TCP/IP Over SATCOM

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Abstract

Now that the United States Coast Guard is almost finished migrating to Windows NT-based computers, the Coast Guard-wide private Transmission Control Protocol / Internet Protocol (TCP/IP) communications network has replaced the old network. This network is known as the Coast Guard Data Network Plus (CGDN+). Current Coast Guard messaging and information access systems are being rewritten to run on the CGDN+ using web browser and e-mail applications as the front ends. As the Coast Guard moves into the 21st Century it is becoming increasingly important for the ships and the aircraft to be able to access the information stored on this network in near real-time. Unfortunately, at the present time they do not have reliable dedicated access to this network. However, plans are in progress to link these mobile assets into the network using commercial mobile satellite systems. The systems available now, or in the near future (Inmarsat, AMSC, and Globalstar) provide low-speed and/or high-delay connections. Over the next year or so, all of the large cutters will be migrated from the current analog Inmarsat-A technology to the digital Inmarsat-B service, including the high-speed data option. However, even this is only at 64 kbps, and the latency in the geostationary satellite link is still high. Also, "online" time using these systems is very expensive. In order to improve performance and reduce the operating cost of using such a system, it is necessary to increase the efficiency of the applications used over the satellite link. Previous work at the Coast Guard Academy has focused on improving the performance of Windows NT-based TCP/IP stacks over very slow speed links (specifically the 2400 bps Inmarsat-M service). Current research has extended this to include the Inmarsat-B high-speed link (64 kbps) as well. In addition, a system architecture to improve the performance on both of these links is being developed. This includes the use of an "intelligent router" which is being developed for the Coast Guard under an SBIR (Small Business Innovative Research Contract) by Architecture Technology Corp. (ATC) in Minneapolis, MN. The intelligent router allows the satellite links to be managed more efficiently by setting TCP/IP parameters to match the known characteristics of the link. To save on airtime, virtual connections are maintained between two intelligent routers while the physical link is taken down temporarily when there is no traffic. The intelligent routers also incorporate other performance enhancing features such as e-mail and web proxies.

Introduction

Communication by satellite has come a long ways since it was first developed. Now you can communicate reliably and quickly over satellite. The major downfall to satellite communications is that time is very expensive on a satellite link. That is where this project comes into play. We are tasked with improving the TCP/IP performance over satellite links so that the same amount of data takes less time to transmit across. If it takes less time, then it saves the Coast Guard money because we are no longer paying for the time that we do not need. The need for improving the performance of TCP/IP over satellite links is primarily being pushed by the effort to provide connectivity to all the cutters in the fleet while underway. This connectivity includes email and limited web access. The big problem with TCP/IP right now is that there is a large amount of overhead that is associated with it. Overhead is extra information that is not actually part of the data that was requested.

By optimizing the TCP/IP performance, we can cut down on the amount of data that gets sent without sacrificing the quality of the data that is being sent. In other words, we are looking at trying to reduce the amount of extra information that the two computers sent between each other.

This year the project has been split into two different sides. There is the large cutter side that is testing a larger and faster link that will be available on all cutters 210 foot in length or longer, and the small cutter side that is continuing where the project left off last year.

Background

The background of this project is that we are trying to optimize satellite communications for Coast Guard Cutters in order to save money on connection fees. Last year, ENS Tobias Reid worked on the project as a first class cadet. He basically limited his testing to improving the connection for small cutters. For this project, a small cutter is defined as any cutter that is less than 210 foot in length. The link tested was a 2400-baud asynchronous connection using the known characteristics of an Inmarsat Mini-M. The items that were tested included transmission efficiency of web pages and simple email. Some of the results that he discovered was that the most efficient maximum transmission unit (MTU) size was 500 bytes and that the initial time-out needed to be set to 5000 milliseconds.

Large Cutter

Objective

The overall goal of the large cutter side was to improve TCP/IP performance over a satellite link. The large cutter side is being sponsored by TISCOM and is being done in parallel with a similar test bed that they have set up. The link that I am simulating was an Inmarsat-B link. The reason for simulating the Inmarsat-B is that all the large cutters in the fleet already have or will be getting Inmarsat-B phones installed. The first thing that we looked at was how long it took to load different web pages with different Maximum Transmission Unit (MTU) sizes and time out values. After testing different values, the next step was to test a commercial product to see if it would improve performance any more than just changing the MTU size or retransmission delay time. At the same time we were going to test those same settings on sending email across the 64,000 bits per second link. The hope of all of this is to be able to speed communications across satellite links since they are very costly to use.

***Table 1* – Inmarsat-B Parameters**

Data Rate	64,000 bps
Channel Delay	442 ms (one way)
Bit Error Rate	10^{-6} errors/bit
Set-up time	17 sec

Technical Approach

To start out with, we set up two small networks. One represented the shore based CGDN network, while the other represented a ship's network. These two networks were initially connected with a pair of Intel routers but we were going to use CISCO routers as soon as they came in. After the long wait for the routers to actually arrive, and the problems we ran into trying to set them up, the network was finally ready to begin testing.

For the tests we loaded two different web pages initially. There was a predominantly text page that was really small in size, and then a page with numerous different graphics. The page containing the numerous graphics is a larger web page and therefore takes longer to load. After

collecting data for loading the web pages with default settings, we tried to improve performance by changing the MTU size and time out delay. Once the optimal values were found, we started testing a pair of SkyX Gateways across the link. There were a few problems we ran across while testing with the gateways, but those were overcome with a few minor fixes.

Though we initially wanted to be able to test the email capabilities across the link, we ran into some technical issues that prevented us from being able to properly test Microsoft Exchange Mail services across the link.

Results

The testing of the link provided numerous results that allowed us to improve the link performance. One of those was the discover that if the retransmit request delay was left at 3 seconds, we did not experience many requests for retransmission of packets across the link due to reaching the time out limit. We also found out that the default MTU size was the best size to select since anything smaller would increase the amount of time that it took to load the web pages. Below is a sample of some of the data that was collected. This graph shows the bytes transmitted over time for the large web page. The downward drops in the curve around the 10-second mark and again at about 44 seconds are packets that were requested again because they were either lost or unrecognizable by the computer on the cutter network. Those retransmissions were due to the bit error rate of the satellite link. For this particular link, there is a bit error approximately ever 15 seconds on average.

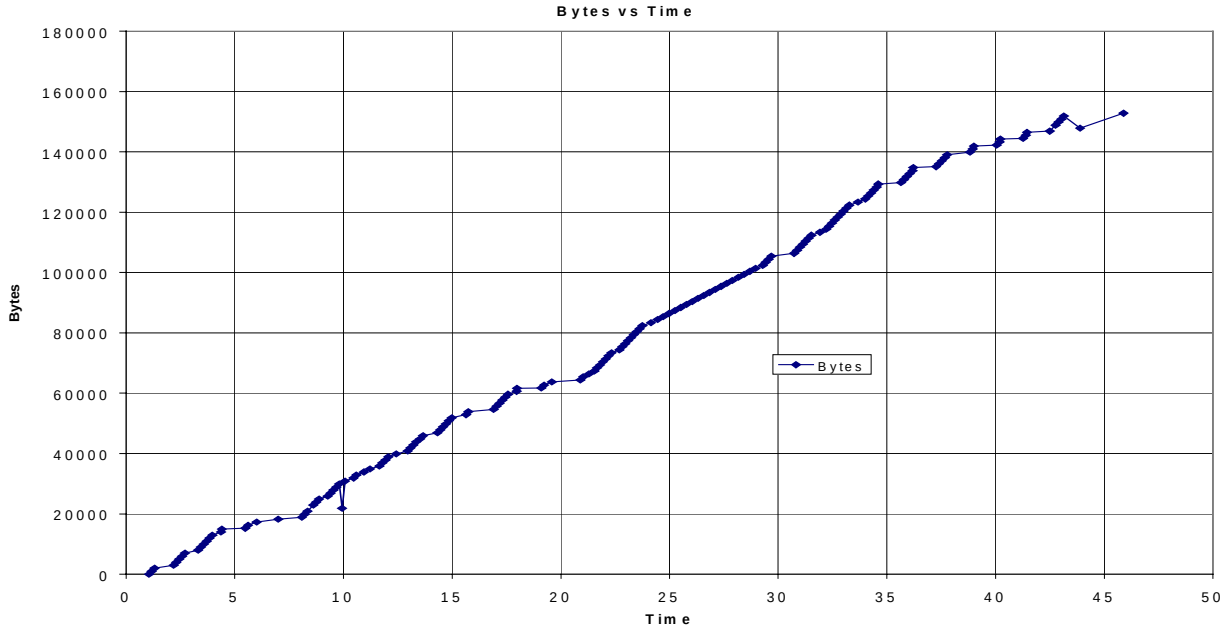

Figure 1 **– Large web page transmission time**

The following diagram shows how the network was set up between the show and large cutter. This model includes the SkyX Gateways. For the initial testing, the model is the same except that the SkyX Gateways were not included at that time.

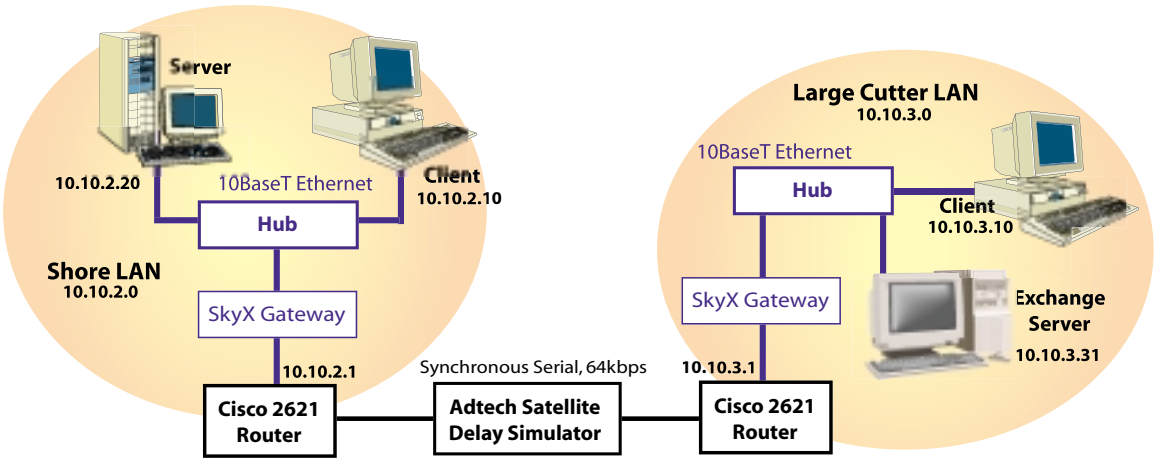

Figure 2 **– Large Cutter Network Configuration**

Once we started to test things with the SkyX Gateways, we were able to see some improvement in general throughput and FTP performance, but the Gateways do not appear to aide in the transmission of web pages as we initially thought that they would. The following graph shows the throughput values we achieved using a basic throughput test using some commercial software called Ping Pro Pack.

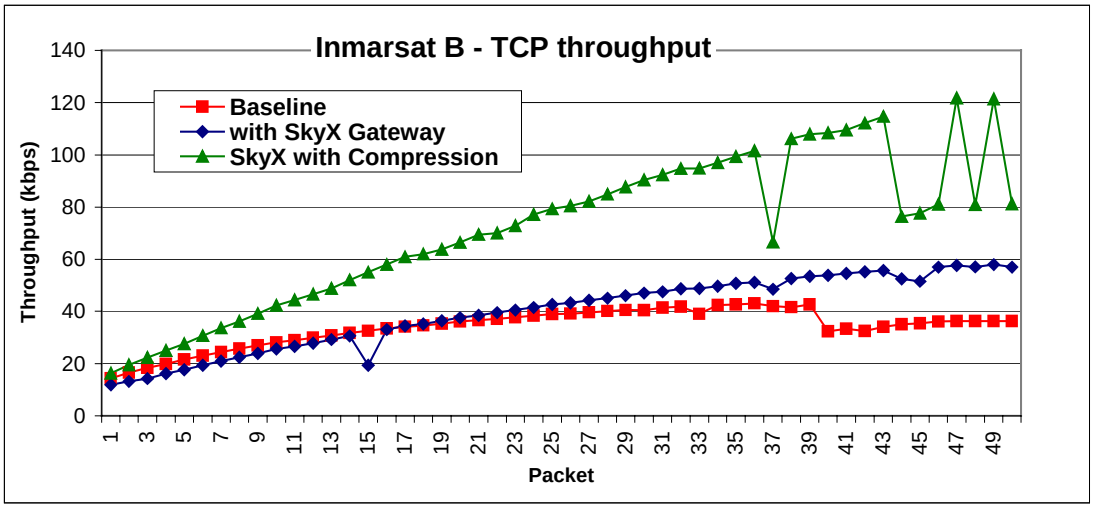

Figure 3 **– Inmarsat-B TCP Throughput**

As you can see in the above graph, the throughput with compression enabled was as fast as twice the actual speed of the link. This is very beneficial when dealing with large files that need to be transferred like possibly email attachments or large documents. Even without compression on the SkyX Gateways enabled, there was still some improvement on the speed of the link.

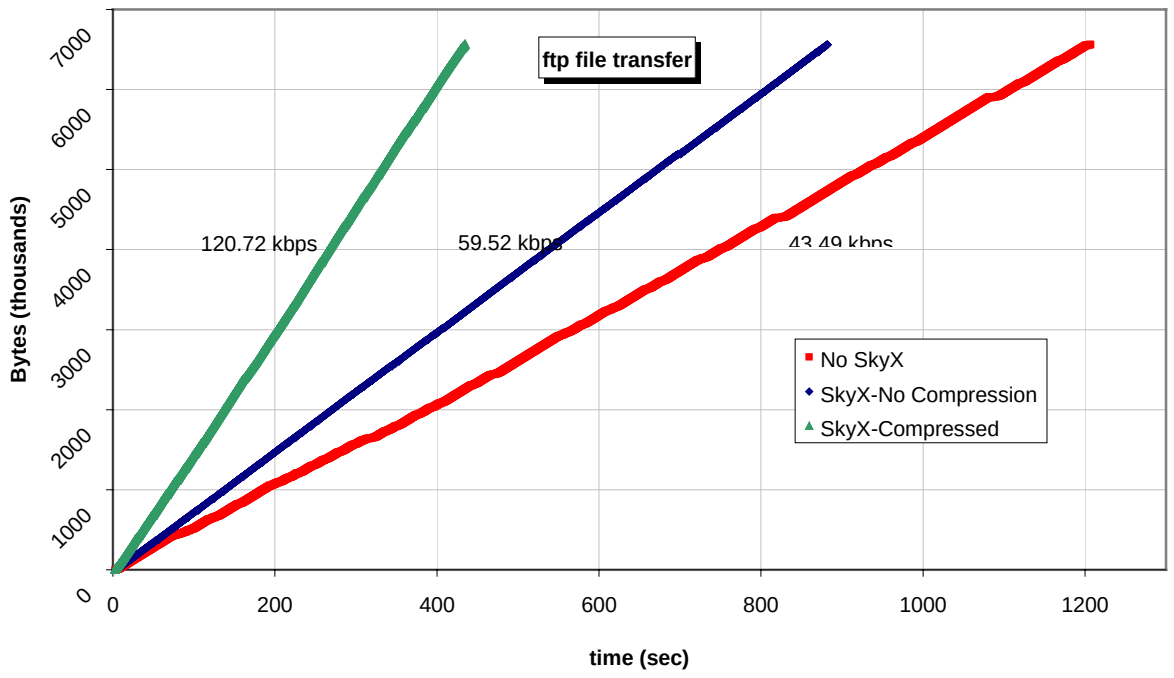

***Figure 4* – FTP results**

Another test that was conducted was measuring the performance of FTP file transfer with and without the SkyX gateways. As shown in figure 4 above, the SkyX gateway showed improvement over the link versus not using the gateway. While this is true for FTP, normal web traffic it did not improve that much. The overall results for that are shown below in figure 5.

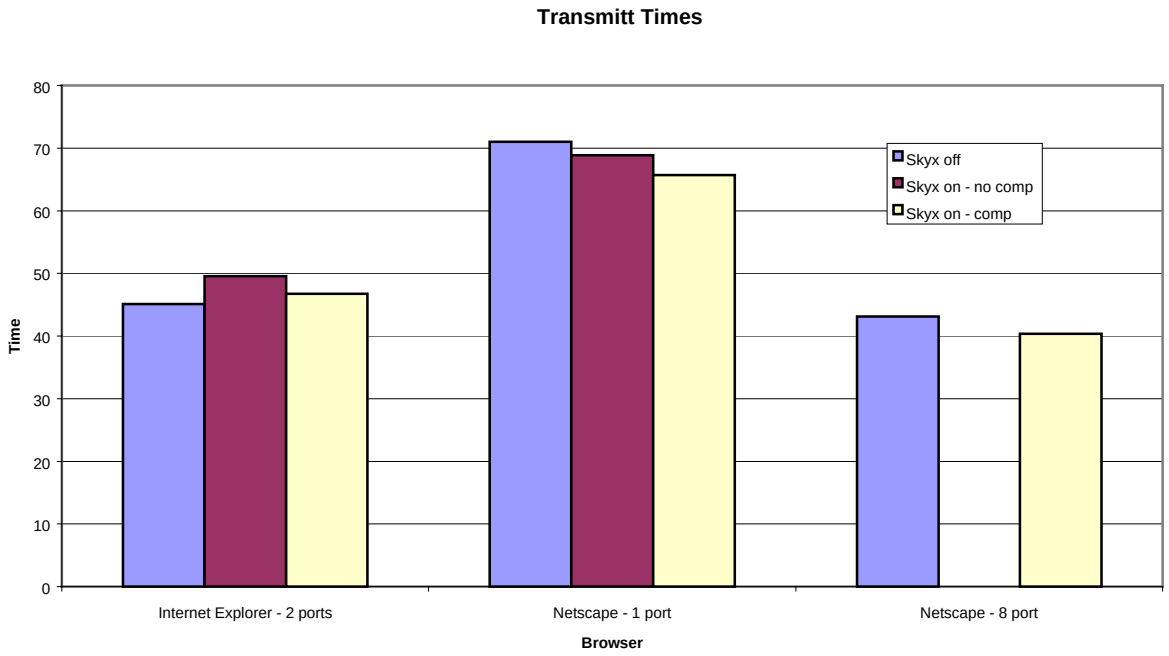

***Figure 5* – Web Transmit times**

Small Cutter

Objective

In this project, the task was to evaluate the Dial-on-Demand Router, e-mail and web proxies developed by ATC and provide any feedback on how to improve it. If time permitted, I would use a commercial product, Mentat SkyX Gateway, to see if it improved the performance. Below is the testbed that I used.

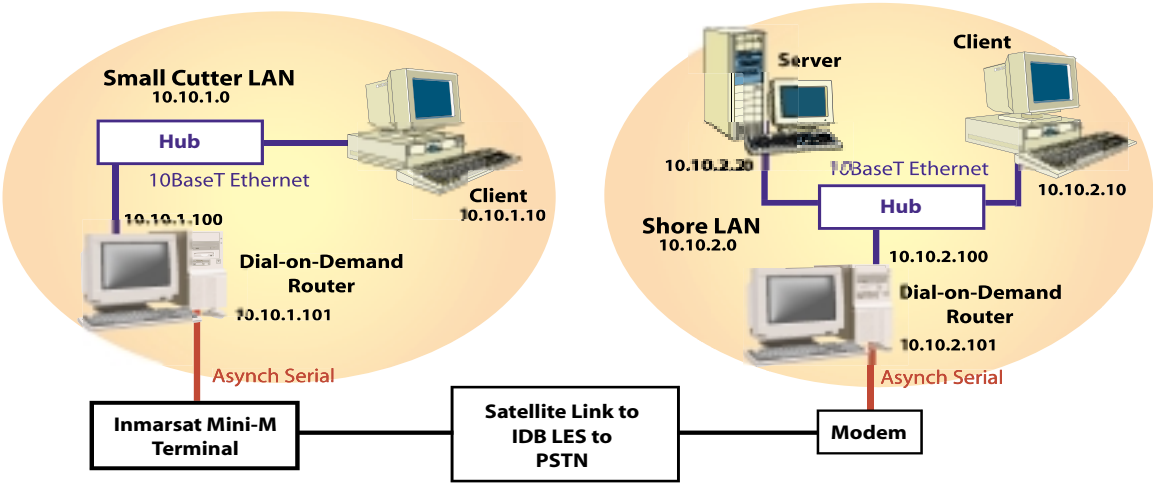

***Figure 6* – Small Cutter Testbed**

Technical Approach

This year I planned to run tests on a possible software router and optimized TCP/IP protocol that is being developed under a Small Business Innovation Research (SBIR) contract. Phase I of the SBIR contract was completed and work on Phase II began in May 2000. This phase of the project is expected to be finished at the end of the 2000 calendar year or the start of the 2001 calendar year. Once those results can be received from the SBIR contract work, they can be integrated into our project work here.

The dial-on-demand router, e-mail proxies and web proxies created by Architecture Technology Corporation (ATC) will attack the conventional way of transmitting data. The e-mail and web proxies will reduce the amount of data being transmitted (by compression and caching multiple layers of the OSI model). Another way that the e-mail and web proxies will improve performance is by improving the efficiency of the protocols at various layers and maximizing the link utilization. The dial-on-demand router will help in the efficiency by reducing the amount of time to connect to the network.

Results

To date, only the Dial-on-Demand Router (DDR) and e-mail proxy has been tested. In order to measure the improvements of using the DDR, I used a standard dial-up configuration with Windows NT RAS services and Dial-up Networking, to test the link established by the TCP/IP connection over PPP. The results were determined by timing measurements (with a stopwatch) and performing multiple trials. The first three time marks are parts of the Mini-M system and not subject to optimization; the first time is for the terminal to get a channel and connect to the Land

Earth Station (LES), the second time mark is when the terminal has established the connection on the PSTN, and the third is when both modems are connected. The final time is when a network connection has been established. The results are in the table below (times are averages and are elapsed time from the previous mark).

***Table 2* -- Inmarsat Mini-M Standard Network Connect Times: times are averages, and are the elapsed time from the previous mark**

LES	Data	Modems Connected	Total Physical layer	On Network	Total
6.8	11.01	10.28	28.28	22.64	50.92

***Table 3* – Windows NT RAS service vs. Dial-on-Demand Router "On Network" Time**

	On Network (seconds)
Windows NT RAS service	22.64
Dial-on-Demand Router	3.386

As you can see from Table 2, ATC's Dial-on-Demand Router has drastically reduced the amount of time that the Mini-m needs to connect to the network. Hence, by using the DDR, the Coast Guard would save a lot of money. However, by using the DDR, the testing resulted in showing an increase in the amount of time required to ping 56-bytes across the network. The amount of time increase approximately 155 ms. This could a result of extra overhead bytes required to speed up the connect time. Below is the comparison between Windows NT RAS service and the ATC's DDR throughput table and graph for the conditions of:

Timeout 10000 Packet size 1000

Delay 100 ms 10 Packets

***Table 4* – Windows NT RAS service vs. Dial-on-Demand Router "Throughput" Time**

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RAS	548	816	994.9	1089	1199	1314	1390	1454	1507	1552
DDR	452.6	779	946	1111	1222	1320	1389	1448	1499	1553

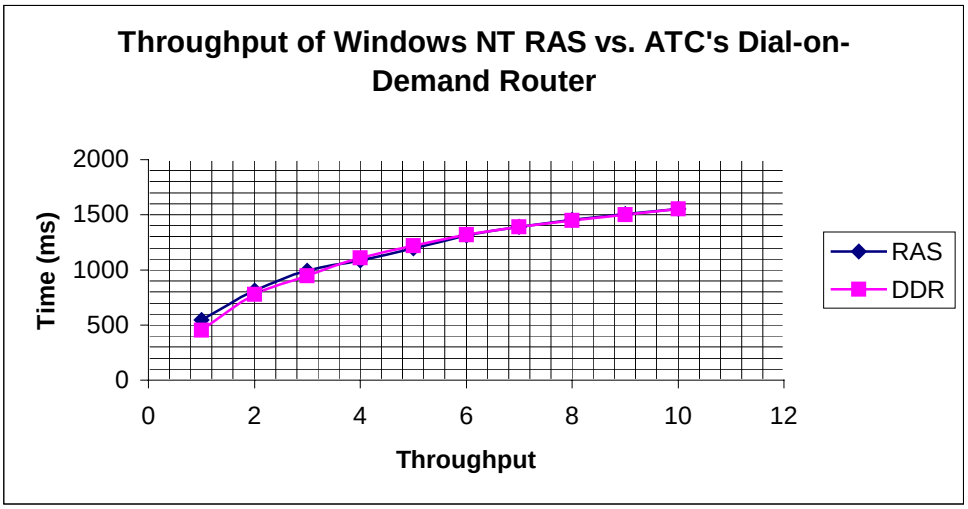

***Figure 7* – Windows NT RAS service vs. Dial-on-Demand Router "Throughput" Time**

Upon receiving the e-mail proxy, I began to have problems configuring it. However, after working with ATC, we solved the e-mail configuration problems and began testing. Using the same 2K, 4K, and 8K letters that ENS Reid used last year, I began to test how much the e-mail proxy improved the results. Below is the comparison with and without the e-mail proxy:

***Table 5* – 2K, 4K, and 8K messages with and without the e-mail proxy**

	2k (sec)	4k (sec)	8k (sec)	Batch of 3 4k's (sec)
With the e-mail proxy	16.7	22.0	21.1	69.3
Without the e-mail proxy	31.79	41.06	60.66	106.83

As you can see from the table above, the e-mail proxy definitely improve the results of sending messages via e-mail. Also, you may notice that the e-mail sent the 4k and 8k messages with approximately the same about of time. At first this puzzled me, and I re-ran the 4k and 8k messages test. The results came up the same. Then, I looked at the size of the message. My findings indicated that the messages are not exactly 2k, 4k and 8k. Instead, 1.5k, 4.07k, and 7.5k respectfully. Since the message was not the same size, I tried to look at the compression of the 4k and 8k message with Winzip. The 8k-compressed message was still larger than the 4k-compressed message. Therefore, the only explanation that I can come up for the 8k message taking up the same amount of time is that the e-mail proxy is more efficient with larger messages.

Conclusions

In conclusion, due to external problems that we experience, we do not believe that it would be possible for us to perform all the necessary tests that we originally plan. In the Large Cutter project, all the necessary testing for web pages were accomplished, however, no e-mail testing was started. During the testing of web pages, 1/c Bauer learned that the Mentat SkyX Gateway seem to improve web transmission, even though they generally improve TCP.

In Small Cutter side, 1/c Kawamoto learned that working with prototype software is difficult and can be frustrating. Overall, he was able to give comments and suggest to ATC on any ways they could improve their software. 1/c Kawamoto was unable to begin testing the web proxy. 1/c Kawamoto was unable to see if the Mentat SkyX Gateway would improve results due to the time spent trying to get the Dial-on-Demand Router to work.

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