   Code:                 0
   Checksum:             0x08e3
   Identifier:           0x0100
   Sequence Number:      26649
   ICMP Data Area:
   ¡GÐB,I:M#?_Q3|ÍJ   a1 47 18 42 2c 49 3a 4d 23 3f 5f 51 33 7c cd 4a
   ±VÐ]ÐW• WÐw^)>MÐ+   b1 56 1e 5d fc 57 9e 57 f8 77 5e 29 3e 4d 1c 2b
   ÐÐ3Ð‡|&jbÐ“"ÈnÐÐ   f7 1f 33 15 87 7c 26 6a 62 0c 93 22 c8 6e 7f 0d
   DXg0Ð7|ÐÐKÐÐ¥aÐÊ   44 58 67 30 14 37 7c 0c e9 4b e3 1a a5 61 00 20
   ÐcÐ6ÊTª1ÐS·VÐÐMK   fb 63 13 36 20 54 aa 31 eb 53 b7 56 19 03 4d 4b
   ’ÐQ]ÐÊ¡ÐÐh|w`)8]   92 07 51 5d da 20 a1 1a 19 68 7c 77 60 29 38 5d
   ÐhÐÐ               16 68 7f 0b
Frame Check Sequence:  0x2746cf98
```

FIGURE 38: ETHERNET PACKET

APPENDIX I
JURISDICTION DOCUMENTATION

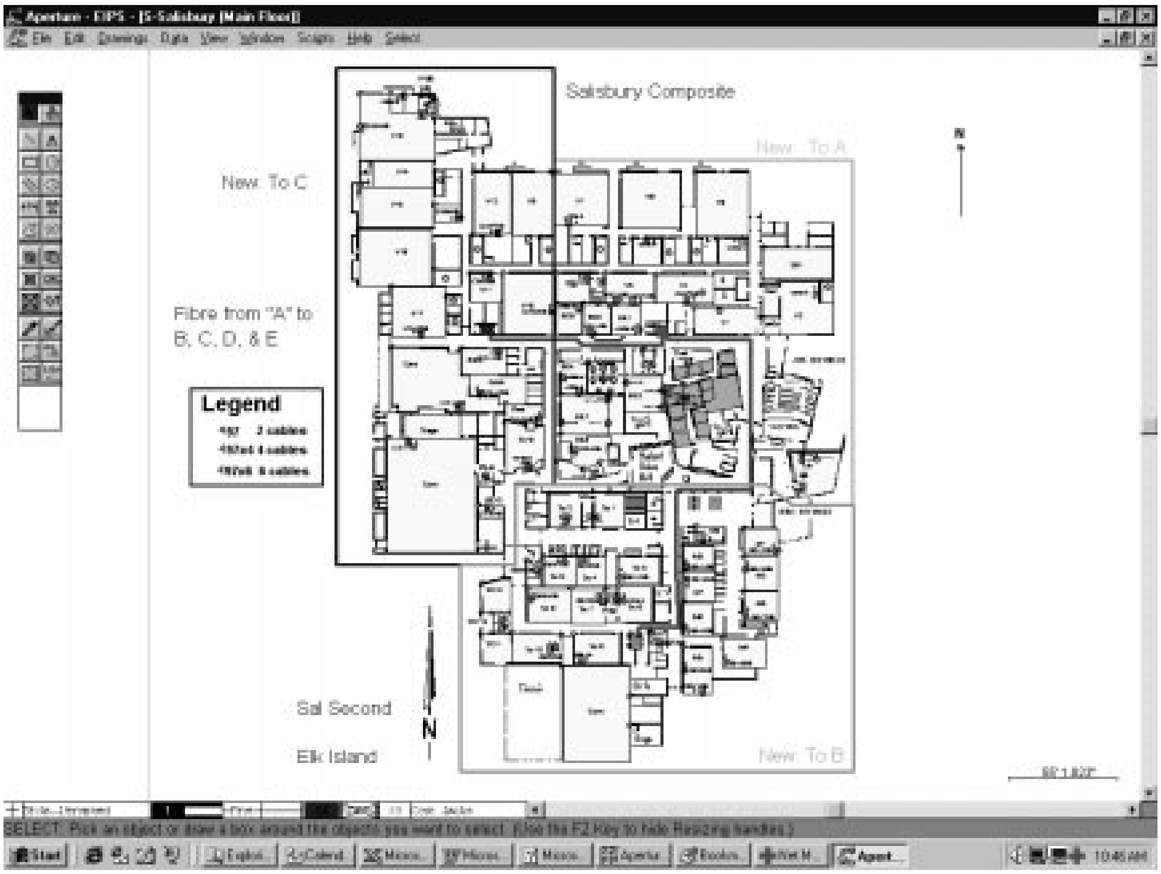

FIGURE 39: SCHOOL DIAGRAM

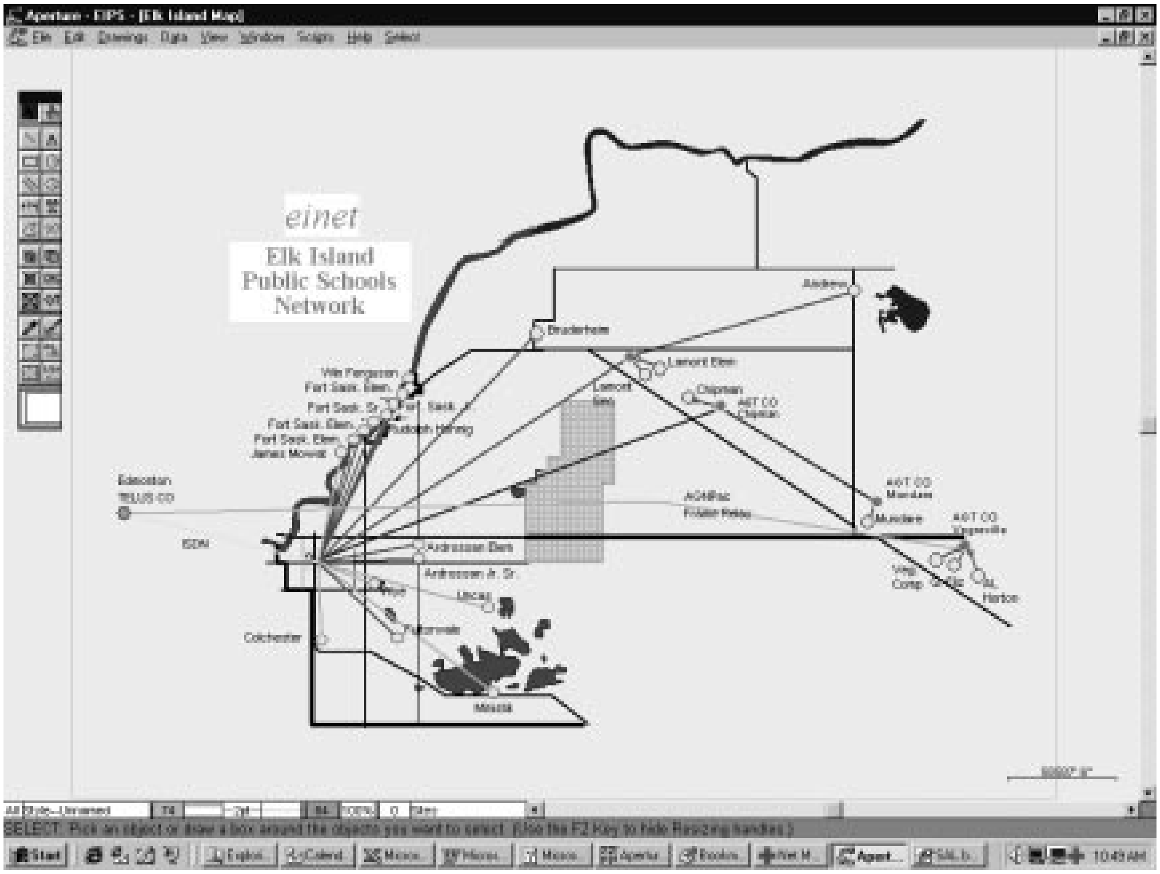

FIGURE 40: EIPS DIAGRAM

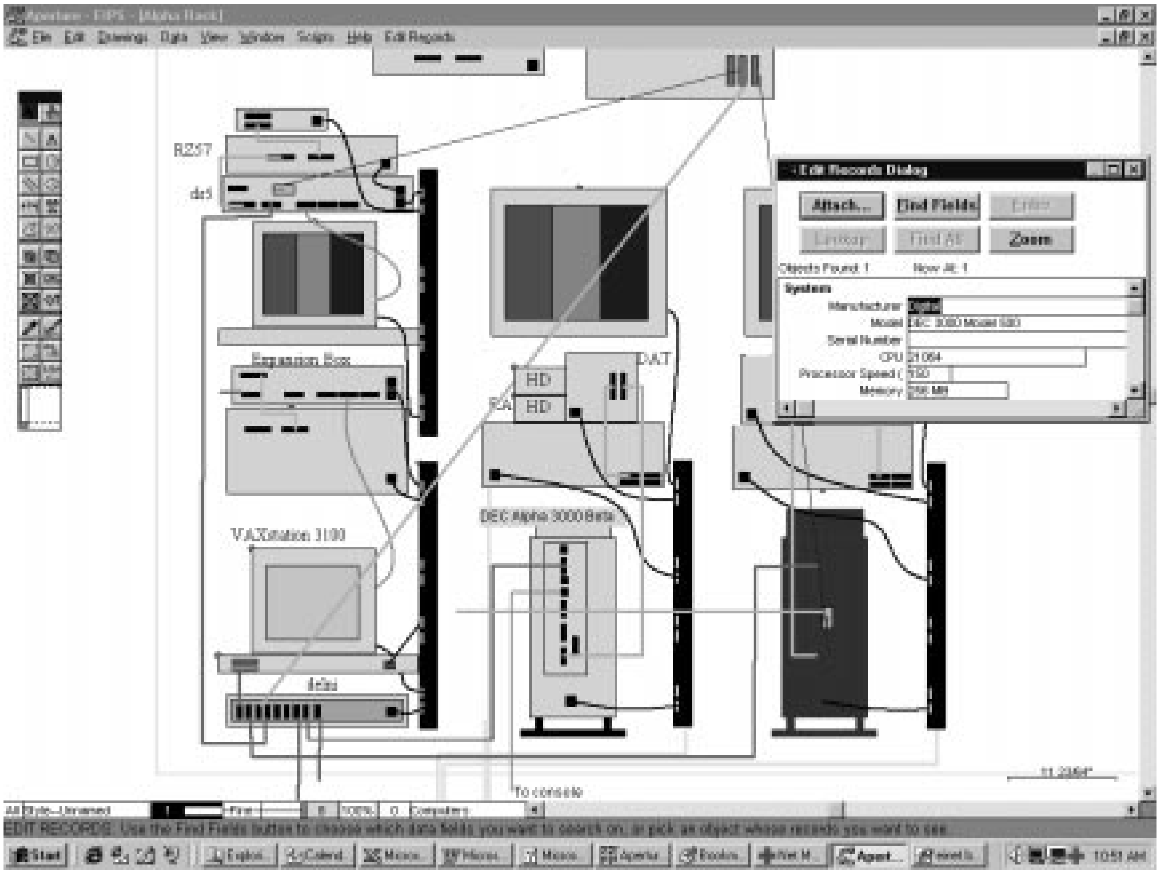

FIGURE 41: DETAILED INFRASTRUCTURE RECORDS

APPENDIX J
ANALYSIS OF INTERNET TRAFFIC WITH OVER 500,000 BYTES:

Time	Service	S Port	Elapsed	Packets	Bytes	Resource
17:49:26	666	1553	2:10:28	23,395	19,255,018	
11:48:34	FTP	3955	0:38:40	12,868	7,523,148	
10:24:47	HTTP	1072	1:03:45	9236	5,768,933	http://207.240.151.14:80/trailers/scream2/scream2.mov
15:43:40	FTP	2048	0:20:32	7370	4,621,788	
16:27:42	HTTP	1286	0:08:14	6353	3,614,410	http://207.137.168.46:80/z64/movies/zelda51.mov
16:28:10	HTTP	1287	0:08:31	6418	3,604,569	http://207.137.168.46:80/z64/movies/zelda2.mov
13:52:52	RealAudio	1170	0:23:43	4695	3,546,466	
16:34:45	HTTP	1290	0:04:51	5629	3,412,162	http://207.137.168.46:80/z64/movies/zelda2.mov
16:29:44	HTTP	1289	0:08:54	5901	3,409,744	http://207.137.168.46:80/z64/movies/zelda3.mov
14:49:47	HTTP	1314	0:07:51	4153	3,339,033	http://206.29.22.39:80/maverick/deftones/dld/video/shoveit1.mov
10:31:53	pop-3	1176	0:17:51	8406	2,745,975	
16:16:17	HTTP	1279	0:05:25	4532	2,520,812	http://207.137.168.46:80/z64/movies/zelda2e3.mov
16:18:41	HTTP	1281	0:06:10	4339	2,398,457	http://207.137.168.46:80/z64/movies/zeldae31.mov
8:27:58	HTTP	1469	0:02:59	2665	2,215,982	http://204.71.186.40:80/media/previews/Nintendo64/video/hybr2.mov
16:19:22	HTTP	1284	0:04:54	3819	2,126,439	http://207.137.168.46:80/z64/movies/zelda3e3.mov
12:28:12	HTTP	1249	0:05:19	3768	1,974,036	http://209.66.78.67:80/media/JOADMOV.AVI
15:16:57	HTTP	1257	0:08:24	2528	1,942,616	http://152.2.25.83:80/student/orgs/uncbands/songs/gotyou.au
15:57:23	HTTP	1247	0:04:32	2413	1,940,251	http://209.75.1.67:80/zelda/index/zeldav/1996.mov
16:11:22	HTTP	1278	0:02:43	2400	1,918,822	http://207.137.168.46:80/z64/movies/zeldaa.mov
15:49:32	HTTP	1646	0:11:41	4839	1,575,670	http://205.166.76.101:80/n64/yoshisstory/egg.mov
9:41:51	HTTP	1202	0:12:19	2787	1,533,173	http://128.10.19.20:80/homes/merrilti/sounds/empirelong.au
10:52:33	HTTP	1300	0:05:58	1914	1,522,562	http://209.66.98.16:80/156ad8ff3c7fbc98d317/windows/rp32_50.exe
13:27:22	HTTP	1322	0:11:17	1924	1,517,215	http://204.236.5.1:80/151316fb888d6cc86620/windows/rp32_50.exe
9:41:46	HTTP	1201	0:13:04	2424	1,491,576	http://128.10.19.20:80/homes/merrilti/sounds/empirelong.au
9:12:35	HTTP	1057	0:11:32	2359	1,483,396	http://207.240.151.12:80/ie/fifth_element/video/milla.mov
10:16:01	HTTP	1298	0:13:08	2552	1,471,083	http://207.25.71.225:80/soundboard/wav_files/duggan.wav
13:26:44	RealAudio	1070	0:13:24	2375	1,388,740	
10:11:46	HTTP	3592	0:15:45	2188	1,355,203	http://207.25.71.225:80/soundboard/wav_files/arn.wav

FIGURE 42: INTERNET DESTINATIONS—JANUARY 15, 1998 (CONTINUED ON NEXT PAGE)

,3:57:23	HTTP	1102	0:04:37	1607	1,253,861	http://24.64.1.28:80/files/dz95.exe
10:03:41	RealAudio	1445	0:22:35	1680	1,193,190	
00-Jan-00	HTTP	1502	0:01:49	1343	1,189,040	http://204.71.186.40:80/media/movies/previews/wargods11.mov
00-Jan-00	HTTP	1295	0:13:30	1965	1,157,780	http://207.25.71.225:80/soundboard/wav_files/duggan.wav
00-Jan-00	HTTP	1507	0:01:56	1239	1,050,716	http://204.71.186.40:80/media/movies/previews/wargods1.mov
00-Jan-00	HTTP	3746	0:09:58	1360	1,003,219	http://166.77.14.113:80/news/mov/e/elliot970718.mov
00-Jan-00	HTTP	1822	0:12:37	1511	922,878	http://205.181.114.40:80/download/MAC/ADMUpdt.hqx
00-Jan-00	HTTP	1156	0:04:26	1434	889,356	http://208.197.117.40:80/files/installsplatter.exe
00-Jan-00	HTTP	1464	0:01:36	1026	889,236	http://204.71.186.40:80/media/previews/Nintendo64/video/hybr1.mov
00-Jan-00	HTTP	1124	0:03:07	1122	873,372	http://152.2.25.83:80/student/orgs/uncbands/songs/fight.au
00-Jan-00	HTTP	1161	0:03:58	1121	864,382	http://205.162.110.170:80/bengal.exe
00-Jan-00	HTTP	1159	0:05:28	1099	844,100	http://192.41.48.155:80/canrock.exe
00-Jan-00	5000	3224	2:15:13	7475	778,987	
00-Jan-00	HTTP	1150	0:05:57	971	740,163	http://134.117.69.87:80/~cdavidso/muppet/muppet.wav
00-Jan-00	HTTP	1149	0:06:16	982	734,099	http://134.117.69.87:80/~cdavidso/muppet/muppet.wav
00-Jan-00	HTTP	3234	0:04:13	886	727,416	http://134.117.69.87:80/~cdavidso/muppet/muppet.wav
00-Jan-00	HTTP	2609	0:10:34	990	725,005	http://209.24.120.79:80/bcs/atc101.zip
00-Jan-00	HTTP	1127	0:07:02	1124	708,744	http://152.2.25.83:80/student/orgs/uncbands/songs/fight.au
00-Jan-00	HTTP	1285	0:02:25	1235	681,986	http://207.137.168.46:80/z64/movies/zelda.mov
00-Jan-00	6667	1728	0:44:24	1948	679,919	
00-Jan-00	HTTP	1177	0:03:31	878	672,025	http://205.243.60.2:80/~dragon/sounds/ACTOR.WAV
00-Jan-00	HTTP	2403	0:07:12	831	602,740	http://208.17.148.37:80/pulse.gif
00-Jan-00	5000	3225	1:46:26	5873	583,996	
00-Jan-00	HTTP	4451	0:03:22	782	581,648	http://204.62.129.193:80/People/Staff/janelle/janelle150.GIF
00-Jan-00	HTTP	1277	0:01:29	735	577,645	http://207.137.168.46:80/z64/movies/Zelda64.qt
00-Jan-00	HTTP	1126	0:03:47	953	574,572	http://152.2.25.83:80/student/orgs/uncbands/songs/fight.au
00-Jan-00	HTTP	1501	0:01:21	681	566,168	http://204.71.186.40:80/media/movies/previews/wargods8.mov
00-Jan-00	RealAudio	1208	0:05:05	776	552,198	
00-Jan-00	HTTP	1209	0:10:54	1671	524,459	http://141.164.1.20:80/~lton/Eva_Img/Eva3.jpg
00-Jan-00	HTTP	1119	0:01:51	763	513,938	http://152.2.25.83:80/student/orgs/uncbands/songs/tag.au
00-Jan-00	HTTP	1120	0:02:07	696	505,354	http://152.2.25.83:80/student/orgs/uncbands/songs/tag.au

FIGURE 42: INTERNET DESTINATIONS—JANUARY 15, 1998

APPENDIX K
RELATED ALBERTA EDUCATION RESOURCES

Computer Network Security: Best Practices for Alberta School Jurisdictions (1999).

Developing A Three-Year Technology Integration Plan: A Resource for School Jurisdictions (1998).

FOIPP and Technology: Best Practices for Alberta School Jurisdictions (1999).

FOIPP and Technology Highlights: Best Practices for Alberta School Jurisdictions (1999).

Implementing and Managing Web Site Development in Education: Best Practices for Alberta School Jurisdictions (1999).

Managing Technology Funding: Best Practices for Alberta School Jurisdictions (1999).

On-Line Learning: Best Practices for Alberta School Jurisdictions (1999).

Preparing to Implement Learner Outcomes in Technology: Best Practices for Alberta School Jurisdictions (1999).

Professional Development for Teaching Technology Across the Curriculum: Best Practices for Alberta School Jurisdictions (1999).

Technical Support Planning: Best Practices for Alberta School Jurisdictions (1999).

Technology Implementation Review, Grande Yellowhead Regional Division No. 24 and Wolf Creek Regional Division No. 32: Best Practices and Key Learnings with Respect to Technology, Its Implementation and Management in Education (1997).