Schienbein, Ralph


Alberta Dept. of Education, Edmonton.

ISBN-0-7785-0324-0

1999-02-00

Learning Resources Distributing Centre, 12360-142 St., Edmonton, Alberta, Canada T5L 4X9; Tel: 780-427-5775; Fax: 780-422-9750; Web site: http://ednet.edc.gov.ab.ca/technology/

This report examines subsections of the computer network topology that relate to end-to-end performance and capacity planning in schools. Active star topology, Category 5 wiring, Ethernet, and intelligent devices are assumed. The report describes a model that can be used to project WAN (wide area network) connection speeds based on user traffic, describes end-to-end performance issues, characterizes and identifies tools for online analysis, describes how network traffic has an impact on network design as well as computer architectures, provides basic metrics where available, and identifies industry trends. The introduction discusses end-to-end performance, WAN connection, and bandwidth model. A WAN analysis is then presented, describing: tools; packet size; performance monitor; WAN traffic; WAN equity; shared bandwidth; cache server; multiple WAN connections; subnets and filters; case analysis; pornography, hackers, and other problems; and diagrams and documentation. A section on layers and computer performance covers the central processing unit, memory, network interface card, greening, hard disk subsystem, graphics subsystem, and motherboards. A glossary of terms is provided. Links to relevant World Wide Web sites, the structure of the Alberta Education home page, and a list of related Alberta Education resources are appended. Also appended are several configuration diagrams and illustrations of displays. (AEF)

Reproductions supplied by EDRS are the best that can be made from the original document.
ALBERTA EDUCATION CATALOGUING IN PUBLICATION DATA


Available in electronic format on the World Wide Web:
URL: http://ednet.edc.gov.ab.ca/technology/
ISBN 0-7785-0324-0

I. Title.

TK5105.5.A333 1998 621.381

Additional copies are available through:

Learning Resources Distributing Centre
12360–142 Street
Edmonton, Alberta, Canada T5L 4X9
Telephone: 780–427–5775
Facsimile: 780–422–9750

For more information, contact:

Bonnie Brooks
School Technology Task Group
Alberta Education
11160 Jasper Avenue
Edmonton, Alberta, Canada T5K 0L2
Telephone: 780–427–9001
Facsimile: 780–415–1091

To be connected toll free outside Edmonton, dial 310-0000.

The primary intended audience for this framework is:

| Administrator | √ |
| Counselors | |
| General Audience | |
| Information Technologists | √ |
| Parents | |
| Students | |
| Teachers | √ |

Copyright © 1999, the Crown in Right of Alberta, as represented by the Minister of Education. Alberta Education, School Technology Task Group, 11160 Jasper Avenue, Edmonton, Alberta, Canada, T5K 0L2.

Permission is given by the copyright owner to reproduce this document, or any part thereof, for educational purposes and on a nonprofit basis.
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
ACKNOWLEDGEMENTS

Alberta Education wishes to acknowledge the contributions of the following individuals:

**PROJECT DIRECTOR**
Terry Gunderson  
Superintendent  
Elk Island Public Schools Regional Division No. 14

**AUTHOR**
Ralph Schienbein, PhD.  
Co-ordinator, Standards, Research and Development  
Elk Island Public Schools Regional Division No. 14

**SCHOOL TECHNOLOGY ADVISORY COUNCIL MEMBERS DURING DEVELOPMENT**

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Travers (Chair)</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>Peter Balding</td>
<td>Black Gold Regional Division No. 18</td>
</tr>
<tr>
<td>Marika Bourque</td>
<td>Calgary School District No. 19</td>
</tr>
<tr>
<td>Bonnie Brooks</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>George Buck</td>
<td>Universities Co-ordinating Council</td>
</tr>
<tr>
<td>David Burch</td>
<td>Alberta Home and School Councils' Association</td>
</tr>
<tr>
<td>Edna Dach</td>
<td>Elk Island Public Schools Regional Division No. 14</td>
</tr>
<tr>
<td>Jack Dale</td>
<td>Calgary School District No. 19</td>
</tr>
<tr>
<td>Peter Darby</td>
<td>Chinook's Edge School Division No. 73</td>
</tr>
<tr>
<td>John Darroch</td>
<td>Palliser Regional Division No. 26</td>
</tr>
<tr>
<td>Dale Erickson</td>
<td>Alberta School Boards' Association</td>
</tr>
<tr>
<td>Chris Farthing</td>
<td>Edmonton Catholic Regional Division No. 40</td>
</tr>
<tr>
<td>Toni Hafso</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>Gary Heck</td>
<td>Lethbridge School District No. 51</td>
</tr>
<tr>
<td>Harry Henshaw</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>Robert Hogg</td>
<td>St. Albert Protestant Separate School District No. 6</td>
</tr>
<tr>
<td>Maurice Hollingsworth</td>
<td>Palliser Regional Division No. 26</td>
</tr>
<tr>
<td>Judi Hunter</td>
<td>Calgary School District No. 19</td>
</tr>
<tr>
<td>Glen Johnson</td>
<td>Edmonton School District No. 7</td>
</tr>
<tr>
<td>Doug Knight</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>Catherine Kullman</td>
<td>TELUS Learning Connection</td>
</tr>
<tr>
<td>Norma Nocente</td>
<td>Universities Co-ordinating Council</td>
</tr>
<tr>
<td>John Percevault</td>
<td>Grande Yellowhead Regional Division No. 35</td>
</tr>
<tr>
<td>Archie Pick</td>
<td>Alberta Chamber of Resources</td>
</tr>
<tr>
<td>Doug Pudwell</td>
<td>Medicine Hat School Division No. 76</td>
</tr>
<tr>
<td>Randy Rudd</td>
<td>Association of School Business Officials of Alberta</td>
</tr>
<tr>
<td>Ralph Schienbein</td>
<td>Elk Island Public Schools Regional Division No. 14</td>
</tr>
<tr>
<td>Jacqueline Skytt</td>
<td>The Alberta Teachers' Association</td>
</tr>
<tr>
<td>Ron Sohle</td>
<td>Alberta Education</td>
</tr>
<tr>
<td>Gary Spence</td>
<td>Wolf Creek School Division No. 72</td>
</tr>
<tr>
<td>Lonnie Springer</td>
<td>Calgary Roman Catholic Separate School District No.1</td>
</tr>
<tr>
<td>Mary Stephenson</td>
<td>Alberta Chamber of Commerce</td>
</tr>
<tr>
<td>Barbara Stevenson</td>
<td>Calgary School District No. 19</td>
</tr>
<tr>
<td></td>
<td>The Alberta Teachers' Association</td>
</tr>
</tbody>
</table>
RESOURCE PERSONNEL

John Hogarth
Peter Wright

ConsultNet
University of Alberta
# TABLE OF CONTENTS

Executive Summary ................................................................. 1
Introduction ................................................................................. 7
  Performance Is An End-to-End Issue ......................................... 7
  Purpose and Objectives ............................................................ 7
  End-to-End Performance .......................................................... 9
  WAN Connection ...................................................................... 11
  Bandwidth Model ................................................................... 11
WAN Analysis ................................................................. 17
  Tools ....................................................................................... 17
  Packet Size ........................................................................... 18
  EIPS WAN Analysis—Packet Size .............................................. 21
  EIPS WAN Analysis—Performance Monitor ............................. 25
  WAN Traffic—Content ........................................................... 27
  WAN Equity ........................................................................... 30
  Shared Bandwidth—The Case for a Switch ................................. 33
  Cache Server ......................................................................... 34
  Multiple WAN Connections ...................................................... 38
  Subnets and Filters ................................................................ 39
  Case Analysis—Listening to the Radio ....................................... 41
  Pornography, Hackers, and Other Unmentionables .................. 43
  Diagrams and Documentation .................................................. 45
  WAN Analysis Summary .......................................................... 45
Layers and Computer Performance ............................................. 47
  Central Processing Unit ............................................................ 47
    CPU Metrics ........................................................................ 48
    State of the Art .................................................................... 51
  Memory .................................................................................... 53
  Network Interface Card ............................................................ 53
  Greening ................................................................................ 59
  Hard Disk Subsystem ............................................................... 60
    Case Analysis: CD Server on HD ........................................... 67
  Graphics Subsystem ................................................................. 67
  Motherboards ......................................................................... 70
Layers and Computer Performance Summary ................................ 72
Summary ....................................................................................... 73
Glossary of Terms ....................................................................... 75
Appendix A: Useful Links ............................................................. 85
Appendix B: Alberta Education Web Site Home Page .................. 87
Appendix C: NetMedic Output ...................................................... 89
Appendix D: HP OpenView ........................................................... 91
Appendix E: AGNPac Analysis ..................................................... 93
Appendix F: Technically Elite RMON Probe Mware Software ....... 95
Appendix G: Firewall-1 Analysis .................................................. 99
Appendix H: Ethernet Packet ........................................................ 101
Appendix I: Jurisdiction Documentation ....................................... 103
Appendix J: Analysis of Internet Traffic With Over 500,000 Bytes: .. 107
Appendix K: Related Alberta Education Resources ....................... 109
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WAN Connection Speeds</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Download Times for Various Numbers of Users</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>Ethernet Packet</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>Internet Packet Analysis</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>Summary of Traffic by Service</td>
<td>29</td>
</tr>
<tr>
<td>6</td>
<td>Summary of Traffic by File Type</td>
<td>29</td>
</tr>
<tr>
<td>7</td>
<td>School Bandwidth Projection</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>School Bandwidth Estimation</td>
<td>31</td>
</tr>
<tr>
<td>9</td>
<td>Cache Site Analysis</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>&quot;com&quot; Cache Analysis</td>
<td>37</td>
</tr>
<tr>
<td>11</td>
<td>Filter Address and Mask</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td>Disk Speed Metrics</td>
<td>62</td>
</tr>
<tr>
<td>13</td>
<td>Sample Disk Drive Specifications</td>
<td>63</td>
</tr>
<tr>
<td>14</td>
<td>WinBench98 Disk results</td>
<td>64</td>
</tr>
<tr>
<td>15</td>
<td>Graphic RAM Requirements</td>
<td>68</td>
</tr>
<tr>
<td>16</td>
<td>Comparison of Graphics Cards</td>
<td>69</td>
</tr>
<tr>
<td>17</td>
<td>Firewall-1 Access Accounting Database (sorted descending on bytes)</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Source IP suppressed</td>
<td></td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Layered View of Network Design</td>
<td>8</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Relative &quot;Pipesizes&quot;; 10, 100, 1000 Mbps</td>
<td>8</td>
</tr>
<tr>
<td>Figure 3</td>
<td>End User Accessing a Server Through a LAN and WAN</td>
<td>9</td>
</tr>
<tr>
<td>Figure 4</td>
<td>End-to-End Block Browser Diagram</td>
<td>10</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Trace Route from User to Alberta Education</td>
<td>10</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Alberta Education Web Site Home Page</td>
<td>14</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Alberta Education Header</td>
<td>14</td>
</tr>
<tr>
<td>Figure 8</td>
<td>RMON Packet Size Trend (15-Second Sample, March 6, 1998)</td>
<td>22</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Internet Packet Sizes</td>
<td>24</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Performance Monitor of 256 Kbps from Ethernet</td>
<td>25</td>
</tr>
<tr>
<td>Figure 11</td>
<td>FTP on WAN and Local NIC</td>
<td>27</td>
</tr>
<tr>
<td>Figure 12</td>
<td>WAN Traffic by Site</td>
<td>28</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Hub versus Switch</td>
<td>34</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Cache Server</td>
<td>35</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Multiple WAN Connections from a School</td>
<td>38</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Filter on Address/Protocol</td>
<td>40</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Live Radio</td>
<td>42</td>
</tr>
<tr>
<td>Figure 18</td>
<td>A Firewall-1 Rule</td>
<td>43</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Audible Alert</td>
<td>44</td>
</tr>
<tr>
<td>Figure 20</td>
<td>CPU Utilization: Moving a Window and Launching an Application</td>
<td>49</td>
</tr>
<tr>
<td>Figure 21</td>
<td>File Transfer Through a NIC</td>
<td>55</td>
</tr>
<tr>
<td>Figure 22</td>
<td>File Transfer Through NIC—Non UW</td>
<td>56</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Packet Size Trend</td>
<td>57</td>
</tr>
<tr>
<td>Figure 24</td>
<td>Utilization and Packet Rate</td>
<td>58</td>
</tr>
<tr>
<td>Figure 25</td>
<td>NIC-Disk Transfer Rates</td>
<td>59</td>
</tr>
<tr>
<td>Figure 26</td>
<td>Alberta Education Web Site Home Page File Sizes</td>
<td>87</td>
</tr>
<tr>
<td>Figure 27</td>
<td>NetMedic Web Page</td>
<td>89</td>
</tr>
<tr>
<td>Figure 28</td>
<td>NetMedic Panel</td>
<td>90</td>
</tr>
<tr>
<td>Figure 29</td>
<td>Elk Island Internet Traffic—1 week</td>
<td>91</td>
</tr>
<tr>
<td>Figure 30</td>
<td>Elk Island Internet Traffic—1 day (expanded from previous)</td>
<td>91</td>
</tr>
<tr>
<td>Figure 31</td>
<td>Grande Cache Frame Relay Circuit Utilization</td>
<td>93</td>
</tr>
<tr>
<td>Figure 32</td>
<td>Network Utilization in PPS and Percentage</td>
<td>95</td>
</tr>
<tr>
<td>Figure 33</td>
<td>RMON History MIB</td>
<td>96</td>
</tr>
<tr>
<td>Figure 34</td>
<td>RMON History MIB—Tabular Form</td>
<td>96</td>
</tr>
<tr>
<td>Figure 35</td>
<td>Packet Size Trends and Cumulative Statistics</td>
<td>97</td>
</tr>
<tr>
<td>Figure 36</td>
<td>Firewall-1 Log File (source IP suppressed)</td>
<td>99</td>
</tr>
<tr>
<td>Figure 37</td>
<td>Firewall-1 Active Sessions (source IP suppressed)</td>
<td>99</td>
</tr>
<tr>
<td>Figure 38</td>
<td>Ethernet Packet</td>
<td>101</td>
</tr>
<tr>
<td>Figure 39</td>
<td>School Diagram</td>
<td>103</td>
</tr>
<tr>
<td>Figure 40</td>
<td>District-Level Diagram</td>
<td>104</td>
</tr>
<tr>
<td>Figure 41</td>
<td>Detailed Infrastructure Records</td>
<td>105</td>
</tr>
<tr>
<td>Figure 42</td>
<td>Internet Destinations—January 15, 1998</td>
<td>108</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

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 listserv <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.
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**
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](image)

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.
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.

---

**FIGURE 4: END-TO-END BLOCK BROWSER DIAGRAM**

**FIGURE 5: TRACE ROUTE FROM USER TO ALBERTA EDUCATION**
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.

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).
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.

<table>
<thead>
<tr>
<th>Type</th>
<th>Bandwidth</th>
<th>64 byte</th>
<th>pps</th>
<th>1518 + 64</th>
<th>Max</th>
<th>100 KB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kbps</td>
<td>pps</td>
<td>at 80%</td>
<td>pps</td>
<td>Bytes per second</td>
<td>Kbps</td>
</tr>
<tr>
<td>Centrex</td>
<td>56</td>
<td>109</td>
<td>88</td>
<td>3.5</td>
<td>7000</td>
<td>7.0</td>
</tr>
<tr>
<td>ISDN</td>
<td>128</td>
<td>250</td>
<td>200</td>
<td>8.1</td>
<td>16,000</td>
<td>16.0</td>
</tr>
<tr>
<td>256</td>
<td>256</td>
<td>500</td>
<td>400</td>
<td>16.2</td>
<td>32,000</td>
<td>32.0</td>
</tr>
<tr>
<td>512</td>
<td>512</td>
<td>1000</td>
<td>800</td>
<td>32.4</td>
<td>64,000</td>
<td>64.0</td>
</tr>
<tr>
<td>T1</td>
<td>1540</td>
<td>3008</td>
<td>2406</td>
<td>97.3</td>
<td>192,500</td>
<td>192.5</td>
</tr>
<tr>
<td>Ethernet</td>
<td>10,000</td>
<td>19,531</td>
<td>15,625</td>
<td>632.1</td>
<td>1,250,000</td>
<td>1250.0</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th></th>
<th>100 KB</th>
<th>Users</th>
<th>Users</th>
<th>Users</th>
<th>Users</th>
<th>Users</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># sec</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Centrex</td>
<td>14.286</td>
<td>142.9</td>
<td>285.7</td>
<td>428.6</td>
<td>571.4</td>
<td>714.3</td>
<td>857.1</td>
</tr>
<tr>
<td>ISDN</td>
<td>6.250</td>
<td>62.5</td>
<td>125.0</td>
<td>187.5</td>
<td>250</td>
<td>312.5</td>
<td>375.0</td>
</tr>
<tr>
<td>256</td>
<td>3.125</td>
<td>31.3</td>
<td>62.5</td>
<td>93.8</td>
<td>125</td>
<td>156.3</td>
<td>187.5</td>
</tr>
<tr>
<td>512</td>
<td>1.563</td>
<td>15.6</td>
<td>31.3</td>
<td>46.9</td>
<td>62.5</td>
<td>78.1</td>
<td>93.8</td>
</tr>
<tr>
<td>T1</td>
<td>0.519</td>
<td>5.2</td>
<td>10.4</td>
<td>15.6</td>
<td>20.8</td>
<td>26.0</td>
<td>31.2</td>
</tr>
<tr>
<td>Ethernet</td>
<td>0.080</td>
<td>0.8</td>
<td>1.6</td>
<td>2.4</td>
<td>3.2</td>
<td>4.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

**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>. 
The Alberta Education website (Ednet) is a comprehensive internet guide for K-12 education in the province of Alberta. Inside you will find the latest information on education-enabling technology, curriculum documents, policy and legislation documents, news releases, past diploma examinations, demographic statistics of jurisdictions, schools on the web, and much more. Ednet also contains links to other education stakeholder websites in the province of Alberta and around the world, and features a comprehensive search engine for finding documents onsite.

If you are looking for information about Alberta's post-secondary institutions and other learning opportunities in Alberta, check out the Alberta Learning Information Service (ALIS).

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.
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.
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 is included in Appendix H, Figure 38.

### Packet #1

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet Length</td>
<td>146</td>
</tr>
<tr>
<td>Timestamp</td>
<td>14:12:29.820935 02/04/1998</td>
</tr>
<tr>
<td>Ethernet Header</td>
<td></td>
</tr>
<tr>
<td>Destination</td>
<td>00:e0:b0:63:b3:eb</td>
</tr>
<tr>
<td>Source</td>
<td>00:60:08:a3:11:bd</td>
</tr>
<tr>
<td>Source IP Address</td>
<td>142.60.255.43</td>
</tr>
<tr>
<td>Dest. IP Address</td>
<td>142.229.18.199</td>
</tr>
<tr>
<td>Data</td>
<td></td>
</tr>
</tbody>
</table>

**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 troubleshooting. 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.
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.

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

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.
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 cannot 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).

![Performance Monitor of 256 Kbps from Ethernet](image)

**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.
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).
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.

<table>
<thead>
<tr>
<th>Service</th>
<th>BYTES</th>
<th>Top</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>1,362,983</td>
<td>1.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>666</td>
<td>19,255,018</td>
<td>16.7%</td>
<td>3.6%</td>
</tr>
<tr>
<td>6667</td>
<td>679,919</td>
<td>0.6%</td>
<td>0.1%</td>
</tr>
<tr>
<td>FTP</td>
<td>12,144,936</td>
<td>10.5%</td>
<td>2.3%</td>
</tr>
<tr>
<td>HTTP</td>
<td>72,510,046</td>
<td>62.8%</td>
<td>13.5%</td>
</tr>
<tr>
<td>pop-3</td>
<td>2,745,975</td>
<td>2.4%</td>
<td>0.5%</td>
</tr>
<tr>
<td>RealAudio</td>
<td>6,680,594</td>
<td>5.8%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>115,379,471</td>
<td>21.4%</td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Type</th>
<th>BYTES</th>
<th>Top</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>.au</td>
<td>42,869,425</td>
<td>37.2%</td>
<td>8.0%</td>
</tr>
<tr>
<td>.qt</td>
<td>8,143,345</td>
<td>7.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td>AVI</td>
<td>577,645</td>
<td>0.5%</td>
<td>0.1%</td>
</tr>
<tr>
<td>exe</td>
<td>1,974,036</td>
<td>1.7%</td>
<td>0.4%</td>
</tr>
<tr>
<td>gif</td>
<td>6,891,476</td>
<td>6.0%</td>
<td>1.3%</td>
</tr>
<tr>
<td>hqx</td>
<td>1,184,388</td>
<td>1.0%</td>
<td>0.2%</td>
</tr>
<tr>
<td>jpg</td>
<td>922,878</td>
<td>0.8%</td>
<td>0.2%</td>
</tr>
<tr>
<td>mov</td>
<td>524,459</td>
<td>0.5%</td>
<td>0.1%</td>
</tr>
<tr>
<td>wav</td>
<td>44,709,045</td>
<td>38.7%</td>
<td>8.3%</td>
</tr>
<tr>
<td>zip</td>
<td>6,857,769</td>
<td>5.9%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>115,379,471</td>
<td>21.4%</td>
<td></td>
</tr>
</tbody>
</table>

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 than 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 56 Kbps per student, a school with 987 students would require 55,210 Kbps or 55.2 Mbps. Clearly, this model is too simplistic.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th># Students</th>
<th>Kbps per student</th>
<th>Total Kbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECS</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4–6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7–9</td>
<td>476</td>
<td>56</td>
<td>26,656</td>
</tr>
<tr>
<td>10–12</td>
<td>510</td>
<td>56</td>
<td>28,560</td>
</tr>
<tr>
<td>Total</td>
<td>987</td>
<td></td>
<td>55,210</td>
</tr>
</tbody>
</table>

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.
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.

**SHAREDBANDWIDTH—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-MbpsEthernet segment generally becomes "saturated" above 30 per cent or 3 Mbps.
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.

**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).
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.

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

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).

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

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.

![Diagram of multiple WAN connections from a school](image)
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).
### TABLE 11: FILTER ADDRESS AND MASK

<table>
<thead>
<tr>
<th>Interface</th>
<th>Proto</th>
<th>Port</th>
<th>Address</th>
<th>Mask</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destination</td>
<td>TCP</td>
<td>25</td>
<td>x.x.125.0</td>
<td>255.255.255.0</td>
<td>Forward</td>
</tr>
<tr>
<td>Source</td>
<td>All</td>
<td></td>
<td>x.x.126.z</td>
<td>255.255.255.255</td>
<td></td>
</tr>
</tbody>
</table>

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.
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.
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](image)

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.

52
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.
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 CPUmark₃₂. One metric used within PCs is CPUmark₃₂ 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 CPUmark₃₂ 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 CPUmark₃₂ score of 693 (PC Magazine, December 2, 1997, p. 185).

Note: The above points are cited as magazine references instead of just CPUmark₃₂ 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

A good metric for PC CPU performance is the CPUmark₃₂. 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/desquid/> 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 CPUmark32 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 Pentium Pro (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 CPUmark32, 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.
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).
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.

**Metric**

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.

**Tip**

Standardize on 10/100-Mbps NICs.
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.

**BEST COPY AVAILABLE**
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 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.
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.
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 “autolode 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.
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.
<table>
<thead>
<tr>
<th>Column1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
<th>Column 5</th>
<th>Column 6</th>
<th>Column 7</th>
<th>Column 8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pentium</td>
<td>Pentium</td>
<td>Pentium</td>
<td>Pentium</td>
<td>Pentium</td>
<td>Pentium</td>
<td>Pentium</td>
</tr>
<tr>
<td>MHz</td>
<td>120</td>
<td>133</td>
<td>200</td>
<td>180</td>
<td>233</td>
<td>266</td>
<td>266</td>
</tr>
<tr>
<td>SpeedRate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>357</td>
<td>297</td>
<td>806</td>
<td>811</td>
<td>864</td>
<td>983</td>
<td>994</td>
</tr>
<tr>
<td>Disk</td>
<td>90</td>
<td>164</td>
<td>232</td>
<td>410</td>
<td>269</td>
<td>233</td>
<td>254</td>
</tr>
<tr>
<td>Graphics</td>
<td>332</td>
<td>418</td>
<td>277</td>
<td>537</td>
<td>951</td>
<td>1143</td>
<td></td>
</tr>
<tr>
<td>Threadmark 2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Transfer</td>
<td>1.93</td>
<td>3.23</td>
<td>2.51</td>
<td>5.22</td>
<td>5.20</td>
<td>3.41</td>
<td>5.92</td>
</tr>
<tr>
<td>Rate in MBps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average CPU</td>
<td>37.05%</td>
<td>40.64%</td>
<td>55.18%</td>
<td>12.90%</td>
<td>10.16%</td>
<td>70.27%</td>
<td>11.34%</td>
</tr>
</tbody>
</table>

**TABLE 12: DISK SPEED METRICS**

**Tips**

- According to Microsoft (<www.microsoft.com/hwdev/express/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.
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Quantum</th>
<th>Western Digital</th>
<th>Quantum</th>
<th>Quantum</th>
<th>Seagate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Bigfoot TX</td>
<td>AC22100</td>
<td>Atlas II</td>
<td>Viking II</td>
<td>Cheeta 9</td>
</tr>
<tr>
<td>Formatted Capacity (MB)</td>
<td>4018</td>
<td>2111.8</td>
<td>4550</td>
<td>9100</td>
<td>9100</td>
</tr>
<tr>
<td>Interface</td>
<td>Ultra DMA/33</td>
<td>EIDE</td>
<td>UltraSCSI-3</td>
<td>Ultra LVD</td>
<td>Ultra 2 SCSI</td>
</tr>
<tr>
<td>Seek Time (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Average (read)</td>
<td>&lt;12</td>
<td>&lt;12</td>
<td>8</td>
<td>7.5</td>
<td>5.7</td>
</tr>
<tr>
<td>- Track-to-Track</td>
<td>2.5</td>
<td>3</td>
<td>1</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>- Full Stroke</td>
<td>24</td>
<td>22</td>
<td>&lt;18</td>
<td>&lt;=15</td>
<td></td>
</tr>
<tr>
<td>Average Rotational Latency (ms)</td>
<td>7.5</td>
<td>5.76</td>
<td>4.17</td>
<td>4.17</td>
<td>2.9</td>
</tr>
<tr>
<td>Rotational Speed (rpm)</td>
<td>4000</td>
<td>5200</td>
<td>7200</td>
<td>7200</td>
<td>10,025</td>
</tr>
<tr>
<td>Maximum Areal Density (MB per square inch)</td>
<td></td>
<td>659</td>
<td>1340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buffer Size (KB)</td>
<td>128</td>
<td>128</td>
<td>512</td>
<td>512</td>
<td>1024</td>
</tr>
<tr>
<td>Internal Data Rate (MB/s)</td>
<td>142</td>
<td>53-104</td>
<td>121</td>
<td>98-170</td>
<td>122-177</td>
</tr>
<tr>
<td>Internal Formatted Transfer Rate (MB/s)</td>
<td></td>
<td></td>
<td></td>
<td>14.5-23</td>
<td></td>
</tr>
<tr>
<td>Transfer Rate - Host (MB/s)</td>
<td>33.3</td>
<td>33.3</td>
<td>40</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>MTBF (hours)</td>
<td>300,000</td>
<td></td>
<td></td>
<td>1,000,000</td>
<td></td>
</tr>
<tr>
<td>Warranty (years)</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 13: SAMPLE DISK DRIVE SPECIFICATIONS**

The Ziff-Davis Winstone and WinBench benchmarks are for business and high-end users. Business Winstone 98 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 4.0, 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.

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>WinBench 98/Business Disk WinMark 98</td>
<td>1360</td>
<td>3,4,5</td>
</tr>
<tr>
<td>WinBench 98/High-End Disk WinMark 98</td>
<td>3380</td>
<td>3,4,5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benchmark</th>
<th>Result</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>WinBench 98/Disk Playback/Bus:Publishing</td>
<td>1580</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/Bus:SS/Database</td>
<td>949</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/Bus:Task Switching</td>
<td>1640</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/Bus:WP</td>
<td>1620</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:AVS/Express 3.1</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:FrontPage 97</td>
<td>2360</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:MicroStation 95</td>
<td>6650</td>
<td>3,4,5</td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:Overall</td>
<td>3380</td>
<td>3,4,5</td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:Photoshop 4.0</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:Premiere 4.2</td>
<td>4400</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:PV-Wave 6.1</td>
<td>2830</td>
<td></td>
</tr>
<tr>
<td>WinBench 98/Disk Playback/HE:Visual C++ 5.0</td>
<td>8510</td>
<td>3,4,5,10,11</td>
</tr>
<tr>
<td>WinBench 98/Disk/Read CPU Utilization</td>
<td>5.9</td>
<td>3,4,5,10,11</td>
</tr>
<tr>
<td>WinBench 98/Disk/Read Random Access</td>
<td>10.5</td>
<td>3,4,5</td>
</tr>
<tr>
<td>WinBench 98/Disk/Read Transfer Rate:Beginning</td>
<td>9630</td>
<td>3,4,5</td>
</tr>
<tr>
<td>WinBench 98/Disk/Read Transfer Rate:End</td>
<td>8920</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 14: WINBENCH98 DISK RESULTS**

**Notes:**

3. The playback directory was c:\wbdtmp.
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/>

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**

<table>
<thead>
<tr>
<th></th>
<th>1394/FireWire</th>
<th>USB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Devices</td>
<td>62</td>
<td>127</td>
</tr>
<tr>
<td>Data Transfer Rate</td>
<td>200 Mbps (25 MB/s)</td>
<td>12 Mbps (1.5 MB/s)</td>
</tr>
<tr>
<td>Macintosh</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>16 colour 4 bit MB</th>
<th>256 colour 8 bit MB</th>
<th>65,000 colour 16 bit MB</th>
<th>16.7 M 24 bit MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>640 X 480</td>
<td>0.5</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>800 X 600</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1024 X 768</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1280 X 1024</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>1600 X 1200</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>1800 X 1440</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

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

**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 capacity.
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/>

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 **acknowledgment packet** is sent back to verify that the packet was received.

**AGP** Short for **Accelerated Graphics Port**, 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 **American National Standards Institute**. 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 **Advanced Technology Attachment**, 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 Central Processing Unit. The CPU is simply the brain of the computer.

CSMA/CD
Short for Carrier Sense Multiple Access/Collision Detection, 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 Direct Memory Access, 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 Domain Name System (or Service), 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 Dynamic RAM, a type of memory used in most personal computers.

DV
Short for Digital Video. Refers to the capturing, manipulation and storage of video in digital formats.

ECC
Short for Error-Correcting Code 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 Extended Data Output DRAM, a type of DRAM that is faster than conventional DRAM.

EIA
Short for Electronic Industries Association. 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 *Enhanced 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 cooperation 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 *File Transfer Protocol*, the protocol used on the Internet for sending files.

**Gbps**

Short for *Gigabits per second*, 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 *High-Definition Television*, a new type of television that provides much better resolution than current televisions based on the NTSC (National Television Standards Committee) 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 Hertz. This number represents the number of cycles per second. It often is used to measure screen refreshes.

IDE
Short for Intelligent Drive Electronics or Integrated Drive Electronics, 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 Institute of Electrical and Electronics Engineers, 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 Internet Message Access Protocol, a protocol for retrieving e-mail messages.

I/O
Short for Input/Output, 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 Internet Protocol, 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 Integrated Services Digital Network, 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 Industry Standard Architecture. 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 Internet Service Provider, 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 KiloByte. 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 Kilobits per second, 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 Local Area Network. 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 Media Access Control address, a hardware address that uniquely identifies each node of a network.

MB

Short for megabyte (1,000,000 or 1,048,576 bytes, depending on the context).

Mbps/MBps

See Data Transfer Rates.

MHz

Short for megahertz. One MHz represents one million cycles per second.

MPEG

Short for Moving Picture Experts Group, 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 Network Interface Card. 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 New Technology. 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 Private Branch eXchange, 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 Peripheral Component Interconnect, 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 Post Office Protocol, 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 Random Access Memory. RAM is volatile, meaning that it loses its contents when the power is turned off.

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 Remote MONitoring, 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 Rotations Per Minute. Used when referring to hard disk drive units or CD-ROM drives.
SCSI

Abbreviation of Small Computer System Interface. 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.
- Ultra2 SCSI: Uses an 8-bit bus and supports data rates of 40 MBps. Also called Ultra Wide SCSI.
- Wide Ultra2 SCSI: Uses a 16-bit bus and supports data rates of 80 MBps.

SDRAM

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

SMTP

Short for Simple Mail Transfer Protocol, 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 Simple Network Management Protocol, 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 (Open System Interconnection) 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 *Transport Control Protocol* (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 *Universal Serial Bus*, 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 *Unshielded Twisted Pair*, 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 *video RAM*, and pronounced *vee-ram*. VRAM is special-purpose memory used by video adapters.

**VRML**  

**WAN**  
Short for *Wide Area Network*. 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 *Windows 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 *Digital Subscriber Lines*, the two main categories being ADSL (asynchronous) and SDSL (synchronous). Two other types of xDSL technologies are High-data-rate DSL (HDSL) and Single-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/>
Matrox <http://www.matrox.com/>
NetMedic <http://www.vitalsigns.com>
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 CPUmark32 <http://www.zdbop.com>
# APPENDIX B
## ALBERTA EDUCATION WEB SITE HOME PAGE

The Alberta Education web site has the following structure:

   - Background Image: [http://ednet.edc.gov.ab.ca/graphics/titlebar/5.gif](http://ednet.edc.gov.ab.ca/graphics/titlebar/5.gif)
   - Image: [http://ednet.edc.gov.ab.ca/features/topie.png](http://ednet.edc.gov.ab.ca/features/topie.png)

---

**FIGURE 26: ALBERTA EDUCATION WEB SITE HOME PAGE FILE SIZES**

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Type</th>
<th>Modified</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>acrobat.gif</td>
<td>1KB</td>
<td>GIF Image</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>addupcomingevent.jpg</td>
<td>5KB</td>
<td>Image Expert</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>albertatext.gif</td>
<td>2KB</td>
<td>GIF Image</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>bbluev.jpg</td>
<td>7KB</td>
<td>Image Expert</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>darkblueline.html</td>
<td>1KB</td>
<td>Internet Document</td>
<td>8/19/97 9:14 AM</td>
<td>A</td>
</tr>
<tr>
<td>default.asp</td>
<td>1KB</td>
<td>ASP File</td>
<td>11/6/97 4:03 PM</td>
<td>A</td>
</tr>
<tr>
<td>DIPLOMAEXAM.JPG</td>
<td>5KB</td>
<td>Image Expert</td>
<td>4/1/98 9:38 AM</td>
<td>A</td>
</tr>
<tr>
<td>GRADIENTYELLOW.GIF</td>
<td>1KB</td>
<td>GIF Image</td>
<td>4/1/98 10:15 AM</td>
<td>A</td>
</tr>
<tr>
<td>homepage.asp</td>
<td>4KB</td>
<td>ASP File</td>
<td>4/1/98 10:20 AM</td>
<td>A</td>
</tr>
<tr>
<td>lineblue.gif</td>
<td>1KB</td>
<td>GIF Image</td>
<td>3/31/99 9:10 AM</td>
<td>A</td>
</tr>
<tr>
<td>rightbar.gif</td>
<td>23KB</td>
<td>GIF Image</td>
<td>4/1/98 8:57 AM</td>
<td>A</td>
</tr>
<tr>
<td>rndbutton.gif</td>
<td>1KB</td>
<td>GIF Image</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>sections.asp</td>
<td>2KB</td>
<td>ASP File</td>
<td>10/10/97 7:47 AM</td>
<td>A</td>
</tr>
<tr>
<td>tabhighlights.gif</td>
<td>1KB</td>
<td>GIF Image</td>
<td>4/1/98 9:01 AM</td>
<td>A</td>
</tr>
<tr>
<td>titlebar.asp</td>
<td>1KB</td>
<td>ASP File</td>
<td>3/16/98 2:41 PM</td>
<td>A</td>
</tr>
<tr>
<td>topie.png</td>
<td>9KB</td>
<td>Image Expert</td>
<td>4/1/98 11:35 AM</td>
<td>A</td>
</tr>
<tr>
<td>WHITETOBLEU.GIF</td>
<td>1KB</td>
<td>GIF Image</td>
<td>4/1/98 10:18 AM</td>
<td>A</td>
</tr>
</tbody>
</table>

18 object(s)   61.3KB
APPENDIX C
NETMEDIC OUTPUT

FIGURE 27: NETMEDIC WEB PAGE

BEST COPY AVAILABLE
Print reports on your Internet performance including your ISP’s service levels.

Check the vital signs of your unique Internet path with Net.Medic’s animated end-to-end overview.

Track data transfer in real time at a glance.

Index each Web page’s retrieval time to determine if delays are caused by the network or the server (Web site).

Monitor and optimize the online performance of your PC.

Optimize your modem’s compression and error-checking performance to speed Web page retrieval.

Track traffic levels, delays, and the overall health of your ISP’s performance.

Isolate network problems to the Internet backbone.

Analyze real-time Web site performance, including Web application (HTTP) response time.

Track your actual online time to ensure proper billing.

FIGURE 28: NETMEDIC PANEL

BEST COPY AVAILABLE
APPENDIX D
HP OPENVIEW

FIGURE 29: ELK ISLAND INTERNET TRAFFIC—1 WEEK

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

BEST COPY AVAILABLE
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
FIGURE 32: NETWORK UTILIZATION IN PPS AND PERCENTAGE
FIGURE 33: RMON HISTORY MIB

FIGURE 34: RMON HISTORY MIB—TABULAR FORM

BEST COPY AVAILABLE
FIGURE 35: PACKET SIZE TRENDS AND CUMULATIVE STATISTICS
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)**
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: 148
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: iGDB, I:M#? Co3I1J

Frame Check Sequence: 0x2746cf98

FIGURE 38: ETHERNET PACKET
Figure 39: School Diagram
FIGURE 40: EIPS DIAGRAM
FIGURE 41: DETAILED INFRASTRUCTURE RECORDS

BEST COPY AVAILABLE
## APPENDIX J

### ANALYSIS OF INTERNET TRAFFIC WITH OVER 500,000 BYTES:

<table>
<thead>
<tr>
<th>Time</th>
<th>Service</th>
<th>S Port</th>
<th>Elapsed</th>
<th>Packets</th>
<th>Bytes</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:43:40</td>
<td>FTP</td>
<td>2048</td>
<td>0:20:32</td>
<td>7370</td>
<td>4,621,788</td>
<td></td>
</tr>
<tr>
<td>16:28:10</td>
<td>HTTP</td>
<td>1287</td>
<td>0:08:31</td>
<td>6418</td>
<td>3,604,569</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda2.mov">http://207.137.168.46:80/z64/movies/zelda2.mov</a></td>
</tr>
<tr>
<td>13:52:52</td>
<td>RealAudio</td>
<td>1170</td>
<td>0:23:43</td>
<td>4695</td>
<td>3,546,466</td>
<td></td>
</tr>
<tr>
<td>16:34:45</td>
<td>HTTP</td>
<td>1290</td>
<td>0:04:51</td>
<td>5629</td>
<td>3,412,162</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda2.mov">http://207.137.168.46:80/z64/movies/zelda2.mov</a></td>
</tr>
<tr>
<td>16:29:44</td>
<td>HTTP</td>
<td>1289</td>
<td>0:08:54</td>
<td>5901</td>
<td>3,409,744</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda3.mov">http://207.137.168.46:80/z64/movies/zelda3.mov</a></td>
</tr>
<tr>
<td>10:31:53</td>
<td>pop-3</td>
<td>1176</td>
<td>0:17:51</td>
<td>8406</td>
<td>2,745,975</td>
<td></td>
</tr>
<tr>
<td>16:16:17</td>
<td>HTTP</td>
<td>1279</td>
<td>0:05:25</td>
<td>4532</td>
<td>2,520,812</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda2e3_mov">http://207.137.168.46:80/z64/movies/zelda2e3_mov</a></td>
</tr>
<tr>
<td>16:18:41</td>
<td>HTTP</td>
<td>1281</td>
<td>0:06:10</td>
<td>4339</td>
<td>2,398,457</td>
<td><a href="http://207.137.168.46:80/z64/movies/zeldae31_mov">http://207.137.168.46:80/z64/movies/zeldae31_mov</a></td>
</tr>
<tr>
<td>8:27:58</td>
<td>HTTP</td>
<td>1469</td>
<td>0:02:59</td>
<td>2665</td>
<td>2,215,982</td>
<td><a href="http://204.71.186.40:80/media/previews/Nintendo64/video/hybr2_mov">http://204.71.186.40:80/media/previews/Nintendo64/video/hybr2_mov</a></td>
</tr>
<tr>
<td>16:19:22</td>
<td>HTTP</td>
<td>1284</td>
<td>0:04:54</td>
<td>3819</td>
<td>2,126,439</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda3e3_mov">http://207.137.168.46:80/z64/movies/zelda3e3_mov</a></td>
</tr>
<tr>
<td>12:28:12</td>
<td>HTTP</td>
<td>1249</td>
<td>0:05:19</td>
<td>3768</td>
<td>1,974,036</td>
<td><a href="http://209.66.78.67:80/media/JOADMV.AVI">http://209.66.78.67:80/media/JOADMV.AVI</a></td>
</tr>
<tr>
<td>15:16:57</td>
<td>HTTP</td>
<td>1257</td>
<td>0:08:24</td>
<td>2528</td>
<td>1,942,616</td>
<td><a href="http://152.2.25.83:80/student/orgs/uncbands/songs/gotyou.au">http://152.2.25.83:80/student/orgs/uncbands/songs/gotyou.au</a></td>
</tr>
<tr>
<td>16:11:22</td>
<td>HTTP</td>
<td>1278</td>
<td>0:02:43</td>
<td>2400</td>
<td>1,918,822</td>
<td><a href="http://207.137.168.46:80/z64/movies/zeldaa_mov">http://207.137.168.46:80/z64/movies/zeldaa_mov</a></td>
</tr>
<tr>
<td>15:49:32</td>
<td>HTTP</td>
<td>1646</td>
<td>0:11:41</td>
<td>4839</td>
<td>1,575,670</td>
<td><a href="http://205.166.76.101:80/n64/yoshisstory/egg.mov">http://205.166.76.101:80/n64/yoshisstory/egg.mov</a></td>
</tr>
<tr>
<td>10:52:33</td>
<td>HTTP</td>
<td>1300</td>
<td>0:05:58</td>
<td>1914</td>
<td>1,522,562</td>
<td><a href="http://209.66.98.16:80/156a/ad8ff3c7/bc98d317/windows/rp32_50.exe">http://209.66.98.16:80/156a/ad8ff3c7/bc98d317/windows/rp32_50.exe</a></td>
</tr>
<tr>
<td>10:16:01</td>
<td>HTTP</td>
<td>1298</td>
<td>0:13:08</td>
<td>2552</td>
<td>1,471,083</td>
<td><a href="http://207.25.71.225:80/soundboard/wav_files/duggan.wav">http://207.25.71.225:80/soundboard/wav_files/duggan.wav</a></td>
</tr>
<tr>
<td>13:26:44</td>
<td>RealAudio</td>
<td>1070</td>
<td>0:15:45</td>
<td>2188</td>
<td>1,355,203</td>
<td><a href="http://207.25.71.225:80/soundboard/wav_files/arn.wav">http://207.25.71.225:80/soundboard/wav_files/arn.wav</a></td>
</tr>
</tbody>
</table>

**FIGURE 42: INTERNET DESTINATIONS—JANUARY 15, 1998 (CONTINUED ON NEXT PAGE)**
<table>
<thead>
<tr>
<th>Time</th>
<th>Protocol</th>
<th>Code</th>
<th>Start Date</th>
<th>Duration</th>
<th>File Size</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00:00</td>
<td>HTTP</td>
<td>1102</td>
<td>01:00:43</td>
<td>1607</td>
<td>1,253,861</td>
<td><a href="http://24.64.1.28:80/files/dz95.exe">http://24.64.1.28:80/files/dz95.exe</a></td>
</tr>
<tr>
<td>10:03:41</td>
<td>RealAudio</td>
<td>1445</td>
<td>01:22:35</td>
<td>1680</td>
<td>1,193,190</td>
<td><a href="http://204.71.186.40:80/media/movies/previews/wargasds11_mov">http://204.71.186.40:80/media/movies/previews/wargasds11_mov</a></td>
</tr>
<tr>
<td>10:00:00</td>
<td>HTTP</td>
<td>1502</td>
<td>01:01:49</td>
<td>1343</td>
<td>1,189,040</td>
<td><a href="http://204.71.186.40:80/media/movies/previews/wargasds1_mov">http://204.71.186.40:80/media/movies/previews/wargasds1_mov</a></td>
</tr>
<tr>
<td>10:00:00</td>
<td>HTTP</td>
<td>1295</td>
<td>01:13:30</td>
<td>1965</td>
<td>1,157,780</td>
<td><a href="http://207.25.71.225:80/soundboard/wav/files/dugan.wav">http://207.25.71.225:80/soundboard/wav/files/dugan.wav</a></td>
</tr>
<tr>
<td>10:00:00</td>
<td>HTTP</td>
<td>1507</td>
<td>01:01:56</td>
<td>1239</td>
<td>1,050,716</td>
<td><a href="http://204.71.186.40:80/media/movies/previews/wargasds1_mov">http://204.71.186.40:80/media/movies/previews/wargasds1_mov</a></td>
</tr>
<tr>
<td>10:00:00</td>
<td>HTTP</td>
<td>3746</td>
<td>01:09:58</td>
<td>1360</td>
<td>1,003,219</td>
<td><a href="http://166.77.14.113:80/news/movies/elliott970718.mov">http://166.77.14.113:80/news/movies/elliott970718.mov</a></td>
</tr>
<tr>
<td>10:00:00</td>
<td>HTTP</td>
<td>1822</td>
<td>01:12:37</td>
<td>1511</td>
<td>922,878</td>
<td><a href="http://205.181.114.40:80/download/MAC/ADMUpt.hqx">http://205.181.114.40:80/download/MAC/ADMUpt.hqx</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1464</td>
<td>01:01:36</td>
<td>1026</td>
<td>889,236</td>
<td><a href="http://204.71.186.40:80/media/previews/Nintend-O64/video/hybr1_mov">http://204.71.186.40:80/media/previews/Nintend-O64/video/hybr1_mov</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1124</td>
<td>01:03:07</td>
<td>1122</td>
<td>747,322</td>
<td><a href="http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au">http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1161</td>
<td>01:03:58</td>
<td>1121</td>
<td>864,382</td>
<td><a href="http://205.162.110.170:80/benqal.exe">http://205.162.110.170:80/benqal.exe</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1159</td>
<td>01:05:28</td>
<td>1099</td>
<td>844,100</td>
<td><a href="http://192.41.48.155:80/canrock.exe">http://192.41.48.155:80/canrock.exe</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>3224</td>
<td>02:15:13</td>
<td>7475</td>
<td>778,987</td>
<td><a href="http://192.41.48.155:80/canrock.exe">http://192.41.48.155:80/canrock.exe</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1150</td>
<td>01:05:57</td>
<td>971</td>
<td>740,163</td>
<td><a href="http://134.117.69.87:80/~cdavidso/muppet/muppet.wav">http://134.117.69.87:80/~cdavidso/muppet/muppet.wav</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1149</td>
<td>01:06:16</td>
<td>982</td>
<td>734,099</td>
<td><a href="http://134.117.69.87:80/~cdavidso/muppet/muppet.wav">http://134.117.69.87:80/~cdavidso/muppet/muppet.wav</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>3234</td>
<td>04:14:13</td>
<td>886</td>
<td>727,416</td>
<td><a href="http://134.117.69.87:80/~cdavidso/muppet/muppet.wav">http://134.117.69.87:80/~cdavidso/muppet/muppet.wav</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>2609</td>
<td>04:10:34</td>
<td>990</td>
<td>725,055</td>
<td><a href="http://209.24.120.79:80/bcs/atc101.zip">http://209.24.120.79:80/bcs/atc101.zip</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1127</td>
<td>04:07:02</td>
<td>1124</td>
<td>708,744</td>
<td><a href="http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au">http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1285</td>
<td>02:25:26</td>
<td>1235</td>
<td>681,986</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda_mov">http://207.137.168.46:80/z64/movies/zelda_mov</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1728</td>
<td>04:44:24</td>
<td>1948</td>
<td>679,919</td>
<td><a href="http://207.137.168.46:80/z64/movies/zelda_mov">http://207.137.168.46:80/z64/movies/zelda_mov</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1177</td>
<td>03:31:31</td>
<td>878</td>
<td>672,025</td>
<td><a href="http://205.243.60.2:80/~dragon/sounds/ACTOR.WAV">http://205.243.60.2:80/~dragon/sounds/ACTOR.WAV</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>2403</td>
<td>07:12:07</td>
<td>831</td>
<td>602,740</td>
<td><a href="http://208.17.148.37:80/pulse.gif">http://208.17.148.37:80/pulse.gif</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>3225</td>
<td>14:6:26</td>
<td>5873</td>
<td>583,996</td>
<td><a href="http://208.17.148.37:80/pulse.gif">http://208.17.148.37:80/pulse.gif</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>4451</td>
<td>03:22:03</td>
<td>782</td>
<td>581,648</td>
<td><a href="http://204.62.129.193:80/People/Staff/janelle/janelle150.GIF">http://204.62.129.193:80/People/Staff/janelle/janelle150.GIF</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1277</td>
<td>01:29:23</td>
<td>735</td>
<td>577,645</td>
<td><a href="http://207.137.168.46:80/z64/movies/Zelda64.qt">http://207.137.168.46:80/z64/movies/Zelda64.qt</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1126</td>
<td>03:47:34</td>
<td>953</td>
<td>574,572</td>
<td><a href="http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au">http://152.2.25.83:80/student/orqs/uncbands/songs/fight.au</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1501</td>
<td>01:21:61</td>
<td>681</td>
<td>566,168</td>
<td><a href="http://204.71.186.40:80/media/movies/wargasds8_mov">http://204.71.186.40:80/media/movies/wargasds8_mov</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>RealAudio</td>
<td>1208</td>
<td>05:05:05</td>
<td>776</td>
<td>552,198</td>
<td><a href="http://192.41.48.155:80/canrock.exe">http://192.41.48.155:80/canrock.exe</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1209</td>
<td>10:54:12</td>
<td>1671</td>
<td>524,459</td>
<td><a href="http://141.164.1.20:80/~ltin/Eva_img/Eva3.jpg">http://141.164.1.20:80/~ltin/Eva_img/Eva3.jpg</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1119</td>
<td>01:51:51</td>
<td>763</td>
<td>513,938</td>
<td><a href="http://152.2.25.83:80/student/orqs/uncbands/songs/tag.au">http://152.2.25.83:80/student/orqs/uncbands/songs/tag.au</a></td>
</tr>
<tr>
<td>11:00:00</td>
<td>HTTP</td>
<td>1120</td>
<td>02:07:03</td>
<td>696</td>
<td>505,354</td>
<td><a href="http://152.2.25.83:80/student/orqs/uncbands/songs/tag.au">http://152.2.25.83:80/student/orqs/uncbands/songs/tag.au</a></td>
</tr>
</tbody>
</table>

FIGURE 42: INTERNET DESTINATIONS—JANUARY 15, 1998
APPENDIX K
RELATED ALBERTA EDUCATION RESOURCES


NOTICE

REPRODUCTION BASIS

☒ This document is covered by a signed “Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a “Specific Document” Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either “Specific Document” or “Blanket”).