Winter 1-31-1994

Performance of national research and education network while transmitting healthcare information data

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ABSTRACT

National Research and Education Network(NREN) is a first step in the process of building a National Information Infrastructure(NII). NII will ultimately lead to Broadband Integrated Services Digital Network(B-ISDN), a network which will support global exchange of voice, data, images and video.

NREN will evolve out of present National Science Foundation Network (NSFNET), also known as Interim NREN. At present NSFNET operates at 45 MBits/sec. By 1996, there are plans to boost the data rate to 155 MBits/sec and to 620 MBits/sec by the turn of century.

In this thesis, present actual NSFNET is simulated using software simulation tool NetworkII.5. The simulation is carried out for different Baud rates like 45 MBits/sec, 155 MBits/sec and 620 MBits/sec with increase in load or data rate traveling on the bus. The simulation helps in predicating the evolution and behavior of NREN.

Ultimately, NREN is modeled as transmitting healthcare information data and simulation is carried out for different Baud rates. In this model, NREN is transmitting both, the healthcare data for different types of services and other regular non-healthcare data.

Thus, research on National Research and Education Network evolution is carried out. The applications for such networks are expected to expand very rapidly, once these networks are available.

PERFORMANCE OF NATIONAL RESEARCH AND EDUCATION NETWORK WHILE TRANSMITTING HEALTHCARE INFORMATION DATA

by
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A Thesis
Submitted to the Faculty of
New Jersey Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Electrical Engineering

Department of Electrical and Computer Engineering

January 1994

APPROVAL PAGE

PERFORMANCE OF NATIONAL RESEARCH AND EDUCATION NETWORK WHILE TRANSMITTING HEALTHCARE INFORMATION DATA

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This dissertation is dedicated to my loving parents
Mr. Mahendra R. Shukla and Mrs. Damyanti M. Shukla.

ACKNOWLEDGMENT

The author is grateful to Dr. C. N. Manikopoulos, for his timely help, advice, suggestions and in guiding the thesis to it's destination.

The author wishes to express his sincere gratitude to Dr. Dan N. Celenti, for his guidance, friendship, and moral support throughout this research.

Special thanks to Dr. Edwin Hou and Dr. Sergey Belikov for serving as members of the committee.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Why We Need Gigabit Networks?

1.1.1 Evolution Of Networks

What is a network? The word has many different definitions in the world of automation, and its meaning has changed as technology has developed. Initially, computing was only done on large mainframe computers that, due to their expense and the specialized environments required for their operation, were centralized. During this period, network referred to the distributed system of terminals that were connected to a central mainframe computer. The single purpose of the network was to link terminals to a host computer that provided a particular service or a set of services.

As computers became more dependable, costs came down, more applications were developed, decentralization occurred. As developments took place, a change occurred in the use of networks. Microcomputers could not only communicate with mainframe and each other, but data could be moved to and from other computers and processed on these desktop machines. They could also provide many other capabilities which mainframe can do. With these developments networks became the central part instead of the mainframes. Initially, the quantity of data being transferred was less, hence data transfer time was also less, but as applications requiring large data transfer became popular interest shifted on in increasing the baud rate of transfer devices. Thus evolved, the megabits per second and gigabits per second networks[1]. The evolution of computer networks has been done in stages and is still not over.

1.1.2 Gigabit Networks

There has been a great deal of work in the last five to ten years on fast packet switching systems capable of providing much higher performance than conventional systems. Several laboratories have constructed experimental systems supporting large number of links operating at speed of about 100 MB/s and attention is now turning to systems that can support gigabit rate links. Much of this work has been technology-driven. The high speeds possible in fiber optic transmission systems have spurred development of networks that can exploit this capacity and allocate it flexibly among users with a variety of different applications.

It's natural to ask if we really need such networks in the first place. Only ten years ago, people used to ask, "Who needs a five MIPS personal graphics workstation?" and they used a minicomputer having a computation speed of under one million instructions per second, about 100 kilobytes of memory, strictly text display, dialup access to other computers and about 100 megabytes of storage. Moreover, the minicomputer was shared by about 50 people. Today, people use personal workstations with computation speeds of several million instructions per second, 4-16 megabytes of memory, graphic displays with over a million pixels and direct connection to local area networks that provide shared access to file servers with over a gigabyte of mass storage. Do we really need such computational power for individuals? We certainly do. The new workstation-based computing environment has unquestionably made systems more productive and has allowed to do things that would simply not have been possible with the older systems. The new systems are well worth the cost.

This revolution shows every sign of continuing unabated. Display technology continues to improve with inexpensive 2000 * 2000 displays expected in the near future. Higher speed LANs such as FDDI are becoming available and fast packet/ATM networks promise the extension of high speed networking to national and global networks. Moreover, high speed protocol processors are being developed to allow these networks to be more fully exploited. Workstations with memory sizes of up to one hundred megabytes are being available common, along with inexpensive removable read/write magneto-optical disks with capacities of several hundred megabytes. In the next few years, we expect personal workstations to be equipped not only with the standard amenities of high resolution graphics but also with options for audio and video input and output.

Of course, while the technology changes have been astounding, the real payoff in this revolution is in the applications that use the technology to solve problems that were beyond the reach of our previous computing environments. The emergence and widespread application of computer-aided design systems based on graphic workstations has changed the practice of engineering and architectural design. The development of workstations capable of displaying and processing images promises to revolutionize the fields of radiological medicine and publishing. The development of multimedia workstations that can integrate sound, still images, graphics and video, together with an appropriate supporting network infrastructure, promises to have a tremendous impact on education, professional collaboration and businesses.

While many of the applications of high speed networks and workstations will undoubtedly be specialized and highly sophisticated, the ones that will have the broadest impact will almost certainly be those that are useful to a wide segment of the population. One important application is video teleconferencing. This is an old idea, which has yet to be really successful, but which can be, given an implementation which is inexpensive enough to be widely available and that integrates the conferencing system with workstations that have the ability of placing one or more incoming full-rate video signals in a window on a large-screen workstation so that users could prepare presentations on their workstation and then present them to an audience at one or more remote locations, using "electronic viewgraphs" or even video-taped sequence to illustrate their talk. Such a system could have a dramatic impact on collaboration among professionals in many different disciplines.

Applications based on still images are also likely to be of considerable importance. The medical imaging application is a particularly interesting one at the moment, as it represents a significant application area with demanding and fairly well-understood requirements and in which the application of new technology can have a very significant benefit. Currently, roughly 75% images produced by radiology departments are the classical x-ray[2]. These are produced by exposing a photographic film to x-ray radiation that has passed through the patient's body. A growing fraction comprises newer imaging modalities such as ultrasound, nuclear medicine, x-ray and emission tomography and magnetic resonance imaging. These modalities are inherently digital, requiring computer processing to create the image using data obtained from a variety of different sensors. They are capable of producing images of slices through the patient's body and can be used to generate three-dimensional models of a portion of a patient's anatomy, allowing a physician to see not only cross sections, but three-dimensional views of joints and organs, with selected layers of tissue removed to facilitate diagnosis and evaluation of therapy. Even the classical x-ray is now being produced in digital form, allowing to bring out features not otherwise readily apparent on an unprocessed film. Different imaging modalities have different requirements for display. Digital x-rays require 2000 * 2000 displays with 12 bits of gray scale. Computerized tomography is currently done at resolutions of 512 * 512, but this is currently moving to 1024 * 1024. Ultrasound is inherently limited to lower resolutions, typically 256 * 256. Some modalities, including ultrasound and nuclear medicine are capable of producing moving images allowing physicians to observe blood flow through the heart, for example.

There is a present need to distribute radiological images to over a thousand locations within the medical center, as well as to clinics throughout the community where physicians carry out their practice. In some cases these applications require peak user channel speeds of about more than 100 MB/s and as three-dimensional reconstructions become more widely used, another order of magnitude will be needed. These are real applications that exist today and a much broader set of applications are likely to spring up in other disciplines as the enabling technology becomes inexpensive enough to spur their development.

We're clearly in the midst of a technological revolution that is changing the way we work in fundamental ways. Gigabit networks are but one element of that revolution, albeit a particularly important one as they will provide the "glue" that allows the other pieces to interact. The applications of gigabit networks that will have the widest impact will be those that rely on visual information in one form or another, in part, because such applications require the higher bandwidths that gigabit networks can provide and in part because they will make the new technology useful to a much wider population of users. There are many applications of such networks that we can readily envision, but this technology will certainly enable many applications that we cannot now foresee. Hence the ultimate answer to the question of "Who needs gigabit networks?" is "almost everybody," but we will only know that for sure once we have built them and start putting them to use.

1.2 Broadband Integrated Services Digital Network(B-ISDN)

1.2.1 Broadband Integrated Services Digital Network

Broadband integrated services digital network (broadband ISDN) is a network designed to carry data, voice, images and video. Asynchronous Transfer Mode (ATM) is now decided as new physical layer to be developed for use in broadband ISDN systems. The applications for such networks are expected to expand rapidly after such networks are available[4].

A high -resolution image represented by 10^9 bits requires over four hours for transmission on a 64 Kbits/sec circuit and would require 11 minutes on a 1.5 Mbits/sec circuit. Broadband ISDN is an effort to provide, among other things, data rates that are high enough to comfortably handle image data in the future. The planned access rate for broadband ISDN is in gigabits per second, which is adequate for image traffic and also allows for the interconnection of high-speed local area networks[5]. This access rate also allows video broadcast, video conferencing and many potential new applications.

Despite the enormous difference between broadband ISDN and the voice network, broadband ISDN will probably evolve out of the present-day voice network. The reason for this is that the bulk of transmission and switching facilities currently exists within the current voice network, and current wide area data networks typically lease their transmission facilities from the voice network[6]. Because of this, the early thinking about broadband ISDN focused on using the synchronous 125 micro second frame structure of the voice network to provide the physical layer transmission[3].

1.2.2 Comparison Of Broadband ISDN With Data Networks

1. The link speed in broadband ISDN is very great compared to the link speed

in conventional data networks. Hence, the designers of broadband ISDN are more concerned with computational complexity and less concerned with efficient link utilization, while the designers of conventional data networks are more concerned with efficient link utilization.

2. Because of speed constraints, the broadband ISDN protocols should be simple and amenable to both parallel and VLSI implementation. The conventional data networks protocols should have higher throughput rate.

3. Data applications that require fixed bit rate and/or fixed delay usually avoid data networks and instead use dedicated leased lines from the voice network, because data networks adopt packet switching which has packets having variable delays, as flow control is used to reduce data rates. In contrast broadband ISDN is intended to supply all necessary telecommunication services, and thus must provide those services, since there will be no additional voice network on which to lease lines.

1.2.3 Comparison Of Broadband ISDN With Voice Networks

1. All voice sessions on a voice network are time-division multiplexed together. They use the SONET standard, i.e. use a 125 micro sec frame broken up into a large number of one byte slots on 64 Kbits/sec line. Switching is accomplished at a node by mapping the slots in the incoming frames into the appropriate slots of the outgoing frames. In contrast, broadband ISDN must cope with potential user rates from less than 1 bit/sec to hundreds of megabits per second. It must also cope with both bursty traffic and constant-rate traffic[7].

1.3 Thesis Overview

The main aim of the Thesis is research on evolution of National Research and Education network (NREN). NREN will be a gigabit speed network transporting billions of bit of information per second. NREN is a great step in the direction of Broadband Integrated Services Digital Network. It is said that NREN will evolve out of the present NSFNET (also known as Interim NREN).

The second chapter describes National Research and Education Network in detail.

The third chapter is devoted to Asynchronous Transfer Mode - the physical layer for NREN and future high speed networks.

The fourth chapter explains how the advance computer networks can help the healthcare industry.

NREN does not exist at present, so the structure or how NREN actual will be is difficult to predict. But, it will definitely evolve out of the present day telecommunications system that is sure. Present day telecommunication system is layered distributed, i.e. there are central switches which do the routing and transmission. Chapter five analysis a one layer distributed network.

Chapter six deals with the analysis of actual present NSFNET. Simulations in chapter four and five are carried out using software simulation tool NETWORKII.5 on asynchronous transfer mode. Chapter six also deals with the conclusions of NREN evolution.

In Chapter 7, NREN is simulated as transmitting healthcare information data on NREN. The healthcare information data is generated in proportion to the population around each node of NREN. Again, simulation is carried out using NETWORKII.5 The result's obtained are shown in Table 3.

CHAPTER 2

NATIONAL RESEARCH AND EDUCATION NETWORK (NREN)

2.1 Introduction

National Research And Education Network (NREN) is a first step in the process of building a national data highway[8]. It is a federally funded gigabit-speed networking program. Some call NREN as a national information superhighway. NREN will be a gigabit network that would transmit billion bits of information or more per second. The thought of NREN as a national information infrastructure is very exciting but most of it's details are yet to be specified.

Initially, the major goal of NREN is to create a high-speed computing network among dozens of government labs, agencies and institutions such as the Department of Energy, the Defense Department and the National Aeronautics and Space Administration[8]. However, ultimately research labs, universities, libraries, hospitals, businesses and eventually consumers will be hooked into this vast high speed computing network capable of shipping billions of bits of digital information anywhere in the country on fiber optic cables.

With such network, researchers in labs thousands of miles away from each other might share a supercomputer in order to work simultaneously on the same experiment. A doctor in a poor, rural community could use advanced diagnostic equipment from a large research hospital in a distant city to analyze the medical information of a patient[8]. Some other applications are information retrieval services, multimedia file transfer, interactive videoconferencing, multimedia mail, electronic data interchange etc. The network would allow researchers, business-people, educators and students around the US to communicate with each other and access a broad range of research tools and information resources. Since NREN will be a gigabit speed network, it will have sufficient capacity for researchers in different laboratories to simultaneously manipulate real-time, shared computer simulations and CAD models[9].

NREN can offer thousand of times more the capacity than the Internet T1 and variety of advanced telecommunications services. In essence, we can say that NREN is a step towards broadband integrated services digital network (B-ISDN) designed to carry data, voice, images and video[11].

Despite the enormous difference between NREN and the present voice network, NREN will evolve out of the present day voice network. The reason for this is that the bulk of transmission and switching facilities currently exists within the current voice network and current wide area data network typically lease their transmission facilities from the voice network. The voice networks are upgraded using fiber optic cables for the very same reason[10].

According to the National Science Foundation (NSF), NREN will evolve out of Interagency Interim NREN (otherwise known as NSFNET). The Internet's T3, operating at 45 M bit/sec backbone spans the country and NSF is planning to boast it's data rate to 155 M bit/sec over a next few years[12]. As an expansion of the National Science Foundation's Network (NSFNET), portion of the Internet, NREN is already a commercially viable information highway. NREN today consists of the NSFNET backbone and five gigabit testbeds. By 1996, the NSFNET will run at 155 M bit/sec or faster and will be joined with the test-beds which will be operating at 1.2 G bit/sec or higher[13].

The test-beds of NREN are Aurora, Blanca, Casa, Nectar and Vistanet[12]. These, are collaborative efforts between industry and academia. The test-beds actually have twin goals, to experiment with different gigabit network architecture and to develop applications for such networks. At Casa, for example, work is underway on distributed computing software for such computational intense tasks as chemical reaction analysis and visualization. Vistanet researchers are mapping out medical imaging applications.

Some of the most innovative architectural work is being done at Aurora, Blanca and Nectar. Aurora will link four sites: Bellcore's Research and Engineering Laboratory (Morristown, N.J.), IBM's T. J. Watson Research Center (Hawthorne, N.Y.), Massachusetts Institute of Technology's Laboratory for Computer Science (Cambridge, Mass.) and the University of Pennsylvania's Distributed Systems Laboratory (Philadelphia)[12]. Links between sites will consist of multiple Sonet OC-12 (622 M bits/sec) circuits. There will be atleast two switches at each site. One will be an experimental ATM switch from Bellcore called Sunshine; the other, an experimental switch from IBM called Planet. Planet can handle ATM cells and an IBM developed technology known as packet transfer mode (PTM). The key difference between the two switching schemes is that PTM works with variable-length packets while ATM uses fixed-length (53 byte) cells[12].

Researchers used to suspect that PTM may outperform ATM for data transmission for several reasons. For one thing, it can accommodate the data units naturally generated by applications without requiring them to be disassembled and reassembled into cells. Eliminating this processing reduces switching overhead and improves throughput. For another, it improves the header/packet ratio. ATM uses a 5 byte header for each 48 byte cell; PTM uses the same size header, but packets can be much larger, so the percentage of bandwidth devoted to the header is lower. Finally, researchers also suspected that PTM may have better delay characteristic. One of the goals at Aurora was to compare the performance of ATM and PTM with different types of traffic[12].

However, ultimately it was decided to use ATM as the physical layer mode for NREN[16]. Blanca will connect FDDI LAN's at three sites via routers and ATM switches. Connectivity is the chief concern at Nectar and Aurora. Research at Vistanet is geared to supercomputing and medical imaging.

Attaining gigabit per second data rates for NREN means turning to technologies like SONET (Synchronous Optical Network) and HPPI (High Performance Parallel Interface) as well as ATM and PTM related switching schemes[14].

As a first step towards NREN, the Department of Energy awarded a 5 year, $ 50 million contract for high speed public switched Asynchronous Transfer mode (ATM) services to Sprint Corporation, in August 1992. Under the contract Sprint will supply the Department of Energy and NASA with ATM service at 45 M bit/sec T3 speeds (which can be later increased to 622 M bits/sec) based on a specification approved by ATM forum. Hence ATM can be considered as NREN's underlying technology.

2.2 Proposed Evolution Of NREN And It's Relationship With National Information Infrastructure(NII)

2.2.1 The NREN And NII

The ultimate aim is to have all computers linked by an infrastructure like the highway system and the electric power grid, creating a new kind of free market for information services. There are multiple paths to achieving the long-range goal of an affordable, ubiquitous, high-performance communications infrastructure for the nation. The NREN will be an important part of the evolution to the NII, and the research and education community has important roles to play in this evolution.

NREN will provide research, development, technology transfer, and

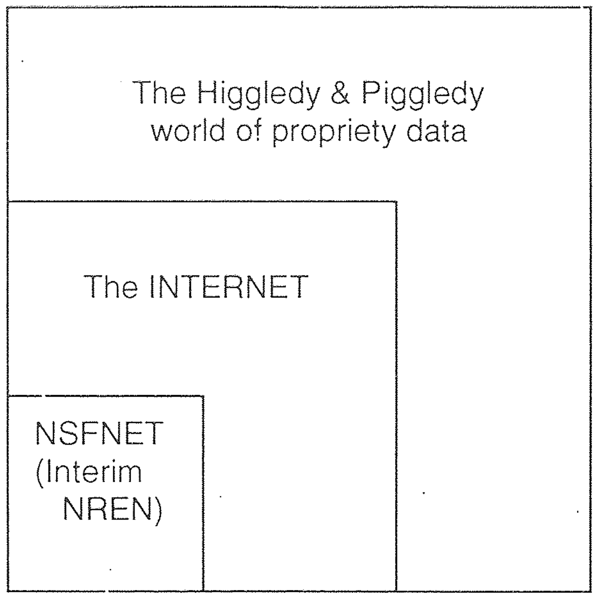


Figure 1 The present computer network structure

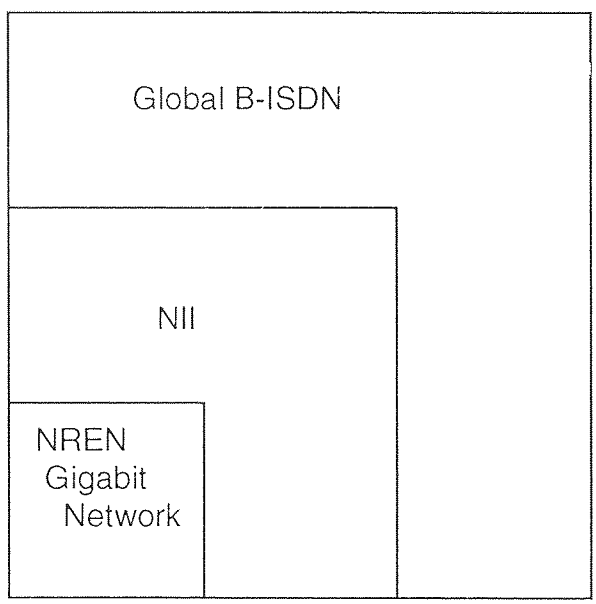


Figure 2 The future computer network structure

market-making functions for the NII. The process of proceeding from technological feasibility to functional utility to consumer services on the NII will be enhanced by the work within research and education to build the NREN.

Figure 1 is a schematic view of the current universe of computer networks. It is a diverse landscape of new and old technologies, a higgledy-piggledy world into which computer and communications firms have launched every imaginable form of proprietary system in search of markets and profits. Within that world, there is the rapidly growing Internet, a family of networks devoted largely to research and education, which all share a single packet architecture called TCP/IP. Within the Internet community is NSFNET. Each of these major network sectors is driven by a different set of service, technical, and economic factors, and each has its own barriers to adoption of advanced communications technology[17].

Figure 2 is a future view of the evolution of computer-based networks. On a worldwide basis, broadband digital communications technology will become pervasive and will form the underlying fast packet transport system for all forms of communications media[17].

Within the global world of Broadband-Integrated Services Digital Networks(B-ISDN), national communications infrastructure will form. The speed and architectural flexibility of B-ISDN will create dozens of new market opportunities for communications services of all kinds. Thus, we can say that NREN will give way to NII and NII will in turn give way to B-ISDN.

2.2.2 NREN Transition to NII

Building the NREN has frequently been described as akin to building a house, with various layers of the network architecture compared to parts of the house. In an expanded view of this analogy, planning the NII is like designing a large, urban city. The NREN is a big new subdivision on the edge of the metropolis, reserved for researchers and educators. It is going to be built first and is going to look lonely out there in the middle of the pasture for a while. But the city will grow up around it in time, and as construction proceeds, the misadventures encountered in the NREN subdivision will not have to be repeated in others[18]. And there will be many house designs, not just those the NREN families are comfortable with. The lessons we learn today in building the NREN will be used tomorrow in building the NII.

2.3 Some major difficulties in implementing NREN

1) Building such a network in the US could cost as much as $150 billion[8]. Financing, NREN is one of the major problems. Updating present Internet by installing fiber optic cables is also very expensive.

2) NREN is supposed to be a national gigabit network. Connectivity is one of the chief problems, also speeding up the data rate of transmission is a problem[15].

3) NREN will require advanced routing and addressing schemes, besides sophisticated protocols[19].

4) Shaping applications suitable for NREN also causes problems.

CHAPTER 3

ASYNCHRONOUS TRANSFER MODE

3.1 Introduction

Asynchronous transfer mode is a new physical layer developed for use in broadband ISDN systems[16]. A broadband integrated services digital network(broadband ISDN) is a network designed to carry data, voice, images andvideo. As interest in broadband ISDN increased and as standardizations efforts started, people debated on use of the conventional synchronous frame structure known as STM (synchronous transfer mode) or use of a packet structure known as ATM (asynchronous transfer mode). Fundamentally, therefore, the choice between STM and ATM is the choice between circuit switching and packet switching.

The lack of flexibility in STM is particular troublesome at the local loop. Here, given a small set of sessions, each would have to be assigned one of the standard rates. Any attempt to multiplex several sessions on one standard rate, or to use several standard rates for one session, would lead to considerable complexity. In comparison with these problems of matching sessions to standard rates, the ATM solution of simply packetizing all the data looks very simple. While the relative merits of STM and ATM were being debated, there was great activity in developing high-speed packet-switching techniques. These techniques were highly parallelizable and amenable to VLSI implementation. As a result of both the flexibility of ATM for local access and the promise of simple implementation, the CCITT study group on broadband ISDN selected ATM for standardization[16].

3.2 Asynchronous Transfer Mode (ATM)

3.2.1 Asynchronous Transfer Mode

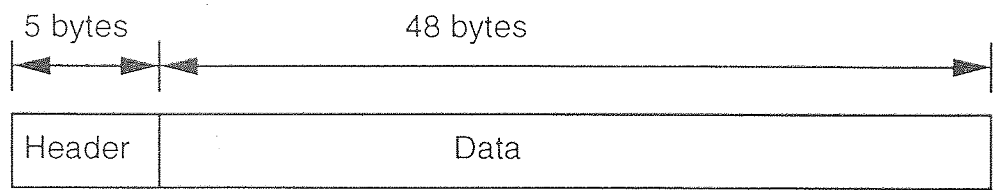
ATM packets (or cells) all have the same length, 53 bytes, consisting of 5 bytes of header information followed by 48 bytes of data as shown in figure. The reason for choosing a fixed length was that implementation of fast packet switches seems to be somewhat simpler if packets arrive synchronously at the switch and this would allow early implementation.

The major reason for choosing 48 bytes of data for this standard lengtn was because of the packetization delay of voice. Standard 64 Kbit/sec voice is generated by an eight bit sample of the voice waveform each 125 microsec[20]. Thus, the time required to collect 48 bytes of voice data in a cell is 6 msec. Even, if a cell is transmitted with no delay, the reconstruction of the analog voice signal at the destination must include this 6 msec delay. The problem now is that this reconstructed voice can be partially reflected at the destination and be added to the voice in the return path, and thus an overall delay of 12 msec in the returning echo. A delayed echo is quite objectionable in speech, so it should either be kept small or be avoided by echo cancellation In the absence of echo cancellation everywhere, it is desirable to keep the delay small. There are several reasons to keep a larger cell.

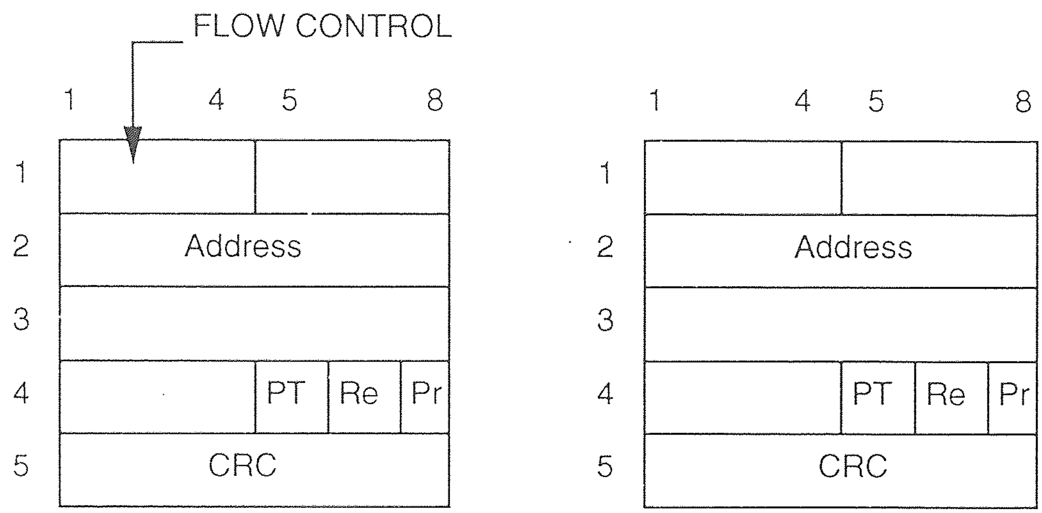
1. There is a fixed amount of computation that must be done on each cell in an ATM switch, and thus the total computational overhead on each switch increases with small cell size.
2. Small cell size leads to communication inefficiency, due to cell header.

The length of 48 bytes was a compromise between voice packetization delay and above reasons for wanting larger cells[20].

Hence, 48 bytes of data and 5 bytes of header makes total length of an ATM cell as 53 bytes.



Packet (cell) format in ATM. The Cell size is fixed.



User-subnet access

Internal subnet

ATM header format for the user-subnet interface and for the internal subnet. PT stands for payload type, Re for reserved and Pr for priority bit.

Figure 3 The format of the header for ATM cells

3.2.2 Format of the Header for ATM cells

The format of the header for ATM cells has two slightly different forms, one for the access from user to subnet and the other within the subnet. The only difference between the header at the user-subnet interface and that inside the network is a four bit "generic flow control " field provided at the user-subnet interface. This is intended to allow the user to mediate between the demands of different applications at the user site. The user of this field is not standardized and is used only to help the user to statistically multiplex the cells from different applications onto the access link to the network[21].

The contents of the address field in the header can change as the cell travels from link to link. ATM uses virtual circuits, and when a virtual circuit is set up for a session, a virtual channel number is assigned to that session on each link along the session's path. Since the address field contains 24 bits for the user-network interface, over 16 million session can access the network from one user site. Within the network, the address field contains 28 bits, allowing for over 268 million sessions to share a link[22].

In ATM, the address field is divided into two subfields, called the *virtual channel identifier* (VCI) and the *virtual path identifier* (VPI). The reason for this is to allow sharing the same path (or at least sharing the same path over some portion of their entire paths) to be assigned the same virtual path identifier and to be switched together. For example, two office buildings of a given corporation might require a large number of virtual circuits between the two offices, but they could all use the same virtual path identifier and be switched together within the network. The VCI subfield contains 16 bits, and the VPI subfield contains 8 bits at the user-subnet interface and 12 bits within the subnet[22].

After the address field comes the "payload type" field, which is used to distinguish between cells carrying user data and cells containing network control information. The next field "reserved field" is not used. At the end of the header is an eight bit CRC checking on the ATM header. The generator polynomial of this CRC is $g(D) = D^8 + D^2 + D + 1$[21]. This is the product of a primitive polynomial of degree 7 times D + 1. CRC checks only on the cell header, not on the data. Thus errors in the data are delivered to the destination and some other means is required to achieve error-free transmission of user information. The reason for checking the header is to reduce the probability of having data for one user get delivered to another user. CRC is used not only to detect errors but also if possible rectify them.

In an attempt to guard against burst of errors due to equipment problems, the receiving node switches between single error correction and pure error detection. After either correcting an error or detecting more than a single error, the decoder switches to an error-detecting mode and stays there until the next header is received without detected errors.

3.2.3 The Adaptation layer

3.2.3.1 Function

The adaptation layer of broadband ISDN sits on top of the ATM layer and has the function of breaking incoming source data into small enough segments to fit into the data portions of ATM cells. In the sense that ATM is performing the functions of a network layer, the adaptation layer performs the function of a transport layer. Thus the adaptation layer is normally used only on entry and exit from the network[23]. Since the adaptation layer interfaces with incoming voice, video, and message data, its function must depend on the type of input. The adaptation layer is not yet well defined within the standards bodies and is in a state of flux.

Different types of inputs are separated into the following four major classes within the adaptation layer[24]:

CLASS 1: CONNECTION-ORIENTED DATA

Examples of this include all the conventional applications of data networks (assuming that a connection is set up before transferring data). This class includes the signaling used within the subnet for network control and establishment of connections.

Finally, it includes very-low-rate stream-type data.

CLASS 2: CONNECTIONLESS DATA

Examples include the conventional applications of data networks in cases where no connection is set up.

CLASS 3: CONSTANT-BIT-RATE TRAFFIC.

Examples of this are 64 Kbit/sec voice, fixed-rate video, and leased lines for private data networks.

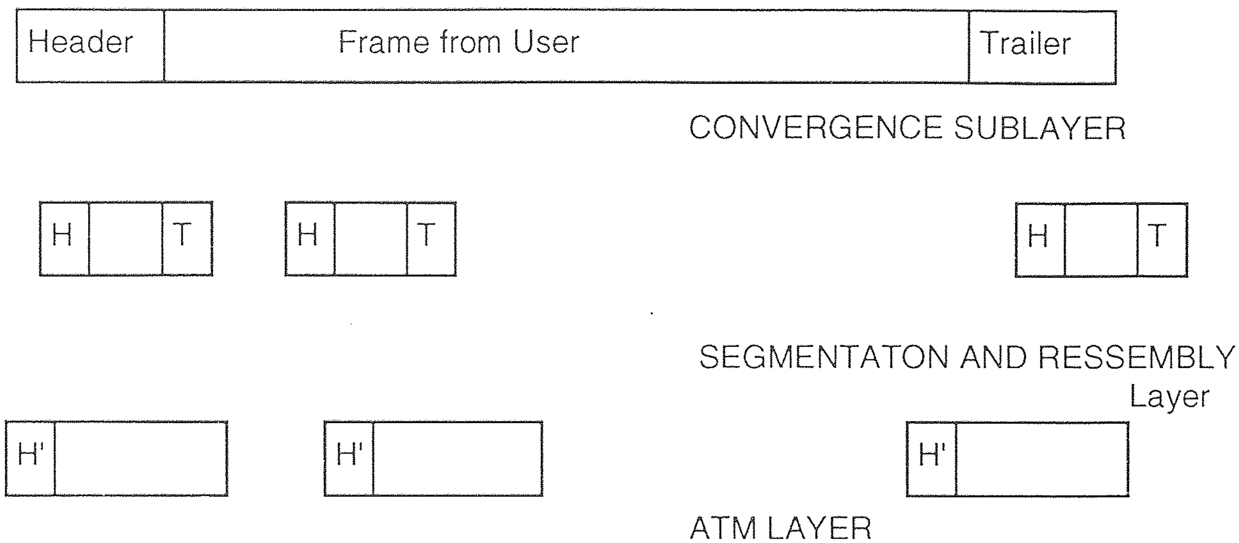
CLASS 4: VARIABLE-BIT-RATE PACKETIZED DATA THAT MUST BE DELIVERED WITH FIXED DELAY.

Examples of this are packetized voice or video; the packetization allows for data compression, but the fixed delay is necessary to reconstruct the actual voice or video signal at the receiver.

For classes 1, 2, and 4, the source data coming into the adaptation layer are in the form of frames or messages. The adaptation layer must break these frames into segments that fit into the ATM cells and provide enough extra information for the destination to be able to reconstruct the original frames.

3.2.3.2 CLASS 1 Connection-Oriented Traffic

The adaptation layer is split into two sublayers, called the convergence sublayer and the segmentation and reassembly sublayer. The first treats



Headers and Trailers at the Convergence Sublayer and Segmentation & Reassembley Sublayer of the Adaptation layer. The Data plus Header and Trailer at the Segmentation and Reassembly sublayer must be exactly 48 bytes in length to fit into the ATM data area.

Figure 4 The breakdown of frame into ATM cells the user frames as units and is concerned with flow control and error recovery. The second treats the segments of a frame as units and is concerned with reassembling the segments into frames. As usual, peer communication between nodes at each sublayer takes place via header and trailers. Current plans call for a two byte header and two byte trailer in the segmentation and reassembly sublayer.

The header consists of the following fields[21]:

Segment type (2 bits) . This distinguishes whether a segment is the beginning segment of the convergence sublayer frame, an intermediate segment, a final segment, or a segment that contains an entire frame.

Sequence number (4 bits). This number segments within a convergence sublayer frame; this helps check on dropped or misdirect cells.

Reserved (10 bits). This might be used to multiplex multiple-user sessions on a single virtual circuit.

The trailer consists of the following fields[21]:

Length indicator (6 bits). This tells how many bytes from the convergence sublayer frame are contained in the given segment. This is useful primarily for the last segment of a frame.

CRC (10 bits). The CRC polynomial is $D^{10} + D^9 + D^5 + D^4 + D + 1$. This is a primitive polynomial times $D + 1$ and is used to check on the entire segment, including the header and the length indicator of the trailer.

The header and trailer above provide enough data to reconstruct the convergence sublayer frames from the received segments. The sequence number and CRC also provide some protection against bit errors and dropped or misdirected cells.

3.2.3.3 CLASS 2 Connectionless Traffic

The headers and trailers at the segmentation and reassembly sublayer are expected to be the same for class 2 and class 1 traffic. The problem is that of connectionless traffic in a network where the cells are routed by virtual circuits. The most promising approach to this traffic is to view the routing as taking place at a higher layer than the adaptation layer; essentially this means viewing the datagram traffic as a higher-layer network using ATM virtual circuits as links.

Thus, whereas connection-oriented traffic enters the adaptation layer only at origin and destination, connectionless traffic passes through the adaptation layer at each node used as a datagram switch. Between any two datagram switches, the traffic would use permanent virtual circuits assigned to carry all the connectionless traffic between the two switches[21].

3.2.3.4 CLASS 3 and 4 Traffic

The Class 3 traffic is constant-bit-rate traffic without any framing structure on the input to the adaptation layer. Thus a user data stream simply has to be broken into segments. The current plan is to use a one byte header and no trailer at the segmentation and reassembly sublayer(thus providing 47 bytes of user data per ATM cell). The header consists of a four bit segment number plus a four bit CRC on the segment number. The reason for this is that occasional errors in this type of data are permissible, but to maintain framing, it is important to know when data have been dropped or misinserted, and the segment numbers provide this protection. Class 4 traffic has the same resilience to occasional errors as class 3 and the same need to know about dropped cells. At the same time, it has an incoming frame structure, requiring some of the features of the class 3 protocol for reassembling the frames[21].

3.3 Synchronous Transfer Mode

The early objective for broadband ISDN was simply to increase data rates to allow for video, high-resolution images, and interconnection of high-speed local area networks. Within the frame structure of the voice network, it is possible to group multiple slots per frame into a single circuit whose rate is a multiple of 64 Kbits/sec. This synchronous frame structure of the voice network is known as synchronous transfer mode (STM). These higher-rate circuits could also be used in broadband ISDN for high-rate services such as video. In this sense, broadband ISDN was initially visualized as an evolution from narrowband ISDN, maintaining the emphasis of the 64 Kbit/sec speed.

3.4 Comparison between STM and ATM

1. Fundamentally, the choice between STM and ATM is the choice between circuit switching and packet switching.
2. ATM offers greater flexibility compared to STM. STM would require each circuit- switched application to use some standard multiple of 64 Kbits/sec.
3. STM leads to greater switching complexity, if the number of standard rates were large. On the contrary, the ATM solution of simply packetizing all the data is very simple.
4. In a local loop, for STM, given a small set of sessions, each would have to be assigned one of the standard rates. Any attempt to multiplex several sessions on one standard rate, or to use several standard rates for one sessions, would lead to considerable complexity. While in ATM, as all data are packetized there is no great switching problem[25].

3.5 ATM and OSI Seven Layer Architecture

Let us see how ATM fits into the OSI seven-layer architecture. In the original view of ISDN, the synchronous frame structure of STM was viewed as the physical layer for data transmission. Thus, when ATM replaced STM, it was reasonable to consider ATM as the physical layer for data transmission. This had the added advantage of relieving ATM from any responsibility to conform to the OSI standard network layer. Another consequence of using ATM in place of STM, is that there is no longer a need for a packet-switched network on top of ATM. ATM deals with bursty data directly as a packet-switching technique in its own right. ATM, as a packet-switching layer, has an adaptation layer on top of it. This adaptation layer is much like the transport layer of OSI; it breaks up the incoming messages or bit streams into fixed-length packets, and it is the responsibility of the adaptation layer, using the ATM layer, to reconstitute the messages or data stream at the other end. What comes in could be OSI layer 2 frames; the adaptation layer will view this as a user message, break it into "cells" and reconstitute the user message (i.e. the frame) at the destination. Thus, as far as the OSI layer 2 is concerned, the broadband ISDN looks like a bit pipe. Naturally, there is no need for a user to go through all the OSI layers, since data can be presented to the broadband ISDN[26].

There is no Data Link Layer beneath ATM, because there is no need for ARQ nor framing. There is no need for ARQ for two reasons:

1. The error probability is very low on the links.
2. Large part of traffic is expected to be voice or video, where retransmission is inappropriate.

Thus, error recovery is more appropriate on an end-to end basis.

Since, all cells are of same length, framing information is not needed on each cell[27].

CHAPTER 4

IMPACT OF COMPUTER NETWORKS ON HEALTHCARE INFORMATION DATA

4.1 Introduction

Communication is fundamental to the practice of medicine, yet medical communication is less efficient than in any other sector.

Transport of healthcare information, on computer networks can save millions of dollars yearly. As stated by Kadas and Butler[28] in, Computer in Healthcare the data on electronic claims is as follows:

-Each year patients and healthcare providers file nearly 4 billion insurance claims.

-Industry experts estimate that electronic filing (with use of computer networks) could cut costs by as much as $1 per claim, saving about $8 billion in national healthcare costs annually, according to the Health Insurance Association of America.

-More than 300 electronic claim formats are now in use by payers throughout the nation, but it is still not sufficient.

-Most private claims submitted manually take, on average, 12 to 25 days to process. Electronic filing cuts processing time to about 10 days and is considerably more accurate. Medicare takes about 21 days to process manual claims, and 17 days to process electronic claims.

-Health and Human Services officials note that by incorporating electronic funds transfer services into a nationwide electronic claims systems, administrative costs of paying claims will drop from a current average of 29 cents per transaction to just 3 to 10 cents. In addition, providers will have quicker access to their money and be assured funds are deposited. The

Health Care Financing Administration(HCFA) wants to implement direct deposit as soon as possible.

-HCFA has created a strategic plan to increase electronic claims. According to HCFA, the agency now receives more than 75 percent of all hospital and 44 percent of other claims electronically.

This all indicates that people do realize the importance of transferring healthcare information data on networks and much work has been done in this direction.

4.2 Medical Communication Network

What should be the characteristics of a medical communication network? According to Hanlon and Kaskiw[29]:

The network should be designed to enhance the efficiency and effectiveness of communication among the hospitals, specialists and primary-care physician. Its main application should be interconnecting hospitals and physicians over normal dial-up telephone lines. It could be used to deliver automatic lab and radiology reports, patient information, referral and admission information, selected clinical graphics and digitized voice file.

In addition to these, the medical communication networks should be capable of shipping x-rays, CAT-scans and also video data in case specialists should decide to form a video-conference to discuss something.

Such an advance health information network could be used to send data from physician's office to the hospitals or vice versa. A physician can use the system to schedule appointments for his patients with specialists, send patient records and test results to other physicians and receive results of tests as soon as they are transcribed. Reports that take weeks can arrive in minutes[15]. The hospital- physician computer link is one of the most popular tactics in the field of medical, such prompt communications can cement relations between specialists, primary-care physicians and hospitals and help them improve patient care[31].

4.3 Advantages of NREN on National Health Care System

Telecommunications technology can be used to solve problems of high costs and inadequate access currently dogging the national health care system as stated before. A study conducted by the consulting firm Arthur D. Little Inc., Cambridge, MA, supports this view[32]. The study projects that U.S. health care costs could be trimmed by more than $36 billion annually through wide spread electronic management of patient information, electronic claims processing, electronic inventory procedures and videoconferencing. Predicted annual savings through wider use of telecommunications[32].

$30 billion	: Electronic management of patient information
$6 billion	: Electronic claims processing
$600 million	: Electronic inventory controls
$200 million	: Videoconferencing

When access to NREN is available for transfer of health care information, annually billions of dollars could be saved. Doctors will be able to form one gigantic consulting group, shipping X-rays, CAT scans and other test results to specialists for expert opinions. Saving are also projected to result from early intervention in medical problems, fewer patient visits to emergency departments and clinics and directing patients to the most appropriate level of care. Improving the flow of information between hospitals and physicians is especially critical. A physician can access the records of his patient (pathology, radiology, medical etc. test results) easily from a distant hospital's mainframe computer through NREN. This means using information in a truly integrated way.

NREN can be used to send laboratory test results and reports, admissions data to each physician's office from the hospital. A physician can use the system to schedule appointments for his patient's with specialists. Reports that take weeks can arrive in seconds.

NREN can be used to transmit health care research data, and physicians thousands of miles away can communicate with each other to find solutions to dreadful diseases like AIDS. NREN can reduce turnaround time from days to minutes.

Financial functions, such as verification of insurance eligibility and claims submission cost less through an information network reducing administrative costs. Computer networks are mentioned as a key strategy for rapid development of health care systems with less cost since many years. However, much has to be done in development of health care information systems. NREN may solve most of the problems associated with health information network. NREN may stop paper processes in healthcare. Electronic information can be reused and enriched without duplication within an "integrated" institution. Gabler[33] says that the time has come for healthcare providers to stop hoarding information. By building healthcare information networks, providers at all levels can gain a competitive edge not by "owing" information, but by better using richer, more complete, "shared" information. Lumsdon[34] says computer networks place clinical information into the hands of physicians sooner. He adds in our heavily managed care environment. this is desirable thing to do, and there is plenty of evidence that it leads to better outcomes.

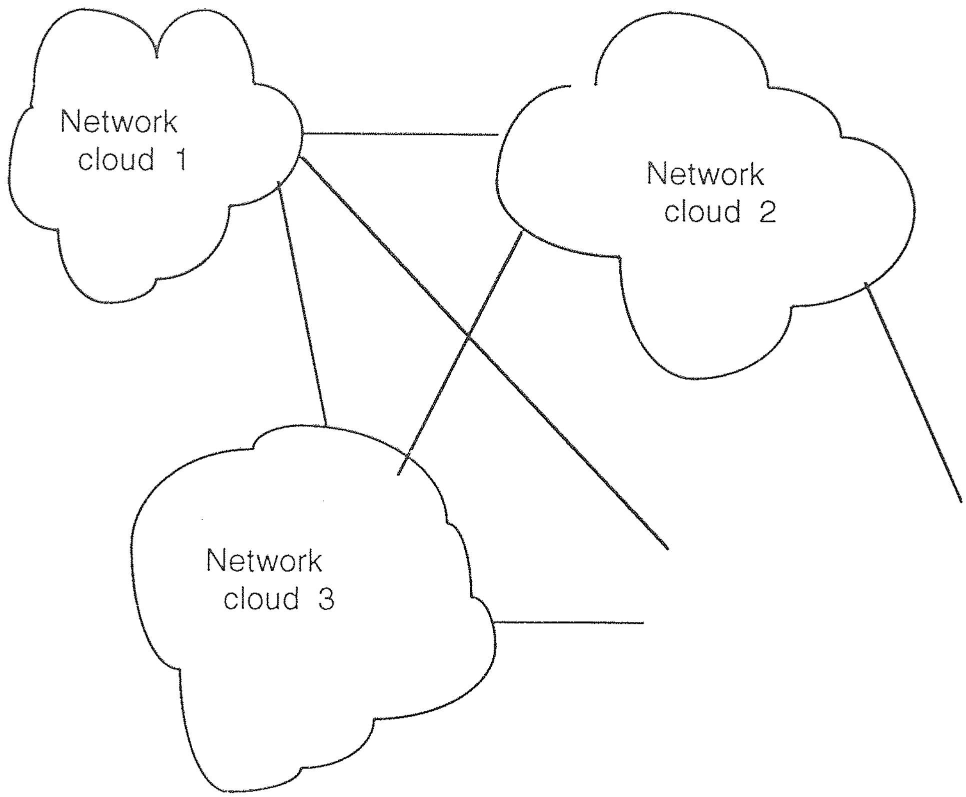


Figure 5 The distributed present day Telecommunication System

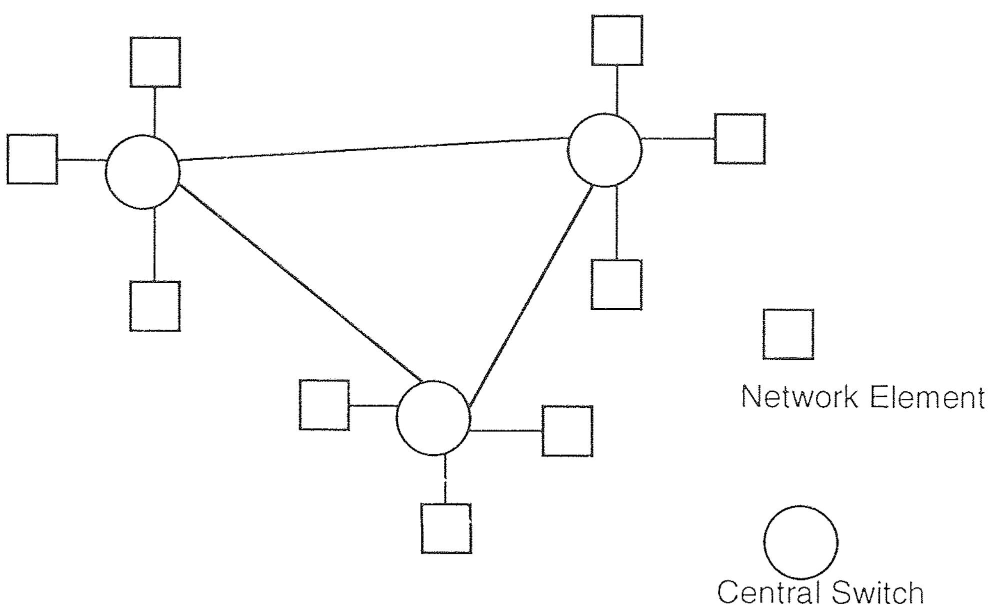


Figure 6 The Simulated Network

CHAPTER 5

THE SIMULATED NETWORK

5.1 Introduction

Present day, telecommunications network is distributed. For example, if a person wants to call to London from New York, his call would first be transferred to a central New York telecommunication switch, then to one of the central USA telecommunication switch, then to one of the central European telecommunication switch and then to central England or London switch and finally to its destination[35]. National Research and Education Network (NREN) will evolve out of present day telecommunications system. We can reasonably assume NREN to be distributed in a similar way as shown in figure 5.

5.2 The Simulated Network

It is difficult to simulate a distributed network. Hence for our purpose a one layer distributed network as shown in next figure 6 is simulated assuming NREN will evolve out of such network. As shown in figure there are nine Network elements and three Central switches connected by various transfer devices representing buses.

The simulation is carried out using software simulation tool NetworkII.5. All the network elements and the central switches are represented in the software program using high-level language of NetworkII.5 as processing elements. These processing elements operate at 50 MHz frequency with input controllers (DMA). The buses are represented as transfer devices operating on Asynchronous transfer mode switches. The Baud rate of these transfer devices varies as 45 Mbits/sec, 155 Mbits/sec and 620 Mbits/sec. The protocol used is first come first served always. Each processing element has independent software modules assigned to it, which when activated execute to the respective processing element and the processing element carries out the function as asked by the module (sends data to the respective destination). The arrival of data at a node is random and also the length of the message is random. Poisson arrivals are simulated (exponential distributed inter-arrival times). This is incorporated in the software program by use of statistical distribution functions which are exponential. The iteration period of activation of each module for transmission of data is exponential statistical distribution function with mean 30 seconds.

The Network elements shown in figure can be either computers, telephones, Facsimile, Image transmitters, video conferencing machines or servers connecting to other different networks which wish to utilize the services of NREN.

5.3 The Software Program

In all there are twelve processing elements- nine representing, nine network elements and three representing, three central switches.

Each network processing element has eight instructions in it. When a instruction is executed by the processing element it sends data towards the destination to the nearest next processing element (which is the central switch in this case). Thus it is the responsibility of the network element to generate all the data in the network.

The main function of the central switch processing element is routing. Each central switch processing element contains nine instructions in it which when executed sends data towards the destination to the next nearest processing element.

There are in all 99 independent software modules. Each network element is associated with eight software modules. Hence total network element software modules is 9*8=72. These software modules are iterated by exponential statistical distribution function to simulate Poisson arrivals. The main function to these modules is to executed a respective instruction on the assigned network processing element. When this is done, the network processing element sends out data as requested by the module.

Each central switch processing element is associated to nine software modules. Hence total number of central switch processing element modules is 9*3=27. Each central switch processing element module gets activated, when the respective processing element receives data for transmission to the destination. The module then executed a assigned instruction on the processing element which sends data towards the destination.

The transfer devices are represented as buses operating at different speeds for different simulation. Asynchronous transfer mode is used as the physical layer for transmission. The software permits to break the incoming frame in blocks and words. The word overhead takes care of the five byte ATM cell header and the actual word length is 384 bits (48 bytes). The block overhead takes care of the extra bits incorporated by the segmentation & reassembly layer as well as the convergence layer of the adaptation layer in ATM.

The simulation is carried out for nine sets to study the increase in load with increase in transmission speeds. Three sets (file length 1 Mbits, 10 Mbits and 100 Mbits) each for three transmission speeds (45 Mbits/sec, 155 Mbits/sec and 620 Mbits/sec). The total length of the program is 44 pages or 2500 lines. Hence it is not feasible to put the program in the thesis.

5.4 Results

As said before, the simulation is carried out for Baud rates, 45 MBits/sec, 155 MBits/sec and 620 MBits/sec with increase in load for 1 MBits, 10 MBits and 620 MBits file length. The results obtained for all transfer devices connecting Network elements and Central switches is same. Similarly the results obtained for all transfer devices connecting two central switches is same. This is observed because the network simulated is very symmetrical.

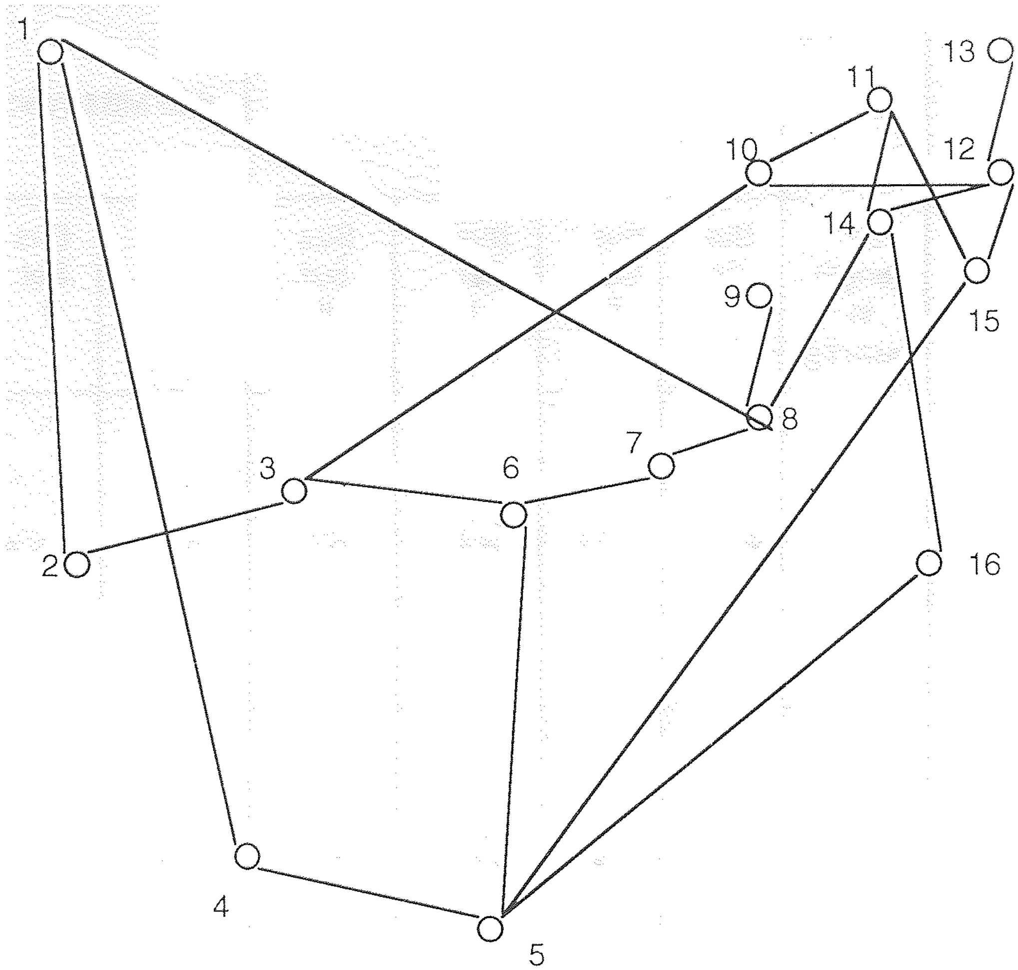
From the results on next page it is clearly seen that as the amount of data traveling on the bus increases, the utilization of the individual bus too increases. The maximum queue size was three for Bus-Set II (transfer devices connecting two central switches) in 100 MBits file length-45MBits/sec Baud rate simulation. The maximum wait time was 0.1 seconds.

For all other simulations the maximum queue size was 1 and wait time less than 0.001 seconds.

	45 MBits/sec		155 MBits/sec		620 MBits/sec	
File length in MBITS	Bus Set I	Bus Set II	Bus Set I	Bus Set II	Bus Set I	Bus Set II
1	0.45	0.75	0.3	0.6	0.1	0.3
10	4.5	7.5	3.0	6.0	1.0	3.0
100	45	75	30	60	10	30

All values, in percentage of utilization of bus

Table 1 Results of the simulation of The Simulated Network



1 Seattle
2 Palo Alto
3 Salt lake city
4 San Diego
5 Houston
6 Boulder
7 Lincoln
8 Champaign
9 Argonne
10 Ann Arbor
11 Ithaca
12 Princeton
13 Cambridge
14 Pittsburg
15 College Park
16 Atlanta

Figure 7 The National Science Foundation Network

CHAPTER 6

THE NATIONAL SCIENCE FOUNDATION NETWORK (NSFNET)

6.1 Introduction

These days, almost all articles on communications and fast speed networks state that the U.S. government's NREN project is a proving ground for 21st century applications and technologies. NREN today consists of the National Science Foundation Network (NSFnet) backbone and five gigabit testbeds. By 1996, the NSFnet will run at 155 Mbits/sec or faster and will be joined with the test beds, which will be operating at 1.2 Gbits/sec or higher[37].

6.2 The National Science Foundation Network

The actual National Science Foundation Network (NSFnet) is as shown in adjoining figure7[37]. This network is known as Interim NREN, because it is believed that NREN will evolve out of this network. In this chapter, using software simulation tool NetworkII.5, work is done on how this network will behave with increase in load and increase in transmission rate (Baud rate). Ofcourse, the actual NREN will be very large and will be connected to many nodes, but these basic network will remain the same.

6.3 The Software Program Description Of NSFNET

The software simulation is carried out in a similar way as before for The Simulated Network. However, this simulation is much more complicated because the each city simulated as processing element has to do both the type of functions, routing and random Poisson data generation. Also, the network is very distributed with almost 16 cities connected by about 22 transfer devices. Each city in the network is simulated as a processing element and has about 15 instructions in it for sending data to various other cities. When an instruction is executed on the processing element by it's corresponding software module, the processing element sends data as per requested by the module towards its destination to its next nearest city node(processing element).

The only assumption made in the simulation is that all the links or transfer devices are up and in running condition i.e. the routing table is very simple.

All the transfer devices in the network are modeled as buses with asynchronous transfer mode as it's physical layer same as in the previous simulation.

The protocol used is first come first served and transmission rate of these transfer devices varies for different sets.

There are in all 358 independent modules in the software program. About 240 modules (15 modules associated with each of 16 processing element cities) are used for exponential data generation to simulated Poisson arrivals. And the remaining 118 modules are used for routing purposes.

The main body of the program in each processing element is somewhat similar to the previous simulation network element and central switch together combined.

When a module for data generation gets activated, it executes an instruction on the assigned processing element city. When the instruction is executed, the processing element using the transfer device it is connected to transmits a random length data using ATM as physical layer towards the destination to the data. When an intermediate node receives data, the corresponding routing software module gets activated and it executes a particular instruction on the intermediate node processing element city.

On execution of this instruction, the processing element sends data again to either its destination or to another intermediate node.

Simulation is again carried out for nine sets of data. Three(1 Mbit, 10 Mbit and 100 Mbit) for each transfer rate (45 Mbits/sec, 155 Mbits/sec and 620 Mbits/sec). The total length of the program is 75 pages or about 5800 lines. Hence, it is not feasible to incorporate the program here.

6.4 Results

In the result table shown on page # 37, there are three Bus-Set's. Bus Set I consist's of following transfer devices:

Bus 1,4 -Transfer device between Seattle and San Diego

Bus 1,2 -Transfer device between Seattle and Palo Alto

Bus 1,8 -Transfer device between Seattle and Champaign

Bus 4,5 -Transfer device between San Diego and Houston

Bus 5,6 -Transfer device between Houston and Boulder

Bus 5,15 -Transfer device between Houston and College Park

Bus 5,16 -Transfer device between Houston and Atlanta

Bus 14,16 -Transfer device between Pittsburgh and Atlanta

Bus Set II consist's of following transfer devices:

Bus 2,3 -Transfer device between Palo Alto and Salt lake city

Bus 3,6 -Transfer device between Salt lake city and Boulder

Bus 3,10 -Transfer device between Salt lake city and Ann Arbor

Bus 6,7 -Transfer device between Boulder and Lincoln

Bus 7,8 -Transfer device between Lincoln and Champaign

Bus 8,14 -Transfer device between Champaign and Pittsburgh

Bus 10,11 -Transfer device between Ann Arbor and Ithaca

Bus 10,12 -Transfer device between Ann Arbor and Princeton

Bus 11,14 -Transfer device between Ithaca and Pittsburgh

Bus 11,15 -Transfer device between Ithaca and College Park

Bus 12,14 -Transfer device between Princeton and Pittsburgh

Bus 12,15 -Transfer device between Princeton and College Park

Bus Set III consist's of following transfer devices:

Bus 8,9 -Transfer device between Champaign and Argonne

Bus 12,13 -Transfer device between Princeton and Cambridge

The result table clearly divides the whole NSFNET into three distinct regions:

1) Bus Set I - The outer transfer devices of the network
2) Bus Set II - The Central Cluster of transfer devices and
3) Bus Set III - The transfer devices connected to lone nodes

The Central Cluster of transfer devices is going to be utilized maximum. Hence, as data rates traveling through it will increase, it is likely to be more congested.

The outer transfer devices are moderately utilized, because most of the data is traveling through central cluster. Even in absence of sophisticated routing table, we can derive that these transfer devices are going to be less utilized than the central cluster of devices.

The transfer devices connecting lone nodes stand out as being least utilized or mostly unutilized because the data traveling through it is only it's own data. No data of other nodes is being routed through these transfer devices.

	45 MBits/sec			155 MBits/sec			620 MBits/sec		
File length in MBITS	BUS SETS								
	I	II	III	I	II	III	I	II	III
1	0.44	0.64	0.32	0.36	0.5	0.2	0.22	0.32	0.12
10	4.4	6.4	3.2	3.6	5.0	2.0	2.2	3.2	1.2
100	44	64	32	36	50	20	22	32	12

All values, in percentage of utilization of bus

Table 2 Results of the simulation of The National Science Foundation Network

6.5 CONCLUSIONS

Some conclusions can be derived for more efficient link utilization as follows;

-Clustering of transfer devices should be avoided. Because these transfer devices are utilized maximum and get congested very soon.

-Nodes in the network should be placed such that no nodes stand out alone. This is because the transfer devices connecting to these nodes are mostly unutilized and most of it's capacity is wasted.

-For efficient utilization of all transfer devices, the nodes should be arranged such that the network resulting is mostly symmetrical. The full capacity of all transfer devices is utilized in this case.

Moreover, it is assumed that as the Baud rate of transfer devices increases to hundreds of megabits or gigabits per second, the future planning should be under the assumption that bits are free. However, this will not be the case as the Baud rate increases the applications requiring higher Baud rate and more data transfer will take shape, which will ultimately lead to congestion in NREN.

6.5.1 Steps To Reduce Congestion In Gigabit Networks

Some mechanisms for limiting congestion in gigabit networks such as NREN or B-ISDN are stated below[38]:

1) The network and user has to agree to the required rate of the user at connection setup time. This agreement should involve quantities such as the burstiness of the source and the quality of service required.

2) The network has to monitor each connection to ensure that the user is complying with the agreed upon rate and burstiness. This can be done at the convergence sublayer of the adaptation layer in the ATM.

3) The last mechanism is the priority bit in the ATM cell header.

CHAPTER 7

PERFORMANCE OF NATIONAL RESEARCH AND EDUCATION NETWORK WHILE TRANSMITTING HEALTHCARE INFORMATION DATA

7.1 Introduction

Healthcare Information data will be one of the most crucial data traveling on National Research and Education Network. Healthcare Information data consists of all data concerning the healthcare system such as patient information, insurance checking, claims processing, laboratory results, X-rays, CAT scans and so on. Even some videoconferencing data, when doctors form a gigantic consulting group and discuss patient's reports and share opinions.

NREN will be a very important factor in converting turnabout time for processing from days to seconds. Let us divide the healthcare data into following three types of service which NREN would support.

Service 1: Only text data

Service 2: Both text and graphics data

Service 3: All kinds of data text, graphics, X-rays, CAT scans

It is clearly seen as the quality of service increases, the total amount of healthcare data traveling on NREN increases. Quantity of data generated by each type of service is the only way of distinguishing each service. For service 1, the quantity of data generated is minimum while it is maximum for service 3.

7.2 Modeling Healthcare Information Data Travel On NREN

National Research and Education Network is very distributed as seen from Figure 7 in Chapter 6. The nodes of NREN are distributed throughout the United States. One thing is certain that the healthcare information data traveling on NREN will not be symmetric. The quantity of data generated by one node is going to be very different from the quantity of data generated by other node.

It is seen that most of the nodes of NREN are located in different states. The healthcare information data which will be generated, will be directly proportional to the population around each node. Since most of the nodes are situated in different states, the healthcare information data generated by each node will be directly proportional to the population in the state. This means that the data generated by Houston node in Texas is going to be more then that generated by Salt Lake City node in Utah because Texas is more densely populated than Utah.

There are about 650,000 physicians in all over United States. Most of the healthcare data will be generated by them. Each physician, on an average treats about 25 patients daily. It has been observed that only text files of Service 1 will be about 1 MBits long. Service 2, text and graphic files will be about 10 MBits long and Service 3 files will be about 100 MBits long.

Total Healthcare data generated per second for each mode of service can be calculated as follows:

Service 1: 650,000 physicians * 25 patients * 1 MBits / work day

= 650,000 * 25 * 1 / 24 * 60 * 60 =188 MBits/sec

Service 2: 650,000 physicians * 25 patients * 10 MBits / work day

= 650,000 * 25 * 10 / 24 * 60 * 60 =1880 MBits/sec

Service 3: 650,000 physicians * 25 patients * 100 MBits / work day

= 650,000 * 25 * 100 / 24 * 60 * 60 = 18,800 MBits/sec

As mentioned before, the geographic population around each node is the population of the state the node is located in. The following table states the name of node, population around it[39] and the percentage of total it represents.

The percentage is calculated by dividing the population around each node by the total population around the sixteen nodes. This percentage is then used to determine the amount of healthcare data generated by each node from the total healthcare data.

Name of the node		*Population around node*	*Percentage*
Seattle, Washington	:	5,018,000	3.568 %
Palo Alto, California	:	30,380,000 / 2	10.802 %
San Diego, California	:	30,380,000 / 2	10.802 %
Salt Lake City, Utah	:	1,770,000	1.258 %
Boulder, Colorado	:	3,377,000	2.401 %
Houston, Texas	:	17,349,000	12.338 %
Lincoln, Nab.	:	1,593,000	1.132 %
Argonne, Wisconsin	:	4,955,000	3.523 %
Champaign, Illinois	:	11,543,000	8.209 %
Ann Arbor, Michigan	:	9,368,000	6.662 %
Ithaca, New York	:	18,058,000	12.842 %
Pittsburgh, Pennsylvania	:	11,961,000	8.506 %
Atlanta, Georgia	:	6,623,000	4.710 %
College Park, MD.	:	4,860,000	3.456 %
Princeton, NJ	:	7,760,000	5.518 %
Cambridge, Mass.	:	5,996,000	4.273 %

If T is the sum of total population around all nodes and P_i is the population around node i, and H is the total Healthcare data generated for a particular service then the healthcare data generated by node i can be calculated as follows;

$$P_i * H / T$$

In this way we can model different amount of data for each node.

7.3 The Software Program

The software program will be mostly similar as discussed in section 6.3 of chapter 6. However, there will be some changes for simulating healthcare information data. There will be sixteen extra modules, one module associated with each processing element city node. The iteration period of these modules will be random exponentially distributed number with mean 1 second. Hence, when a module gets activated it executes on the respective processing element and send data which is again a random exponentially distributed number of Bits with mean according to the amount of healthcare data the node has to transmit per second. All the remaining software program for processing elements, transfer devices and modules remain the same. Although, in each processing element an additional instruction is to be added for the execution of the healthcare module instruction. The result table is shown on next page.

7.4 Explanation of Result Table 3

The result table is obtained when NREN is simulated using NETWORKII.5 as transmitting both the healthcare information data and other regular non-healthcare data. As said before, the total healthcare data for all three services is always fixed.

Service 1 : Total healthcare information data generated is 188 MBits/sec

Service 2 : Total healthcare information data generated is 1880 MBits/sec

Service 3 : Total healthcare information data generated is 188,00 MBits/sec

For each service, the total healthcare information data means the total data generated from all the 16 nodes of NREN. Again, the transfer devices are grouped into three Bus-sets because the results obtained for transfer devices in each bus-set is almost same. The simulation is carried out for Baud rates 45 MBits/sec, 155 MBits/sec and 620 MBits/sec.

The result table contains three sets, one when non- healthcare data file length is 1 MBits long, second when non-healthcare data file length is 10 MBits long and last when the non-healthcare data file length is 100 MBits long. This helps us in predicting the behavior of NREN with increase in traffic or load for different services of healthcare data.

The first column in result table states regular (non-healthcare) data file length in MBits and healthcare data service. The first reading in Set 1 is for non-healthcare data with file length 1 MBits i.e. when the 16 nodes transmit data with each file length 1 MBits and Service 1(total healthcare data generated from 16 nodes, 188 MBits/sec). This indicates that there will be two kinds of data traveling on NREN. The transfer bus utilization values decrease as the baud rate increase. The last column indicates the percentage of healthcare date traveling on NREN at a given time. For first reading the value is 20, which means the total data traveling on NREN is 100*188/20 MBits/sec and healthcare data is 188 MBits/sec. The second reading in Set 1 is again for non-healthcare data file length 1 MBits but the healthcare service is 2(total healthcare data generated from 16 nodes is 1880 MBits/sec). The healthcare data percentage is 35, which has increased because as the service increases the quantity of healthcare data also increases. The third reading in Set 1 is again for non-healthcare data file length 1 MBits but healthcare service is 3. The percentage of healthcare data traveling on NREN at the given time is 50, which has again increased as the quantity of healthcare data increases with service.

The Set 2 readings are for constant file length 10 MBits but with increase in service. Similarly Set 3 readings are for constant file length 100 MBits, with increase in service.

It is observed from the result table that as the Baud rate increases from 45 MBits/sec to 620 MBits/sec, the utilization of the transfer bus decreases. As the quality of service increases, the data traveling on NREN increases and the percentage of healthcare data increases. As the non-healthcare data file length increases from 1 Mbits to 100 MBits the percentage of healthcare data compared to the same reading in the previous set decreases. This is because the quantity of non-helathcare data increases rapidly then the quantity of healthcare data as the service increases.

7.5 Results

From the result table, one thing is apparent which was expected that as the quality of service increases, the traffic on the transfer devices also increases i.e. the percentage utilization of each bus increases. The result table also contains three Bus Sets I, II and III as in previous result Table 2. Each Bus Set consists of a group of transfer devices as mentioned in section 6.4.

The results of Service 1 are almost identical to the results obtained in Table 2, which indicates that this service does not affect the characteristics of NREN very much. For simulation, with Baud rate 45 MBits/sec the transfer devices get saturated for Services 2 and 3 when the file length is 100 MBits. This indicates that 45 MBits/sec Baud rate does not support Service 2 or 3. Similarly, the transfer devices get saturated for simulation carried out on Baud rate 155 MBits/sec for Service 3 when file length is 100 MBits. This indicates that 155 MBits/sec Baud rate does not support Service 3.

From the result table, it is also seen that utilization of all transfer devices is satisfactory for simulation carried out with Baud rate 620 MBits/sec when the file length is 100 MBits/sec.

Hence, we can say that in general

Baud rate 45 MBits/sec supports Service 1 only.

Baud rate 155 MBits/sec supports Service 1 and 2

Baud rate 620 MBits/sec supports Service 1, 2 and 3.

The graphs plotted also show the same conclusion. The graphs are plotted for Bus Set II(because, it get's congested sooner than other Bus Sets) and Baud rates 45 MBits/sec, 155 MBits/sec, 620 MBits/sec.

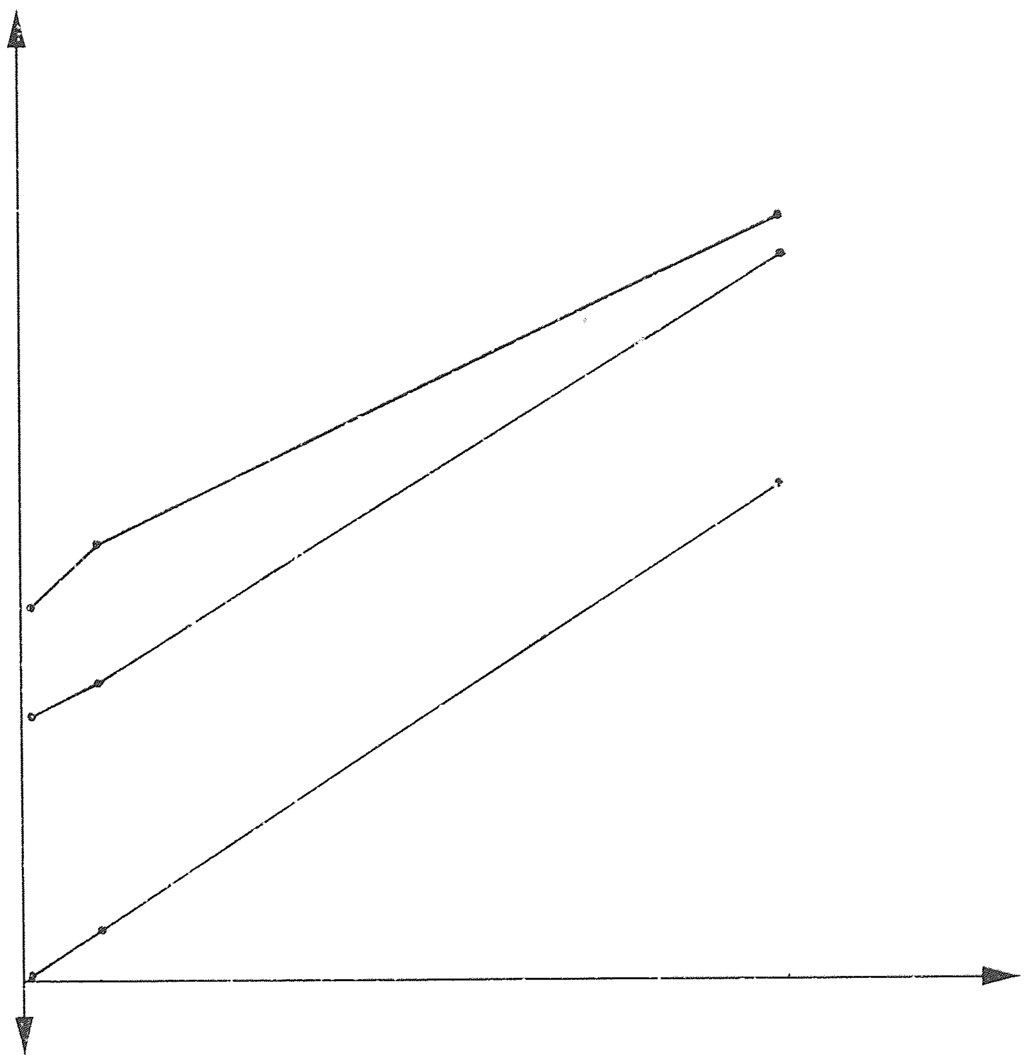
Graph I indicates, if Baud rate is 45 MBits/sec the transfer devices get saturated for Service 2 and 3 because the initial jump is very high. However, the performance of 45 MBits/sec Baud rate of transfer devices is satisfactory for Service 1. Similarly, Graph II indicates that 155 MBits/sec Baud rate does not support the Service 3, but it's performance is satisfactory for Services 1 and 2. Graph III indicates that 620 MBits/sec Baud rate supports all the three services.

The above conclusions are when the average length of files traveling on NREN is 100 MBits/sec, which is the expected length of each file in future.

Regular data file length in MBits and health care data service	45 MBits/sec			155 MBits/sec			620 MBits/sec			Percentage of health care data
	BUS SETS									
	I	II	III	I	II	III	I	II	III	
1										
Service 1	0.44	0.64	0.32	0.36	0.5	0.2	0.22	0.32	0.12	20
Service 2	14	34	10	9	23	7	3	11	2	35
Service 3	22	48	17	18	44	10	11	31	7	50
10										
Service 1	4.4	6.4	3.2	3.6	5.0	2.0	2.2	3.2	1.2	18
Service 2	17	38	13	12	26	9	5	16	3	30
Service 3	42	56	20	32	50	17	28	43	14	45
100										
Service 1	44	64	32	36	50	20	22	32	12	23
Service 2	83	94	72	56	70	41	48	54	21	23
Service 3	96	99	94	86	92	80	50	63	25	38

All values, in percentage of utilization of bus

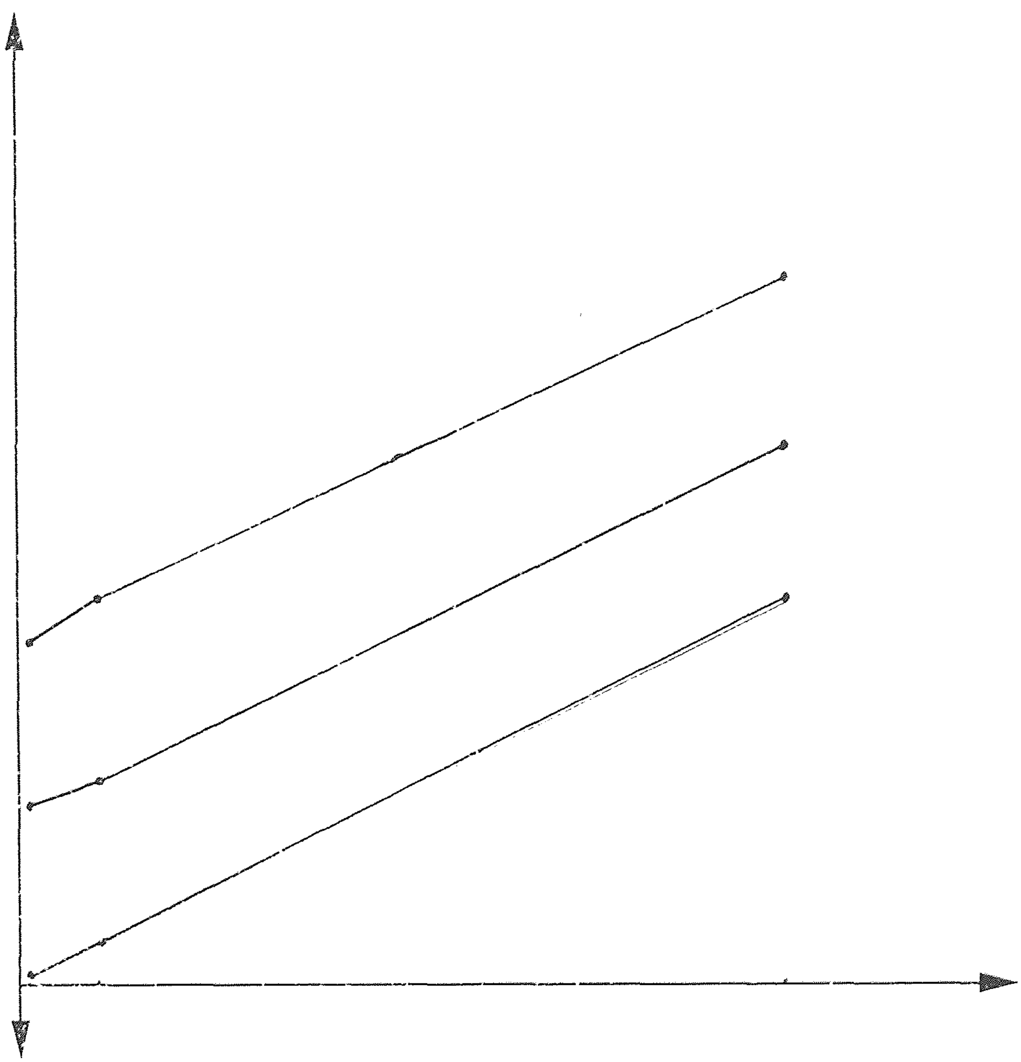
Table 3 Results of the simulation of NREN transmitting healthcare information data



X- Axis - File length in MBits

Y- Axis - Percentage of Bus Utilization

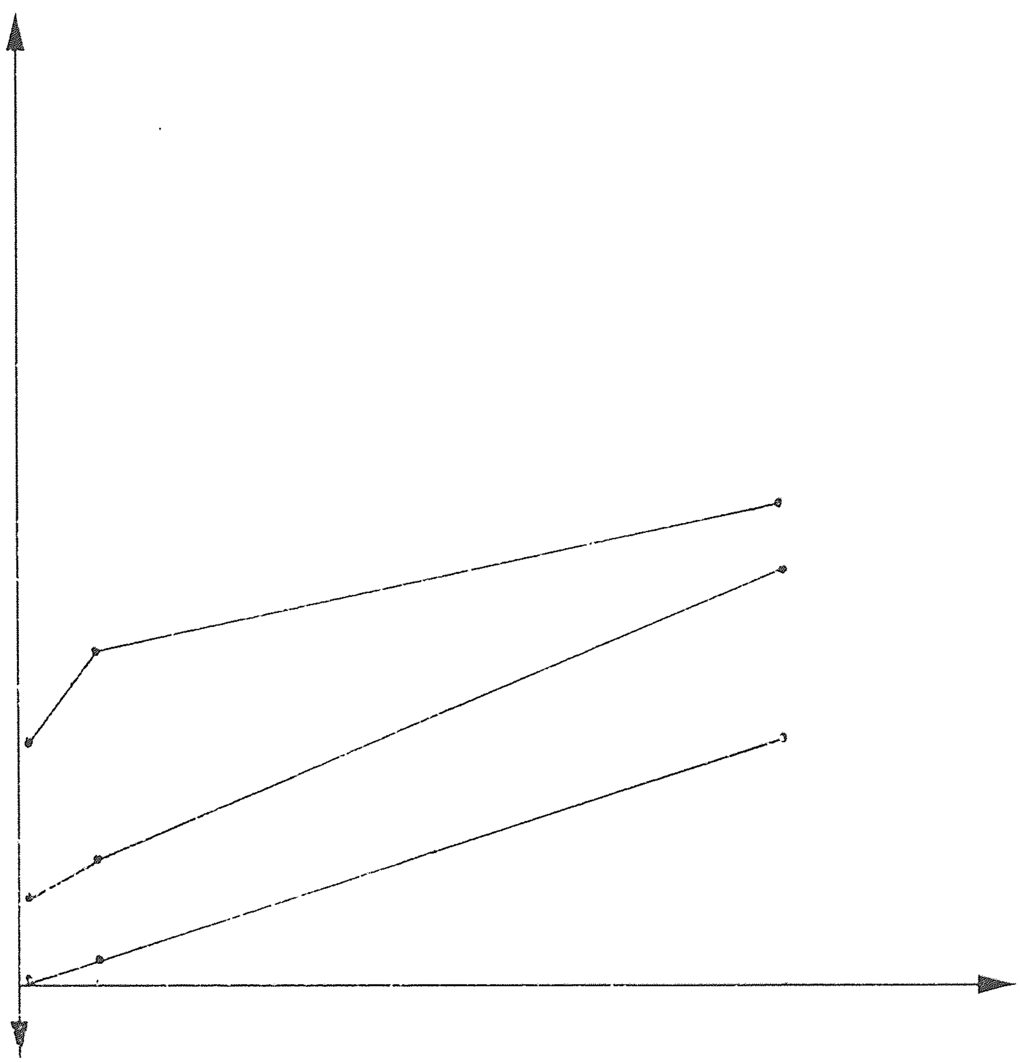
Graph 1 For Bus Set II - Baud rate 45 MBits/sec



X- Axis - File length in MBits

Y- Axis - Percentage of Bus Utilization

Graph 2 For Bus Set II - Baud rate 155 MBits/sec



X- Axis - File length in MBits

Y- Axis - Percentage of Bus Utilization

Graph 3 For Bus Set II - Baud rate 620 MBits/sec

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