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ANALYSIS OF NETWORK TRAFFIC AND BANDWIDTH CAPACITY: LOAD BALANCING AND RIGHTSIZING OF WIDE AREA NETWORK LINKS

by

Kevin L. Trovini

September 1996

Thesis Advisor: Suresh Sridhar
Thesis Co-Advisor: Rex Buddenberg

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The purpose of this thesis is to provide a process model to assist organizations in analyzing their Wide Area Network communication lines. The Naval Medical Information Management Center (NMIMC), in Bethesda, Maryland, is used as the model site, due to its imminent deployment of World Wide Web (WWW) servers to Navy Medical Treatment Facilities (MTF's). To model the typical MTF, an analysis of the data traffic transmitted from the existing WAN links managed and monitored by NMIMC will be performed. These WAN links are critical for the delivery of health care related information transmitted between MTF's. The WAN links must be analyzed to ensure that adequate bandwidth is available to allow unobstructed traffic flow between destinations. The data traffic will be plotted to illustrate problematic conditions caused by high utilization rates. Corrective actions will be recommended that should help to reduce or eliminate the bottlenecks and increase network bandwidth, such as: load balancing, rightsizing of the WAN links, and increasing operational availability. The hypothesis is that the WWW servers should be installed after the WAN links are analyzed and either balanced or properly sized. The load balancing and rightsizing of the WAN links will ensure that adequate bandwidth is available for the proper and timely transmission and access of vital WWW server information.

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ANALYSIS OF NETWORK TRAFFIC AND BANDWIDTH CAPACITY: LOAD BALANCING AND RIGHTSIZING OF WIDE AREA NETWORK LINKS

Kevin L. Trovini
Lieutenant, United States Navy
B.S., Park College, 1989

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Author: ______________________
Kevin L. Trovini

Approved by: ______________________
Suresh Sridhar, Thesis Advisor

____
Rex Buddenberg, Thesis Co-Advisor

____
Reuben Harris, Chairman
Department of Systems Management

ABSTRACT

The purpose of this thesis is to provide a process model to assist organizations in analyzing their Wide Area Network communication lines. The Naval Medical Information Management Center (NMIMC), in Bethesda, Maryland, is used as the model site, due to its imminent deployment of World Wide Web (WWW) servers to Navy Medical Treatment Facilities (MTF's). To model the typical MTF, an analysis of the data traffic transmitted from the existing WAN links managed and monitored by NMIMC will be performed. These WAN links are critical for the delivery of health care related information transmitted between MTF's. The WAN links must be analyzed to ensure that adequate bandwidth is available to allow unobstructed traffic flow between destinations. The data traffic will be plotted to illustrate problematic conditions caused by high utilization rates. Corrective actions will be recommended that should help to reduce or eliminate the bottlenecks and increase network bandwidth, such as: load balancing, rightsizing of the WAN links, and increasing operational availability. The hypothesis is that the WWW servers should be installed after the WAN links are analyzed and either balanced or properly sized. The load balancing and rightsizing of the WAN links will ensure that adequate bandwidth is available for the proper and timely transmission and access of vital WWW server information.

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I. INTRODUCTION

A. PURPOSE

The purpose of this research is to provide a process model to assist organizations, whether military or civilian, in analyzing their Wide Area Network (WAN) communication links. The main goal of this study is to ensure that proper bandwidth requirements are firmly incorporated prior to implementing a new network server into an existing network.

The initial intention of this study was to assist the Naval Medical Information Management Center (NMIMC), located in Bethesda, Maryland, in developing implementation and deployment plans for their World Wide Web (WWW) servers. These servers are scheduled for deployment to Naval Medical Treatment Facilities (MTF), as directed by the Assistant Secretary of Defense, Health Affairs (ASD/HA). These directives are discussed in the background section below. However, upon further investigation, it became apparent that the main problem to be encountered with this initiative would be network data-traffic bottlenecks and how to identify, reduce, or eliminate them. The analysis of NMIMC's WAN links will model a typical Navy MTF.

Therefore, the focal point of this thesis is to analyze the primary WAN links emanating from NMIMC. The data traffic will be plotted to illustrate problematic scenarios caused by high utilization rates. Recommendations offered to correct those problems will include corrective actions that will help balance the network traffic loads, and methods of rightsizing the WAN links. Various telecommunications services currently available in today's marketplace will be also be addressed.

B. OBJECTIVES AND SCOPE

This thesis will focus on analyzing NMIMC's existing WAN links and the associated network data-traffic. The purpose of this analysis is to identify interesting trends, and to pinpoint distinct problems associated with the transmission of data. Specific issues such as the timing of transmission bursts and network traffic load will be researched. Some of these issues are greatly influenced by traffic congestion. The cause of the congestion, also known as a bottleneck, will be investigated. Certain problem resolutions will be presented to assist in reducing or eliminating these bottlenecks, and freeing up precious network bandwidth.

The hypothesis is that the WWW servers should be installed only after the WAN links are analyzed and properly sized. The rightsizing of the WAN links will ensure that adequate bandwidth is available for the proper and timely distribution and access of WWW server information.

C. BACKGROUND

1. Health Affairs Directives

Information management at naval MTF's is becoming increasingly important. To provide enhanced electronic information interchange within the Military Health Support System (MHSS), the Assistant Secretary of Defense for Health Affairs (ASD/HA) has initiated directives and guidelines for implementing a global information system utilizing the internet and the WWW. [Ref. 1]

In support of this initiative, HA has agreed to fund the implementation and operation of a HA Internet/Web server, including hardware, software, contractor support regarding deployment issues, first year maintenance, and first year connectivity (T-1 access to the internet). Funds will be transferred from HA to the three Services. Each Service then assumes the responsibility of funding the implementation and operation of Internet/Web servers to support the electronic information interchange and web home pages that will allow complete interoperability across Health Affairs, the Surgeons General, and MTF's. Life cycle management, as well as funding for continued maintenance and internet access for the out-years, will be performed and provided by NMIMC. [Ref. 2]

2. Requirements

Per HA directives, the requirements for implementing WWW servers to DoD agencies have been set [Ref. 1]. Each agency, or service, is responsible for their implementation and deployment plans. The Naval Bureau of Medicine and Surgery (BUMED) has set the requirements for the Navy's WWW Enhanced Electronic Information Interchange System, and has tasked NMIMC with the implementation and deployment plans [Ref. 2]. More detailed information surrounding this request may be found in Appendix A.

NMIMC was established to design, deploy, and support naval medical information management systems and telecommunications infrastructures. Therefore, the inherent nature of NMIMC makes it uniquely qualified for the assigned task of deploying the Navy's WWW servers.

Questions revolving around the current and target infrastructure design, load balancing, WAN connectivity, bandwidth requirements, deployment, training, support, and maintenance are still unresolved. The results of this research may assist in answering some of these questions and in formalizing the plans required to successfully deploy and implement this critical medical information requirement.

II. DATA COLLECTION AND CONVERSION

A. PROBLEM DEFINITION

1. NMIMC Site Visit

A briefing between the author and key management personnel of NMIMC took place in an effort to arrive at the true nature of the problem surrounding the deployment of the WWW servers in support of the HA initiatives. In-depth discussions over the course of several days revealed the urgent requirement of ensuring proper bandwidth for the transmission of healthcare related data. The discussion quickly evolved into a WAN link capacity planning meeting. Existing WAN link capacity charts were reviewed, and recommendations for analyzing the links out of NMIMC were made. [Ref. 3]

The discussion then turned to the issue of how to estimate the growth pattern of the network traffic due to the installation of the WWW servers. While several good ideas were proposed, the discussion eventually became a stalemate, as no accurate methods of forecasting and projecting the growth pattern of network traffic were readily known.

The nature of traffic growth due to the installation of WWW servers is extremely difficult to quantify and predict accurately without the proper equipment, resources, and time to properly justify the analysis. Since forecasting and predicting of both near and long-term growth of network traffic is difficult to determine, due to its various unknown variables, it is left as an exercise that must be further studied by NMIMC. The primary focus shifted to the existing network traffic, and how to analyze it and make recommendations for rightsizing the WAN links and balancing the loads prior to the deployment of the web servers.

2. Network Data-Traffic Review

To fully understand the peculiar characteristics of the data traffic in question, a review of the incoming and outgoing network traffic was conducted. Several network managers and technical engineers were pooled to perform an initial review of the network traffic. The following data set is an example of the information that was generated as a result of taking a snapshot of the network traffic at a random point in time from the router in the computer room at NMIMC [Ref. 3]. This data set, seen in Figure 2.1, represents just one of the five links that are being analyzed; it was our first look at the data that was being collected and monitored by the router. The line numbers are not part of the data set, but are included for ease in future referencing of the lines of code.

```
1.  Fddi 0 is up, line protocol is up
2.    Hardware is cBus Fddi, address is aa00.0400.1c04 (bia 0000.0c18.1e38)
3.    Description: FDDI Base Backbone
4.    Internet address is 131.158.100.8, subnet mask is 255.255.255.0
5.    MTU 4470 bytes, BW 100000 Kbit, DLY 100 usec, rely 255/255, load 1/255
6.    Encapsulation SNAP, loopback not set, keepalive not set
7.    ARP type: SNAP, ARP Timeout 4:00:00
8.    Phy-A state is active, neighbor is B, cmt signal bits 008/20C, status ILS
9.    Phy-B state is active, neighbor is A, cmt signal bits 20C/008, status ILS
10.   CFM is thru A, token rotation 5000 usec, ring operational 1w0d
11.   Upstream neighbor 0000.0c18.1e3b, downstream neighbor aa00.0400.1604
12.   Last input 0:00:00, output 0:00:00, output hang never
13.   Output queue 0/40, 0 drops; input queue 0/75, 0 drops
14.   Five minute input rate 66000 bits/sec, 34 packets/sec
15.   Five minute output rate 54000 bits/sec, 44 packets/sec
16.      661479 packets input, 169499079 bytes, 0 no buffer
17.      Received 5722 broadcasts, 0 runts, 0 giants
18.      34 input errors, 0 CRC, 34 frame, 0 overrun, 0 ignored, 0 abort
19.      903492 packets output, 137036303 bytes, 0 underruns
20.      0 output errors, 0 collisions, 0 interface resets, 0 restarts
21.      0 transitions, 0 traces, 0 claims, 0 beacon
```

Figure 2.1. Initial Data Set. From Ref.[3].

B. CAPTURING NETWORK DATA-TRAFFIC

1. Shell Programming

Once the data traffic under review was fully understood, the next step was to figure out how to extract the relevant data so that it could be analyzed. The data that we were interested in is shown in lines 1, 5, 14, and 15 of the previous data set. Since the data generated by the router snapshot was discrete and repetitive, it was decided that shell programming in Unix would allow us a mechanism by which the relevant data could be captured.

The "shell" is the systems command interpreter. It reads each command you enter at your terminal and performs the operation that you called for. The shell is just an ordinary program that can be called by a Unix command. [Ref. 4]

A mutual decision was made between the author and the network engineer to generate shell scripts that would take a sample of the data at 30 minute intervals, 24 hours a day, seven days a week, for at least two months. Obviously, in statistical analysis, the more samples (observations) taken, the more precise the calculations and inferences will be. Nevertheless, the observations for this study were intentionally limited to this time sequence in order to have sufficient time to analyze the data and complete this study. This random sampling should, however, generate a fairly accurate picture of the utilization rates of NMIMC's five WAN links, and should show any potentially problematic peak utilization rates.

The scripts were written in a Unix Bourne shell, version 3.2.2, and run on an AT&T 3B2 server. They are described in short detail in Appendix B.

2. Revised Data Set

To clarify once again, we defined the data that we were interested in. The scripts pulled this data from the original data set that was processed by the Cisco router. This revised data set, which is shown in Figure 2.2, presents the relevant data in a more meaningful format. The five data links are now represented in this new data set, which at this time becomes our primary file of interest. As indicated earlier, the numbers on the extreme left side are not actually part of the data set. They are provided so that it will be easy to refer to specific lines of the data set in explaining the meaning of the data in the following section.

```
1.  ==========================================================
2.  Fri May 17 16:31:00 EDT 1996
3.  ==========================================================
4.  Serial 1 is up, line protocol is up
5.  MTU 1500 bytes, BW 56 Kbit, DLY 20000 usec, rely 255/255, load 13/255
6.  Five minute input rate 2000 bits/sec, 3 packets/sec
7.  Five minute output rate 3000 bits/sec, 3 packets/sec
8.  Serial 4 is up, line protocol is up
9.  MTU 1500 bytes, BW 56 Kbit, DLY 20000 usec, rely 255/255, load 150/255
10. Five minute input rate 4000 bits/sec, 22 packets/sec
11. Five minute output rate 33000 bits/sec, 22 packets/sec
12. Serial 5 is up, line protocol is up
13. MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec, rely 255/255, load 1/255
14. Five minute input rate 19000 bits/sec, 14 packets/sec
15. Five minute output rate 5000 bits/sec, 6 packets/sec
16. Serial 7 is up, line protocol is up
17. MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec, rely 255/255, load 1/255
18. Five minute input rate 0 bits/sec, 1 packets/sec
19. Five minute output rate 2000 bits/sec, 2 packets/sec
20. Fddi 0 is up, line protocol is up
21. MTU 4470 bytes, BW 100000 Kbit, DLY 100 usec, rely 255/255, load 1/255
22. Five minute input rate 85000 bits/sec, 75 packets/sec
23. Five minute output rate 83000 bits/sec, 81 packets/sec
```

Figure 2.2. Revised Data Set. From Ref. [3].

This revised data set is comprised of 23 lines of raw ASCII code that has been extracted from the original data set that was taken from the Cisco 7000 router [Ref. 5]. This data set represents data-traffic statistics for the five WAN links coming out of NMIMC. The data for each link is described in four lines of code. Since the code is identical for each link, only lines 4-7 will be explained here.

On line 4, "Serial 1" is the identifier of the interface (link). Line 5 shows us MTU (maximum transmission units) in bytes, the BW (bandwidth) of the connection, the DLY (delay) for the interface, the RELY (reliability) of the link, and the load. Lines 6 and 7 show the five minute input and output rates, respectively, in both bits/second and packets/second.

The sample data set shown above depicts the Serial 1 interface with a 100% reliability rate and a load of 13/255, or approximately 5 percent. The rely and the load are displayed as a percentage in which the denominator is 255. The load counter operates on an 8-bit value, thus the significance of the 255 denominator (11111111 in binary equals 255). The load is computed by dividing the higher of the input or output rates by the BW. For example, the Serial 1 link has a BW of 56Kbit, an input rate of 2Kbits/second, and an output rate of 3Kbits/second. If you divide 3Kbits (the output rate) by 56Kbits, the result is 5.357%, which is displayed as a load of 13/255. All results are rounded down prior to displaying the load values.

The termination points of the five links out of NMIMC are shown in Table 2.1. Figure 2.3 illustrates those links coming out of NMIMC, and their associated termination locations.

INTERFACE (Link)	TERMINATION POINT (LOCATION)
Serial 1	Naval Medical Logistics Command, Fort Detrick, MD
Serial 4	NAVNET
Serial 5	Bureau of Medicine and Surgery (TPC/IP Traffic)
Serial 7	Bureau of Medicine and Surgery (DEC LAT Traffic)
FDDI 0	Fiber ring on Bethesda campus; connects Medical Center and Uniformed Services University of Health Sciences routers to the internet

Table 2.1. Termination Points of NMIMC's WAN Links.

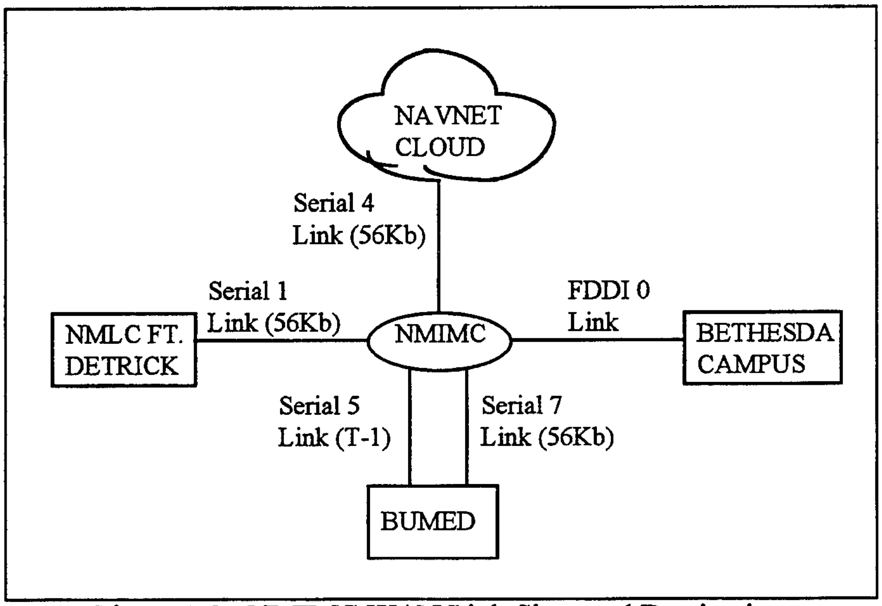

Figure 2.3. NMIMC WAN Link Sizes and Destinations.

3. Data Collection and Distribution

The raw ASCII data that was captured from the Cisco router was immediately dumped into a separate ASCII text file, which was shown in the cron entry in Appendix B as /usr/dsc3cjc/trovini. Once enough data was acquired, it was transferred by the technical engineer at NMIMC to the author at the Naval Postgraduate School (NPS) by attaching the /usr/dsc3cjc/trovini data file to an email message.

There was no specific cut-off time for the collection and transmission of the data; a random stopping point was chosen by the network technician who generated the script. Emails were generally received by the author from NMIMC once a week, typically at the end of the business week. It was feared that if the script was allowed to run and capture and dump the data for longer than a week at a time, the /user/dsc3cjc/trovini data file would be too large to transmit properly without incurring an occasional "time-out" error.[1]

Once the data was transmitted, the /user/dsc3cjc/trovini file was emptied, and new data was captured for the next transmission. This iterative process was continued by the NMIMC network technician until the author deemed that enough data was captured to perform an accurate analysis of the existing traffic loads of the five WAN links.

[1] This is somewhat of an insignificant factor, but is included as background information on the data collection process. This scheme may be of some value for those organizations that are contemplating performing their own network traffic analysis, and need to collect their data from a remote source.

C. ANALYSIS OF NETWORK DATA-TRAFFIC

1. Network Traffic File Generation

Approximately 10 weeks worth of network traffic data was collected from NMIMC. Each transmission, or data dump, that was received from NMIMC was converted from the email message format into a separate file in the author's home directory on the Unix server at NPS. The email header and signature data was stripped out of the message, and only the raw traffic data was saved as a new ASCII text file. The server platform used throughout this study consisted of a Sun workstation running Sun O.S. version 4.1.3.

2. Initial Review of Captured Network Traffic

The initial review of the pure traffic data consisted of a quick skimming of the load values as seen in lines 5, 9, 13, 17, and 21 of the revised data set. A portion of the first data file received was printed in order to expedite this first review; this hardcopy printout was used to highlight specific data. By using this printout, it was easier to identify the load values that were principally needed to study. The individual WAN link load values were reviewed specifically for extremely high utilization rates. It is these high utilization rates that are the main concern of this study and the foundation of this research. This basic review showed some peak load values, as well as those links that appeared to have the highest utilization rates. The next step was to determine how to extract that data from the revised data set.

3. SAS Script Generation

a. Traffic Load File

Once the preliminary review was completed, plans were made to extract the dates, the time of the observations, the link names, and the load values from the individual data files so that a statistical analyses could be performed on the data using the Statistical Analysis Software (SAS) application. That script, called traffic.sas, is presented in Appendix C [Ref. 6]. It computes the frequency distributions for the five links, the overall minimum and maximum utilization rates of the five links, and generates a breakdown chart showing the minimum and maximum utilization rates by hour. After the SAS scripts were written and tested on a small traffic data file, the individual traffic data files were concatenated into one file, and the overall SAS script was executed. Although this SAS script does not contain many lines of code, it is very powerful in what it accomplishes. A brief discussion of this SAS script is presented below to explain how the data was extracted from the raw data traffic.

b. Traffic.sas Script Breakdown

The idea behind the SAS script is very easy to understand. All the data found on the lines of code that are of interest from the revised data set must first be read into the SAS file. Once that has been done, all the data that is not of value is "dropped", leaving only the relevant data to be acted upon.

To read in the data, the individual words, or "chunks" of data on each line, which are separated by a space, must first be labeled. These individual chunks are identified for data set lines #2, #5, #9, #13, #17, and #21. For example, line 2 of the data set, as seen below, displays the date and time information of a particular observation.

#2. Fri May 17 16:31:00 EDT 1996

The data chunks that need to be read in are day, month, date, and time of day, as shown in the following traffic.sas script segment.

```
# 2
day $
month $
date $
tod $
```

Lines #5, #9, #13, #17, and #21 are fairly redundant, and all contain 13 chunks of data. All chunks are dropped except the last one, which defines the load value for that particular WAN link. As an example, the data chunks for line #5 are identified in table 2.2, where s1 is the SAS variable name assigned to the data chunk "MTU", s2 is the SAS variable name assigned to data chunk "1500", and so forth and so on.

SAS Variable	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	load1
Line #5 Data Chunk	MTU	1500	bytes,	BW	56	Kbit,	DLY	20000	usec,	rely	255/255,	load	13/255

Table 2.2. SAS Variable Name Definitions.

All the values are dropped except the load1 value, which is the actual load rate, or utilization rate, for the serial1 link. The other links loads are captured in the same way. If you look back to the beginning of the traffic.sas script, you will see where all the irrelevant data has been dropped. The only data that are being captured now are the specific dates, times, and load values for the five WAN links. Once the relevant data was filtered out from the raw data, the traffic loads were then ready to import into a spreadsheet application for plotting.

III. DATA ANALYSIS AND REPRESENTATION

A. VISUAL GRAPHICS

Once the exact data to be analyzed had been captured, a method of illustrating the data in an easy to review format was needed. Since SAS does not adequately do justice to the graphing and plotting of data sets, the author chose Microsoft Word and Microsoft Excel to plot the graphs of traffic loads. This chosen format was thought to display the data in a manner that presents the clearest mental and visual image of the data traffic.

B. A COMPARISON OF MEAN VS. MAXIMUM LOADS

1. Mean Load Values

The SAS traffic.sas program generated a chart that shows the mean load rates, the standard deviations, and the minimum and maximum load rates of the five WAN links under review. This chart is presented as Figure 3.1. These rate values were computed from data accumulated over the period of 23 April - 27 June, 1996. The details of the computations are described in Appendix D.

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	2359	3.9325404	10.6395563	0.3921569	98.0392157
XLOAD4	2359	34.9420243	23.3059572	0.3921569	100.0000000
XLOAD5	2359	0.7138286	1.1494338	0.3921569	28.6274510
XLOAD7	2359	0.8830595	5.1087385	0.3921569	98.0392157
XLOADF	2359	0.3921569	0	0.3921569	0.3921569

Figure 3.1. Load Values. From Ref. [6].

There was approximately 60 days worth of data generated from the router scripts. Some of the data was lost due to a router upgrade on 23 May, when the Cisco AGS+ router was upgraded to a Cisco 7000 series router. This lost data is not expected to make much of an impact, if any, on the outcome of this study, as the values were all averaged over this observation period. There were 2,359 total observations performed on each of the five links. The observations are shown in Figure 3.1 under the variable "N". The load variables, the mean load values, and the maximum load values were the data of interest, and are duplicated in Table 3.1.

Link Name	Variable Name	Line Size	Mean	Maximum
Serial1	XLOAD1	56 Kbps	3.93	98.0
Serial4	XLOAD4	56 Kbps	34.94	100
Serial5	XLOAD5	T1 (1.544 Mbps)	0.71	28.6
Serial7	XLOAD7	56 Kbps	0.88	98.0
FDDI0	XLOADF	100 Mbps	0.39	0.39

Table 3.1. Mean and Maximum Load Rates. After Ref. [6].

Table 3.1 shows the mean load values and the maximum load values for each of the five WAN links being reviewed. The data contained in this table was used to generate the graphs of the mean and maximum load rates, which will hereafter be referred to as utilization rates. Figure 3.2 compares the mean utilization rates of the five links.

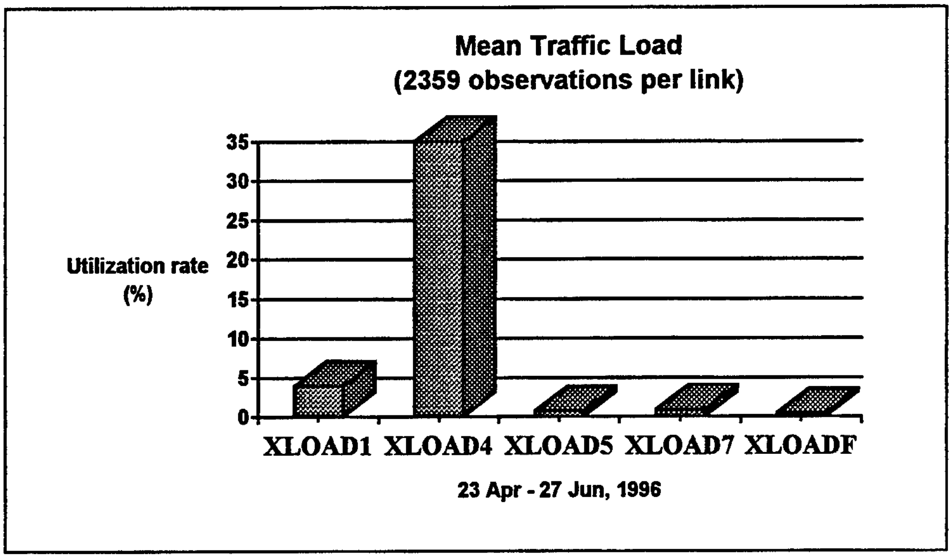

Figure 3.2. Mean Utilization Rates.

This graphs clearly shows that the utilization rates of all 5 links are well below what the industry considers the maximum ceiling of 80%. [Ref. 7] If we compare the rates against the capacity of the links, we can begin our interpretation of whether the links appear to be rightsized or not. Notice the high mean rate for XLOAD4. According to Table 3.1, XLOAD4 is identified as a 56Kbps line. The initial indication is that this link appears to be properly sized; however, the maximum load rates should also be examined to get a better indication of the variable traffic utilization rates.

Table 3.1 also matches the variable names, such as XLOAD1, to the link names, such as Serial1. Since the variable names and link names are used interchangeably through out this study, this table will help to reduce some of the confusion surrounding the naming conventions. The SAS scripts refer to the links as XLOAD1, XLOAD4, XLOAD5, XLOAD7, and XLOADF, while the Unix scripts and router data sets refer to the links as Serial1, Serial4, Serial5, Serial7, and FDDI0.

2. Maximum Load Values

To fully appreciate the value of the accumulated traffic data, you need to look beyond the mean rates to the maximum rates. The peak loads shown in Figure 3.3 are of great concern, because at those high rates data transmissions not only tend to slow down due to latency issues, but data packets may be lost once saturation of the line is reached if the buffers overflow. Generally, TCP will recovers this loss, which will be transparent to the user. What the user may notice is a slowing in responsiveness. Three of the five WAN links - Serial1, Serial4, and Serial7 - are shown as exceeding the threshold level of 80%. These links should undergo further evaluation to determine the cause of the high rates. The type of data being transmitted and the time of day the transmissions occur should be looked at to uncover the reason for such a high rate. Plans to either balance the loads or rightsize the WAN links to a higher bandwidth should be implemented. Methods of load balancing and rightsizing of WAN links will be addressed in Chapter IV.

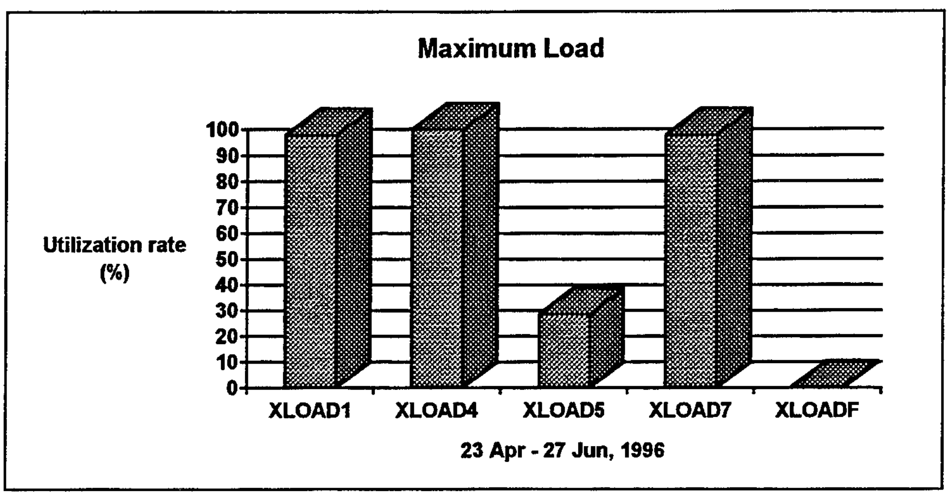

Figure 3.3. Maximum Utilization Rates.

C. GRAPHS AND CHARTS OF UTILIZATION RATES

1. Hourly Utilization Rates

a. Mean Load Graphs

The SAS script traffic.sas generated hourly breakdown charts, showing the mean loads for each WAN link. Figures 3.4 through 3.8 illustrate the hourly trends of the five links. The data used to generate these graphs are provided in Appendix D.

Figure 3.4 shows that the daily traffic for the Serial1 link increases around the hour of 0600, where it remains fairly stable until it begins a sharp drop between the hours of 1500-1700. This would seem to indicate that the traffic load corresponds to normal business hours. All the traffic flowing over the five NMIMC links is IP traffic, such as Email and FTP [Ref. 8]. The load rates seen in Figure 3.4 indicate that users are either checking their mail or transmitting files via FTP when they first arrive to work in the morning, again around lunch time, and finally, just before they go home in the afternoon. Although there are three distinct peaks seen for XLOAD1, the low utilization rates, which vary between .58 and 9.42 percent, give a good indication that this link is not stressed and is properly sized. It is worth repeating that the values represented by these graphs are listed in Appendix D.

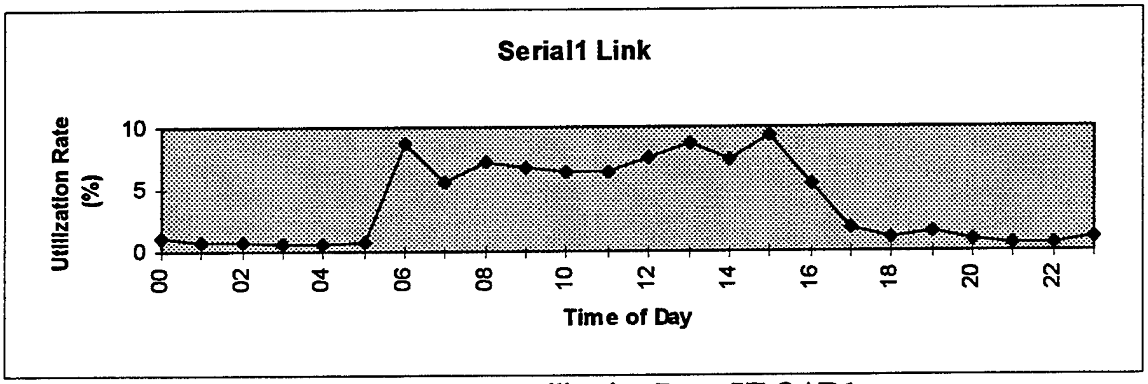

Figure 3.4. Mean Utilization Rate, XLOAD1.

Figure 3.5 shows that the traffic pattern for the Serial4 link is similar to that of the Serial1 link. The traffic takes a significant jump at 0600, remains fairly stable throughout the day, and begins to decline steadily at 1400. The noticeable peaks at 0600 and 1400 also follow a similar pattern noticed for the Serial1 link. The traffic load for this link varies between 18.3 and 48.9 percent. This is a significant increase from the rate seen for the Serial1 link. This link should be looked at more closely to determine if it is in fact properly sized. We will be able to determine a more accurate indication when the maximum load rates are presented in the next section.

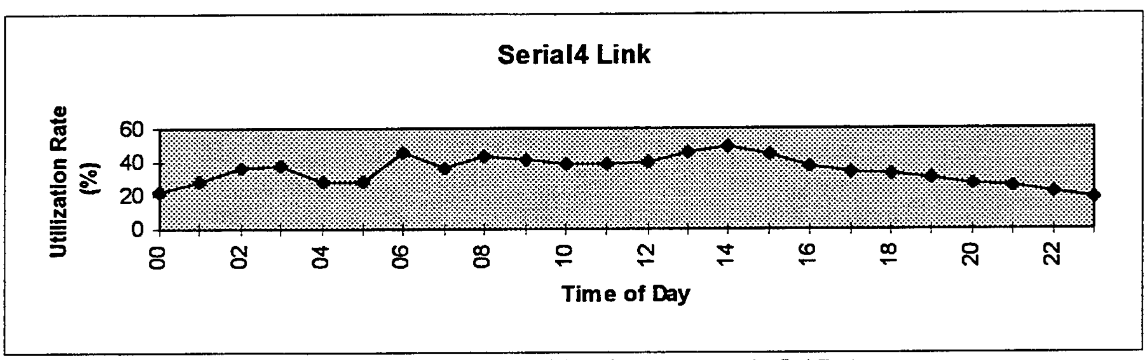

Figure 3.5. Mean Utilization Rate, XLOAD4.

Figure 3.6 shows a trend that is similar in nature to the previous graphs. The traffic begins to increase around 0700, and begins to drop around 1400. Two distinct peaks occur at 0900 and 1400. The traffic load for this link varies between .39 and 1.54 percent. At these low utilization rates the slight increases for this link would not be noticeable.

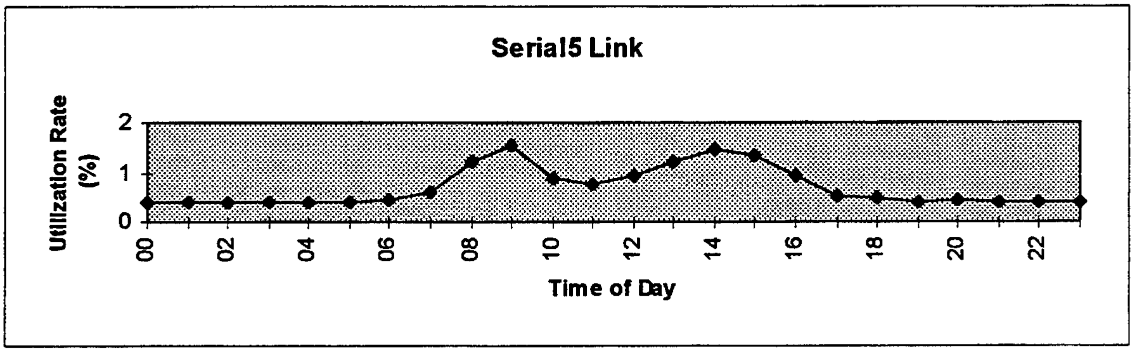

Figure 3.6. Mean Utilization Rate, XLOAD5.

Figure 3.7 shows an increase in utilization beginning at 0700, and tailing off just after 1200. The peaks for this link occur at 1000 and 1200. The remaining times of the day show a very stable rate. The traffic load for this link varies between .39 and 2.83 percent. Again, at this low utilization rate, the increased usage at the peak times would not be noticed.

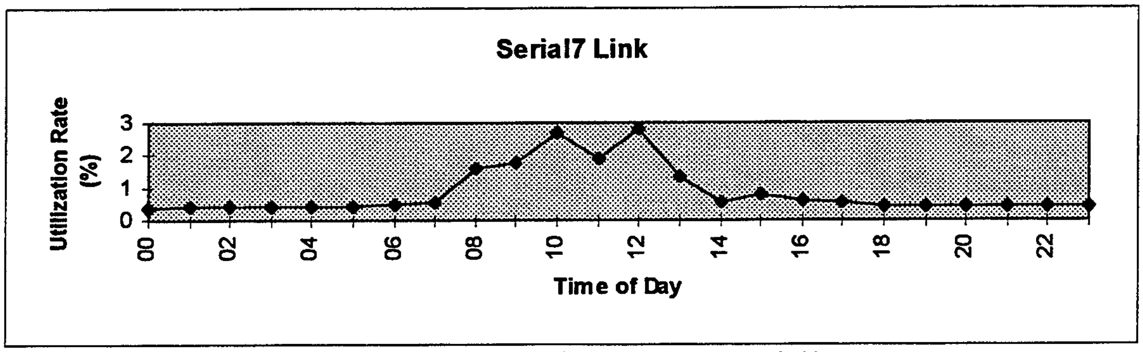

Figure 3.7. Mean Utilization Rate, XLOAD7.

The utilization rate shown in Figure 3.8 shows a steady rate throughout the day. This may seem like an error at first glance, however, this steady rate is due to the fact that the FDDI0 link is a dual fiber optic link, running at 100Mbps capacity. At a rate of 0.4%, this means that no data transmissions were above 400Kbps. As discussed in Chapter II, the loads are computed by dividing the higher of the input or output rates by a divisor of 255. With the bandwidth set at 100 Mbps, and the input or output rate set at less than or equal to 400 Kbps, the load would be seen as a steady value of 1/255, or .4%, since this is the smallest value that can be represented. The FDDI0 link provides the highest bandwidth of all the links at NMIMC. Refer back to Table 3.1 for a better indication of the orders of magnitude differences in the capacities of the links. This graph appears to indicate that there is a significant excess of bandwidth. However, the link is actually a dual fiber-optic cable, and the one time cost of installing this fiber is significantly less than the monthly recurring cost of a 56Kbps or higher communication line. Additionally, this link acts as the backbone for the campus network in Bethesda, MD. Had this been a T1 link, then the cost of providing this excess capacity would surely have to be justified. A chart showing some of the costs that NMIMC pays for their links is provided in Chapter IV. Therefore, a discussion of these costs will be deferred until then.

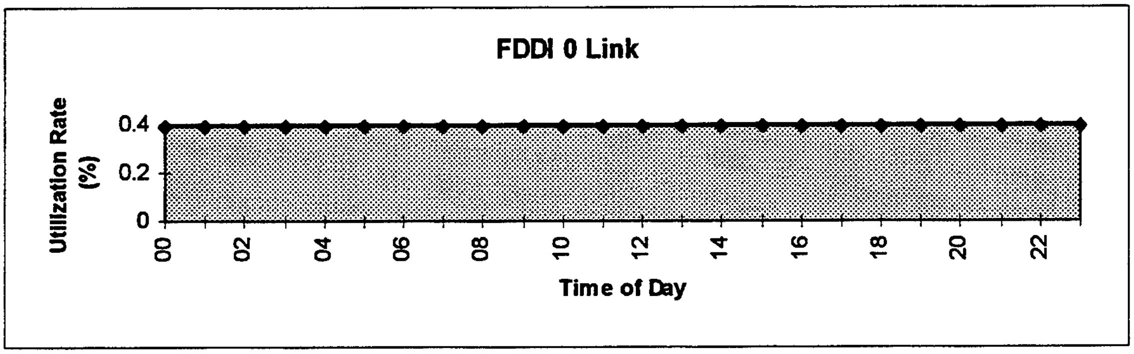

Figure 3.8. Mean Utilization Rate, XLOADF.

b. Maximum Load Graphs

Just as in the case for the mean loads discussed in the previous section, the SAS script traffic.sas generated hourly breakdown charts which show the maximum loads for each of the five NMIMC WAN links. Figures 3.9 through 3.15 illustrate the hourly trends of these links. The data used to generate these graphs are provided in Appendix D along with the mean load data. Figure 3.9 shows peak loads for the Serial1 link at 0600, 1200, and 1500, with utilization rates of 98%, 94.5%, and 94.5% respectively. Since these peaks all exceed the 80% threshold, the Serial1 link needs to be looked at to see if load balancing can alleviate its high utilization rate.

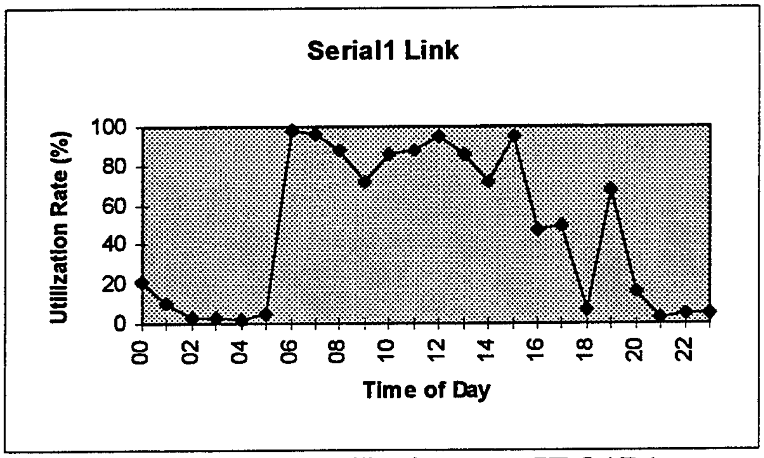

Figure 3.9. Peak Utilization Rate, XLOAD1.

Figure 3.10 indicates that this link peaks well above the 80% threshold during almost every hour of the day. In fact, it falls below the 80% threshold only once at 2300 with a utilization rate of 76.4%. Since this link is NMIMC's only connection to the internet, the statistics indicate that it should be rightsized as soon as possible.

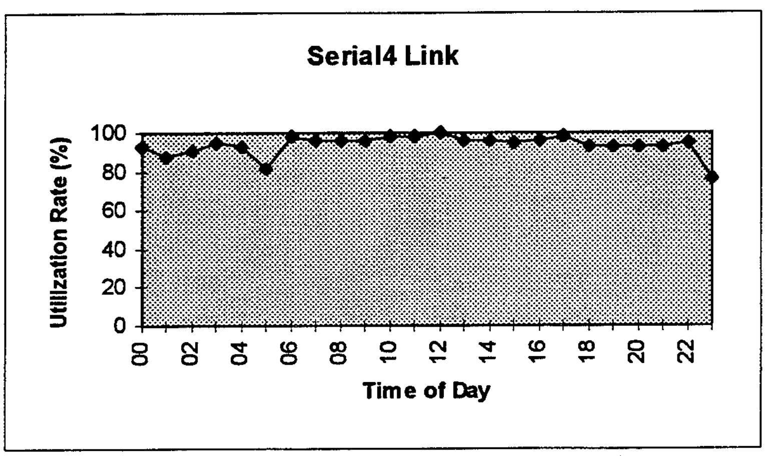

Figure 3.10. Peak Utilization Rate, XLOAD4.

Figure 3.11 shows a very pronounced peak at 0900. However, since this peak load has a utilization rate of just 28.6%, it appears that this link is properly sized, and no further action needs to be taken. However, the spike in the busy hour traffic may be smoothed by moving some of that traffic to non-peak times.

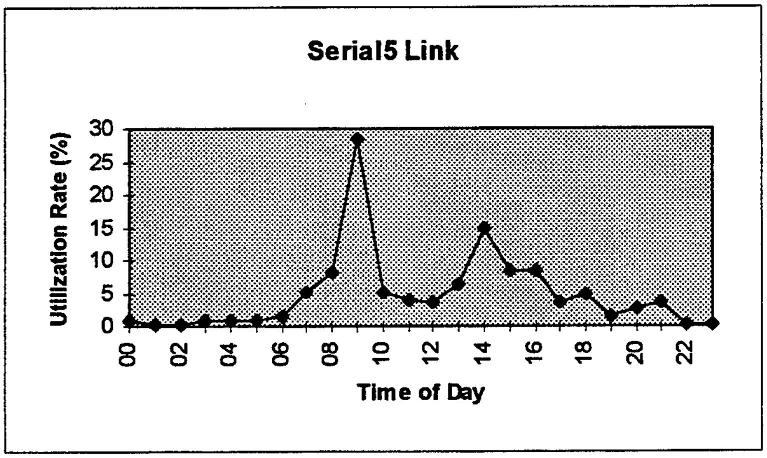

Figure 3.11. Peak Utilization Rate, XLOAD5.

The utilization rates seen in Figure 3.12 indicate an above threshold level between the hours of 0800 and 1200. The utilization rates vary during this period from 83.9% to 98.0%. Load balancing may be able to smooth these peaks, and should be viewed as a possible corrective action.

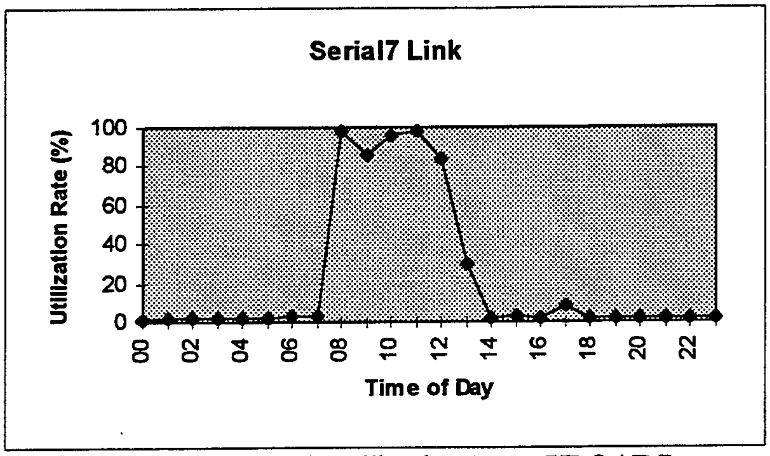

Figure 3.12. Peak Utilization Rate, XLOAD7.

The utilization rates of the FDDI0 link, shown in Figure 3.13, show a steady rate of .39%. This is the same as the mean rate shown in Figure 3.8. It seems that this fiber link has a tremendous amount of excess capacity to satisfy both near term and long term traffic increases.

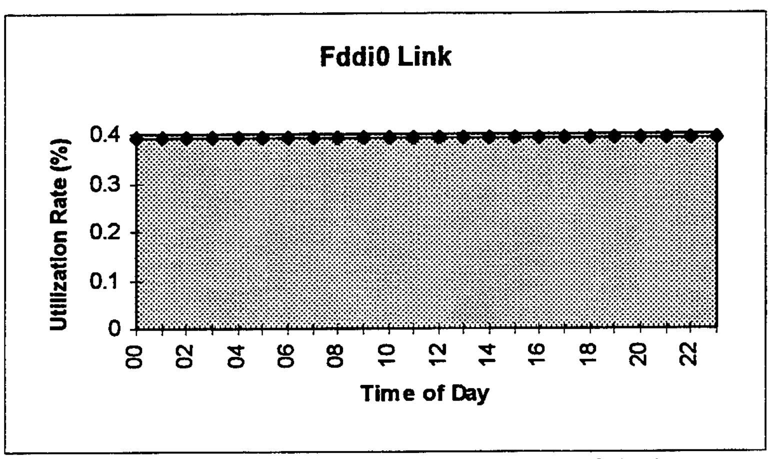

Figure 3.13. Peak Utilization Rate, XLOADF.

2. Daily Utilization Rates

a. Mean Load Graphs

Figures 3.14 through 3.20 show that the only link that spikes throughout the week is XLOAD4. The highest spike occurs on Wednesdays, as seen in Figure 3.16. The utilization rate at that point is 39.2. The mean loads of the other links are extremely low, an indication that those WAN links are properly sized.

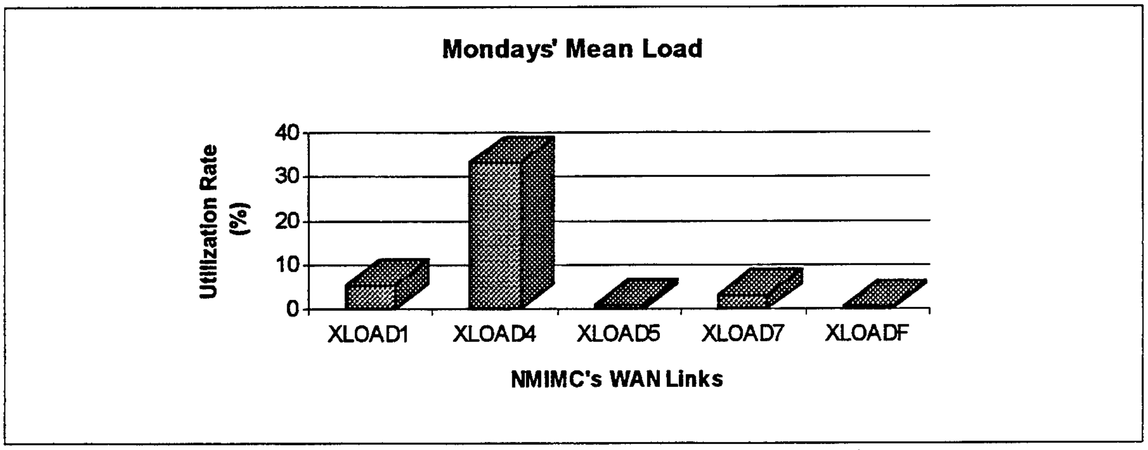

Figure 3.14. Average Load Per Link (Monday).

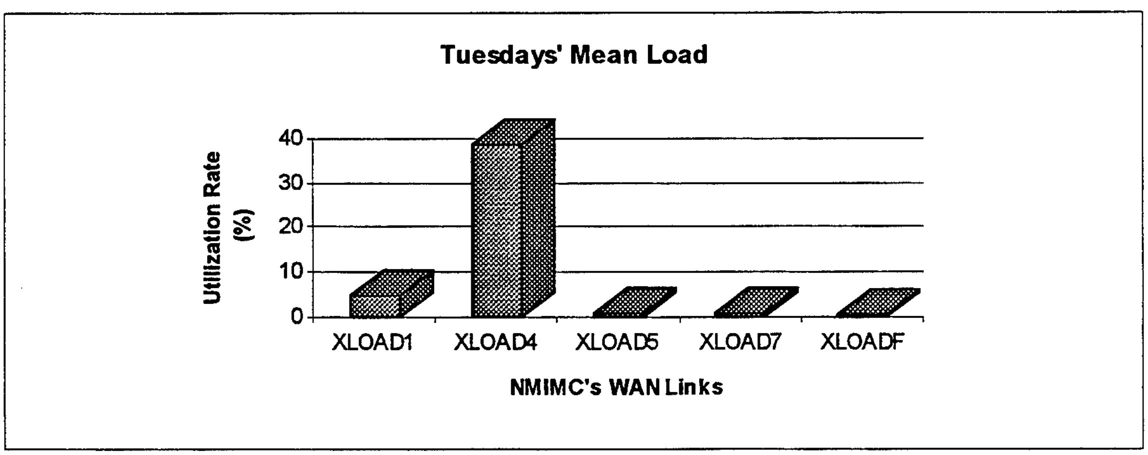

Figure 3.15. Average Load Per Link (Tuesday).

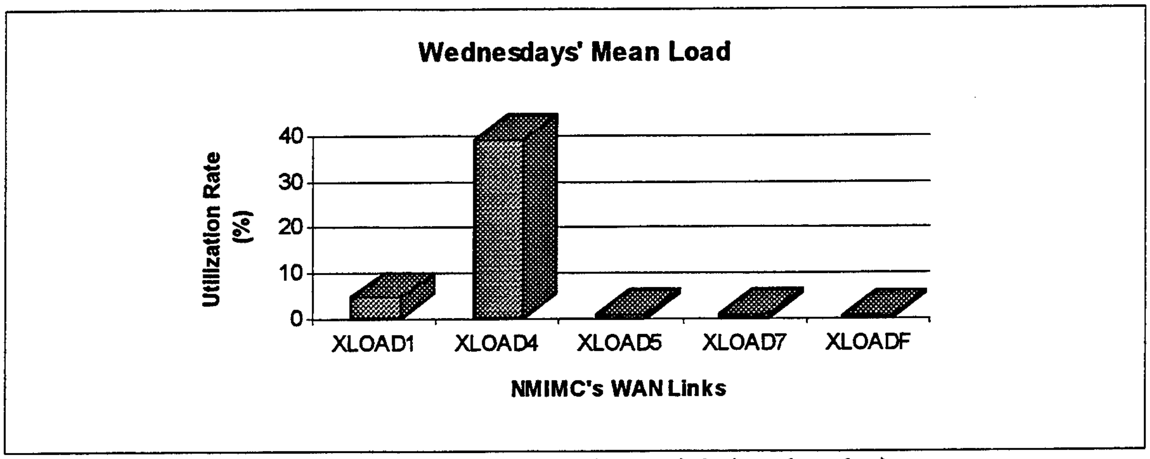

Figure 3.16. Average Load Per Link (Wednesday).

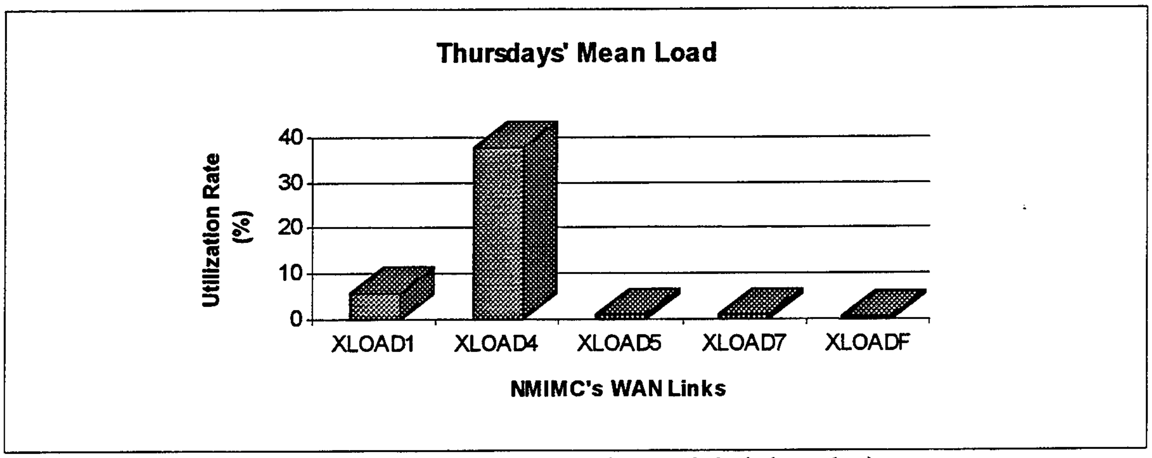

Figure 3.17. Average Load Per Link (Thursday).

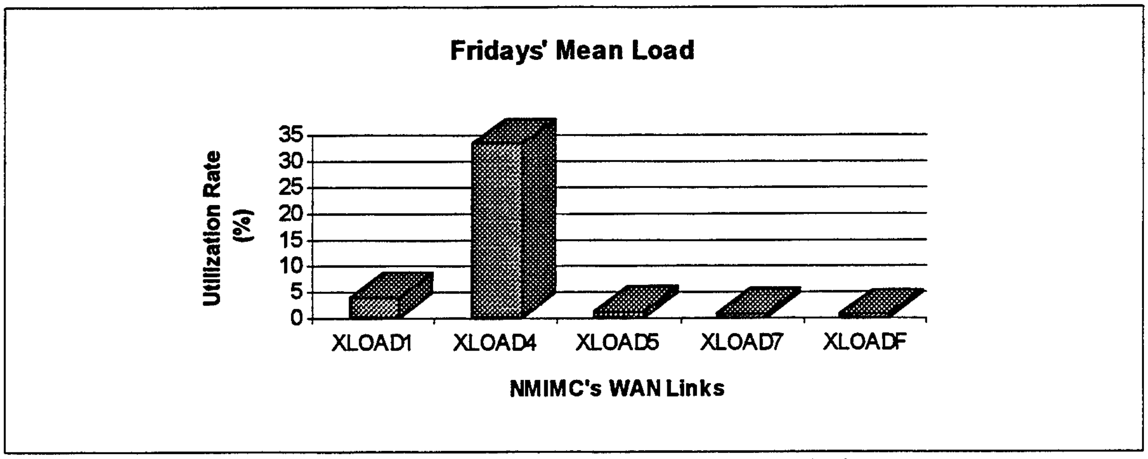

Figure 3.18. Average Load Per Link (Friday).

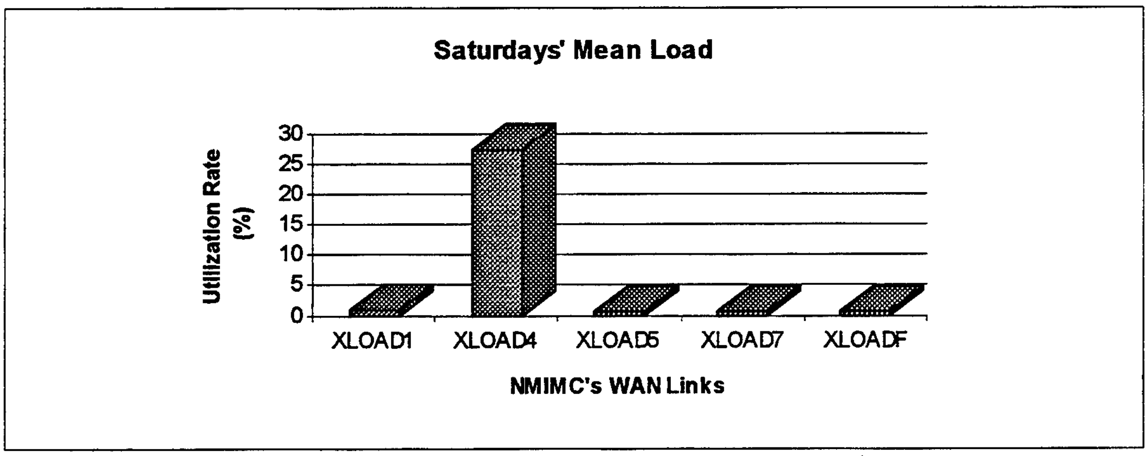

Figure 3.19. Average Load Per Link (Saturday).

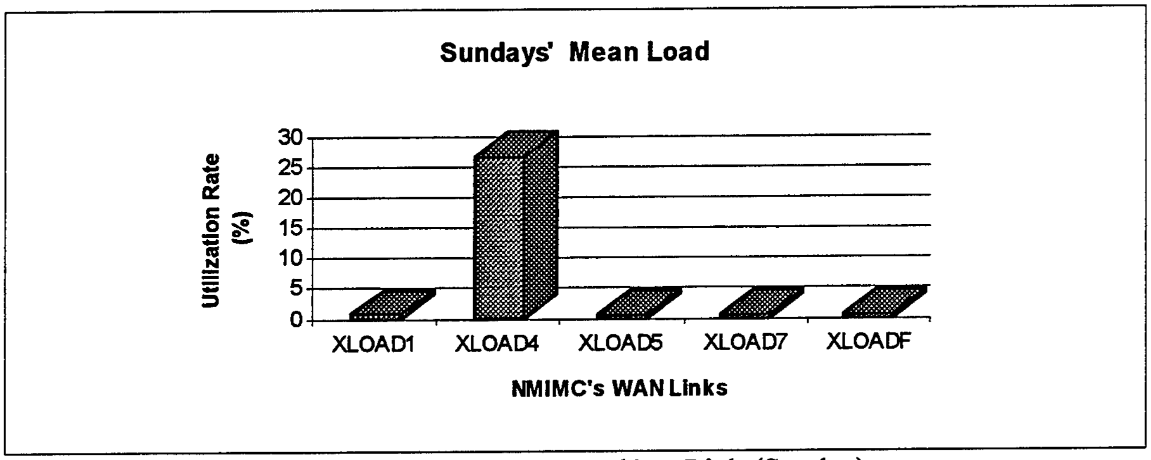

Figure 3.20. Average Load Per Link (Sunday).

b. Maximum Load Graphs

The maximum load utilization rates shown in Figures 3.21 through 3.27 provide a different indication than the mean load rates. Figure 3.21 shows three links, XLOAD1, XLOAD4, and XLOAD7 as having utilization rates that exceed the 80% threshold. Their load rates are 83.9%, 98%, and 98% respectively.

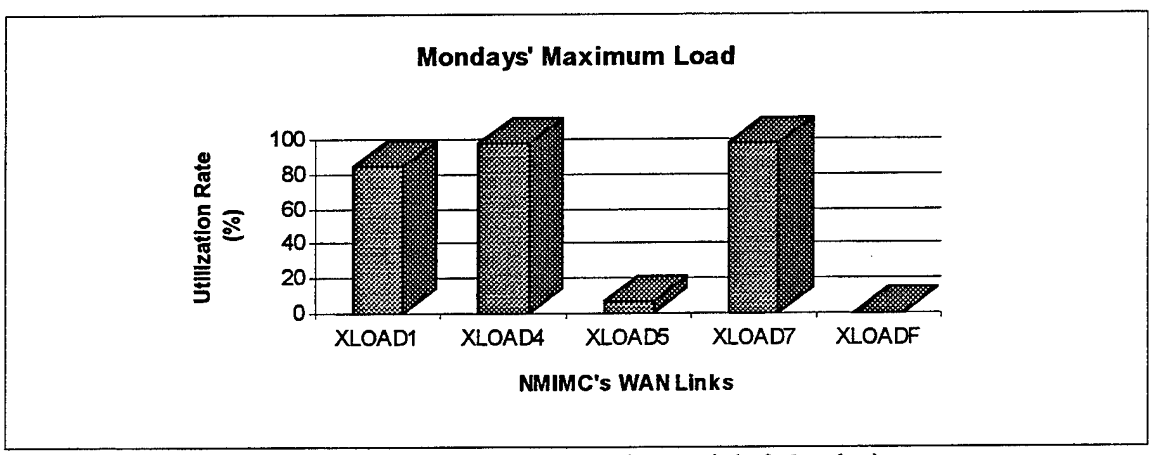

Figure 3.21. Maximum Load Per Link (Monday).

Figure 3.22 is similar to the previous graph, except XLOAD7 drops from 98% to 56.8%. The utilization rates for XLOAD1 and XLOAD4 remain extremely high at 92.5% and 98% respectively.

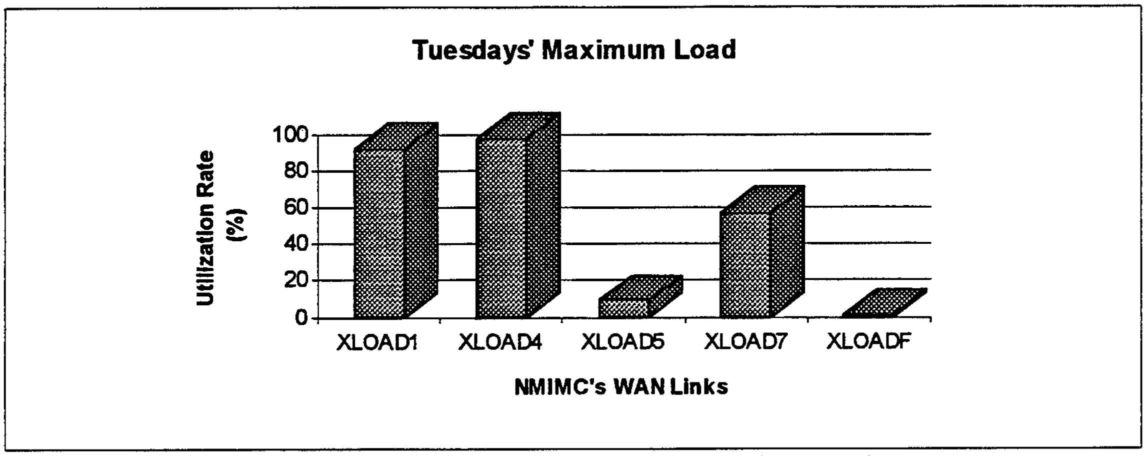

Figure 3.22. Maximum Load Per Link (Tuesday).

The utilization rates in Figures 3.23 through 3.25 are nearly identical, with XLOAD1 and XLOAD4 again nearly maxing out with utilization rates that fluctuate between 94.5% and 100%.

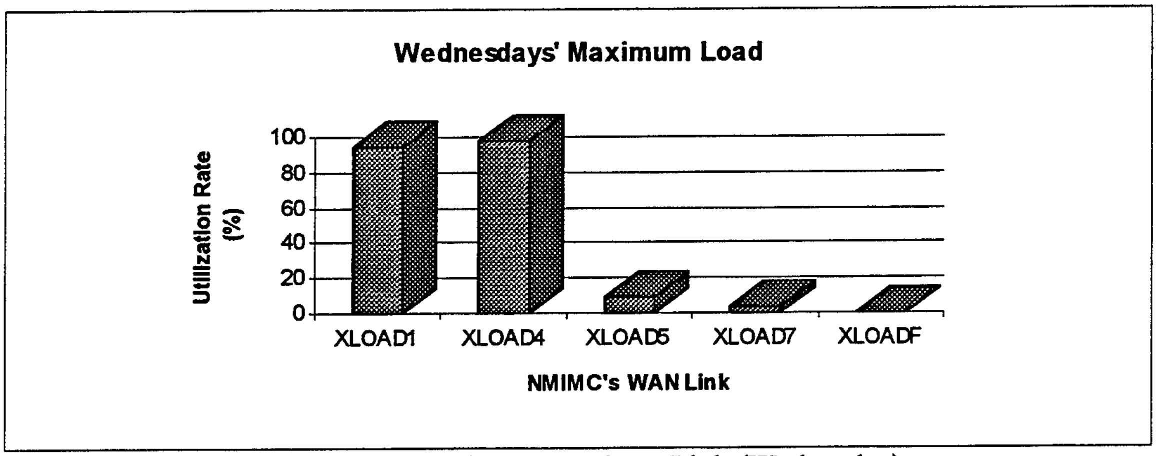

Figure 3.23. Maximum Load Per Link (Wednesday).

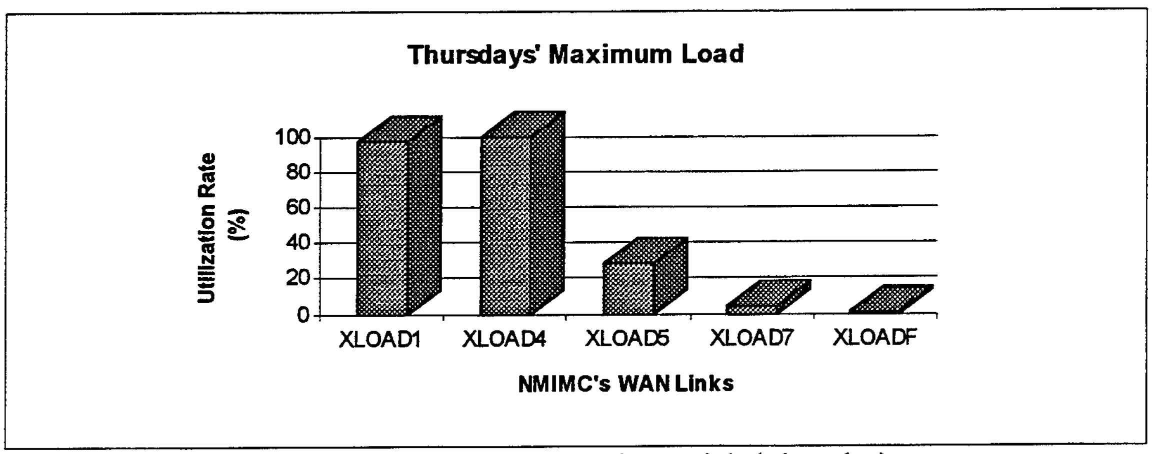

Figure 3.24. Maximum Load Per Link (Thursday).

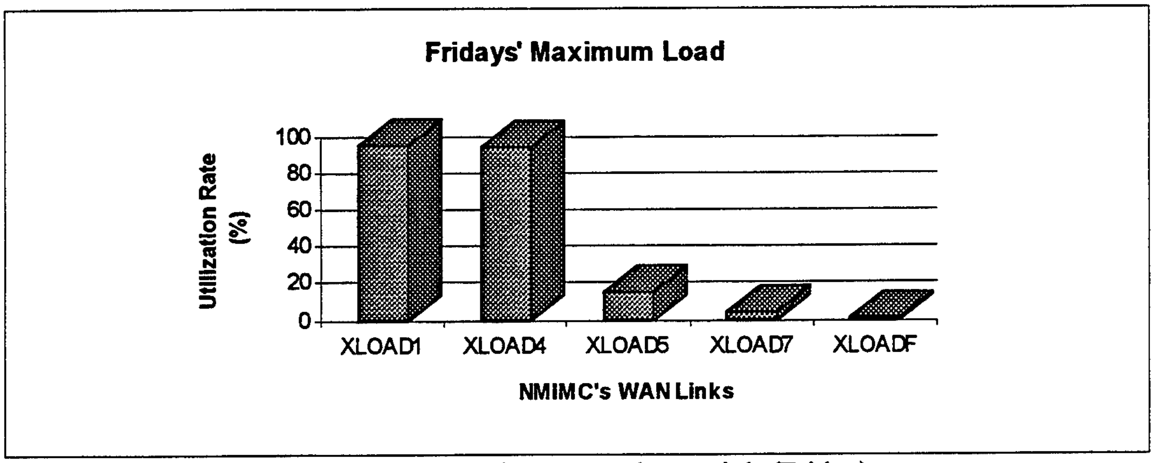

Figure 3.25. Maximum Load Per Link (Friday).

Figures 3.26 and 3.27 show the XLOAD1 rates dropping below 20%, while XLOAD4 remains peaked at 92.5% and 94.5% respectively.

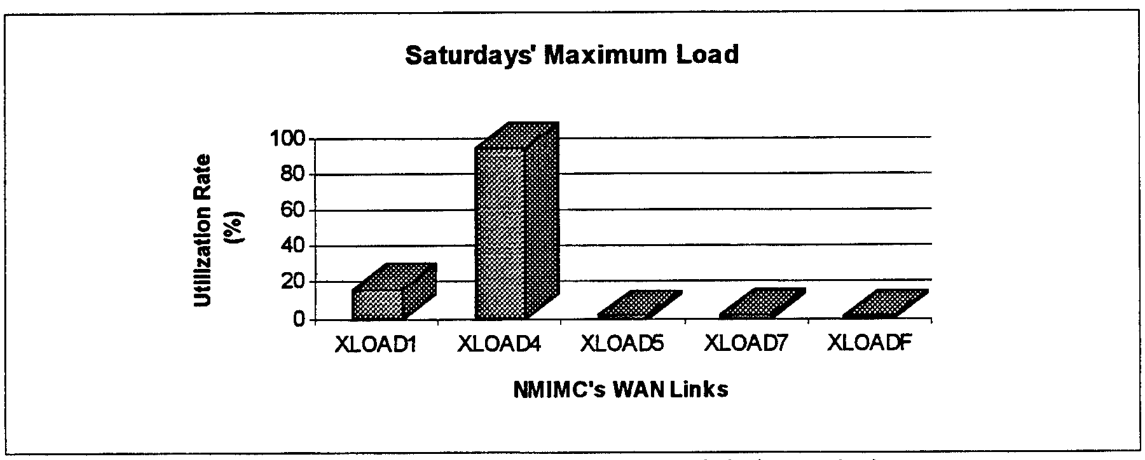

Figure 3.26. Maximum Load Per Link (Saturday).

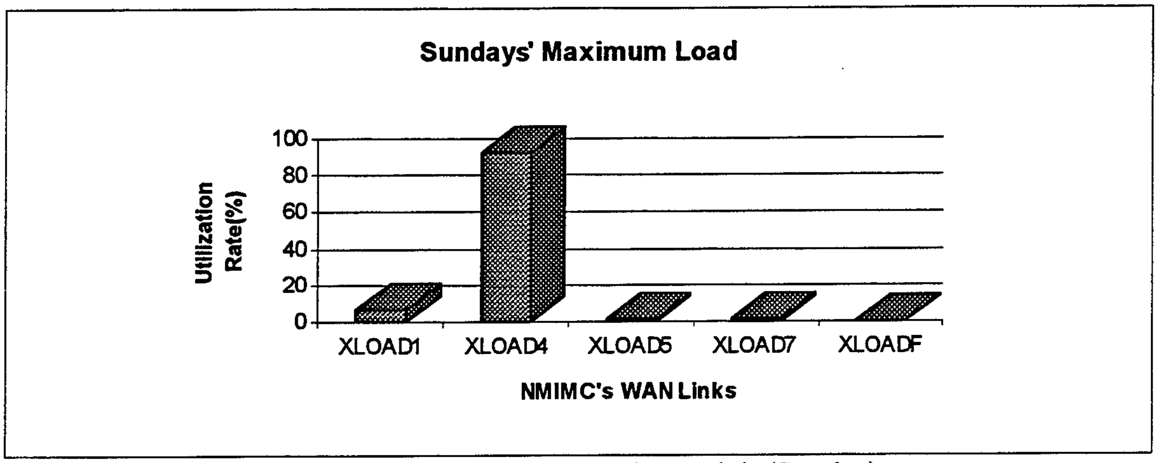

Figure 3.27. Maximum Load Per Link (Sunday).

It is interesting to note that XLOAD4 was the only link that nearly attained the maximum value with spikes up to 100%. These graphs indicate the need to thoroughly review links XLOAD1, XLOAD4, and XLOAD7. Plans to either balance the loads on those links or increase the size of the links need to be implemented immediately. These methodologies will be discussed briefly in Chapter IV.

D. BENEFITS OF TREND ANALYSIS

1. Needs Assessment

The primary significance of analyzing the utilization rates is to help you assess your need to adjust your bandwidth requirements. The average rates, as illustrated in Figure 3.2, do not provide an accurate measurement of the usage of the various WAN links. You must also identify the peak loads, as identified in Figure 3.3, and let the data tell you if you are properly positioned to provide the support necessary to handle your organizations traffic loads. If not, corrective actions must be taken to rightsize those links.

2. Down Time and Scheduled Maintenance

An added benefit of performing an analysis of the hourly and daily utilization rates is the identification of low utilization periods. These lower usage periods are of significant value because they pinpoint times that can be used to the organization's advantage. From an IT manager's and system administrator's point of view, these sags in utilization rates are an ideal time for scheduling down-time required to support periodic maintenance of systems, including mainframes, routers, and other peripheral equipment.

3. Reliability and Availability

The data sets that were provided by the router, shown in Chapter II, show the reliability of the network links, as well as the traffic loads. Analyzing the statistics from the network router can help you identify any degradation in the reliability of your network links. Less than perfect reliability rates impact the availability of your links, which in turn causes delays in data transmissions, and significantly decreases the support that you are able to offer your customers. Chapter VI discusses the meaning and the importance of operational availability, so details will be deferred until then.

IV. LOAD BALANCING AND RIGHTSIZING OF WAN LINKS

A. PROBLEM ISOLATION AND RESOLUTION

This chapter focuses on identifying, isolating, and solving problems that impede throughput performance in networks. In general, performance slowdowns are considered lower-priority problems than reachability issues. However, poorly performing internetworks can degrade organizational productivity and often can effectively halt operations of network applications if communications degenerates enough. Performance problems can reveal themselves in many ways. Slow host response, dropped connections, latency, and high error counts all suggest that network performance is not optimal. Unfortunately, the actual sources of performance problems are often difficult to detect. [Ref. 9]

This chapter introduces an example problem-solving scenario that illustrates the process of problem isolation and resolution. Since certain common themes are present in most connectivity problems, this chapter is provided in an effort to illustrate the use of troubleshooting tools and techniques to identify those common themes. [Ref. 9].

B. METHODS OF LOAD BALANCING

1. Redundant Links

Remote bridges and routers often utilize load balancing, which is a uniform distribution of data over parallel links. These links can be similar or dissimilar. One link may have a transmission rate of 56 Kbps, while the other may be transmitting at 128 Kbps.

Generally, the network administrator will define the two links as a single logical link. The benefit of redundant links is that in the event the primary link goes down, the secondary link becomes active and allows the continued transmission of data packets throughout the network. [Ref. 10]

2. Improving Poor Performance Over A TCP/IP WAN

a. Environment Description

This section is concerned with performance in a TCP/IP internetwork featuring parallel serial links that join two geographically separated locations via IP routers[1]. This analysis focuses on isolating problems and then considering options for relieving congestion.

Figure 4.1 shows the layout of the routers of the internetwork discussed in this example. The assumption is that the traffic to the main campus consists of FTP, Telnet, and E-mail[2]. For discussion purposes, we shall say that the users at Remote Site-A are complaining about poor host response and slow performance when connecting to hosts at the main Campus. In addition, during certain times of the day, large files are being transferred over the serial network. At these times, the traffic becomes especially slow, but does not stop.

The first thing to do is to identify all likely possible causes. The second step is to eliminate each one. The following problems are the most likely candidates for interconnection failure:

---

[1] Any IP router will do; NMIMC uses Cisco routers .
[2] Another assumption is that Unix workstations are being used at the remote site.

- Overloaded server
- Bad Ethernet or serial line
- Congestion:
    1. at routers
    2. at servers
    3. on serial lines
    4. due to inappropriate WAN technology

In an effort to keep this chapter concise, only a brief review of the highlights of these problem isolation processes is given. More detailed information regarding the process of problem isolation can be found by visiting various vendors' home pages[3].

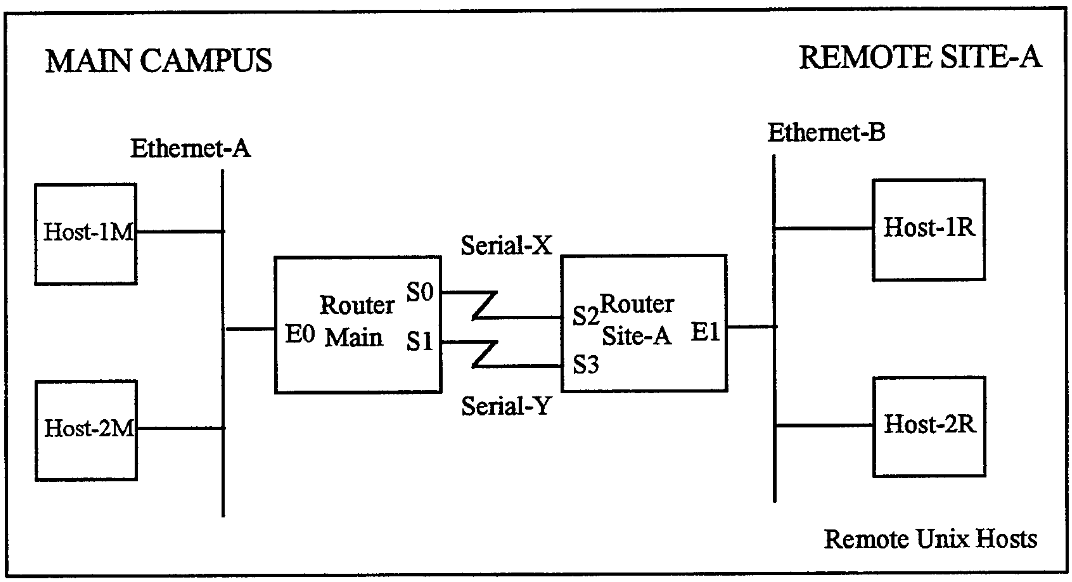

Figure 4.1. Dual 56 Kbps Serial Link TCP/IP Internet. After Ref. [10].

[3] Cisco's home page can be found at URL http://www.cisco.com. The user can sign on as a guest, then go to the first page after the home page and select the hypertext link to Univer CD-ROM. An extensive index of Performance Problem Scenarios and associated problem isolation processes can be found there.

b. Problem Isolation

The first thing to do is to determine the condition of the serial line. A preliminary check can be performed by using the "show interfaces" command. The user should also check to see if input errors, output drops, or interface resets are high, as indicated in Figure 4.2, lines 8, 13, and 15. These conditions would indicate that the Serial-O line is overutilized. If the router reports that "Serial-0 is up, line protocol is up", you can assume that the serial line is functional, as well as the central office switches, intervening CSU/DSU, etc. The user should now perform a "ping" test to isolate the traffic bottleneck. This test should identify excessive packet drops, server failures , and time-out errors. Be sure to ping various nodes in the path, as seen in Figure 4.1, beginning with the router closest to the remote hosts, looking for the point at which drops start to occur. If those tests indicate no problems, ping between the routers. If these tests all pass, and you determine that the problem is indeed one of congestion due to bandwidth overutilization, you must then decide whether it is more effective to add bandwidth or to make an adjustment in the router configuration. [Ref. 9]

If system administrators receive load values of about 50 percent, high input errors or output drops, they may consider implementing priority queuing to force Telnet to be given a higher precedence over other packet types. This helps ensure reasonable connection service to users, even during periods when file transfers are taking place. It is important to note that one reason why Telnet traffic can be bumped from the buffer queues is the tendency of the larger FTP packet types to collect in the router's buffers. When FTP traffic is high, the smaller Telnet packets are squeezed out of the input or output queues, resulting in retransmissions, session time-outs, and generally slower connection performance. By using priority queuing, marginal cases can be relieved. [Ref. 9]

```
1.  Serial 0  is up, line protocol is up
2.  Hardware is MCI Serial
3.  Internet address is 131.158.100.8, subnet mask is 255.255.255.0
4.  MTU 1500 bytes, BW 56 Kbit, DLY 20000 usec, rely 255/255, load 1/255
5.  Encapsulation HDLC, loopback not set, keepalive  set
6.  Last input 0:00:00, output 0:00:00, output hang never
7   Last clearing of "show interface" counters never
8.  Output queue 0/40, 78253 drops; input queue 0/75, 0 drops
9.  Five minute input rate 44000 bits/sec, 58 packets/sec
10. Five minute output rate 41000 bits/sec, 49 packets/sec
11.    4481625 packets input, 681913058 bytes, 19 no buffer
12.    Received 117015 broadcasts, 0 runts, 0 giants
13.    1145 input errors, 160 CRC, 581 frame, 0 overrun, 0 ignored, 0 abort
14.    5003523 packets output, 2819930198 bytes, 0 underruns
15.    0 output errors, 0 collisions, 8631 interface resets,
16.    15 carrier transitions
```

Figure 4.2. Display Output of Show Interfaces Command. From Ref. [9].

If you are seeing load values close to 90 percent, as well as input errors and output drops, priority queuing is not likely to do any good. With consistently high congestion, you are better off adding new serial links, or increasing the size of your existing links. [Ref. 9]

In summary, the following problem resolution topics were discussed as being potential resolutions to performance problems in TCP/IP internetworks:

- Isolating problem nodes and eliminating potential problems using extended ping tests.
- Determining when to tweak your configuration with priority queuing and when to add bandwidth
- Specifying priory queuing to force the router to give a specific TCP/IP socket a higher priority than other protocols

C. RIGHTSIZING THE WAN LINKS

1. Data-Driven Decision Management

Chapter III discussed the traffic flows of the WAN links under review. By continually analyzing their organizations WAN links, administrators will be in better position to rightsize their links before bottlenecks cause excessive delays and causes their system to crash. Organizations should promote a data-driven decision management methodology, which stresses the use of historical data to assist managers in making strategic decisions regarding the networking needs of their customers/users.

The graphs illustrated in chapter III show the need to increase the size of several links. Table 4.1 shows the increase in bandwidth, and the associated recurring and non-recurring costs (NRC), proposed by NMIMC for several CONUS commands currently linked to the DISN NIPRNET. Of these, the increase in bandwidth associated with Naval Hospitals Great Lakes, Groton, Bremerton, and Pensacola are important. These four sites are scheduled to receive WWW servers in the near future. Are the proposed increases in bandwidth sufficient to satisfy the future load requirement placed on those communication lines by the increased traffic from WWW activity? It appears that they are, but the unknown variable in this assessment is the future traffic growth.

The crux of this research has focused on analyzing the existing traffic loads of the WAN links at NMIMC. By analyzing today's traffic loads, we can recommend appropriate sized lines to satisfy our current requirements. The missing link, however, is the future traffic growth placed on those links after the WWW servers are installed. By analyzing today's needs and projecting future requirements, activities can then make recommendations for rightsizing their links accordingly.

#	Site Name	Current BW	Current Cost	New BW	New Cost	Increase	NRC Charge
1	NAVHOSP Bremerton	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
2	NAVHOSP Camp Pendleton	56K	$1,875.00		$8,635.00	$6,760.00	$5,000.00
3	NMC San Diego	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
4	NAVHOSP Jacksonville	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
5	NAVHOSP Camp Lejeune	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
6	NMC Portsmouth	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
7	NAVHOSP Pax River	0	-	256K	$4,024.00	$4,024.00	$2,500.00
8	NNMC Bethesda	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
9	NAVHOSP Groton	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00
10	NAVHOSP Great Lakes	56K	$1,875.00	T-1	$8,635.00	$6,760.00	$5,000.00

Table 4.1. DISN NIPRNET Bandwidth Increases and Monthly Costs. From Ref. [11].

2. Cost vs. Performance Trade-Off

Before deciding to change the size of their communications lines, information managers need to evaluate their current traffic flows and let that data drive their decision as to what size link is the correct size for the organization. Additionally, managers need to check their budgets to see if they can afford the new link. The bottom line is that if they don't install the correct sized links, the organization will not be operating as effectively or efficiently as it could be. Lost data due to incorrectly sized communication lines is not an economically acceptable practice. Organizations will lose their competitive advantage if their data does not flow in a timely fashion.

Likewise, it is not acceptable for an organization to waste funds on installing a link that has excess capacity that will not be used for a year or two. To assist in making the right decision, a cost benefit analysis should be performed. This analysis should balance the funds available for communication lines against the right sized line to accomplish the mission. If you have the funds in your budget, it would be better to get a little extra capacity to ensure that the data will flow when the traffic loads spike. In reality, there is no such thing as "too much capacity". If you can afford it, put in a bigger pipe, but be careful not to install a big pipe just for sake of having one.

Table 4.2 shows the costs associated with various sized lines as provided by DISN, including the monthly recurring fees as well as the one-time installation costs. You will notice that the costs almost double from one size to the next. From this table it should be quite clear that the importance of rightsizing your organizations WAN links can result in a significant cost avoidance if done properly.

Rate	Monthly Recurring Costs CONUS	Monthly Recurring Costs EUROPE	Monthly Recurring Costs PACIFIC	Non Recurring Costs
Ethernet	$3,836.00	$5,385.00	$7,308.00	$2,500.00
9.6 Kb	649.00	884.00	1,103.00	2,500.00
19.2 Kb	1,066.00	1,386.00	1,813.00	2,500.00
56/64 Kb	1,875.00	2,437.00	3,187.00	2,500.00
128 Kb	2,747.00	4,120.00	5,768.00	2,500.00
256 Kb	4,024.00	6,035.00	8,450.00	2,500.00
512 Kb	5,895.00	8,842.00	12,379.00	2,500.00
1.544 Mb (T-1)	8,635.00	N/A	N/A	5,000.00
2.048 Mb (OCONUS)	N/A	12,954.00	12,954.00	5,000.00

Table 4.2. 1996 Cost for DISN Service. From Ref. [11].

V. HEALTH CARE TRENDS AND THE NECESSITY FOR GREATER BANDWIDTH

A. TRENDS IN HEALTH CARE COMPUTING

1. Information Systems Priorities

The most important Information Systems (IS) Priorities for health care organizations are upgrading their IT infrastructures and integrating systems in a multivendor environment. Re-engineering to a patient-centered computing environment is also receiving priority attention from health care organizations. Figure 5.1 shows the breakdown of the IS priorities. The ratio between network and end systems was not available. The survey base was more heavily tilted toward the civilian sector, rather than the military, but applies to both nonetheless. [Ref. 12]

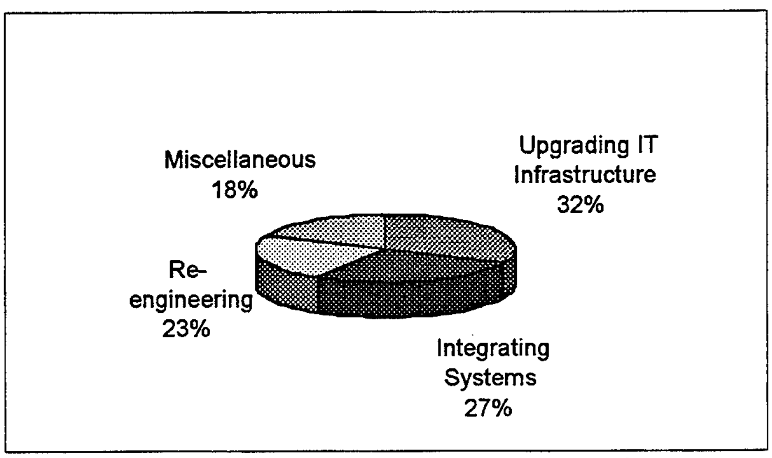

Figure 5.1. Greatest IS Priorities. From Ref. [12].

Reflecting the larger trend in health care delivery, computer technology is distancing itself beyond the boundaries of the traditional hospitals environment. The two largest departmental automation priorities for the upcoming year are physicians' offices and outpatient clinics, far outpacing traditional inpatient settings such as critical care, OR, and Med/Surgery. [Ref. 12]

In the outpatient setting, shown in Figure 5.2, the greatest advantage of IT is access to current patient information across the enterprise, essentially taking the care to the patients, rather than vice versa. Other advantages cited are: automating workflow; better financial management of offices; and better management of non-clinical patient tasks.

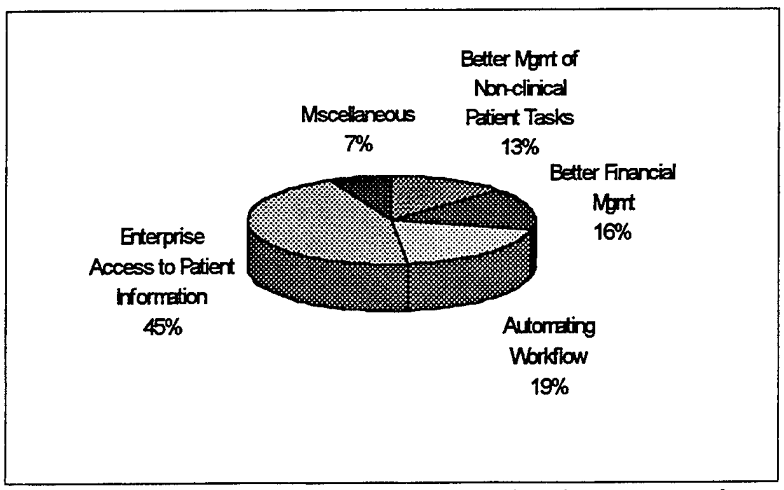

Figure 5.2. The Greatest Advantage of IT in an Outpatient Setting. From Ref. [12].

2. The Internet and the World Wide Web in Health Care

The revolution in cyberspace has reached health care. In a recent survey of trends in health care computing, more than 1,200 respondents provided their answers to questions concerning the use of the Internet, the use of telemedicine, WWW home pages, and future uses of the Internet.

Figure 5.3 shows the telemedicine commitment or those organizations surveyed. The chart shows that 76 percent of the organizations are either currently using this technology, or are actively investigating the use of it.

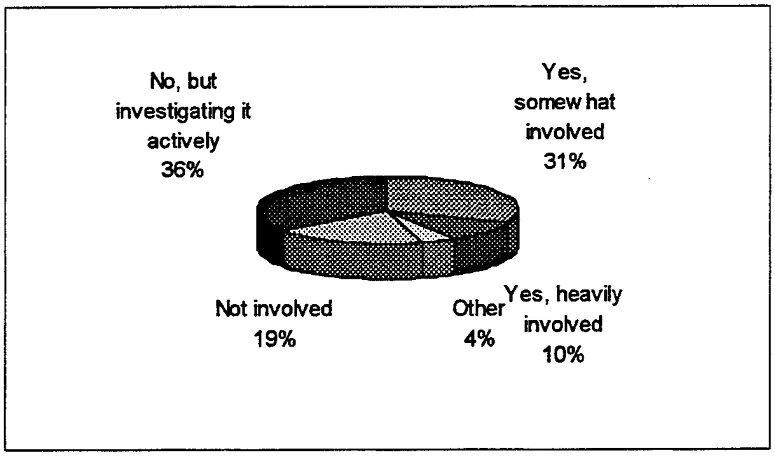

Figure 5.3. Telemedicine Commitment. From Ref. [12].

Those organizations that stated that they were either heavily involved or somewhat involved with telemedicine were asked, 'How many network-based consultations has your organization conducted in the past year"? Those results are illustrated in Figure 5.4. It is interesting to note that 52 percent of those organizations conducted 200 or more telemedicine consultations per year.

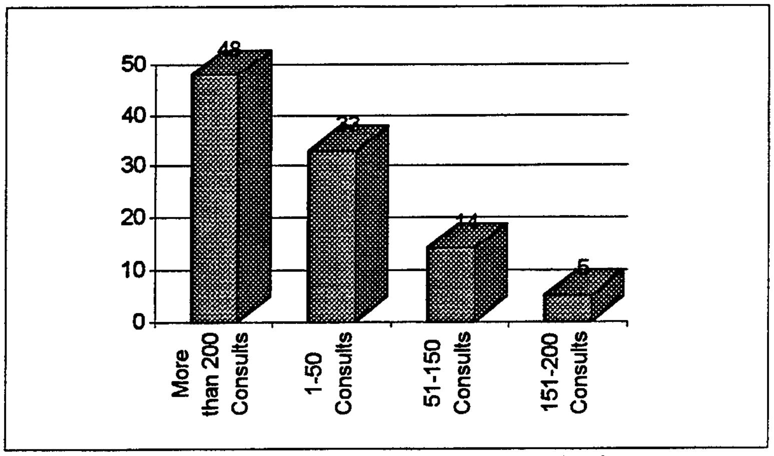

Figure 5.4. Network-based Consultations Conducted in Past Year. From Ref. [12].

Continuing with the telemedicine technology, the using organizations were asked to select all the applications for which their organization was currently using or considering using from a preselected list. Those results are illustrated in Figure 5.5.

Figure 5.6 shows the results of the question, 'How is your organization currently using the Internet'? The numbers add up to more than 100 percent, because they were asked to choose all that apply. Only 19 percent of those surveyed said that their organization was not currently using the internet. This indicates the growing number of organizations who are getting connected to the internet in order to maintain their competitive advantage in their profession.

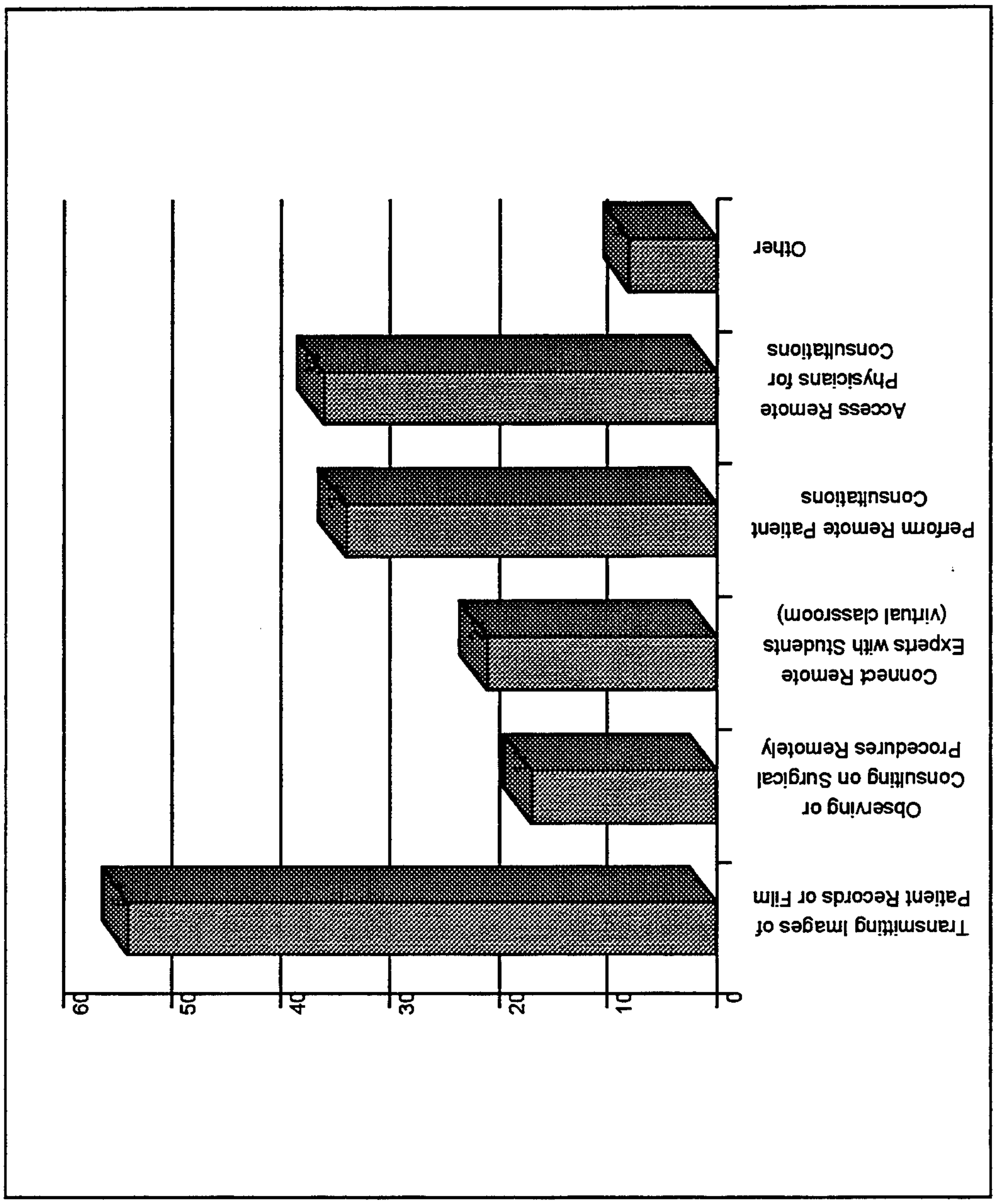

Figure 5.5. Telemedicine Applications. From Ref. [12].

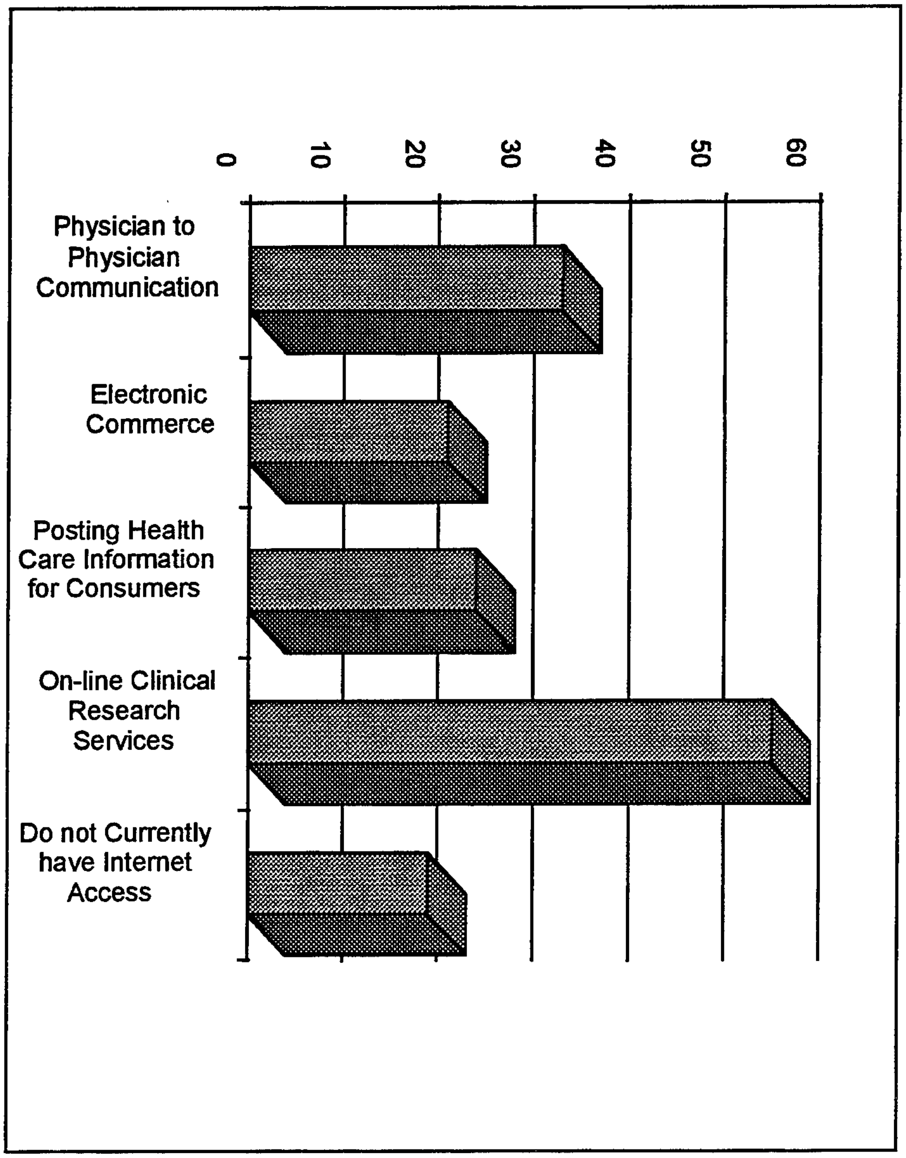

Figure 5.6. Use of the Internet. From Ref. [12].

Figure 5.7 shows the breakdown of those health care organizations that have a WWW home page, and the length of time they have been operational. The chart shows that 73 percent of those activities either have an active web page or are in the process of developing one. Again, this is a clear indication of the direction the health care industry is heading with regard to computer and information technology.

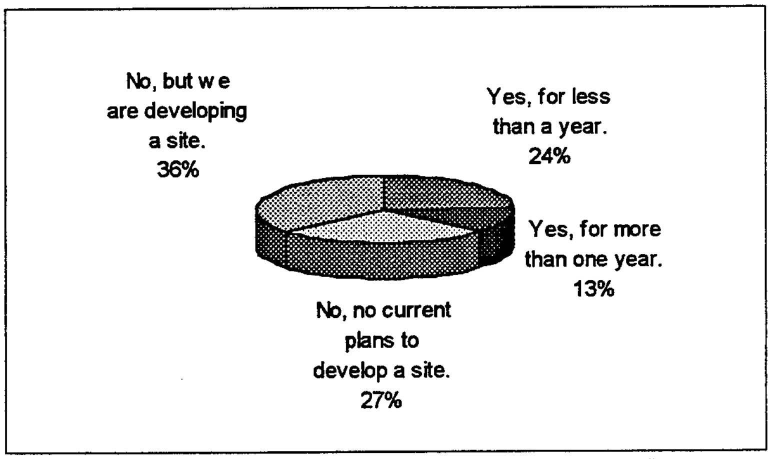

Figure 5.7. Percentage of Active WWW Home Pages.
From Ref. [12].

Figure 5.8 illustrates the top futuristic health care technology that the participating organizations think will probably come into common use within the next five years. The use of the internet is clearly evident by the responses to this question, as 50 percent said either telemedicine from the home or medical records access via the internet would be introduced.

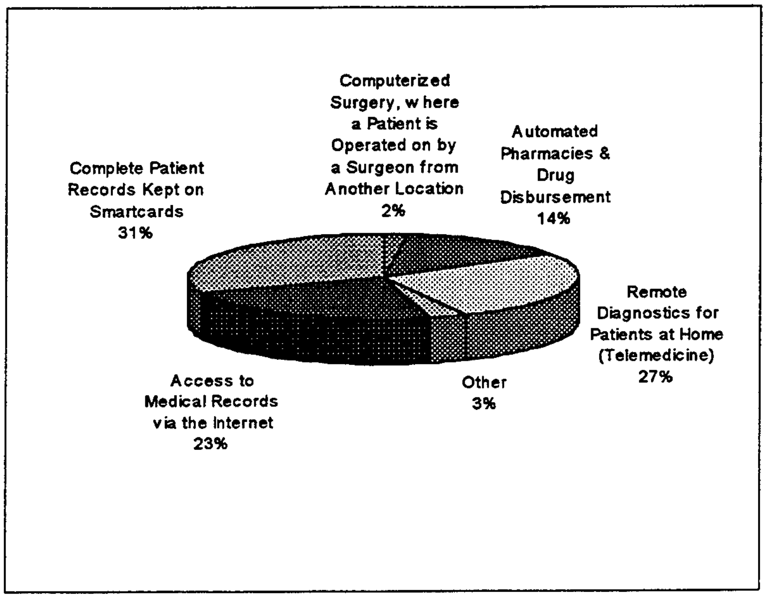

Figure 5.8. Future Health Care Technology.
From Ref. [12].

B. TARGET SYSTEM

It is clear to see that the future of health care is going to be highly dependent on advanced technology. Hospitals, HMOs, and providers must embrace leading edge technology and apply it to their migration systems in order to be in position to provide the best health care to patients. One of the first steps health care facilities should take to ensure that their enterprise is functioning as effectively and efficiently as possible is to ensure that the bandwidth needed to transmit information - whether it is email, transmission of administrative or patient information via FTP, televideo conferencing, or telemedicine - is properly sized and available. By adopting a policy that requires your network administrator to perform a daily analysis of your network data traffic, you will be in a great position to ensure that your WAN links are rightsized and ready to support your users.

C. MILITARY ENVIRONMENT

The results of the survey that generated the figures on the preceding pages are believed to be based on a predominantly civilian based population. However, the results can easily be mapped into the military community. The author believes that most of these trends are amplified in the military environment for the following reasons:

- larger medical trainee population
- larger percentage of remote patients
- higher percentage of independent duty corpsmen
- combat type injuries (higher puncture/shrapnel wounds and shock) vice civilian mix of casualties and ailments

The assumption is that the trends displayed for the civilian sector are also appropriate for the military.

VI. AVAILABILITY OF NETWORK LINKS

A. AVAILABILITY HEURISTIC

The trends in health care, shown in Chapter V, imply an ever increasing need for higher bandwidths and availability. High network availability can be defined as the likelihood that any given user can gain access to and successfully use the system at a given moment. It includes survivability and restorability in both peacetime and wartime emergencies, reliability of individual elements, physical redundancy, and a system design responsive to changes in network design and connectivity. [Ref. 13]

How critical and timely are your data transmissions? Are you dealing with time sensitive, life threatening issues that must be dealt with immediately? Can you afford to experience down time, and if so, how much? These are a few of the questions that you must answer to determine the level of availability that you are seeking for your organization.

This chapter discusses the importance of Operational Availability, which in the engineering field is denoted as Ao [Ref. 14]. Ao is usually expressed as a percentage, and is defined as up time (total time minus down time) divided by total time.

The primary means for achieving high availability consists of: [Ref. 15]

- design - installing or making use of redundant equipment and communications means so that backup alternatives are available when equipment fails
- logistics - planning for component failures with management, backups, spare parts, and maintenance training
- management - rapidly identifying and correcting malfunctioning equipment and bottlenecks

B. AVAILABILITY ENGINEERING MODEL

1. Single-Threaded Model

Figure 6.1 presents a model of a single-threaded network. The availability figures for these components may be obtained from the vendors or suppliers, or may be estimated from experience. The Ao of the individual components for our model are hypothetically set as follows: [Ref. 14]

- WAN (line) Ao = 99.7%
- router Ao = 99.9%
- LAN and end system Ao = 99%

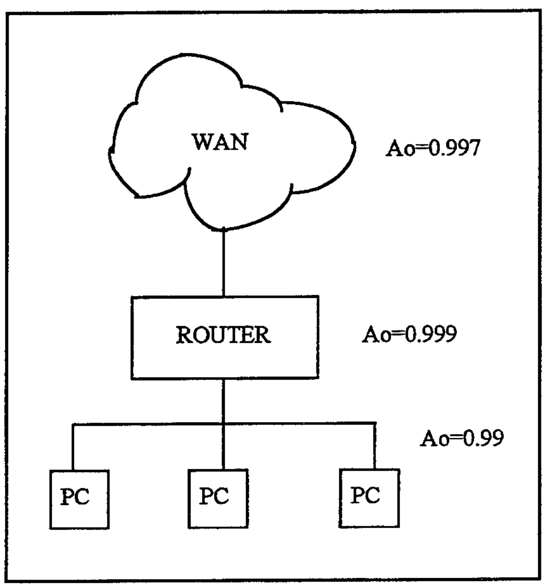

Figure 6.1. Single-Threaded System.
After Ref. [14].

In the field of applied statistics and probability, it is standard procedure to quantify the likelihood, or chance, that an event will occur. The likelihood of a particular outcome is quantified by assigning a number from the interval [0,1] to the outcome (or a percentage from 0 to 100%). The higher the number, the greater the chance of occurrence of that event. A zero indicates that an outcome will never occur, while a 1 indicates that an outcome will occur with certainty. [Ref. 16]

Since the three components in our model are wired in series, the Ao of the system can be expressed as the product of the three component values:

$$\begin{aligned} Ao &= 0.997 \times 0.999 \times 0.99 \\ &= 0.986 \end{aligned}$$

To put our model into perspective, the total time per month should first be computed, as seen in Figure 6.2. When you apply the above Ao value and monthly total time value to the Ao formula, you arrive at a monthly down time value of 605 minutes. This equates to approximately 10 hours of down time per month.

Attempts to increase the Ao value of the components is limited to technology, i.e., solid state devices. Therefore, in order to obtain a greater availability, we must emulate our components and solve our Ao problems through redundancy. [Ref. 14]

60 min/hr x 24 hr/day 1,440 min/day x 30 days/month 43,200 min/month if Ao = up time/total time, where Ao = 0.986 and total time = 43,200 min/mo, then 0.986 = 43,200 - down time/43,200 down time = 605 min/mo

Figure 6.2. Calculation of Down Time.

2. Redundancy Criteria

a. Three Criteria of High Availability

To assist you in maintaining the highest network availability as possible, the three principles of high availability engineering are hereby provided: [Ref. 14]

- eliminate single points of failure
- provide reliable crossover (from primary to backup)
- promptly detect & correct failures upon occurrence

b. Eliminating Common Cause Failures

A common cause failure is defined as a failure of one component that causes another component, typically the backup, to fail. By implementing engineering independence, we can eliminate common cause failures. An example would be placing individual computers within an organization on separate uninterruptable power supplies (UPS) so that the failure of one UPS will not cause all the computers in the office to go down. Another example is to bring in telephone trunks (lines) into a command center from more than one central office (CO). By using two different routes, you will avoid the vulnerability associated with a CO shut down, which could be caused by a fire, or by the rupturing of buried cables. [Ref. 15]

c. *Reliable Crossover*

The changeover of a system from primary to backup mechanisms must be reliable. It simply is not acceptable to have the backup systems unavailable when they are needed. This criterion of high availability coincides with networking standards that tend to use all the connectivity, both primary and backup, all the time. In addition to the efficiency gains (equipment and communications capacity not being idle), the reliability of the changeover mechanism is quite high as it is exercised continually in the course of normal business. Fortunately, this problem is handled quite nicely by the TCP/IP protocol stack for internetworks and by FDDI ring-wrap in LANs. [Ref. 15]

d. *Detection of Failures Upon Occurrence*

Since high availability systems use backups, it is necessary to detect failures in primary equipment so that operations can be switched over to backups so that the primary equipment can be repaired before the backup equipment fails. Although the ability to rectify communications problems in a timely and efficient manner is important, it is more important to recognize potential problems before they occur and cause communication outages, excessive response times, or other types of impairments. This is the function of the network management process, which is defined as: [Ref. 17]

> ...the process of using hardware and software by trained personnel to monitor the status of network components and line facilities, question end-users and carrier personnel, and implement or recommend actions to alleviate outages and/or improve communications performance as well as conduct administrative tasks associated with the operation of the network.

By embracing the high availability principles, you can ensure that your organization is well positioned to deal with any potential network or communication problems that may occur. By maintaining a proactive, rather than a reactive posture, you will be in position to take action to conquer problems before they occur, or before they get out of control.

3. Dual-Threaded Model

Dual-threaded systems are the best way to eliminate single points of failure. As mentioned earlier, connectivity into the facility should be brought in via two separate central offices and through two different cable trenches or conduits. The routers should be cross-connected, protected with separate UPS units, and installed in different wiring closets, preferably in different buildings. Additionally, if the LANs are compatible, they should also be cross-connected by installing a bridge. The ideal situation is one where one line failure can be compensated by the other, one router failure can be compensated by the other, and component failures in the LAN can be compensated by redundant workstations and LAN cabling. Figure 6.3 is a recalculation of the Ao presented in the single-threaded model.

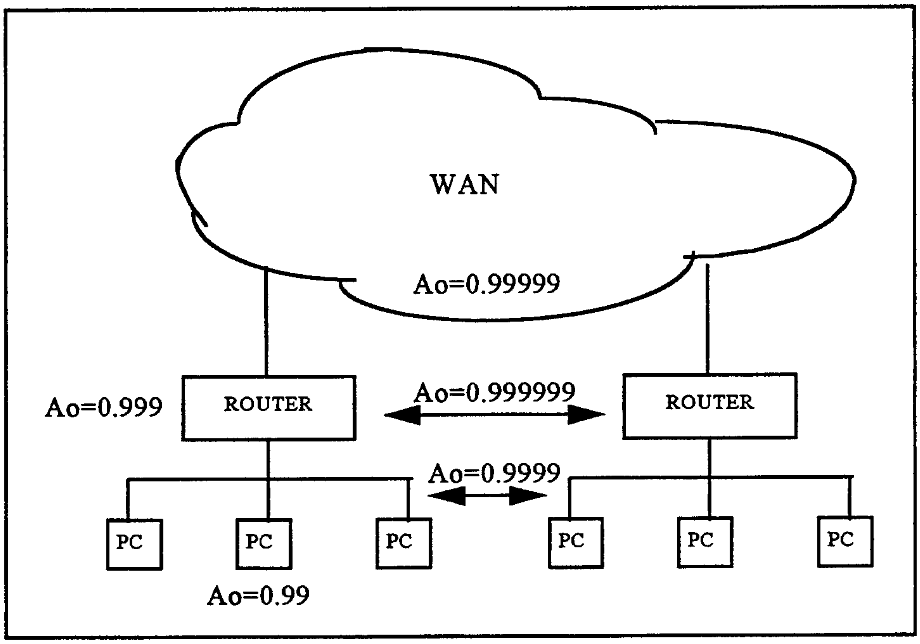

Figure 6.3. Dual-Threaded System. After Ref. [14].

In this example, the Ao of the line remains 99.7%. This means that the probability of failure is .3%, or 0.003. Since we now have two lines working together, either of which being up represents success, we then have a probability of failure of 0.003 x 0.003, or 0.00009. This means that the line now has a combined Ao of 0.999991.[1] By adding yet a third line, while maintaining independence of mode of failure, our model would have an Ao of 0.9999997. This graphically illustrates the importance of redundant lines. In summary, the procedure involves:

- compute the probability of failure (1-Ao).
- multiply the probabilities of failure for all parallel systems.
- convert back to Ao by subtracting the probability of failure from 1.

[1] When computing Ao, engineers count the number of "nines". In this example, we have five "nines".

This procedure should be performed on each module in the model, including the line, the router, and the LAN. In our model, shown in Figure 6.3, we get an Ao for the pair of routers of six "nines", and for the cross-connected LANs we get an Ao of four "nines". To compute the overall Ao for this system, we simply multiply the three Ao values as:

Ao system = Ao WAN (line) x Ao routers x Ao LANs
= 0.99999 x 0.999999 x 0.9999
= 0.999889

By using the same method and hypothetical component values illustrated in Figure 6.2, we compute the predicted down time and get about five minutes of down time per month. This is quite a dramatic difference from the down time computed for the single-threaded system, the results due in large part to the redundancy concept. [Ref. 14]

C. FUNDAMENTAL COMPUTATIONS: THE SIGNIFICANCE OF Ao VALUES

Although the values used for the models presented in this chapter are hypothetical, they are probably not too far from realistic values. While the single-threaded system Ao of 0.986 may be acceptable for a typical office-automation environment, it is definitely not acceptable for mission critical environments such as C3I, combat, or medical. By eliminating the single points of failure, the Ao values shoot up to about four or five "nines". [Ref. 14]

The difference in down time between systems that exhibit two "nines" versus four or five "nines" has been demonstrated. The bottom line is simple - plan on dual-threading your system. It provides the greatest availability possible.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Importance of Analyzing Data Traffic

This research has shown the importance of analyzing network data traffic. The main issue pertaining to the installation of the WWW servers was shown to be the bandwidth of the existing network WAN links, and whether or not the existing links were properly sized and able to support the traffic load placed on the network by the users. Data traffic from the five WAN links out of NMIMC was collected and analyzed. The incoming and outgoing traffic flows were reviewed, and the reliability of the lines were checked. The load values were analyzed, evaluated, and plotted. The data plots were quite graphical in the sense that they pointed out the importance of looking beyond the mean traffic load rates to the peak load rates. Spikes in the utilization rates were evaluated. Those lines that were shown to peak above the industry threshold of 80 percent need to be properly sized prior to the implementation of the WWW servers onto the networks currently in place at the MTF's.

2. Stay Current with Technological Changes

Technology, as applied to the health care field, that involves the use of computers and information systems, continues to grow at a rapid pace. It is difficult to keep an organization running efficiently if administrators do not stay current with respect to the technology employed in their field. To offer an organization the best support possible, to as many users as possible, administrators must be aware of the technology around them. They must evaluate the market leaders. They must stay abreast of the network communication services that both local and national providers have to offer, such as ISDN, Frame Relay, ATM, and ADSL, which are described in short detail in Appendix E. If administrators are current in their field, they are in excellent position to achieve successful changes for their organizations. Chapter V illustrated the direction that the health care field is heading with respect to computers, the internet, and the WWW. Those organizations that fail to stay current with the technological changes within their field will fall behind and lose their competitive advantage, and will not be able to provide the support they need to survive.

3. Continual and Proactive Data Monitoring

The process of analyzing your network traffic should be performed on a daily basis, rather than quarterly, or weekly. By keeping a constant pulse on network traffic utilization rates, organizations can ensure that they are positioned to make the necessary upgrades quickly, based on facts, and eliminate a lot of the guess work that they are currently faced with when trying to compute the bandwidth they really need to support their data flows. Organizations should adopt a data-driven decision management philosophy regarding the rightsizing of vital communication links; they should let the data assist them in making decisions regarding strategic positioning and rightsizing of their WAN links. Finally, by adopting a proactive, rather than reactive, policy on managing IT assets, organizations can keep their vital information flowing, and provide the strategic advantage they need to yield the best support possible to their customers.

B. RECOMMENDATIONS

The evaluation of the WAN links at NMIMC is intended to be used as a model for all sites. This research lead to the following recommendations:

- Deploy a network management platform to all MTF's currently connected to the internet.
- Train staffs in the use of the network management platform.
- Perform load balancing at the sites that have redundant links.
- Rightsize the individual links according to the need specified by the data.
- Implement data-driven decision management; let the data assist managers and network administrators in rightsizing the Wan links.
- Investigate the possibility of transmitting FTP traffic during non-peak times.
- Investigate the possibility of conserving internet bandwidth by caching hard-hit Home Pages or other popular pages. The caching can speed access and reduce the need to buy more internet bandwidth [Ref. 26].
- Monitor network traffic on a daily basis.
- Stay current with technology.
- Be proactive; analyze the network traffic and take action to eliminate problem areas before they cause network bottlenecks.
- Challenge old paradigms; the technology is available to make sound changes, both technically and managerial, that assist administrators in maintaining the competitive advantage their organizations need to survive and thrive in their field.

C. SUGGESTION FOR FURTHER RESEARCH

Although this research is important to organizations in analyzing their WAN links, it falls short in providing a model for forecasting future traffic growth. Ideally, an enterprise network capacity plan should include potential changes and an anticipated traffic growth rate parameter. The author recommends using a network simulation planner, or application, to assist in this research. The equation for properly computing traffic growth should include current traffic loads plus anticipated traffic growth. This should ensure a more precise measurement of an organizations needs, and should better position an organization to provide the best support for their users, which in turn equates to a higher efficiency rating and success of the organization.

APPENDIX A. HEALTH AFFAIRS DIRECTIVES

A. BACKGROUND

In an effort to provide enhanced electronic information interchange (EII) within the Military Health Support System (MHSS), the Assistant Secretary of Defense for Health Affairs (ASD/HA) has initiated guidelines for implementing a global information system utilizing the internet and the World Wide Web (WWW) [Ref. 1].

In support of this initiative, ASD/HA has agreed to fund the deployment and operation of ASD/HA Internet /Web servers to various DoD MTFs. Funds will be transferred from HA to the three Services. Each Service then assumes the responsibility of funding the design, implementation, and operation of Internet/Web servers to support EII and web home pages that will allow complete interoperability across Health Affairs, the Surgeons General, and MTFs.[Ref. 1]

The Naval Medical Information Management Center (NMIMC), located in Bethesda, Maryland, was established to design, deploy, and support naval medical information management systems and telecommunications infrastructure. The inherent nature of NMIMC makes it uniquely qualified to accept the responsible for the assigned task of deploying the Navy's WWW servers.

B. MISSION NEED STATEMENT

The Bureau of Medicine and Surgery (BUMED) has embraced the use of the WWW technologies for the dissemination of information throughout the claimancy. It is crucial that Navy healthcare providers have access to the latest information on topics ranging from policy and administrative procedures to headquarters and MTF staffing rosters.

The ASD/HA has initiated larger-scale programs to support EII, however, BUMED has immediate information dissemination requirements and emerging technology management issues that must be addressed by NMIMC. The system proposed under the NMIMC abbreviated system decision paper (ASDP) will meet these requirements while allowing seemless interaction of Navy Medical home-pages with other MHSS components as directed by ASD/HA. [Ref. 2]

C. TASKING

NMIMC has been charged with design, deployment and support of Naval medical information systems and telecommunications infrastructure. The objective of the task statement (Statement of Work (SOW)) is to acquire support for the design, testing, implementation, installation, and training of the WWW system that is being deployed by NMIMC.

The existing Navy Medical Department Network will be used as the infrastructure to support data transmissions from the WWW servers. This network is classified as a Wide Area Network (WAN), and was installed by a major effort know as the Medical

Open Architecture (MED-OA) Project. Figure A.1 shows the Metropolitan Area Networks that are in place to support Navy Medical administrative needs.

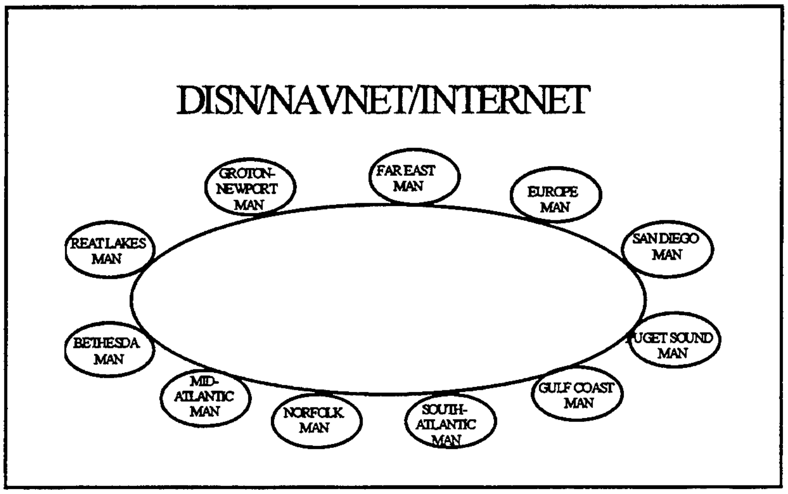

Figure A.1. Navy Medical Department Network.

Specific technical details surrounding this network will not be presented here, other than to say that the WAN links are of various bandwidths, ranging from 56Kb (56 thousand bits per second) to T-1 speeds (1.544 million bits per second). This is of importance to the WWW server acquisition initiative, as the bandwidth in many locations may not be appropriate for the anticipated increase in data traffic due to the addition of the WWW servers onto the existing network. These WAN links must be analyzed for data traffic flow and congestion, and rightsized as deemed necessary. This is perhaps the single most important technical aspect of this initiative, and is addressed in the statement of work.

The contractor shall perform all services prescribed in SOW at the tentative locations listed in Table A.1, which are subject to change at the discretion of NMIMC. [Ref. 18]

Server & Related Sites Listings	Location
1. NAVMEDINFOMGMTCEN	Bethesda, MD
2. Washington BUMED HQ	Washington, DC
3. NMIMC DET/East Coast MTFs	Norfolk, VA
4. NMIMC DET/West Coast MTFs	San Diego, CA
5. Tricare Region Nine	San Diego, CA
6. Tricare Region Two	Portsmouth, VA
7. Great Lakes NH	Chicago, IL
8. Groton NH	Groton, CT
9. Bremerton, NH	Seattle, WA
10. Pensacola NH	Pensacola, FL

Table A.1. Projected WWW Server Locations.

D. STATEMENT OF WORK FOR BUMED WWW SERVICES

In an effort to be consistent with National Health Care Reform, the MHSS is embarking on a major program of health care reform called TRICARE. TRICARE is designed to ensure the most effective execution of the military care mission, recognizing the need to ensure access to a quality health care benefit, control cost, and respond to changing national, military, and health care priorities. A major feature of TRICARE is the division of the United States-based MHSS into twelve Health Service Regions, each headed by a medical center commander designated as the Lead Agent, who has broad, new responsibilities for health care management throughout the region. The department of the Navy BUMED, the TRICARE Lead Agents, and MTFs have a critical need to be able to exchange and disseminate textual and graphical information concerning TRICARE policy, planning and execution, and medical information (including that which can be acquired from on-line sources such as Medline). [Ref. 19]

E. REQUIRED RESOURCES/SCOPE OF WORK

The contractor has been requested to perform the following services: [Ref. 20]

- Develop Detailed Implementation Plan. The contractor shall develop a project plan that describes tasks, subtasks, and schedules; identifies members of the team, including areas of responsibility; and describes methods to be used to implement the project. The contractor will present a work breakdown structure providing detail regarding interim deliverables, resources, milestones, and schedule for the project. This plan may be modified as the tasks progress and the environment changes. It will be approved by the Task Monitor.

- Implement WWW Home Pages. The contractor shall develop a WWW Home Page application for BUMED, NMIMC, Lead Agent Regions 2 and 9, and NMIMC Detachments in San Diego and Portsmouth, consistent with the guidelines developed by Health Affairs. Continuous user feedback will be a critical part of the development effort. The home pages and each subsequent pages will be fielded for "beta" testing within NMIMC before release to the internet.

- Conduct Hyper-Text Markup Language (HTML) Conversion. The contractor shall convert key documents into HTML. It is assumed that all documents will be in an industry standard word processing format, i.e. WordPerfect, Microsoft Word, ASCII, etc. The number of documents and the extent to which each document will contain "hyper-links" will be dependent on the period of performance.

Specific tasks to be provided by the contractor include: [Ref. 19]

- Conduct Site Surveys
- Develop detailed implementation plan
- PPP/SLIP server configuration
- Implement WWW Home Pages
- Conduct Hyper-Text Markup Language (HTML) Conversion
- Design Target System
- Develop Support/Training Plan
- Domain Name Service (DNS) Upgrade Study
- Deploy Servers
- Conduct Training
- Develop USENET Plan
- Implement USENET Capabilities
- Deploy Browsers
- Operate and Maintain Home Pages

Specific deliverables to be provided by the contractor include: [Ref. 19]

- Detailed Implementation Plan
- Communication Upgrade Study
- BUMED WWW Home Pages
- Key Documents in HTML Format
- Target System Specifications
- Support/Training Plan
- Training Material and Documentation
- Site Survey Reports
- USENET Plan
- Operation and Maintenance Home Pages

F. CONTRACT VEHICLE

Initially, the proposed systems were planned on being acquired via the following procurement options, where feasible:

- GSA Schedule
- Existing Procurement Contracts
- Open Market
- A combination of the above options

Where those options are not available, or where high tech or highly specialized items are required but not available on existing contracts, procurement will be accomplished through the establishment of an 8(a) contractor. [Ref. 2]

The contract vehicle that happened to be available to NMIMC was the D/SIDDOMS contract. The acronym stands for Defense Medical Information Systems/Systems Integration, Design, Development, Operations, and Maintenance. This contract is dated 10 March, 1996, and is managed by the United States Army's Defense Medical Program Activity managers, who are based in Skyline, Virginia. The Initiating Proponent is the Office of the Assistant Secretary of Defense for Health Affairs. [Ref. 21]

The Contracting Agency for the Army is the Defense Supply Service, Washington DC. There are approximately 600 support personnel assigned in various satellite offices, including the Pentagon, who handle all task orders and support for this contract. [Ref. 21]

The D/SIDDOMS contract is also a provider of components for one of the DoDs major projects, the Composite Health Care Systems project, which provides numerous services such as patient appointments and scheduling, patient administration, and email service to various MTF departments. Other major Navy projects that are using the D/SIDDOMS contract vehicle include [Ref. 21]:

- Systems Integration Project
- Automated Information Security Project
- Telemedicine Project

The D/SIDDOMS is a follow-on contract to the SIDDOMS, which ran for 6-7 years prior to the signing of the new contract. The type of equipment and services offered by the D/SIDDOMS contract are vast, and include any IT related elements such as:

- Hardware
- Software
- Planning and Development
- Prototyping
- Support Services
- Maintenance

There are three lots available on the D/SIDDOMS contract [Ref. 21]. They are listed as:

- Lot I
  - System Design, Development, Operations, Maintenance, and Support
  - Contractors include: AMS, EDS, PRC, SAIC
  - Ceiling is $325M

- Lot II
  - Systems Integration, Oversight, Requirements Development, Concept Development
  - Contractor: Northrop Grumman
  - Ceiling is $50M

- Lot III
  - Studies and Analysis
  - Contractors: Birch and Davis, Solon Consulting, United Health Care, Vector Research
  - Ceiling is $25M
- POC for Lot I & II: Ms. Julie Phillips (703) 681-6903
- POC for Lot III: Ms. Brenda Mabrey (703)681-8720 [Ref. 22]

The authors' understanding is that the D/SIDDOMS contract is a Requirements Contract, which is defined as:

> A requirements contract provides for filling all actual purchase requirements of designated government activities for specific supplies or services during a specified contract period, with deliveries to be scheduled by placing orders with the contractor. This type is used when the government anticipates recurring requirements, but can not predetermine the precise quantities of supplies or services that will be needed during a definite period. Funds are obligated by each delivery order, not by the contract itself. [Ref. 23]

The NMIMC proposal is to procure the following components from the D/SIDDOMS contract [Ref. 8]:

- Hardware, i.e., WWW servers
- Software, i.e., web browser(s)
- Labor, to include:
    1. Deployment
    2. Communication lines/WAN analysis
    3. Cisco router administration/management
    4. User training
    5. Maintenance
    6. System Support

G. PROPOSED SOLUTION

The proposed solution is to design, engineer, procure, test, deploy, and operate a WWW server suite at NMIMC that supports the BUMED Headquarters, NMIMC, and the Washington DC region. Similar installations will be performed at the NMIMC Detachments to support both the Eastern and Western regions. The WWW servers will support home pages and administrative systems for BUMED, NMIMC, and other MTFs. The system will support interfaces to on-line medical resources like Medline, organize and index medical resources on the Internet, and provide workgroup tools for information sharing among functional groups. Enhanced Internet connectivity will be provided to each site as required to support the increased network traffic anticipated with the introduction of the WWW service. This solution will allow system components to be managed from NMIMC network management systems. Additionally, the proposed solution will incorporate a facility to manage access to systems with restricted access and to control access to the Internet at large. [Ref. 2]

Selected systems will use commercial-off-the-shelf (COTS) hardware and software. Advanced functionality will require some software customization. The emphasis of this system is not on software development, but on providing the platform, structure, tools, and management support for individuals and organizations throughout the claimancy to easily maintain information content and build additional functionality. [Ref. 2]

H. ALTERNATIVES CONSIDERED

1. Maintaining the Status Quo

This alternative will not provide the EII capabilities dictated by ASD/HA and will not address the information dissemination requirements of BUMED, NMIMC, and the MTFs. Therefore, this alternative is deemed unacceptable. [Ref. 2]

2. Central Claimancy Master Server Implementation

This solution would locate all system resources in a single location, rather than distributing systems across major regions. A central solution would cost less but is not desirable for the following reasons:

- loss of local ownership would impact local information sharing and reduce the usefulness of the system
- single point of failure and loss of service redundancy
- communications requirements and Internet connectivity overly taxing oat central host location

It should be noted that some degree of centralization is achieved under the proposed solution, primarily by having claimancy-wide standards and an organized methodology for information sharing and dissemination. [Ref. 2]

I. COSTS AND BENEFITS

The life cycle cost of the alternatives are described below [Ref. 2].

a. Maintaining the Status Quo. This option is not shown since it is not an acceptable alternative as it fails to meet mission requirements.

b. Central Claimancy Master Server Implementation.

The life cycle costs of the alternative centralized solution are shown in Table A.2.

COSTS: ($0,000)	FY96	FY97	FY98	FY99	FY00	TOTAL
SYSTEM HW & SW	$500	$30	$0	$0	$0	$530
Installation & Maintenance	190	45	45	45	45	370
Operations	600	600	450	450	400	2500
Total ($0,000)	$1290	$675	$495	$495	$445	$3400

Table A.2. Life Cycle Costs of Centralized Solution. From Ref. [2].

c. Proposed Solution

The life cycle costs of the proposed BUMED/NMIMC solution are shown in Table A.3.

Costs assumptions are based on [Ref. 2]:

- 2 high capacity WWW production servers and 1 development server (35K per)
- 2 high capacity WWW production multimedia and application link servers and 1 development server (15K per)
- software for the above servers includes development and monitoring tools, and database/application interface software (75K)
- Installation, operational support and other personnel, WWW expertise for server/communications installation and ongoing operations, and programming and design are all outsourced. Each of the four production systems are assumed to require 5K of installation and approximately 10K of operational support per year (development systems require 5K of installation and 5K of operational support per year). Programming and design support is assumed to be 35K per server in the initial 2 years, tapering down in the out years.

Costs: ($0,000)	FY96	FY97	FY98	FY99	FY00	Total
System Servers	150	0	0	0	0	150
Server Software	75	0	10	0	10	95
Comms Hardware	40	0	0	0	0	40
Maintenance	0	10	10	10	10	40
Supplies	3	3	3	3	3	15
Installation	25	0	0	0	0	25
Training	8	15	10	0	0	33
Hardware Upgrade	8	15	25	20	10	78
Software Upgrade	0	12	20	15	10	57
Site Prep	20	0	0	0	0	20
Internet Comms	55	55	45	45	40	240
Operational	45	50	50	35	35	215
Personnel	140	140	110	50	50	490
Total ($0,000)	569	300	283	178	168	1498

Table A.3. Life Cycle Costs of Proposed Solution. From Ref. [2].

J. BENEFITS OF PROPOSED SOLUTION

Electronic information interchange within BUMED will meet the goals of optimizing communications flow and will meet the requirements for connectivity within MHSS as dictated by ASD/HA. The regional approach to WWW server deployment will maximize the local control and therefore, maximize the use and benefits of the technology while minimizing central support costs. [Ref. 2]

Additionally, the claimancy will benefit from improved decision making due to higher quality information being delivered to the appropriate decision maker when and where needed. The claimancy will also benefit from increased availability of training and readiness resources, which will help develop better prepared decision makers. Improving the preparedness and capabilities of Navy medical decision makers will result in higher quality health care delivered to the customer. [Ref. 2]

K. FUNDING ISSUES

The author had the distinct pleasure of meeting Major Fred Peters, USAF, at the American Academy of Medical Administrators (AAMA) conference that was held in Irvine, CA, in November, 1995. Major Peters is the Chief of Operations for Defense Medical Information Management, Office of the ASD/HA. He presented a briefing for the AAMA regarding the status of Health Affairs Information Systems. Afterwards, the author and Major Peters briefly discussed the issues surrounding this thesis - which deal with analyzing the WAN links at NMIMC - since it is directly tied to the WWW server implementation plan. During this conversation, Major Peters stated that the funding for the WWW server components would be provided by the ASD/HA. He further explained that ASD/HA would transfer the funds, via a Military Inter-service Procurement Requirement (MIPR), to the individual DoD agents, who in turn would be responsible for procuring their own components for the WWW server project.

In January, 1996, the author again had the fortune of meeting Major Peters at the Healthcare Information Management Systems Society (HIMSS) conference in Atlanta, Georgia. The ensuing discussion centered around the MIPR, and Major Peters confirmed that the MIPR action had already taken place between the ASD/HA and the Services.

Therefore, once the components ordered on the individual delivery orders are received by the Navy MTFs and the invoices are certified, payment will be made by NMIMC from the funds MIPRed from the ASD/HA and earmarked for the WWW server initiative.

APPENDIX B. UNIX SCRIPTS

A. CRON ENTRY

The cron entry is also known as a daemon process. A daemon is a process that executes "in the background" either waiting for some event to occur, or waiting to perform some specified task on a periodic basis. The cron entry is a standard Unix process that performs periodic tasks at given times during the day, taking its instructions from the file/usr/lib/crontab. The cron entry shown below defines when the data is to be sampled. In our case, the data was requested every 30 minutes. [Ref. 24]

```
cron entry:
/usr/dsc3cjc/test1 | egrep '(==|EDT|protocol|MTU|minute)'
/usr/dsc3cjc/trovini
```

This script basically performs an iterative process at the specified time interval. The shell goes to the /usr/dsc3cjc/test1 script, performs that function, and returns to the cron script.

The remaining portion of the cron entry uses pipes (|) and the egrep command to perform specific operations on the data prior to dumping the results into the /usr/dsc3cjc/trovini file.

Pipes allow you to connect two commands together so the output from one program becomes the input of the next command. The egrep command is simply an extended version of the grep command. The grep command means "globally search for a *r*egular *e*xpression and *p*rint all lines containing it. A *regular expression* combines a string of text with some special characters used for pattern matching. Therefore, the grep is used within the pipe so that only those lines of the input files containing a given string are sent to the standard output. [Ref. 4]

For more information about Unix commands, you should refer to any Unix book or manual. More detailed explanations at this point would just cloud the issue, and you need to stay focused on the basic process here, which is leading up to the plotting of the traffic-data, or more specifically, the utilization rates.

B. THE TEST1 SCRIPT

After the time sequencing is assigned, the shell goes to the /usr/dsc3cjc/test1 file. The test1 script is shown below.

```
test1:
echo "================================================================"
date
echo "================================================================"
telnet < /usr/dsc3cjc/tn.cmd &
sleep 15
kill -9 $!
```

Once in test1, the process is told to echo (regenerate) the "===" lines that surround the date. This command prints the lines onto the screen, allowing the time to stand-out from the other data to make it easier to distinguish the time intervals. After the test1 script echoes the second "===" line, the shell telnets into the /usr/dsc3cjc/tn.cmd script, where it performs that operation, and returns to the test1 script.

The ampersand (&) is used to specify a background process. It allows the kernel (the operating system nucleus), the program in charge of the Unix system, to synchronize two or more processes running concurrently. By using the &, you are telling the kernel to execute a command while the login shell is doing something else. [Ref. 25]

In our case, that something else is sleeping for 15 seconds so that the telnet session can run. Once the tn.cmd is done, the kill -9 command kills the background shell (telnet session). The $! variable is used to hold the process ID (PID) of the last process run in the background; it is used to notify the shell which process to kill.

C. THE TN.CMD SCRIPT

As mentioned earlier, after the test1 script echoes the second "===" line, the shell telnets into the /usr/dsc3cjc/tn.cmd script, which is shown below. This sidestep simply opens a session with the 131.158.50.50 device, which is the Cisco 7000 router, and asks it to show the interfaces of the five WAN links. The "~q" command tells the tn.cmd script to exit and returns to the test1 script. The "aros" command is the super-secret mystery password that the technical engineer uses to gain access to the router.

```
tn.cmd:
escape
~
open 131.158.50.50
aros
sho int serial 4/1
sho int serial 4/4
sho int serial 4/5
sho int serial 4/7
sho int fddi 2/0
~q
```

APPENDIX C. SAS SCRIPT

Chapter II introduced the SAS script that was generated to extract the dates and time of the observations, the link names, and the load values from the individual data files so that a statistical analysis could be performed on the data. The following script was written to accomplish that goal [Ref. 6].

```
options linesize=80;
filename kevin '/h/joshua_u3/kltrovin/thesis/cat.dat';

data one (drop= s1 s2 s3 s4 s5 s6 s7 s8 s9 s10 s11 s12 five
 d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12
 e1 e2 e3 e4 e5 e6 e7 e8 e9 e10 e11 e12
 f1 f2 f3 f4 f5 f6 f7 f8 f9 f10 f11 f12
 g1 g2 g3 g4 g5 g6 g7 g8 g9 g10 g11 g12);
infile kevin ;


input

 # 2
        day $
        month $
        date $
        tod $


 # 5                        s5 $                s10 $
        s1 $                s6 $                s11 $
        s2 $                s7 $                s12 $
        s3 $                s8 $                load1 $
        s4 $                s9 $


 # 9                        d5 $                d10 $
        d1 $                d6 $                d11 $
        d2 $                d7 $                d12 $
        d3 $                d8 $                load4 $
        d4 $                d9 $
```

# 13	e5 $	e10 $
e1 $	e6 $	e11 $
e2 $	e7 $	e12 $
e3 $	e8 $	load5 $
e4 $	e9 $	

# 17	f5 $	f10 $
f1 $	f6 $	f11 $
f2 $	f7 $	f12 $
f3 $	f8 $	load7 $
f4 $	f9 $	

#21	g4$	g9$
g1$	g5$	g10$
g2$	g6$	g11$
g3$	g7$	g12$
	g8$	loadfddi$

#23 five $;

```
nload1= length(load1);
nload4= length(load4);
nload5= length(load5);
nload7= length(load7);
nloadf= length(loadfddi);

array nload{5} nload1 nload4 nload5 nload7 nloadf;
array xload{5} xload1 xload4 xload5 xload7 xloadf;
array load{5} load1 load4 load5 load7 loadfddi;

do i = 1 to 5;
        if nload{i}= 5 then xload{i}=(substr(load{i},1,1)/255*100);
        else if nload{i} = 6 then xload{i}=(substr(load{i},1,2)/255*100);
        else if nload{i}=7 then xload{i}=(substr(load{i},1,3)/255*100);
else xload{i}=-999;
end;

hour = substr(tod,1,2);

proc freq; tables xload1 xload4 xload5 xload7 xloadf;

proc means;
    var xload1 xload4 xload5 xload7 xloadf;

proc sort; by hour;

proc means;
    var xload1 xload4 xload5 xload7 xloadf;
    by hour;
```

APPENDIX D. SAS DATA CHARTS

Chapter III introduced the SAS charts that where generated from the traffic.sas program [Ref.6]. These charts show the frequency distributions and the hourly mean, standard deviation, minimum load values, and maximum load values for the five NMIMC WAN links analyzed in this study. These charts are provided in this appendix for informational and reference purposes. The values in these charts were used to generate the graphs introduced in chapter III that show the trends of the data traffic for the WAN links.

XLOAD1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3921568627	1359	57.6	1359	57.6
0.7843137255	4	0.2	1363	57.8
1.1764705882	2	0.1	1365	57.9
1.568627451	413	17.5	1778	75.4
3.137254902	2	0.1	1780	75.5
3.5294117647	149	6.3	1929	81.8
5.0980392157	87	3.7	2016	85.5
7.0588235294	64	2.7	2080	88.2
8.6274509804	53	2.2	2133	90.4
10.588235294	40	1.7	2173	92.1
12.156862745	20	0.8	2193	93.0
14.117647059	27	1.1	2220	94.1
15.68627451	19	0.8	2239	94.9
17.647058824	15	0.6	2254	95.5
19.607843137	12	0.5	2266	96.1
21.176470588	13	0.6	2279	96.6
23.137254902	6	0.3	2285	96.9
24.705882353	6	0.3	2291	97.1
26.666666667	3	0.1	2294	97.2
28.235294118	5	0.2	2299	97.5
30.196078431	3	0.1	2302	97.6
31.764705882	4	0.2	2306	97.8
33.725490196	5	0.2	2311	98.0
35.68627451	2	0.1	2313	98.1
37.254901961	3	0.1	2316	98.2
39.215686275	1	0.0	2317	98.2
40.784313725	1	0.0	2318	98.3

47.843137255	4	0.2	2327	98.6
49.803921569	1	0.0	2328	98.7
53.333333333	1	0.0	2329	98.7
56.862745098	3	0.1	2332	98.9
62.352941176	1	0.0	2333	98.9
65.882352941	2	0.1	2335	99.0
67.843137255	1	0.0	2336	99.0
69.411764706	1	0.0	2337	99.1
71.37254902	3	0.1	2340	99.2
74.901960784	1	0.0	2341	99.2
80	2	0.1	2343	99.3
81.960784314	1	0.0	2344	99.4
83.921568627	1	0.0	2345	99.4
85.490196078	2	0.1	2347	99.5
87.450980392	2	0.1	2349	99.6
90.980392157	2	0.1	2351	99.7
92.549019608	1	0.0	2352	99.7
94.509803922	3	0.1	2355	99.8
96.078431373	3	0.1	2358	100.0
98.039215686	1	0.0	2359	100.0

XLOAD4	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3921568627	148	6.3	148	6.3
1.568627451	118	5.0	266	11.3
3.5294117647	74	3.1	340	14.4
5.0980392157	54	2.3	394	16.7
7.0588235294	31	1.3	425	18.0
8.6274509804	27	1.1	452	19.2
10.588235294	16	0.7	468	19.8
12.156862745	15	0.6	483	20.5
14.117647059	14	0.6	497	21.1
15.68627451	23	1.0	520	22.0
17.647058824	19	0.8	539	22.8
19.607843137	32	1.4	571	24.2
21.176470588	36	1.5	607	25.7
23.137254902	59	2.5	666	28.2
24.705882353	71	3.0	737	31.2
26.666666667	76	3.2	813	34.5
28.235294118	93	3.9	906	38.4
30.196078431	113	4.8	1019	43.2
31.764705882	127	5.4	1146	48.6
33.725490196	113	4.8	1259	53.4
35.68627451	107	4.5	1366	57.9
37.254901961	88	3.7	1454	61.6
39.215686275	84	3.6	1538	65.2
40.784313725	73	3.1	1611	68.3
42.745098039	61	2.6	1672	70.9

44.31372549	55	2.3	1727	73.2
46.274509804	44	1.9	1771	75.1
47.843137255	50	2.1	1821	77.2
49.803921569	29	1.2	1850	78.4
51.764705882	35	1.5	1885	79.9
53.333333333	31	1.3	1916	81.2
55.294117647	33	1.4	1949	82.6
56.862745098	29	1.2	1978	83.8
58.823529412	28	1.2	2006	85.0
60.392156863	32	1.4	2038	86.4
62.352941176	30	1.3	2068	87.7
63.921568627	31	1.3	2099	89.0
65.882352941	20	0.8	2119	89.8
67.843137255	21	0.9	2140	90.7
69.411764706	19	0.8	2159	91.5
71.37254902	16	0.7	2175	92.2
72.941176471	15	0.6	2190	92.8
74.901960784	14	0.6	2204	93.4
76.470588235	7	0.3	2211	93.7
78.431372549	12	0.5	2223	94.2
80	17	0.7	2240	95.0
81.960784314	17	0.7	2257	95.7
83.921568627	12	0.5	2269	96.2
85.490196078	8	0.3	2277	96.5
87.450980392	8	0.3	2285	96.9
89.019607843	9	0.4	2294	97.2
90.980392157	13	0.6	2307	97.8
92.549019608	16	0.7	2323	98.5
94.509803922	16	0.7	2339	99.2
96.078431373	15	0.6	2354	99.8
98.039215686	4	0.2	2358	100.0
100	1	0.0	2359	100.0

XLOAD5	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3921568627	1927	81.7	1927	81.7
0.7843137255	120	5.1	2047	86.8
1.1764705882	81	3.4	2128	90.2
1.568627451	61	2.6	2189	92.8
1.9607843137	24	1.0	2213	93.8
2.3529411765	30	1.3	2243	95.1
2.7450980392	30	1.3	2273	96.4
3.137254902	18	0.8	2291	97.1
3.5294117647	17	0.7	2308	97.8
3.9215686275	8	0.3	2316	98.2
4.3137254902	6	0.3	2322	98.4
4.7058823529	6	0.3	2328	98.7
5.0980392157	6	0.3	2334	98.9

5.4901960784	3	0.1	2337	99.1
6.2745098039	4	0.2	2341	99.2
6.6666666667	3	0.1	2344	99.4
7.0588235294	3	0.1	2347	99.5
7.4509803922	3	0.1	2350	99.6
8.2352941176	1	0.0	2351	99.7
8.6274509804	2	0.1	2353	99.7
9.0196078431	3	0.1	2356	99.9
9.4117647059	1	0.0	2357	99.9
14.901960784	1	0.0	2358	100.0
28.62745098	1	0.0	2359	100.0

XLOAD7	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3921568627	2019	85.6	2019	85.6
0.7843137255	111	4.7	2130	90.3
1.1764705882	56	2.4	2186	92.7
1.568627451	90	3.8	2276	96.5
1.9607843137	29	1.2	2305	97.7
2.3529411765	16	0.7	2321	98.4
2.7450980392	13	0.6	2334	98.9
3.137254902	7	0.3	2341	99.2
3.5294117647	4	0.2	2345	99.4
8.6274509804	1	0.0	2346	99.4
24.705882353	1	0.0	2347	99.5
30.196078431	1	0.0	2348	99.5
31.764705882	1	0.0	2349	99.6
39.215686275	2	0.1	2351	99.7
47.843137255	1	0.0	2352	99.7
56.862745098	1	0.0	2353	99.7
83.921568627	1	0.0	2354	99.8
85.490196078	1	0.0	2355	99.8
90.980392157	1	0.0	2356	99.9
96.078431373	1	0.0	2357	99.9
98.039215686	2	0.1	2359	100.0

XLOADF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3921568627	2359	100.0	2359	100.0

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	2359	3.9325404	10.6395563	0.3921569	98.0392157
XLOAD4	2359	34.9420243	23.3059572	0.3921569	100.0000000
XLOAD5	2359	0.7138286	1.1494338	0.3921569	28.6274510
XLOAD7	2359	0.8830595	5.1087385	0.3921569	98.0392157
XLOADF	2359	0.3921569	0	0.3921569	0.3921569

------------------------------- HOUR=00 -------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	95	1.1351909	2.5437021	0.3921569	21.1764706
XLOAD4	95	21.9855521	20.5044732	0.3921569	92.5490196
XLOAD5	95	0.3962848	0.0402344	0.3921569	0.7843137
XLOAD7	95	0.3962848	0.0402344	0.3921569	0.7843137
XLOADF	95	0.3921569	0	0.3921569	0.3921569

------------------------------- HOUR=01 -------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	96	0.8537582	1.2150467	0.3921569	10.5882353
XLOAD4	96	28.0269608	21.0668687	0.3921569	87.4509804
XLOAD5	96	0.3921569	0	0.3921569	0.3921569
XLOAD7	96	0.4370915	0.2119083	0.3921569	1.5686275
XLOADF	96	0.3921569	0	0.3921569	0.3921569

------------------------------- HOUR=02 -------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	98	0.7402961	0.6939737	0.3921569	3.5294118
XLOAD4	98	36.6986795	21.4577464	0.3921569	90.9803922
XLOAD5	98	0.3921569	0	0.3921569	0.3921569
XLOAD7	98	0.4161665	0.1671987	0.3921569	1.5686275
XLOADF	98	0.3921569	0	0.3921569	0.3921569

------------------------------- HOUR=03 -------------------------------

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	98	0.7202881	0.6388044	0.3921569	3.5294118
XLOAD4	98	37.8591437	20.3488966	0.3921569	94.5098039
XLOAD5	98	0.3961585	0.0396138	0.3921569	0.7843137
XLOAD7	98	0.4241697	0.1751379	0.3921569	1.5686275
XLOADF	98	0.3921569	0	0.3921569	0.3921569

HOUR=04

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	96	0.5882353	0.4407463	0.3921569	1.5686275
XLOAD4	96	28.0596405	16.7210665	0.3921569	92.5490196
XLOAD5	96	0.4003268	0.0563043	0.3921569	0.7843137
XLOAD7	96	0.4044118	0.1200730	0.3921569	1.5686275
XLOADF	96	0.3921569	0	0.3921569	0.3921569

HOUR=05

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	97	0.7802709	0.9205509	0.3921569	5.0980392
XLOAD4	97	27.9482515	16.4354897	0.3921569	81.9607843
XLOAD5	97	0.3961997	0.0398175	0.3921569	0.7843137
XLOAD7	97	0.4164140	0.1364875	0.3921569	1.5686275
XLOADF	97	0.3921569	0	0.3921569	0.3921569

HOUR=06

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	96	8.6437908	24.9907353	0.3921569	98.0392157
XLOAD4	96	46.2500000	23.2802642	0.3921569	98.0392157
XLOAD5	96	0.4656863	0.2500531	0.3921569	1.5686275
XLOAD7	96	0.4738562	0.3639679	0.3921569	3.5294118
XLOADF	96	0.3921569	0	0.3921569	0.3921569

HOUR=07

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	95	5.6842105	12.6953393	0.3921569	96.0784314
XLOAD4	95	35.9133127	20.0593473	0.3921569	96.0784314
XLOAD5	95	0.6150671	0.6563351	0.3921569	5.0980392
XLOAD7	95	0.5696594	0.5684862	0.3921569	3.5294118
XLOADF	95	0.3921569	0	0.3921569	0.3921569

HOUR=08

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	98	7.2589036	14.7691511	0.3921569	87.4509804
XLOAD4	98	43.5174070	25.5061109	0.3921569	96.0784314
XLOAD5	98	1.2404962	1.8069370	0.3921569	8.2352941
XLOAD7	98	1.5726291	9.8540855	0.3921569	98.0392157
XLOADF	98	0.3921569	0	0.3921569	0.3921569

HOUR=09

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	100	6.7686275	11.3621797	0.3921569	71.3725490
XLOAD4	100	40.9019608	23.1422226	0.3921569	96.0784314
XLOAD5	100	1.5411765	3.3117707	0.3921569	28.6274510
XLOAD7	100	1.7803922	9.0230379	0.3921569	85.4901961
XLOADF	100	0.3921569	0	0.3921569	0.3921569

HOUR=10

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	97	6.5130382	11.2360179	0.3921569	85.4901961
XLOAD4	97	38.8356580	21.5497878	1.5686275	98.0392157
XLOAD5	97	0.9096422	1.0597708	0.3921569	5.0980392
XLOAD7	97	2.6844552	13.2715963	0.3921569	96.0784314
XLOADF	97	0.3921569	0	0.3921569	0.3921569

HOUR=11

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	101	6.4453504	11.2357446	0.3921569	87.4509804
XLOAD4	101	39.3321685	22.2867644	0.3921569	98.0392157
XLOAD5	101	0.7843137	0.7145438	0.3921569	3.9215686
XLOAD7	101	1.9180742	10.4043437	0.3921569	98.0392157
XLOADF	101	0.3921569	0	0.3921569	0.3921569

HOUR=12

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	113	7.5585632	15.9368336	0.3921569	94.5098039
XLOAD4	113	40.5760888	22.9887743	5.0980392	100.0000000
XLOAD5	113	0.9300711	0.8138600	0.3921569	3.5294118
XLOAD7	113	2.8318584	10.9078404	0.3921569	83.9215686
XLOADF	113	0.3921569	0	0.3921569	0.3921569

HOUR=13

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	102	8.6543637	14.9578756	0.3921569	85.4901961
XLOAD4	102	46.1707036	22.7281500	1.5686275	96.0784314
XLOAD5	102	1.2379854	1.2629150	0.3921569	6.2745098
XLOAD7	102	1.3341023	3.8098071	0.3921569	30.1960784
XLOADF	102	0.3921569	0	0.3921569	0.3921569

HOUR=14

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	100	7.4235294	11.9424423	0.3921569	71.3725490
XLOAD4	100	48.9764706	24.2141660	1.5686275	96.0784314
XLOAD5	100	1.4784314	2.2266601	0.3921569	14.9019608
XLOAD7	100	0.5843137	0.3999814	0.3921569	2.3529412
XLOADF	100	0.3921569	0	0.3921569	0.3921569

HOUR=15

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	99	9.4236482	16.3475515	0.3921569	94.5098039
XLOAD4	99	44.7969895	21.5666504	0.3921569	94.5098039
XLOAD5	99	1.3586849	1.4406728	0.3921569	8.6274510
XLOAD7	99	0.7803525	0.7250411	0.3921569	3.5294118
XLOADF	99	0.3921569	0	0.3921569	0.3921569

HOUR=16

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	101	5.5523199	9.2353953	0.3921569	47.8431373
XLOAD4	101	37.5965832	24.2683107	0.3921569	96.0784314
XLOAD5	101	0.9318579	1.2436400	0.3921569	8.6274510
XLOAD7	101	0.6328868	0.4330459	0.3921569	1.9607843
XLOADF	101	0.3921569	0	0.3921569	0.3921569

HOUR=17

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	99	1.9172113	5.3976330	0.3921569	49.8039216
XLOAD4	99	34.6326005	23.4261203	0.3921569	98.0392157
XLOAD5	99	0.5228758	0.5042017	0.3921569	3.5294118
XLOAD7	99	0.5466429	0.8566451	0.3921569	8.6274510
XLOADF	99	0.3921569	0	0.3921569	0.3921569

HOUR=18

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	96	1.2050654	1.4752878	0.3921569	7.0588235
XLOAD4	96	33.4395425	23.1331251	0.3921569	92.5490196
XLOAD5	96	0.5106209	0.5093108	0.3921569	4.7058824
XLOAD7	96	0.4289216	0.2351436	0.3921569	2.3529412
XLOADF	96	0.3921569	0	0.3921569	0.3921569

HOUR=19

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	95	1.6676987	6.9989975	0.3921569	67.8431373
XLOAD4	95	30.8400413	23.5487972	0.3921569	92.5490196
XLOAD5	95	0.4293086	0.1723069	0.3921569	1.5686275
XLOAD7	95	0.4458204	0.2467688	0.3921569	1.9607843
XLOADF	95	0.3921569	0	0.3921569	0.3921569

HOUR=20

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	96	0.9477124	1.7104766	0.3921569	15.6862745
XLOAD4	96	26.7687908	21.3291325	0.3921569	92.5490196
XLOAD5	96	0.4330065	0.2574952	0.3921569	2.7450980
XLOAD7	96	0.4207516	0.1730062	0.3921569	1.5686275
XLOADF	96	0.3921569	0	0.3921569	0.3921569

HOUR=21

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	97	0.7196281	0.6878609	0.3921569	3.5294118
XLOAD4	97	25.9874672	21.1939769	0.3921569	92.5490196
XLOAD5	97	0.4244997	0.3185400	0.3921569	3.5294118
XLOAD7	97	0.4204568	0.1721272	0.3921569	1.5686275
XLOADF	97	0.3921569	0	0.3921569	0.3921569

HOUR=22

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	97	0.7236709	0.7643291	0.3921569	5.0980392
XLOAD4	97	21.9041844	21.2156946	0.3921569	94.5098039
XLOAD5	97	0.3921569	0	0.3921569	0.3921569
XLOAD7	97	0.4164140	0.1680492	0.3921569	1.5686275
XLOADF	97	0.3921569	0	0.3921569	0.3921569

HOUR=23

Variable	N	Mean	Std Dev	Minimum	Maximum
XLOAD1	97	1.0632707	1.1047861	0.3921569	5.0980392
XLOAD4	97	18.3828583	20.1126408	0.3921569	76.4705882
XLOAD5	97	0.3921569	0	0.3921569	0.3921569
XLOAD7	97	0.4244997	0.1760171	0.3921569	1.5686275
XLOADF	97	0.3921569	0	0.3921569	0.3921569

APPENDIX E. CURRENT TECHNOLOGIES

Chapter VII mentioned some of the services that are currently offered by local and national service providers. This Appendix introduces a few of those technologies, and is intended to familiarize the reader with a few of the alternative solutions currently available in the marketplace. As mentioned in Chapter VII, those organizations that fall behind the technology curve will not only loose their competitive advantage, but the productivity, efficiency, and effectiveness of their organizations will also be in jeopardy. The pros and cons of these technologies are varied. Be sure to investigate all available alternatives thoroughly before investing in any one particular service.

A. INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

ISDN is described as a high speed, low cost, all digital dialup telephone service delivered to both businesses and homes over standard copper wires. ISDN maximizes the transmission capability of existing copper wires, allowing the simultaneous transmission of voice, data, and video over a single twisted pair connection [Ref. 27]. This technology was thought to be the great, new, all digital technology that would replace the plain old telephone system (POTS).

The basic unit of switching for ISDN is a 64-Kbps B-channel. A separate 16-Kbps D-channel is provided as a control channel. The main problem with ISDN's B-channel is that it is becoming increasingly inadequate for many subscribers who are using highpowered workstations and graphics and image processing applications [Ref. 28]. Some of the characteristics of ISDN include: [Ref. 29]

- Fast connection time.
- High bandwidth.
- End-to-end digital connection.
- Supports voice, data, and video on a single line.
- May be circuit-switched, packet-switched, or semi-permanently connected.
- Physically, it is a twisted pair wire.
- Available in two rates:
    1. Basic Rate Interface (BRI) - 2B + D for 144 Kbps.
    2. Primary Rate Interface (PRI) - 23B + D for 1.536 Mbps.

Those organizations looking to support a WWW server and MPEG video should look into the ISDN PRI line, which has a rate similar a T-1 link. The ISDN PRI link is reportedly less expensive than a T-1, but for accurate pricing information, interested parties should consult with their local telecommunications providers.

B. FRAME RELAY

The frame relay standard defines an interface between a user device and a network. It is a streamlined version of X.25 packet switching, designed to increase speed by drastically reducing the amount of processing time in data transfer mode. Frame relay eliminates the Level-3 processing (the packet level or Network Layer in X.25), and discards frame sequencing and error recovery at the frame level (Layer 2 in the OSI model). [Ref. 30]

Frames are received by the network over a frame relay interface and forwarded hop-by-hop from source node to destination node. This operation is very similar to the forwarding of packets in virtual circuit-based packet switching networks. The main difference is that sequence number checking and retransmissions due to errors do not get retransmitted at any step along the way. Frames with errors (detected by frame checking sequences) are simply discarded . This hop-by-hop forwarding of frames is called frame relay. The main advantage of frame relay is the high speed physical medium (interface) with statistical multiplexing to combine multiple channels. [Ref. 30]

Frame relay transfers information in variable length packets (frames), and can contain thousands of bytes of data. The amount of overhead needed to transmit data through frame relay is inherently lower than the overhead required for Asynchronous Transfer Mode (ATM), which is discussed in the next section. Some of the characteristics of ISDN include: [Ref. 31]

- Requires five bytes of header information for transmission through network.
- Percentage of bandwidth devoted to overhead varies according to the size of the frame.
- Delay characteristics make it less appropriate for carrying real-time multimedia applications such as video teleconferencing.
- Operates at very high speeds, accommodating large amounts of data with very low delay.
- Provides highly efficient resource sharing by supporting many virtual channels over a high speed line.
- Typical line sizes range from 56-Kbps to T-1/E-1 (1.544/2.048 Mbps).
- Unpredictable due to the variable length packets, which cause confusion for the switches and transmission equipment; they do not know exactly where each cell ends and the next one begins.
- Similar to X.25, except all circuits are permanently assigned.
- Relies on the customer equipment to perform end-to-end error correction.

Visit URL http://www.dcnet.com/notes/framerly.html for a very good overview of Frame Relay terms, or try URL http://www.kalpana.com/warp/public/732/Frame/fratm_wp.htm to compare Frame Relay and ATM WAN technologies.

C. ASYNCHRONOUS TRANSFER MODE (ATM)

ATM is an internationally accepted high-performance multiplexing and switching technology that is touted to be the multi-media communications technology that will take us into the next generation. ATM protocols are designed to handle isochronous (time critical) data such as video and audio, along with the more traditional data communications between computers. [Ref. 32]

The interest in ATM has grown out of the need for a worldwide standard to allow interoperability of information. The goal of ATM is to provide one international standard. Historically, there have been several methods used for the transmission of information between users. ATM is a method that can be used interchangeably for all traffic types, regardless of whether the data is transmitted over a LAN, WAN, or MAN. The goal is to close the gap between the various network types, making the transmission of data between them seamless to the end users based on one standard system - ATM. [Ref. 33]

The following set of User-Network Interfaces has been prescribed by the ATM Forum: [Ref. 29]

- DS-3 (45 Mbps).
- OC-1 (51 Mbps).
- TAXI (100 Mbps and 140 Mbps over multimode fiber).
- OC3c (155 Mbps).
- OC-48 (2.488 Gbps).

Some of the characteristics of ATM include: [Ref. 31]

- Fixed length packets (cells).
    - payload (48 bytes) carries actual information.
    - header (5 bytes) is the addressing mechanism.

- Smaller, fixed-length cells results in much higher overhead than Frame Relay, but offers two advantages over Frame Relay:
    1. Speed - easier to process, since the switching and transmission equipment know exactly where each cell ends and the next one begins.
    2. Small cells with a predictable transmission delay allow for interleaving cells that carry delay-sensitive traffic, such as interactive video and voice along with data cells.
- Layered architecture allows voice, video, and data to be mixed over the network.

The layered architecture mentioned above has three lower layers that have been established to implement the features of ATM: [Ref. 32]

- The Adaptation Layer - assures the appropriate service characteristics and divides all types of data into the 48 byte payload that will make up the ATM cell.
- The ATM Layer - takes the data that is to be sent and adds the 5-byte header information that assures the cell is sent along the correct connection.
- The Physical Layer - defines the electrical characteristics and network interfaces. This layer "puts the bits on the wire".[1]

For more information regarding the ATM Forum, or for more technology, architecture, or benefits related information on ATM, try the following URLs, respectively:

http://www.atmforum.com/atmforum/atm_introduction.html

http://www.npac.syr.edu/users/dpk/ATM_Knowledgebase/ATM_technology.html.

D. ASYMMETRICAL DIGITAL SUBSCRIBER LINE (ADSL)

1. General Information and Features

ADSL provides the highest access speed possible to the internet today over a single copper pair. This technology reportedly achieves near instantaneous home page downloads and file transfers from the internet. ADSL allows users, whether in the

[1] ATM is not tied to a specific type of physical transport.

business or residential environment, to access the internet at T-1 speeds over traditional phone lines. At T-1 speeds, the actual throughput can be up to 50 times faster than the typical 28.8 modem, or 12 times faster than a 128-Kbps ISDN connection. [Ref. 34]

Two companies, Westell and Microsoft, are working together on this new transmission technology. Additionally, GTE Telephone Operations, Irving, Texas, and US West !nterprise Networking Services, Denver, Colorado, are implementing or expanding their market trials of ADSL technology. According to GTE, ADSL is capable of providing up to 6-Mbps downstream (from the network to the user) and up to 640-Kbps upstream (from the user to the network), all over the existing telephone lines. At 4-Mbps, 200 pages of text can be downloaded in less than one second, and a typical WWW page with graphics can be downloaded in less than one-tenth of a second. ADSL also offers the user the opportunity to receive data and use their telephone, fax machine, or modem simultaneously. [Ref. 35]

This new technology is currently undergoing a six-month trial period, designed to test the high speed communications capabilities of ADSL over the existing phone lines. Exact prices for this technology are expected to be available at the end of the year. For more information regarding uses and applications of ADSL, try visiting the ADSL Forum at URL http://www.adsl.com/adsl/home_page.html, or for more information regarding the trial test period visit GTE at URL http://wcn.gte.com/adsl.

2. ADSL Enhances Healthcare

The healthcare field can benefit from the ADSL technology in several ways. This section outlines a few specific areas that are affected [Ref. 34].

a. Telemedicine

This live, two-way, interactive video communication allows patients to consult physicians at remote locations for specialty care not available in the patient's area. ADSL can deliver this extensive service at fraction of the cost of fiber based systems, and provides the versatility of simultaneous records management, image, and file transfer capabilities.

b. Teleradiology

Whether you are working in a PC or Unix based environment, ADSL can deliver biomedical images of any mode, and size, from point-to-point in seconds. Remote-primary diagnoses are now possible in real time with high-quality image resolution that is not degraded by the ADSL system.

c. On-Line Medical Research and Internet Access

The national Library of Medicine estimates that there are over 4,000 medical libraries within the U.S., half of which are accessible throughout the internet. Many of these libraries employ medical literature and retrieval systems (MEDLARS) for on-line information services. Physicians are increasingly turning to these on-line medical data uses to diagnose difficult cases, track new developments, lower costs, and shorten hospital stays. ADSL can provide a high speed link to these services to improve overall quality of care.

d. ADSL Healthcare Advantages

Some of the technological advantages that ADSL offers the healthcare field include:

- Faster response and delivery time in case of emergency care situations.
- Improved overall patient care through resource sharing and high-speed data access.
- Flexible, transparent point-to-point access increases savings for healthcare systems integration's.

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