

**Routing and Data Compression in SONET and Performance of LANs in  
Wide Area Network**

*A Thesis Submitted in partial fulfillment of the  
Requirements for the award of degree of*

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**in**

**Electronics and Communication engineering**

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## CERTIFICATE

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I, **Raman Kumar** hereby certify that the work which is being presented in this thesis entitled "**Routing and data compression in SONET and performance of LANs in wide area network**" by me in partial fulfillment of requirements for the award of degree of **Master of Engineering in Electronics & Communication** from **Thapar University, Patiala** is an authentic record of my own work carried under the supervision and guidance of **Dr. R. S. KALER**, Professor in Electronics & Communication Engineering Department, Thapar University, Patiala.


The matter presented in this thesis has not been submitted in any other University or Institute for the award of any other degree.




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**RAMAN KUMAR**

## **ABSTRACT**

With the increasing growth and demand for capacity in national, regional, and even metropolitan optical networks, we are increasing the bandwidth of the channel so that more data can be sent in appropriate time duration. So transmission delay is the main problem to send a large amount of data. To overcome this problem data should be routed to the minimum possible route for this there are various routing protocols which can be used to route the data in optical networks. In this thesis we are using two routing protocol to send the data and analyzing the performance parameters such as end to end transmission delay and throughput of the network.

The transmission delay is the main problem in today's networks because everyone wants to transmit a large amount of data and this lead to high delay in the network. So data compression may be one alternative to this problem. In this thesis we are also seeing the usefulness of data compression in fast speed and slow speed SONET. By modeling and simulating fast speed and slow speed network in OPNET IT Guru, we observe the overall result that although the throughput between the switch and the client using compression is less than the throughput between the switch and the client that is not using the compression, the response time for the client using compression is higher. In other words, the client loses more time for the compression and decompression processes than it gains from the transmission of the smaller frames. So we can say that there is no need to transmit the compressed data in the high speed network because it transmits uncompressed data to higher speed than the compressed data as compression and decompression of data takes relatively more time. But we also observe that data compression improves the throughput of the high speed network which is the main advantage of data compression.

Wide Area Network (WAN) is a computer network that covers a broad area. So WANs are used to connect LANs and other types of networks together, so that users and computers in one location can communicate with users and computers in other locations. To increase the performance of the WAN it is necessary to connect this with the LANs which are having the better performance. Finally in this thesis we will see the performance of different types of LANs in wide area network. There are various types of

LANs to which a wide area network can be connected such as 10BaseT, 100BaseT, Token Ring based LANs and FDDI based LANs etc. By modeling and simulating the wide area network connected with various LANs in OPNET IT Guru, the overall result demonstrate that FDDI based LAN achieves better performance among all types of LANs and is the least obtrusive on network operations.

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# CHAPTER 1

## INTRODUCTION

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Communication is the process of transmitting information from one end to another and nowadays optical fiber communication is the best way to communicate with each other because optical fiber is the most common type of channel which possesses low loss, allowing long distances between amplifiers or repeaters and its inherently high data-carrying capacity, such that thousands of electrical links would be required to replace a single high bandwidth fiber. Optical networks offer the promise to solve many problems which are in the traditional networks [1]. In addition to providing enormous capacities in the network, an optical network provides a common infrastructure over which a variety of services can be delivered. Optical networks are also increasingly becoming capable of delivering bandwidth in a flexible manner where and when needed [2]. When something is discussed about the optical networks, it is the discussion of the synchronous optical networks (SONET) which are capable to provide lower bit error rates and higher capacities than the simple copper based networks. Also fiber links experience effectively no crosstalk, in contrast to electrical transmission lines.

Before the birth of Synchronous Optical Network (SONET) / Synchronous Digital Hierarchy (SDH), the transmission system widely deployed in the telecommunications industry was known as the Plesiochronous Digital Hierarchy (PDH) [1]. Plesiochronous means the timing of signals across the network is almost but not precise, and there is not a centralized timing source since each node has its own clock [2].

As more and more channels were multiplexed together into higher layers of the PDH hierarchy, each frame need to be completely demultiplexed in order to select an individual channel as the timing across all the nodes was not totally the same [3]. Another problem occurred where different networks with relatively wide differences in timing met, such as between Europe and the U.S.

The SONET standard was designed in the mid 1980's to alleviate these problems [1]. It is more widely used in North America. The International Telecommunications Union later generalized SONET into the SDH in order to accommodate the PDH rates in use outside North America, mainly deployed in Europe and Asia-Pacific Countries.

SONET/SDH standardized the line rates, coding schemes, bit-rate hierarchies, and operations and maintenance functionality. SONET/SDH also defined the types of Network Elements (NEs) required, network architectures that vendors could implement, and the functionality that each node must perform [2, 3].

A typical SONET/SDH network utilizes the Section Data Communications Channels (DCC). Briefly, one or more Operations Systems (OSs) manages the SONET/SDH NEs and the connectivity between them is achieved through a Data Communications Network (DCN) [4].

Open System Interface (OSI) was selected as the standard for SONET Section DCC because OSI protocols were accepted as the basis for the larger set of Telecommunications Management Network (TMN) standards.

G.7712 is the standard for Architecture and Specification of the Data Communications network (DCN) [3, 5]. G.7712 is important for the telecommunication industry since it enables intelligent optical networks with combined IP-managed and OSI-managed equipment. It is also crucial for vendors of network edge devices as it allows for easy transport of network management traffic to these devices via the core optical switches without the need to create expensive and complicated overlay networks.

## **1.1 SONET/SDH EVOLUTION**

In the early 1980s, a revolution in telecommunications networks was ignited by the use of a relatively unassuming technology, fiber-optic cable [2]. Since then, the consequential increase in network quality and tremendous cost savings have led to many advances in technologies required for optical networks. Many of these benefits have yet

to be realized. The digital communications network has evolved through three fundamental stages: asynchronous, synchronous, and optical.

### **1.1.1 ASYNCHRONOUS**

Traditional digital telecommunications services such as T1/DS1s were designed to aggregate analog telephone lines for more efficient transport between central offices. Twenty four digitized voice lines (DS0s) were carried over a DS1 using time-division multiplexing (TDM). To review, in a TDM architecture, multiple channels (24 for DS0) share the circuit basically in rotation, with each DS0 having its own assigned time slot to use or not as the case may be [1]. Data communications networks such as Ethernet are asynchronous, as there is not a centralized timing source and each node has its own clock. As more and more channels are multiplexed together into higher layers of the PDH hierarchy, a number of problems arise. Since the timing on various DS1s going into a DS3 may differ slightly, bit-stuffing is required to align all within the DS3 frame. Once this is done, the individual DS1s are no longer visible unless the DS3 is completely demultiplexed. In order to select an individual channel, the whole DS3 frame must be torn down to extract out the DS1 and then subsequently rebuilt back into the DS3. The equipment required to do this is expensive [2]. Another problem arises with interoperability of different networks with relatively wide differences in timing, such as those in Europe and the U.S. Expensive equipment that also adds latency is required for the interface.

### **1.1.2 SYNCHRONOUS**

To alleviate these problems, the Synchronous Optical Network (SONET) standard was designed in the mid 1980's [1, 2]. It is more widely used in North America. The International Telecommunications Union [3] later generalized SONET into the Synchronous Digital Hierarchy (SDH) in order to accommodate the PDH rates in use outside North America, mainly deployed in Europe and Asia-Pacific Countries.

SONET/SDH standardized line rates, coding schemes, bit-rate hierarchies, and operations and maintenance functionality [5]. SONET/SDH also defined the types of

network elements required, network architectures that vendors could implement, and the functionality that each node must perform [2, 6]. Network providers could now use different vendor's optical equipment with the confidence of at least basic interoperability.

### **1.1.3 OPTICAL**

The one aspect of SONET/SDH that has allowed it to survive during a time of tremendous changes in network capacity needs is its scalability. Based on its open-ended growth plan for higher bit rates, theoretically no upper limit exists for SONET/SDH bit rates (The current maximum bit rate deployed is 40 Gbps). However, as higher bit rates are used, physical limitations in the laser sources and optical fiber begin to make the practice of endlessly increasing the bit rate on each signal an impractical solution. Additionally, connection to the networks through access rings has also had increased requirements. Customers are demanding more services and options and are carrying more and different types of data traffic [6, 7]. To provide full end-to-end connectivity, a new paradigm was needed to meet all the high-capacity and varied needs. Optical networks provide such bandwidth and flexibility to enable end-to-end wavelength services.

Optical networks began with wavelength division multiplexing (WDM) [8], which arose to provide additional capacity on existing fibers. Like SONET/SDH, defined network elements and architectures provide the basis of the optical network. However, unlike SONET/SDH, rather than using a defined bit-rate and frame structure as its basic building block, the optical network will be based on wavelengths. The components of the optical network will be defined according to how the wavelengths are transmitted, groomed, or implemented in the network [8].

Standards are being developed and essentially can provide the same functionality as the SONET/SDH layer, while operating entirely in the optical domain. The optical network also has the additional requirement of carrying varied types of high bit-rate non-SONET/SDH optical signals that bypass the SONET/SDH layer altogether [9, 10]. Just as the SONET/SDH layer is transparent to the services layer, the optical layer will ideally be

transparent to the SONET/SDH layer, providing restoration, performance monitoring, and provisioning of individual wavelengths instead of electrical SONET/SDH signals.

## **1.2 ADVANTAGES OF SONET/SDH**

There are a number of advantages of deploying a SONET/SDH network, for both the customers and service providers. Each of the key benefits is briefly explain below [10]:

### **1.2.1 MULTIPOINT CONFIGURATION**

SONET/SDH is frequently deployed in multipoint configurations. This means several sources of SONET/SDH traffic can be combined and distributed without terminating the digital stream to recover and process the constituent signals. This process is also known as “grooming”. Grooming can concentrate traffic and service more customers with fewer links than without grooming. SONET/SDH grooming requires less equipment, thus reducing the need for linking multiplexers, digital cross-connect and the need for cabling between equipment terminations and patch panels. In simple terms, it also means saving space and money [11].

### **1.2.2 ENHANCED OPERATIONS ADMINISTRATION, MAINTENANCE AND PROVISIONING (OAM&P)**

SONET/SDH enhances the OAM&P capabilities and integrates them into all SONET/SDH network elements, mostly through the inclusion of dedicated overhead bytes reserved for the purpose. The OAM&P procedures are an integral part of the SONET/SDH standard with more bandwidth allocated for them and thus the information available is more sophisticated. This substantial amount of information available allows for quicker troubleshooting and detection of failures before the network degrades to unacceptable levels [10, 11]. It also allows for remote provisioning and configuring of SONET/SDH network elements, and thus can be centrally maintained without disturbing the link and services to the users and indeed reduces the travel expenses for maintenance personnel.

### 1.2.3 NEW SERVICE OFFERINGS

The huge amount of bandwidth available in SONET/SDH can support new services that were not possible previously. Video applications, 100 Mbps LAN interconnections, color faxing, and other bandwidth-hungry applications are now easily supported in an affordable and reliable mean.

### 1.2.4 OPTICAL INTERFACE

Optical interconnect, also known as “mid-span meet” is made possible with multi-vendor compatibility since the SONET/SDH standards are well defined for fiber-to-fiber interfaces at the physical (photonic) layer. These low level aspects define the optical line rate, wavelength, power levels, pulse shapes, and coding for bits on the fiber links. They allow the customer to use a direct SONET/SDH interface, possibly a different vendor equipment to connect to its service provider [11, 12].

## 1.3 DIFFERENCES BETWEEN SONET AND SDH

There are basically only two major differences between SONET and SDH [12, 13], the first one is the naming convention/hierarchical structure for the transmission rates and the second being the framing used for the overhead bytes.

### 1.3.1 NAMING CONVENTION

Table 1 shows the difference transmission rates between SONET and SDH.

<b>Common SONET/SDH Rates</b>			
<b>Speed</b>	<b>SONET (US)</b>	<b>SDH (Europe)</b>	<b>OCx (ATM)</b>
51.84 Mbps	STS-1	STM-0	OC-1
155.52 Mbps	STS-3	STM-1	OC-3
622.08 Mbps	STS-12	STM-4	OC-12

2488.32 Mbps	STS-48	STM-16	OC-48
9953.28 Mbps	STS-192	STM-64	OC-192
39813.12 Mbps	STS-768	STM-256	OC-768

Table 1. Common SONET/SDH Rates (After Ref. [10].)

### 1.3.2. OVERHEAD BYTES

The SONET definitions of some overhead messages are more tuned to the operating conditions within North America [14], while the SDH equivalents are more general in nature.

This tuning of overhead messages are needed as both the SONET and SDH use different terms to describe the three layers of network topology [15, 16]. SONET uses the terms path, line and section while SDH uses the terms path, multiplex section and regenerator section, as shown in Figures (1.1) and (1.2) below.

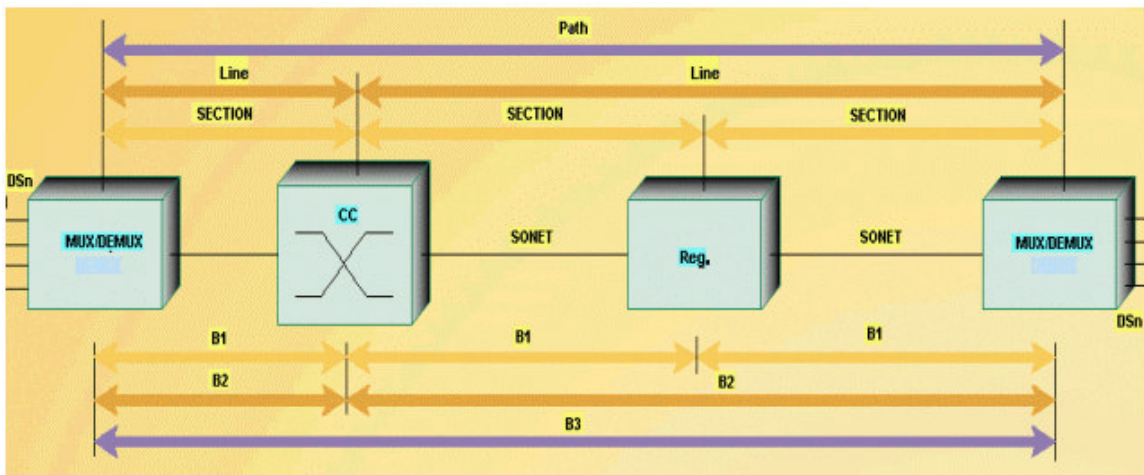


Figure 1.1. SONET Link (From Ref. [17].)

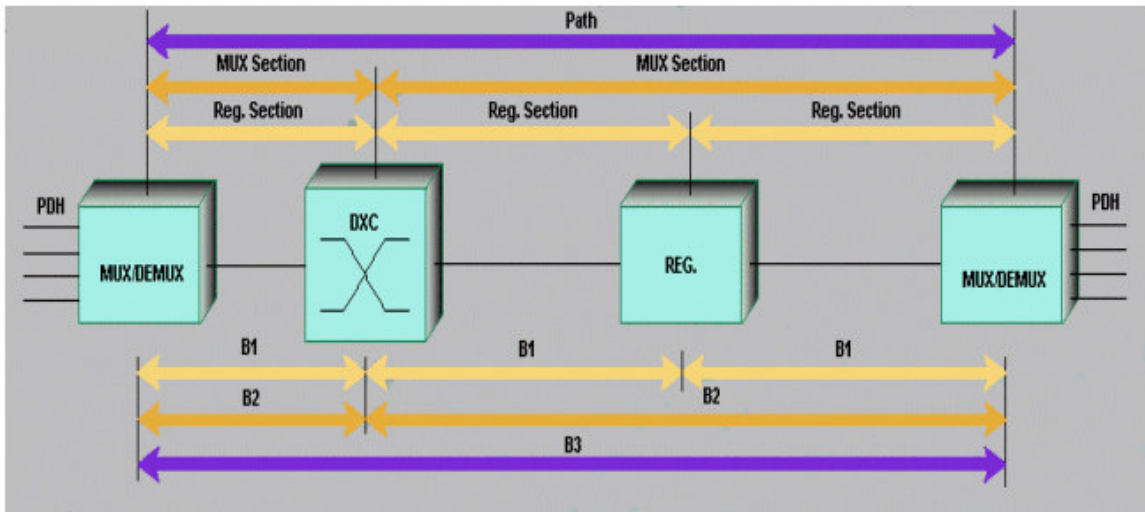


Figure 1.2. SDH Link (From Ref. [17].)

As for specific overhead bytes, the content of Automatic Protection Systems (APS) messages transmitted in the K1/K2 bytes and the values of the C2 Path Overhead (POH) byte are slightly different for SDH as compared to SONET as the frame structures between the two are different as shown in Figures (1.3) and (1.4) below.

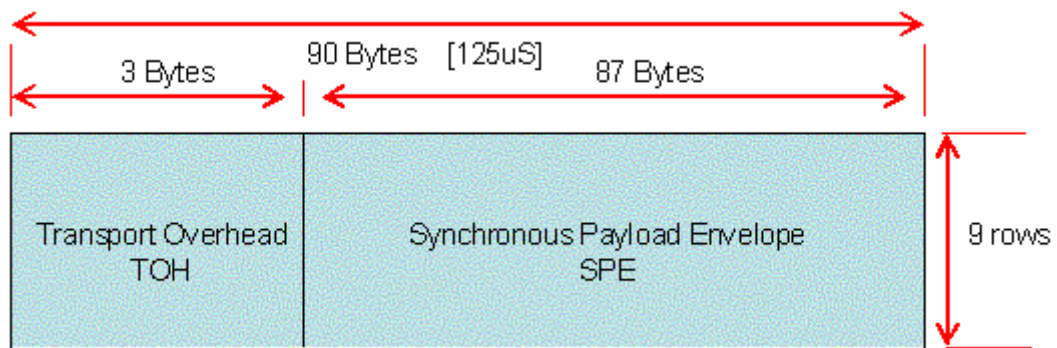


Figure 1.3. SONET Frame Structure (From Ref. [17].)

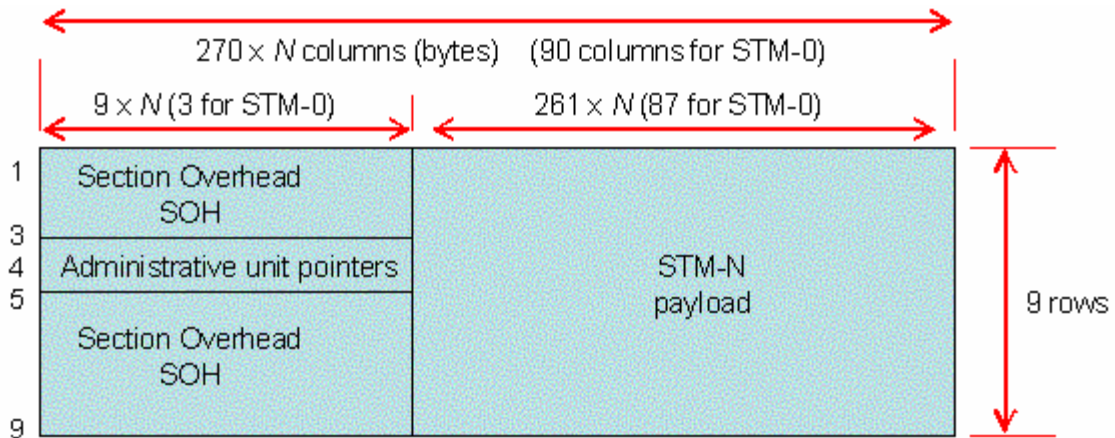


Figure 1.4. STM-N Frame Structure (From Ref. [17].)

## 1.4 BASIC CONFIGURATION

A very simple SONET network could consist of two terminals with a length of fiber between them. If the distance is too long for one fiber link, regenerators are used to amplify and reconstruct the physical signal. An add/drop multiplexer provides two fiber connections with the ability to access the internal structure of the SONET frame to remove or insert individual channels as required for that node while passing the rest of the traffic on through [15]. Digital Cross-connects (DXC) is used to switch, combine, redirect, and otherwise groom traffic, with varying degrees of granularity. All of these elements are section terminating equipment; all except regenerators are also line terminating equipment. Network elements where non-SONET signals are attached to the SONET network are path terminating equipment [15]. All elements are intelligent, accessing in-band management information dedicated to each layer within the SONET frame [1, 15]. Figure (1.5) shows a typical SONET connection.

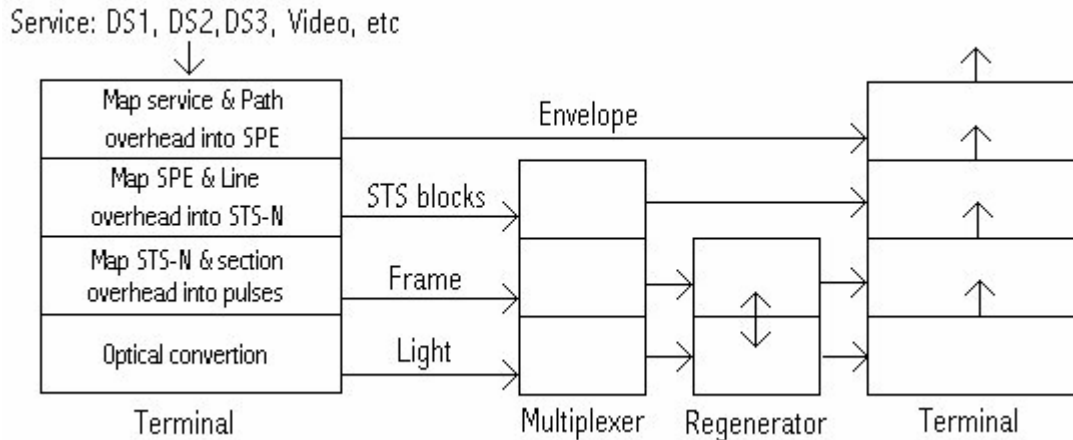


Figure 1.5 Typical SONET Connections (From Ref. [15].)

Within metropolitan areas, SONET networks are typically configured physically as rings, as shown in Figure (1.6) below. A ring topology provides a single level of redundancy, allowing restoration of service if one fiber link is broken. The SONET mechanism for restoration takes less than 50 milliseconds to recover from a break, but is considered somewhat inefficient as half the total ring bandwidth is reserved [7, 15]. Note that even though the physical topology may be a ring, the individual channels (which are manually provisioned) are point-to-point — SONET has no equivalent of Ethernet/IP broadcast or multicast service [7].

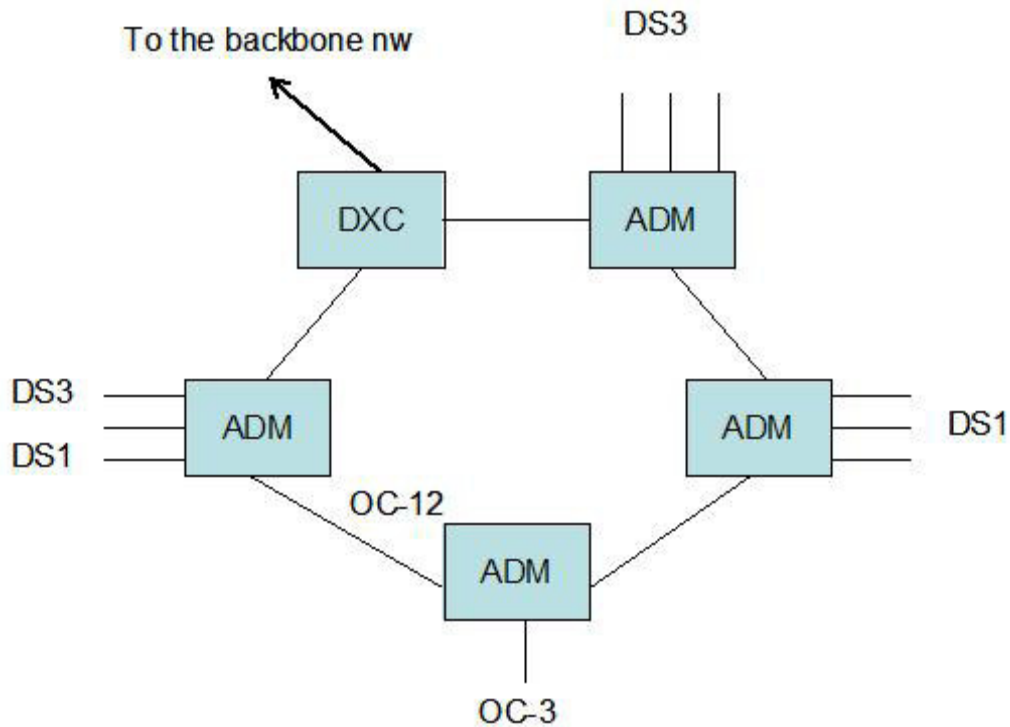


Figure 1.6- An example of a SONET Ring configuration (After Ref. [1].)

## 1.5 ROUTING PROTOCOLS USED IN THE PROJECT

A routing protocol is a protocol that specifies how routers communicate with each other to disseminate information that allows them to select routes between any two nodes on a network. Typically, each router has a priori knowledge only of its immediate neighbors. A routing protocol shares this information so that routers have knowledge of the network topology at large [18, 19].

There are various types of routing protocol. In this thesis only two type of routing protocol which are routing information protocol and open shortest path first was discussed.

### 1.5.1 ROUTING INFORMATION PROTOCOL

RIP (Routing Information Protocol) is a widely-used protocol for managing router information within a self-contained network such as a corporate local area network

(LAN) or an interconnected group of such LANs. RIP is classified by the Internet Engineering Task Force (IETF) as one of several internal gateway protocols (Interior Gateway Protocol) [18].

Using RIP, a gateway host (with a router) sends its entire routing table (which lists all the other hosts it knows about) to its closest neighbor host every 30 seconds. The neighbor host in turn will pass the information on to its next neighbor and so on until all hosts within the network have the same knowledge of routing paths, a state known as *network convergence*. RIP uses a hop count as a way to determine network distance. (Other protocols use more sophisticated algorithms that include timing as well). Each host with a router in the network uses the routing table information to determine the next host to route a packet to for a specified destination [18, 20].

RIP is considered an effective solution for small homogeneous networks. For larger, more complicated networks, RIP's transmission of the entire routing table every 30 seconds may put a heavy amount of extra traffic in the network.

### **1.5.2 OPEN SHORTEST PATH FIRST**

OSPF (Open Shortest Path First) is a router protocol used within larger autonomous system networks in preference to the Routing Information Protocol (RIP), an older routing protocol that is installed in many of today's corporate networks. Like RIP, OSPF is designated by the Internet Engineering Task Force (IETF) as one of several Interior Gateway Protocols (IGPs) [21, 22].

Using OSPF, a host that obtains a change to a routing table or detects a change in the network immediately multicasts the information to all other hosts in the network so that all will have the same routing table information. Unlike the RIP in which the entire routing table is sent, the host using OSPF sends only the part that has changed. With RIP, the routing table is sent to a neighbor host every 30 seconds. OSPF multicasts the updated information only when a change has taken place [23].

Rather than simply counting the number of hops, OSPF bases its path descriptions on "link states" that take into account additional network information. OSPF also lets the user assign cost metrics to a given host router so that some paths are given preference. OSPF supports a variable network subnet mask so that a network can be subdivided. RIP is supported within OSPF for router-to-end station communication. Since many networks using RIP are already in use, router manufacturers tend to include RIP support within a router designed primarily for OSPF [23].

### **1.5.3 DIFFERENCE BETWEEN RIP AND OSPF**

Open Shortest Path First (OSPF) is a particularly efficient IGP routing protocol that is faster than RIP, but also more complex. The following sections describe how OSPF was invented, how OSPF works, and provide more OSPF information.

**How OSPF was invented.** The OSPF routing algorithm was developed to provide an alternative to RIP, based on Shortest Path First algorithms instead of the Bellman-Ford algorithm. It uses a tree that describes the network topology to define the shortest path from each router to each destination address. Since OSPF keeps track of entire paths, it has more overhead than RIP, but provides more options [24].

**How OSPF works.** The main difference between OSPF and RIP is that RIP only keeps track of the closest router for each destination address, while OSPF keeps track of a complete topological database of all connections in the local network. The OSPF algorithm works as described below.

**Startup.** When a router is turned on it sends Hello packets to all of its neighbors, receives their Hello packets in return, and establishes routing connections by synchronizing databases with adjacent routers that agree to synchronize.

**Update.** At regular intervals each router sends an update message called its "link state" describing its routing database to all the other routers, so that all routers have the same description of the topology of the local network.

**Shortest path tree.** Each router then calculates a mathematical data structure called a "shortest path tree" that describes the shortest path to each destination address and therefore indicates the closest router to send to for each communication; in other words -- "open shortest path first"[23,25].

## **1.6 DATA COMPRESSION IN THE NETWORKS**

The spread of computing has led to an explosion in the volume of data to be stored on hard disks and sent over the Internet. This growth has led to a need for "data compression", that is, the ability to reduce the amount of storage or Internet bandwidth required to handle data [26].

Data compression is often referred to as coding, where coding is a very general term encompassing any special representation of data which satisfies a given need. Information theory is defined to be the study of efficient coding and its consequences, in the form of speed of transmission and probability of error. Data compression may be viewed as a branch of information theory in which the primary objective is to minimize the amount of data to be transmitted [27].

A simple characterization of data compression is that it involves transforming a string of characters in some representation (such as ASCII) into a new string (of bits, for example) which contains the same information but whose length is as small as possible. Data compression has important application in the areas of data transmission and data storage. Many data processing applications require storage of large volumes of data, and the number of such applications is constantly increasing as the use of computers extends to new disciplines [28]. At the same time, the proliferation of computer communication networks is resulting in massive transfer of data over communication links. Compressing data to be stored or transmitted reduces storage and/or communication costs. When the amount of data to be transmitted is reduced, the effect is that of increasing the capacity of the communication channel. Similarly, compressing a file to half of its original size is equivalent to doubling the capacity of the storage medium. It may then become feasible

to store the data at a higher, thus faster, level of the storage hierarchy and reduce the load on the input/output channels of the computer system [29].

## 1.7 INTRODUCTION TO WAN TECHNOLOGIES

A WAN is a data communications network that covers a relatively broad geographic area and that often uses transmission facilities provided by common carriers, such as telephone companies. WAN technologies generally function at the lower three layers of the OSI reference model: the physical layer, the data link layer, and the network layer. Figure (1.7) illustrates the relationship between the common WAN technologies and the OSI model [30].

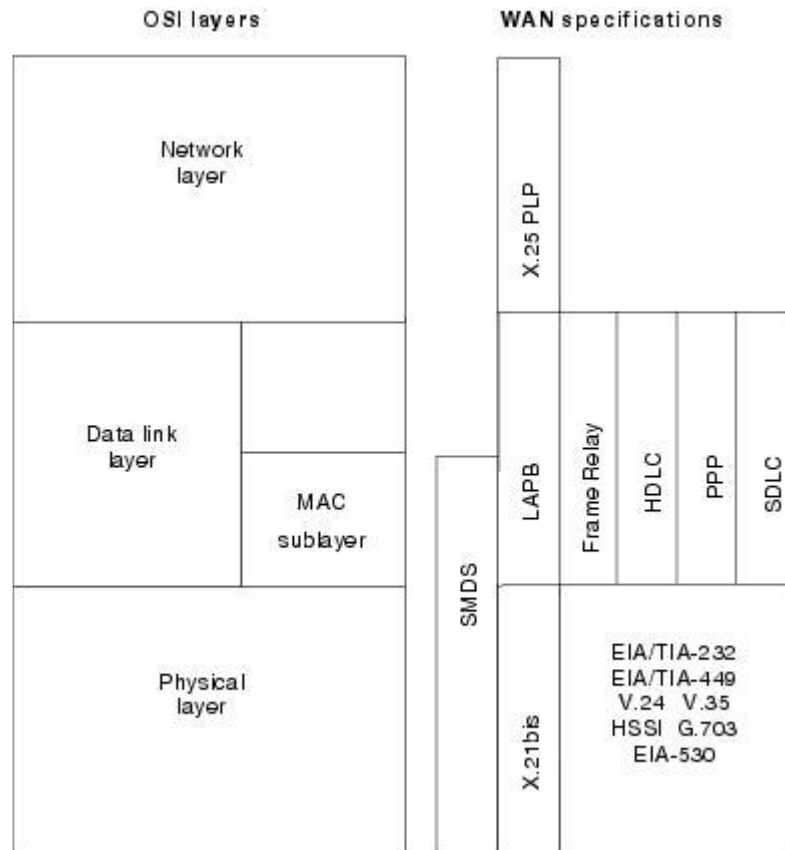


Figure 1.7 WAN Technologies Operate at the Lowest Levels of the OSI Model [17]

## 1.7.1 WAN DEVICES

WANs use numerous types of devices that are specific to WAN environments. WAN switches, access servers, modems, CSU/DSUs, and ISDN terminal adapters are discussed in the following sections. Other devices found in WAN environments that are used in WAN implementations include routers, ATM switches, and multiplexers.

### 1.7.1.1 WAN SWITCH

A WAN switch is a multi port internetworking device used in carrier networks. These devices typically switch such traffic as Frame Relay, X.25, and SMDS, and operate at the data link layer of the OSI reference model [31]. Figure (1.8) illustrates two routers at remote ends of a WAN that are connected by WAN switches.

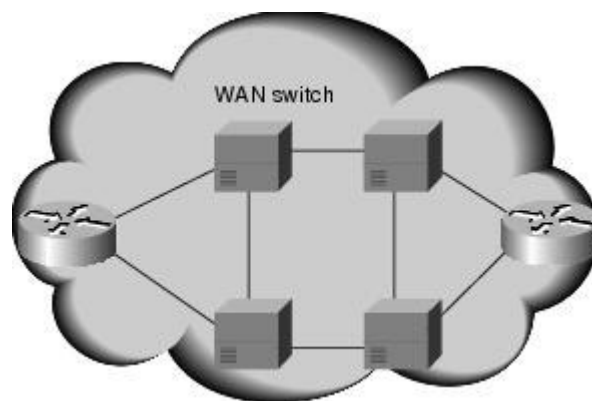


Figure 1.8 Two Routers at Remote Ends of a WAN Can Be Connected by WAN Switches [17]

### 1.7.1.2 ACCESS SERVER

An *access server* acts as a concentration point for dial-in and dial-out connections. Figure (1.9) illustrates an access server concentrating dial-out connections into a WAN.

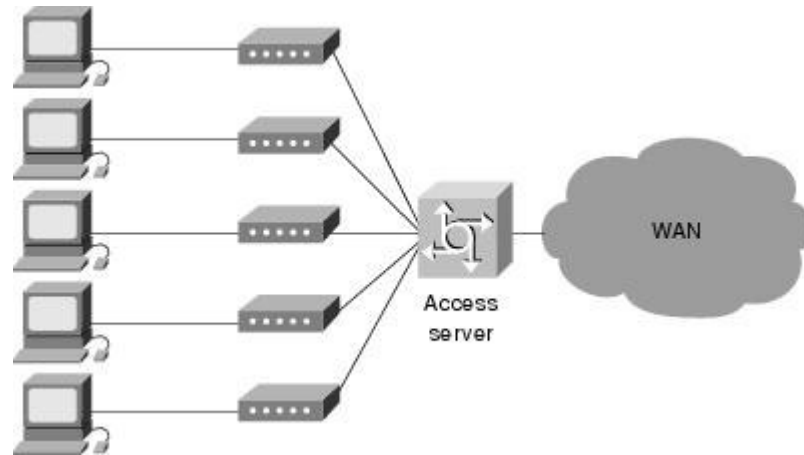


Figure 1.9 Access Servers Concentrates Dial-Out Connections into a WAN [17]

### 1.7.1.3 MODEM

A *modem* is a device that interprets digital and analog signals, enabling data to be transmitted over voice-grade telephone lines. At the source, digital signals are converted to a form suitable for transmission over analog communication facilities. At the destination, these analog signals are returned to their digital form. Figure (1.10) illustrates a simple modem-to-modem connection through a WAN [32].



Figure 1.10A Modem Connection through a WAN Handles Analog and Digital Signal [17]

## 1.8 VARIOUS STANDARDS OF LANS

WANs are used to connect LANs [32, 33] and other types of networks together, so that users and computers in one location can communicate with users and computers in other locations. There are various standards of LANs which are used in WANs.

### **1.8.1 10BASE-T BASED LAN**

10BASE-T, one of several physical media specified in the IEEE 802.3 standard for Ethernet local area networks (LANs)[33], is ordinary telephone twisted pair wire. 10BASE-T supports Ethernet's 10 Mbps transmission speed [34]. In addition to 10BASE-T, 10 megabit Ethernet can be implemented with these media types [34]:

10BASE-2 (Thin wire coaxial cable with a maximum segment length of 185 meters)

10BASE-5 (Thick wire coaxial cable with a maximum segment length of 500 meters)

10BASE-F (optical fiber cable)

10BASE-36 (broadband coaxial cable carrying multiple baseband channels for a maximum length of 3,600 meters)

The 10Base-T standard (also called Twisted Pair Ethernet) uses a twisted-pair cable with maximum lengths of 100 meters. The cable is thinner and more flexible than the coaxial cable used for the 10Base-2 or 10Base-5 standards. Cables in the 10Base-T system connect with RJ-45 connectors. A star topology is common with 12 or more computers connected directly to a hub [34].

This designation is an Institute of Electrical and Electronics Engineers (IEEE) shorthand identifier. The "10" in the media type designation refers to the transmission speed of 10 Mbps. The "BASE" refers to baseband signaling, which means that only Ethernet signals are carried on the medium. The "T" represents twisted-pair; the "F" represents fiber optic cable; and the "2", "5", and "36" refer to the coaxial cable segment length (the 185 meter length has been rounded up to "2" for 200)[33].

### **1.8.2 100BASE T BASED LAN**

100 base-T, a networking standard that supports data transfer rates up to 100 Mbps (100 megabits per second). 100BASE-T is based on the older Ethernet standard. Because it is 10 times faster than Ethernet, it is often referred to as Fast Ethernet. Officially, the 100BASE-T standard is IEEE 802.3u [34, 35].

Also in deeper sense 100base-T is a system designed to achieve 100 Mbps access time on Ethernet networks, which is 10 times the speed of standard Ethernet. The IEEE amended the 802.3 specifications to include 100 BaseTX, 100 BaseT4 and 100 BaseFX. 100 BaseT is configured in a star topology and therefore requires the use of a hub. Signals are transmitted from a central hub directly over one cable segment to the NIC's. Like Ethernet, Fast Ethernet makes use of the same CSMA/CD access method allowing multiple devices to operate while avoiding transmission collisions[31,32]. Although Fast Ethernet works at 10 times the speed of standard Ethernet [35], it also operates at over 10 times less the maximum allowable network diameter - from 2500 meter to 210 meters over copper. Similar to 10BaseT ,100BaseT standard is made up of 3 versions:

100BASE TX is full-duplex capable in point to point unshared applications because it uses 1 pair to receive and 1 pair to transmit. Designed to run over 2 pairs of category 5 unshielded twisted pair cable with RJ45 connectors and EIA/TIA 568B pinning. It can also be run on IBM type 1 shielded twisted pair (existing Token Ring wiring) with an impedance matching device and DB9 connectors or regular STP and DB9 connectors. Max segment length is 100m [36, 37].

100BASE T4 designed to run over 4 pairs of category 3, 4 or 5 UTP cable with RJ45 connectors and EIA/TIA 568B pinning. It can also be run over STP. 1 pair is used to receive while 3 pairs are used to transmit, however full-duplex operation does NOT work because specific pairs are not designated to transmit or receive. Max segment length is 100m [37, 38].

100BASE FX designed to run over 2 strands of duplex multimode fiber optic cable. It's also full-duplex capable because it uses one strand for receive and one for transmit. Maximum cable segment varies depending on the cabling used. Single mode (depending on the manufacturer) can exceed 10 km when full-duplex. Multimode maximum length is 412 meters for half-duplex and 2 km full-duplex. Maximum length from station to repeater is 150 meters [39, 40].

### **1.8.3 TOKEN RING: IEEE 802.5 LAN PROTOCOL**

Token Ring is a LAN protocol defined in the IEEE 802.5 where all stations are connected in a ring and each station can directly hear transmissions only from its immediate neighbor. Permission to transmit is granted by a message (token) that circulates around the ring [41].

Token-passing networks move a small frame, called a token, around the network. Possession of the token grants the right to transmit. If a node receiving the token has no information to send, it seizes the token, alters 1 bit of the token (which turns the token into a start-of-frame sequence), appends the information that it wants to transmit, and sends this information to the next station on the ring[41]. While the information frame is circling the ring, no token is on the network, which means that other stations wanting to transmit must wait. Therefore, collisions cannot occur in Token Ring networks.

The information frame circulates the ring until it reaches the intended destination station, which copies the information for further processing. The information frame continues to circle the ring and is finally removed when it reaches the sending station. The sending station can check the returning frame to see whether the frame was seen and subsequently copied by the destination [41].

### **1.8.4 FDDI**

Fiber distributed data interface (FDDI) provides a standard for data transmission in a local area network that can extend in range up to 200 kilometers (124 miles). Although FDDI protocol is a token ring network, it does not use the IEEE 802.5 token ring protocol as its basis; instead, its protocol is derived from the IEEE 802.4 token bus *timed token* protocol. In addition to covering large geographical areas, FDDI local area networks can support thousands of users. As a standard underlying medium it uses optical fiber (though it can use copper cable, in which case one can refer to CDDI). FDDI uses a dual-attached, counter-rotating token ring topology [42].

A FDDI network contains two token rings, one for possible backup in case the primary ring fails. The primary ring offers up to 100 Mbit/s capacity. When a network has no requirement for the secondary ring to do backup, it can also carry data, extending capacity to 200 Mbit/s [42]. The single ring can extend the maximum distance; a dual ring can extend 100 km (62 miles). FDDI has a larger maximum-frame size than standard 100 Mbit/s Ethernet, allowing better throughput [43]. FDDI requires this network topology because the dual ring actually passes through each connected device and requires each such device to remain continuously operational (the standard actually allows for optical bypasses, but network engineers consider these unreliable and error-prone). Devices such as workstations and minicomputers that may not come under the control of the network managers are not suitable for connection to the dual ring [43]. Due to their speed, cost and ubiquity, fast Ethernet and (since 1998) Gigabit Ethernet has largely made FDDI redundant.

## **1.9 OPNET IT GURU**

OPNET IT Guru is a modeling and simulation tool that provides an environment for analysis of communication networks that include a graphic environment for network modeling (with wireless mobility support), displaying statistics. Many pre-defined types of nodes are present and almost all widely used protocols and technologies are supported. The supported operating system is Windows only. The source code for protocols implementation is available; the application source code is closed. The application is quite sophisticated; it provides many settings for almost everything and it may be difficult for the beginner to get into it. Therefore, it is intended rather for the networking professionals than students. Anyway, without those license restrictions, it would be a nice tool [44].

## **1.10 OBJECTIVES**

There are two objectives of this thesis:

1. To investigate the usefulness of data compression in fast speed and slow speed SONET data communication network.
2. To evaluate the performance of different types of LANs in wide area network.

## **1.11 THESIS ORGANIZATION**

This thesis is divided into five chapters. This chapter provides a brief history on how SONET/SDH has evolved from a relatively unknown technology to become widely deployed in the telecommunications industry is presented. This is followed by some of the advantages and usefulness of SONET/SDH, with the main differences between SONET and SDH. The basic configuration and terminology associated with the equipment of a simple SONET network are also explained in this Chapter. What is data compression, introduction to WANs, introduction to simulation tool used in this thesis and the objectives of this thesis have also described in this chapter. The following paragraphs explained how the various chapters of this thesis report are being organized.

The second chapter includes the literature survey of various works done on routing in SONET.

The third chapter is focused on the first objective which evaluates the usefulness of data compression in fast speed and slow speed SONET data communication network. By modeling and simulating fast speed and slow speed network in OPNET IT Guru, it is observed that although the throughput between the switch and the client using compression is less than the throughput between the switch and the client that is not using the compression, the response time for the client using compression is higher. While, in contrast to a network deploying fast links, a network using slow links but fast compression algorithms reduces the overall response time as well as the throughput of its clients by using data compression.

The fourth chapter is focused on the third objective which evaluates the performance of different types of LANs in wide area network. By modeling and simulating the wide area network connected with various LANs in OPNET IT Guru, the overall result demonstrate that FDDI based LAN achieves better performance among all types of LANs and is the least obtrusive on network operations.

Finally the last chapter concludes the thesis report with outcome of the research and what future research areas can be further explored.

This chapter includes the literature survey of various works done on routing in SONET.

### 2.1 SURVEY ON SONET/SDH

Mordechai Shalom and Shmuel Zaks [45] had demonstrated that SONET ADMs are dominant cost factors in WDM/SONET rings. Where as most previous papers on the topic concentrated on the number of wavelengths assigned to a given set of light paths, recent papers argue that the number of ADMs is a more realistic cost measure. The minimization of this cost factor has been investigated in recent years, where single-hop and multi-hop communication models, with arbitrary traffic and uniform traffic loads have been investigated. This paper looked for a solution which makes full use of the bandwidth and uses the minimum possible number of ADMs. An architecture based on successive nested polygons is developed in this paper and it presents a necessary and sufficient condition for a solution in this architecture to be feasible. This architecture leads to a solution using  $O(W \log W + N)$  ADMs where  $W$  is the number of wavelengths used, and  $N$  is the number of nodes in the ring. This is a substantial improvement compared to  $NW$  ADMs for the basic architecture in [O. Gerstel, P. Lin, G. Sasaki, Combined wdm and SONET network design, in: INFOCOM'99, Eighteenth Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 2, 1999, pp. 734–743], and optimal for  $W=O(N/\log N)$ . This result is further improved into  $O(W \log \bar{W} + N)$  ADMs, where  $\bar{W} = o(W)$ . This architecture constitutes a solution for the traffic grooming problem, which is the subject of many recent works

Hillard; David A. and Anbiah [46] had demonstrated that the invention provides a method and system for enhancing the capability to optimally route VT circuits over SONET networks. The invention discloses a method for identifying Network Elements (NEs) that have VT capability (i.e., VT cross connect capability) and, when desired or

required for VT circuit routing, manually or automatically topologically interconnecting these NEs by STS-1 circuits called VT Tunnels. Once interconnected, these VT Tunnels are suitable for supporting user VT traffic without the network operator being required to upgrade non-VT NE with VT capability or without having to exhaust the limited pool of available VT cross connects on one or more NEs.

Edward E. E. Frietman Roy Crosbie and George Balogh [47] analyzed that Present communication technologies idealize the Internet as a global information infrastructure, while higher bandwidths are still not met. While voice traffic could be handled in the SONET/ SDH network architecture in the past, implementations of combinations of voice and video applications are still not available. Dense Wavelength-Division-Multiplexing has advanced the arrival of semi-optical communications, but even though it has improved overall performances, any two sided conversion between the electrical and optical domain still decelerate the throughput on the superhighway. Introducing optical switching has changed the coherence within and the design of the network because switches cannot direct large streams of information in a single fiber at ultimate speeds. Channeling hundreds of wavelengths into each fiber, whereas each wavelength wraps up thousands of calls or billions of data bits first and than sending them to the demultiplexing section containing all the output fibers is an alternative. Moreover cross-connects, as optical wavelength switches are called, do not only route the incoming wavelengths to any available output fiber, but they also handle the required overall data transfer rate. Packet-switched all-optical networks strive for a combination, amplification, switching and restoring of the various signals without executing the inevitable conversions on the one hand, providing for protocol heterogeneity (the transparency of the transport layer) on the other. This paper described that optical routing becomes a necessity when packet speeds exceed present transfer rates of 200 Gbits/sec. Optical packets are sorted along space, time and wavelength to explore this.

Mazzola, Anthony J. [48] studied a routing method, performed by intelligent network elements of a data communications network having SONET applications, for selecting a path from a source network element to a next network element. Each network element has access to a database containing the addresses of its neighboring network

elements and their types. To select a next network element, a routing network element first attempts to find a neighboring network element that is the same as the destination network element. If it has no such neighbor, the routing network element then attempts to find a neighbor that is in the same area as the destination, or failing such a neighbor, in the same routing domain.

Olivier Goldschmidt, Alexandre Laugier and Eli V. Olinick [5] had considered the problem of interconnecting a set of customer sites using bidirectional SONET rings of equal capacity. Each site is assigned to exactly one ring and a special ring, called the federal ring, interconnects the other rings together. The objective is to minimize the total cost of the network subject to a ring capacity limit where the capacity of a ring is determined by the total bandwidth required between sites assigned to the same ring plus the total bandwidth request between these sites and sites assigned to other rings. It showed that two of the heuristics find solutions that cost at most twice that of an optimal solution. Empirical evidence indicates that in practice the algorithms perform much better than their theoretical bound and often find optimal solutions.

Pankaj K. JHA [49] had studied that with growing volume in data traffic, SONET/SDH networks must now carry a significantly large number of data packets in addition to traditional T1/T3 channels. In this paper it is also observed that current protocols on these networks, however, do not allow transmission of different data types on a single fiber (or wavelength) without seriously compromising timing relationships and/or wasting available bandwidth. This paper described a Hybrid Data Transport (HDT) protocol that allows transmission of Fractional T1 (in increments of DS0, starting at DS0 bandwidth), T1/T3, ATM, IP and any other protocol data in a single SONET frame, allowing maximum bandwidth usage on a fiber. With a unified packet framing across a mix of SONET and non-SONET networks, dynamic bandwidth provisioning on a packet-by-packet basis and hybrid data mixing capability, this protocol maximizes bandwidth usage and yields major cost savings in fiber infrastructure, equipment, and operation.

J. Cole Smith had showed in this paper [7] that a problem arises in the assignment of telecommunication traffic to a set of synchronous optical network (SONET) rings. Prior SONET design algorithms determine node-to-ring assignments while concurrently prescribing an assignment of traffic to the rings. However, due to uncertain voice and data demand among client nodes, it may become necessary to revise the planned routing scheme once the true values of this data are realized. A minimum cost flow algorithm for the case in which demands may be split across multiple rings is developed in this paper, and this also provide a transformation to a maximum flow problem for specially structured data. The case in which each demand pair may be routed on only one ring is proven to be NP-hard, and this paper provided a powerful heuristic and an effective standard valid inequality generation scheme to optimally solve this problem within reasonable computational limits.

Ori Gerstel [9] had analyzed the possible applications for optical networks based on wavelength division multiplexing and how they compete and complement current high-speed networks (SONET, ATM). This paper outlined the best-case scenario for this technology and described the spectrum of proposed optical networks (WDM links, passive optical access networks, broadcast-and-select networks, and wavelength routing networks).

Christine T. Cheng [50] had demonstrated that in the demand routing and slotting problem on unit demands (unit-DRSP), a set of unit demands on an  $n$ -node ring can be given. Each demand, which is a (source, destination) pair, must be routed clockwise or counterclockwise and assigned a slot so that no two routes that overlap occupy the same slot. The objective of this paper was to minimize the total number of slots used. The best deterministic approximation algorithm guaranteed a solution that is  $2 \times \text{OPT}$ .

Huang, [51] had studied a method of assigning capacity and routing flow in a bi-directional line switched SONET ring based upon ring topology and demand data defines for each pair of links of the ring a two-edge cut The capacity assignment method then determines the maximum demand and sets the capacity of each link equal to one-half the maximum demand plus one-half of one demand unit. The flow routing method of the

present invention calculated a cut difference for each two-edge cut. A critical cut is a two-edge cut having a cut difference equal to or less than one. If there is a critical cut with demands greater than zero on the same side of the critical cut, the method performs a first processing routine. If there is no critical cut with demands greater than zero on the same side of the critical cut, the method performs a second processing routine. This paper showed that flow routing method performs the first or second processing routine until the occurrence of a terminating condition.

Ashraf Hamad, Tao Wu, Ahmed E. Kamal and Arun K. Somani [52] had demonstrated in this paper that consider multicasting on wavelength-routing mesh optical networks. Although multicasting has been studied extensively in different network environments, multicasting in this environment is different, and more involved. This paper discussed the challenges of multicast support in optical wavelength routing networks, and reports on the advances made so far in this venue. The paper introduced a classification and a comparison of such techniques, and a study of their advantages and disadvantages

Sandstorm; Mark Henrik [53] had demonstrated a method in this paper that enables building a (logical) SDH/SONET ring where the connections between the packet-switched Access Interfaces of the SDH/SONET ring are automatically and dynamically (at 1 ms time-scale) arranged based on the actual volumes of the packet traffic flows between the Access Interfaces of the SDH/SONET ring and fair sharing of network resources. Traffic prioritizing is possible within the Access Interface to Access Interface traffic flows. This paper showed that no packets are lost in the SDH/SONET ring, unless temporarily in case of line or equipment failure.

Harmon David [54] demonstrated that routing frames in a communication ring includes receiving an invitation at a proxy server of a node of a ring. The invitation indicates that a first endpoint is initiating a call to a second endpoint. An access device operable to communicate the call to the second endpoint is identified. The access device has a private network identifier uniquely identifying the access device within the ring. A media path to the access device is reserved. This paper showed that the private network

identifier is inserted into frames received from the first endpoint in order to route the frames to the second endpoint through the media path.

Mandhyan; Indur B. [55] had demonstrated a method for finding or routing a ring containing predetermined ring offices of a communications network while minimizing costs of communications channels used to route the ring. The ring may be a self-healing ring, the communications channels may be optical communications channels, the costs may be fiber transport costs and the network may be a SONET network.

Achille Pattavina [56] had analyzed theoretically and experimentally in this paper that deals with optical packet switching in a full-IP transport network scenario. For the switching of IP packet flows different node architectures are considered that are based on current optical routing devices. The traffic performance of a mesh network is evaluated with the various node structures, assuming that nodes employ either shortest path routing or deflection routing to forward packets to the addressed destinations. This paper showed how the different node structures behave in terms of packet loss probability with different network configurations when the node parameters are varied.

Alok Baveja, Aravind Srinivasan [57] had contributed to a body of research asserting that the fractional and integral optima of column-sparse integer programs are “nearby”. This yields improved approximation algorithms for some generalizations of the knapsack problem, with applications to low-congestion routing in networks, file replication in distributed databases, and other packing problems.

## **2.2 SURVEY ON DATA COMPRESSION**

Cohen. R, [58] had analyzed in this paper that a method for compressing a packetized SONET/SDH stream for transmission over a packet switched network, comprising identifying a C2 byte in the stream, and, based on the identification, applying a C2 byte-related compression algorithm to compress the stream. The C2 byte is either extracted by a packet processor from a packet payload or header, pre-configured within an ingress packetizer, or identified automatically from examining the SONET circuit sent from an egress packetizer back to an ingress packetizer.

Nag, K.T, Chan, S.C Shum, and H.Y [59] had studied in their paper that panoramic videos are effective means for representing static or dynamic scenes along predefined paths. This paper proposes efficient data compression and transmission techniques for panoramic videos. A high-performance MPEG-2-like compression algorithm, which takes into account the random access requirements and the redundancies of panoramic videos, is proposed. The transmission aspects of panoramic videos over cable networks, local area networks (LANs), and the Internet are also discussed.

### **2.3 SURVEY ON WIDE AREA NETWORK**

C. L. Su C. N. Lu and M. -C. Lin [60] had studied in their paper that distribution automation is considered a necessity for providing better power service in a more competitive environment. When new automatic functions are included in a distribution management system (DMS), loadings of the data links in the supervisory control and data acquisition (SCADA) system will become very heavy. In order to maintain a proper performance, system upgrade or migration will need to be considered. Two wide area network (WAN) architectures for a Taiwan Power Company's regional DMS are investigated. The WAN modeling presented in this paper is aimed to verify whether the hardware design could accommodate the communications load and to avoid overpaying for network equipments.

M. -C. Lin [61] had studied in this paper that Network topology significantly affects the system performance of local area networks. The bus topology was considered for optical local area networks since the degradation of system performance due to propagation delay could be reduced. Power budget constraints severely limited maximum system size which diminished its appeal. On the other hand, the star topology was shown to have excellent fanout and fault tolerance that led to extensive research interest in star based systems.

# COMPARISON AND PERFORMANCE ANALYSIS OF DATA COMPRESSION IN FAST SPEED AND SLOW SPEED SONET BASED NETWORK

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In this chapter, the response of fast speed and slow speed SONET based data communication network will be observed when a compressed and uncompressed data is sent through the link. The usefulness of data compression is determined based on the total response time to transmit the data and throughput (traffic) between the switch and user. Finally on comparing the result of two scenarios it is observed that fast speed network shows less throughput (traffic) but higher overall response time when compressed data is sent through the link in comparison to uncompressed data. While the slow speed network shows less throughput and less overall response time when compressed data is sent through the link in comparison to uncompressed data.

### 3.1 INTRODUCTION

The spread of computing has led to an explosion in the volume of data to be stored on hard disks and sent over the Internet. This growth has led to a need for "data compression", that is, the ability to reduce the amount of storage or Internet bandwidth required to handle data. Data compression is often referred to as coding, where coding is a very general term encompassing any special representation of data which satisfies a given need [26]. Information theory is defined to be the study of efficient coding and its consequences, in the form of speed of transmission and probability of error. Data compression may be viewed as a branch of information theory in which the primary objective is to minimize the amount of data to be transmitted [26]. A simple characterization of data compression is that it involves transforming a string of characters in some representation (such as ASCII) into a new string (of bits, for example) which contains the same information but whose length is as small as possible [27]. Data compression has important application in the areas of data transmission and data storage.

Many data processing applications require storage of large volumes of data, and the number of such applications is constantly increasing as the use of computers extends to new disciplines. At the same time, the proliferation of computer communication networks is resulting in massive transfer of data over communication links. Compressing data to be stored or transmitted reduces storage and/or communication costs [27]. When the amount of data to be transmitted is reduced, the effect is that of increasing the capacity of the communication channel. Similarly, compressing a file to half of its original size is equivalent to doubling the capacity of the storage medium. It may then become feasible to store the data at a higher, thus faster, level of the storage hierarchy and reduce the load on the input/output channels of the computer system. When compressed data is sent over the link, time is gained, because the frames become smaller and the overall transmission delay reduces and the time is lost, because the compression and decompression processes consume a certain amount of time. So data compression in fast speed and slow speed SONET has advantages as well as disadvantages [28]. So it is necessary to analysis the result whether it will be proper to send compressed data over fast speed links as they are already fast. In slow speed SONET the data takes more time to transmit from source to destination due to slow data rate of the link. The main purpose of data compression is to reduce the overall delay of the data transmission [29].

### **3.2 SIMULATION SET UP**

OPNET IT Guru 9.1 is a modeling and simulation tool that provides an environment for analysis of communication networks. However, it does not have a SONET DCC model in its standard model library. Thus a SONET DCC network model was created to facilitate the simulation. Two different scenarios were created using this OPNET model to simulate the packet flow within the SONET DCC network to understand the usefulness of data compression in fast speed and slow speed network. In the first scenario fast speed optical carrier links (OC-192) are used to connect the routers to each other in the network which have data rate 9953.28 Mbps. While in the second scenario slow speed optical carrier links (OC-1) are used to connect the routers to each other in the network which have data rate 51.84 Mbps.

The network configuration for this study consists of two nodes named as servers and clients connected through internet as shown in the figure (3.1) given below:

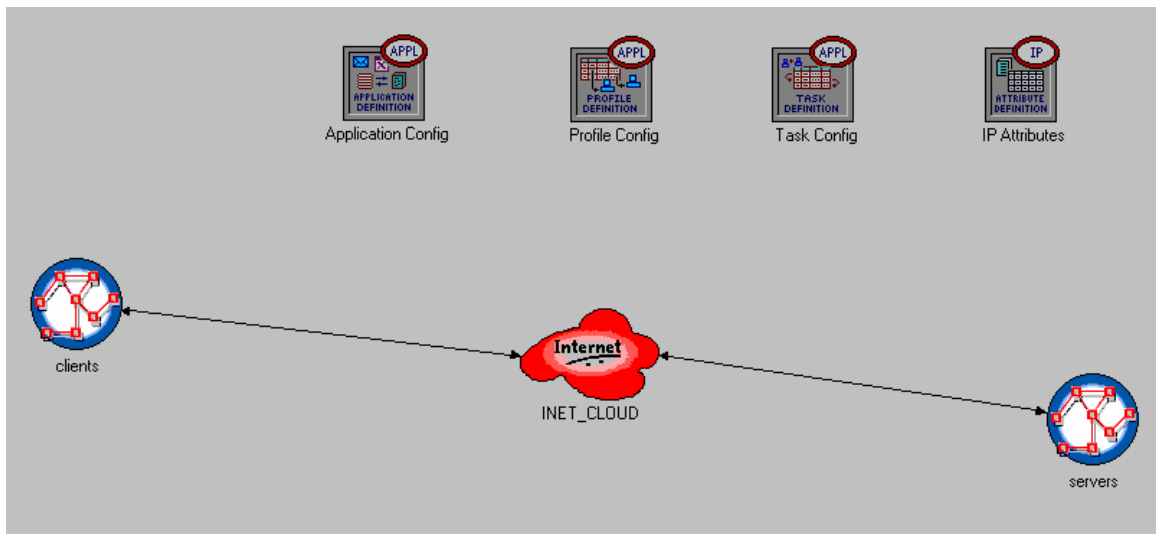


Figure 3.1 SONET based data communication network in OPNET

The servers node consists two servers (one for data compression and other for without data compression) connected with a switch to each other and the switch is connected to a router which is used to route the data to another subnet. The internal view of node servers is shown in the figure (3.2) below.

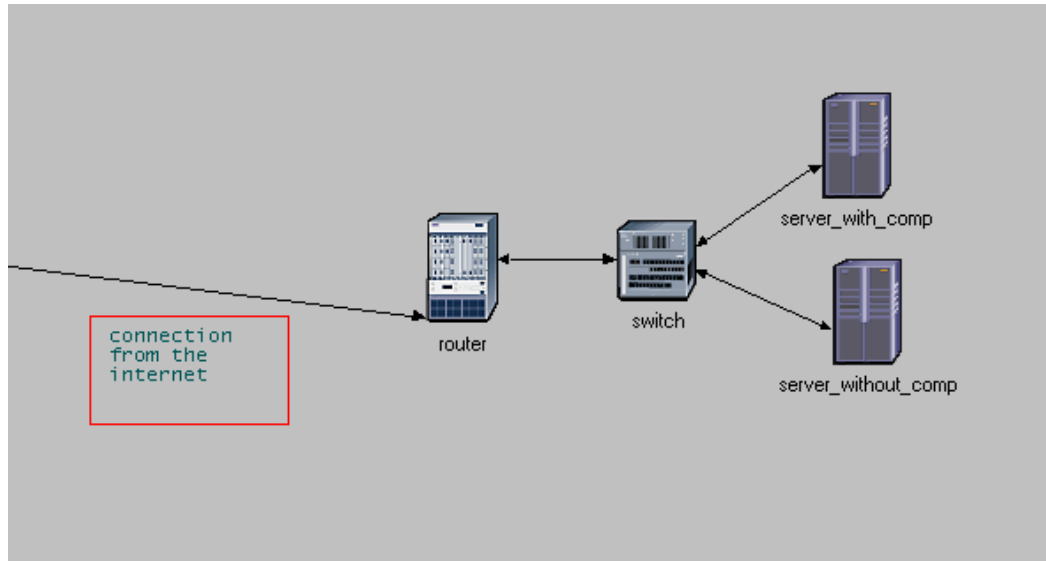


Figure 3.2 – Internal view of node servers

Similarly the clients node consists two clients (one for data compression and other for without data compression) connected with a switch to each other and the switch is connected to a router which is used to route the data to another subnet. The internal view of node named as clients is shown in the figure (3.3) below.

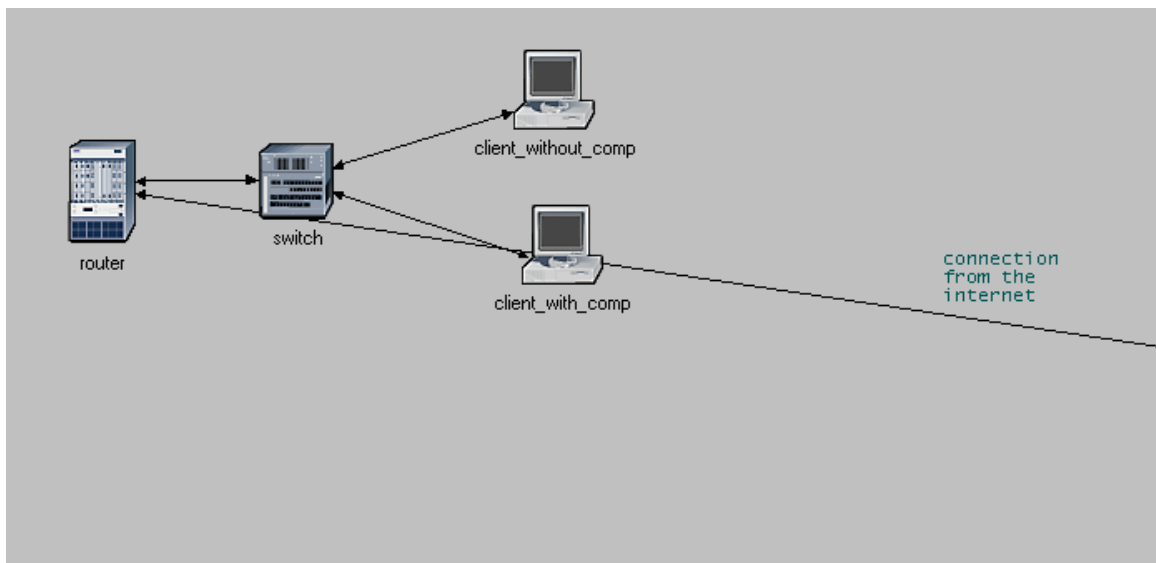


Figure 3.3- Internal view of node clients

Also there are various nodes which are defined in the network for the various applications. These are

1. Application configuration-The "Application Config" node is used to specifies the different tier names used in the network model. The tier name and the corresponding ports at which the tier listens to incoming traffic is cross-referenced by different nodes in the network. Also it specifies applications using available application types.

2. Profile configuration - The "Profile Config" node is used to create user profiles. These user profiles can then be specified on different nodes in the network to generate application layer traffic. The application defined in the "Application Config" objects is used by this object to configure profiles. This specify the traffic patterns followed by the applications as well as the configured profiles on this object.

3. Task configuration - The "Task Config" node is used to define/create tasks used to characterize custom applications. These applications are then used to create profiles, which are applied across different nodes to generate desired traffic.

4. IP attribute—it defines attribute configuration details for protocols supported at the IP layer.

### **3.3 RESULTS AND DISCUSSION OF THE SIMULATION**

The test scenarios vary the type of link to investigate the effect of data compression in fast speed and slow speed SONET based data communication network. Figures (3.4) to (3.7) illustrate the comparisons of data compression in fast speed as well as in slow speed network when compressed data and uncompressed data are sent from server to the workstation. The performance metrics studied were the total response time and throughput.

#### **3.3.1 RESULTS OF DATA COMPRESSION IN FAST SPEED NETWORK**

When compressed data is sent through the link the frame size become small and the transmission delay reduces but some time is lost because the compression and

decompression processes consume a certain amount of time. The usefulness of data compression is determined based on the balance of time gain and time lost. If fast links are used, the high data rate lead to small transmission delays. Hence, there might be no gain in time when using data compression if fast links and slow compression algorithms are deployed.

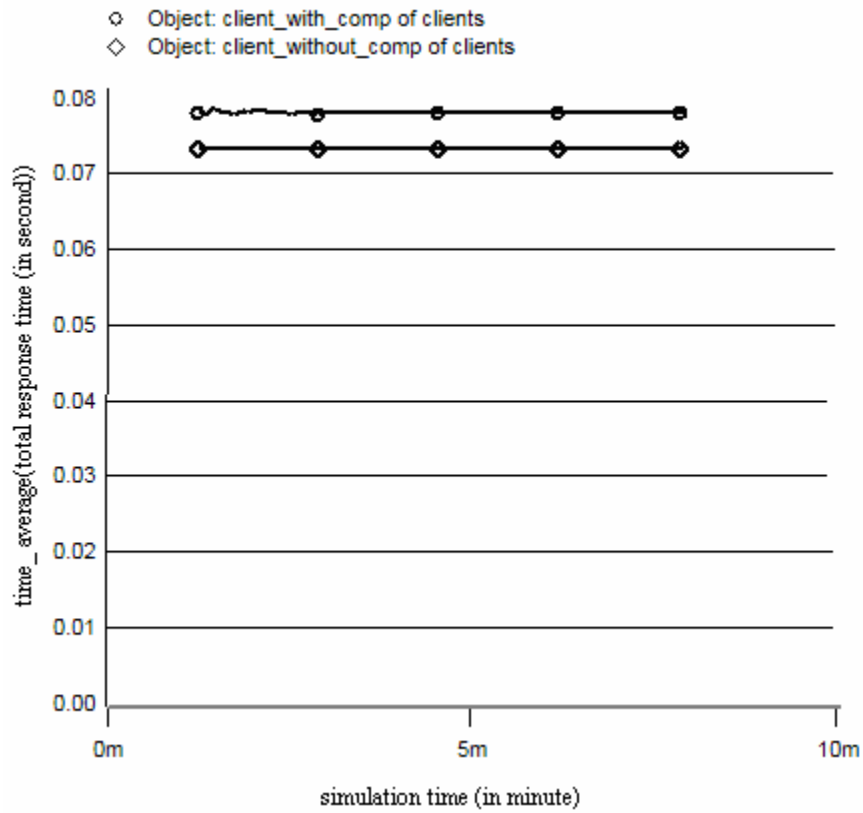


Figure 3.4 – Comparison of total response time in fast speed network between compressed and uncompressed data

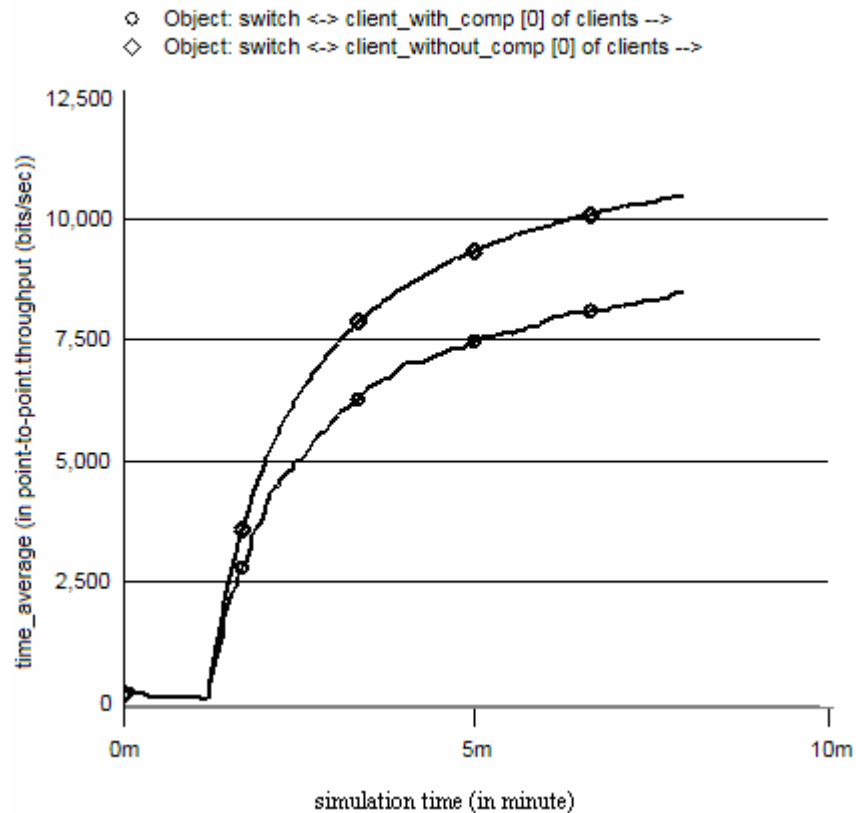


Figure 3.5 – Comparison of throughput in fast speed network between compressed and uncompressed data

The results as shown in the figures (3.4) & (3.5) given above shows that the throughput between the switch and the client using compression is less than the throughput between the switch and the client that is not using the compression but the response time for the client using compression is higher. In other words, the client loses more time for the compression and decompression processes than it gains from the transmission of the smaller frames.

### 3.3.2 RESULTS OF DATA COMPRESSION IN SLOW SPEED NETWORK

In contrast to a network deploying fast links, a network using slow links but fast compression algorithms reduces the overall response time of its clients by using data compression. High transmission delays in slow links are compensated by the smaller frames due to data compression. They might also compensate the additional delays

incurred while compressing and decompressing. Also data compression in slow speed network reduces the throughput between the switch and client as shown in the figures (3.6) and (3.7). As demonstrated in the results of fast speed network, the throughput on the link between the switch and the client using the compression is less than the throughput between the switch and the client without compression because of smaller data frames. The results of slow speed network show that the client using compression observes a faster response time. This implies that its compression and decompression processing delays are paid off by the smaller transmission delays of its smaller packets

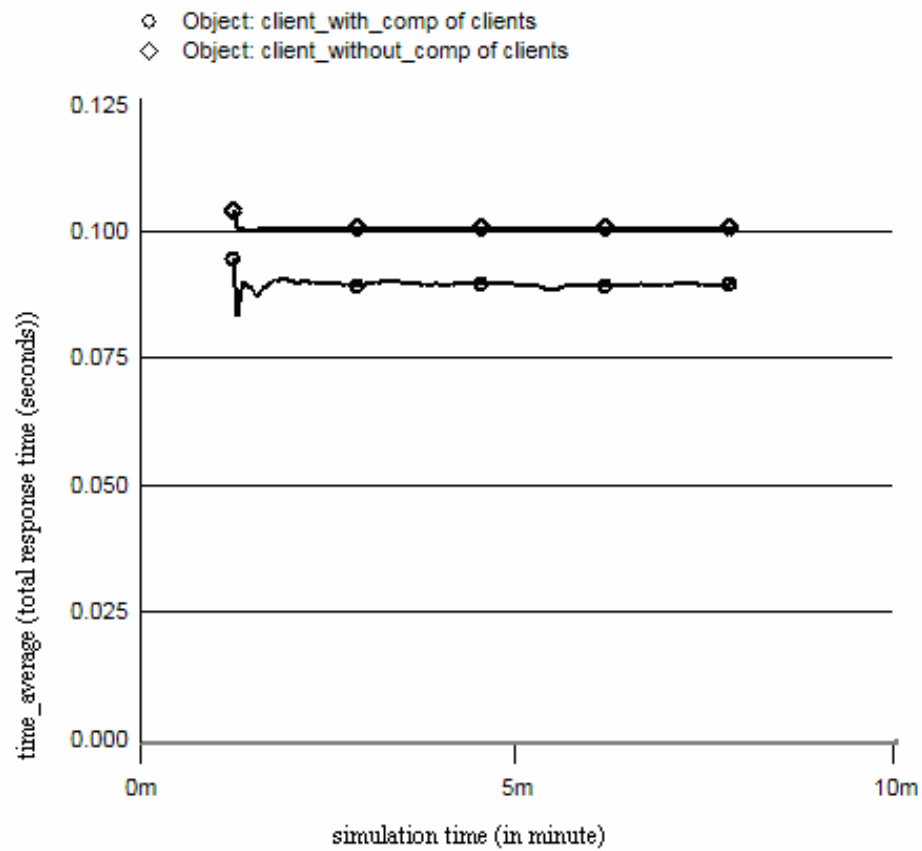


Figure 3.6- Comparison of total response time in slow speed network between compressed and uncompressed data

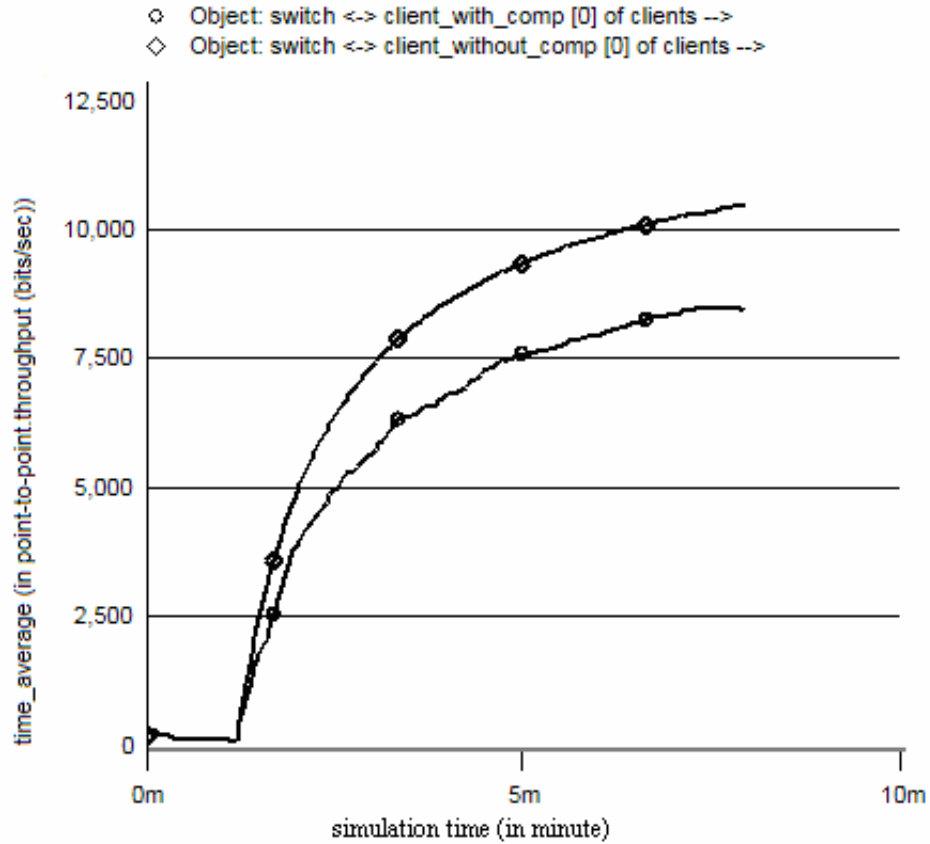


Figure 3.7- Comparison of throughput (traffic) in slow speed network between compressed and uncompressed data

### 3.4 CONCLUSION

Finally on comparing the result of two scenarios we can conclude that high speed network shows less throughput (traffic) but higher overall response time while the slow speed network shows less throughput and less overall response time when compressed data is sent through the link. So we can say that there is no need to transmit the compressed data in the high speed network because it transmits uncompressed data to higher speed than the compressed data as compression and decompression of data takes relatively more time. But we also observe that data compression improves the throughput of the high speed network which is the main advantage of data compression.

# COMPARISON AND PERFORMANCE ANALYSIS OF DIFFERENT TYPE OF LANS IN WIDE AREA NETWORK

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In this chapter, a wide area network is designed which consists different types of local area networks such as 10baseT-LAN, 100baseT-LAN, Token ring LAN and FDDI (fiber distributed data interface) based LAN for optimal performance. The simulation, in this chapter, will examine and compare different performance parameter such as server performance of different types of LANs in terms of load (request/sec), and load (tasks/sec) , LAN delay (overall delay of a LAN). Also client e-mail download response time for different LANs is compared in this chapter. Finally, on comparing all performance parameter, LAN delay and e-mail response time it is investigated that FDDI based LAN achieves better performance among all types of LANs and is the least obtrusive on network operations.

### 4.1 INTRODUCTION

Wide Area Network (WAN) is a computer network that covers a broad area (i.e., any network whose communications links cross metropolitan, regional, or national boundaries) in contrast to personal area networks (PANs), local area networks (LANs), campus area networks (CANs), or metropolitan area networks (MANs) which are usually limited to a room, building, campus or specific metropolitan area (e.g., a city) respectively [29]. The largest and most well-known example of a WAN is the Internet. WANs are used to connect LANs and other types of networks together, so that users and computers in one location can communicate with users and computers in other locations [29]. Many WANs are built for one particular organization and are private. Others, built by Internet service providers, provide connections from an organization's LAN to the Internet. WANs are used to connect LANs [26] and other types of networks together, so that users and computers in one location can communicate with users and computers in other locations. There are various standards of LANs which are used in WANs. 10BASE-

T, one of several physical media specified in the IEEE 802.3 standard for Ethernet local area networks (LANs) [26,27], is ordinary telephone twisted pair wire. 10BASE-T supports Ethernet's 10 Mbps transmission speed [27]. In addition to 10BASE-T, 10 megabit Ethernet can be implemented with these media types [28]. 100base-T, a networking standard that supports data transfer rates up to 100 Mbps (100 megabits per second). 100BASE-T is based on the older Ethernet standard. Because it is 10 times faster than Ethernet, it is often referred to as Fast Ethernet. Officially, the 100BASE-T standard is IEEE 802.3u [29, 30]. Token Ring is a LAN protocol defined in the IEEE 802.5 where all stations are connected in a ring and each station can directly hear transmissions only from its immediate neighbor. Permission to transmit is granted by a message (token) that circulates around the ring [34]. Token-passing networks move a small frame, called a token, around the network. Possession of the token grants the right to transmit. If a node receiving the token has no information to send, it seizes the token, alters 1 bit of the token (which turns the token into a start-of-frame sequence), appends the information that it wants to transmit, and sends this information to the next station on the ring[34]. While the information frame is circling the ring, no token is on the network, which means that other stations wanting to transmit must wait. Therefore, collisions cannot occur in Token Ring networks. Fiber distributed data interface (FDDI) provides a standard for data transmission in a local area network that can extend in range up to 200 kilometers (124 miles) [43]. Although FDDI protocol is a token ring network, it does not use the IEEE 802.5 token ring protocol as its basis; instead, its protocol is derived from the IEEE 802.4 token bus timed token protocol. In addition to covering large geographical areas, FDDI local area networks can support thousands of users. As a standard underlying medium it uses optical fiber (though it can use copper cable, in which case one can refer to CDDI). FDDI uses a dual-attached, counter-rotating token ring topology [35].

## 4.2 SIMULATION SET UP

OPNET IT Guru 9.1 is a modeling and simulation tool that provides an environment for analysis of communication networks. To study network performance a scenario was created using this OPNET model to simulate the packet flow within the WAN network and to examine different performance parameter such as server performance of every LAN in terms of load (requests/sec),load (tasks/sec), LAN delay (overall delay of the LAN). The scenario present a campus network with six local area networks connected to an ATM backbone. The network has 10baseT-LAN, 100baseT-LAN, FDDI based LAN and Token Ring LANs with various numbers of clients and application configuration.

The network configuration for this study consists of a FTP server, six local area networks and routers and is depicted in Figure (4.1) below.

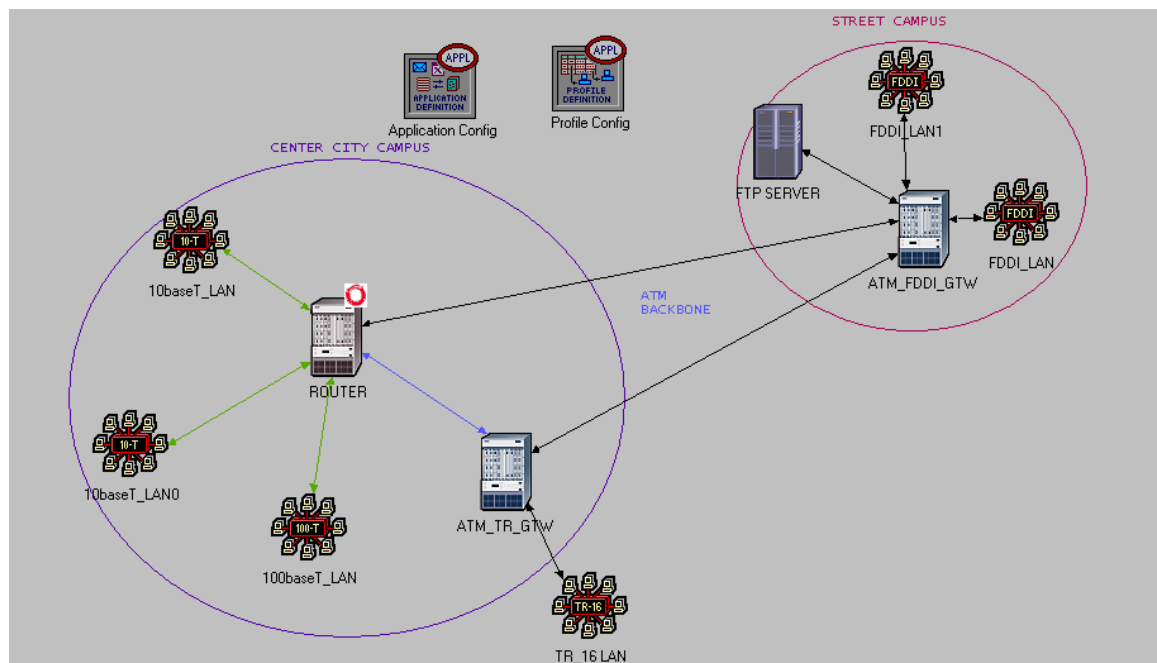


Figure4.1. Wide area network configuration simulated in OPNET

In this network configuration there are four types of local area networks like 10 base-T, 100baseT, Token ring and FDDI based local area network. Data rate of 10 baseT LAN is

10 Mbps. 100baseT local area network has 100 Mbps data rate. While TR-16 local area network which transfers data at the rate of 16Mbps. Four LANs (two 10 base-T, 100base T and TR-16 LAN) are connected through a router in the same city campus while other two LANs (both FDDI based) and a FTP server are connected to each other through an ATM gateway in the another campus and these two campus are connected with a SONET-based optical carrier (OC12) link to form a wide area network. Thus all the clients are indirectly connected to the FTP server via their local routers which are configured to form the DCN for network management of the optical network. The data rate of the links connecting these two cities is 622.08 Mbps or OC-12 (equivalent to STS-12 in SONET frame and STM in SDH) which makes the network to be SONET based data communication network.

### **4.3 RESULT AND DISCUSSION OF THE SIMULATION**

The test scenario varies the type of local area network to determine the optimum performance within the wide area network. In the scenario, there is a wide area network consisting different types of local area networks such as 10baseT-LAN, 100baseT-LAN, Token ring LAN and FDDI (fiber distributed data interface) based LAN. This simulation will examine and compare different performance parameter such as server performance of different types of LANs in terms of load (request/sec), load (task/sec) and task processing time, LAN delay (overall delay of a LAN). Also this will compare client e-mail download response time for different LANs.

All tests were performed using the network configuration as shown in Figure (4.1). The objective of each simulation scenario was to evaluate performance metrics, such as LAN delay, server performance, client e-mail response time that are available in OPNET, collected after the simulation. These performance metrics were studied because LAN delay serves to identify the time taken for a packet to travel across multiple links to the destination within the LAN. Server performance measures the time taken for the server to process a request from the workstations. Since the remote workstations are dispersed throughout the network, both LAN delay and server performance provide a good indication of potential bottlenecks and areas of congestion. A low value of either

LAN delay or server performance indicates a network that is functioning efficiently with minimal overhead intrusion from the routing protocol.

Similarly, client e-mail download response time provides a good measure of time experienced to send a mail from one workstation to another workstation. Again, a lower value of client e-mail download response time indicates the network is not congested with routing overhead.

### 4.3.1 RESULT DISCUSSION OF THE SIMULATION

Figures (4.2) to (4.5) illustrate comparisons between results of these parameters in different type of LANs.

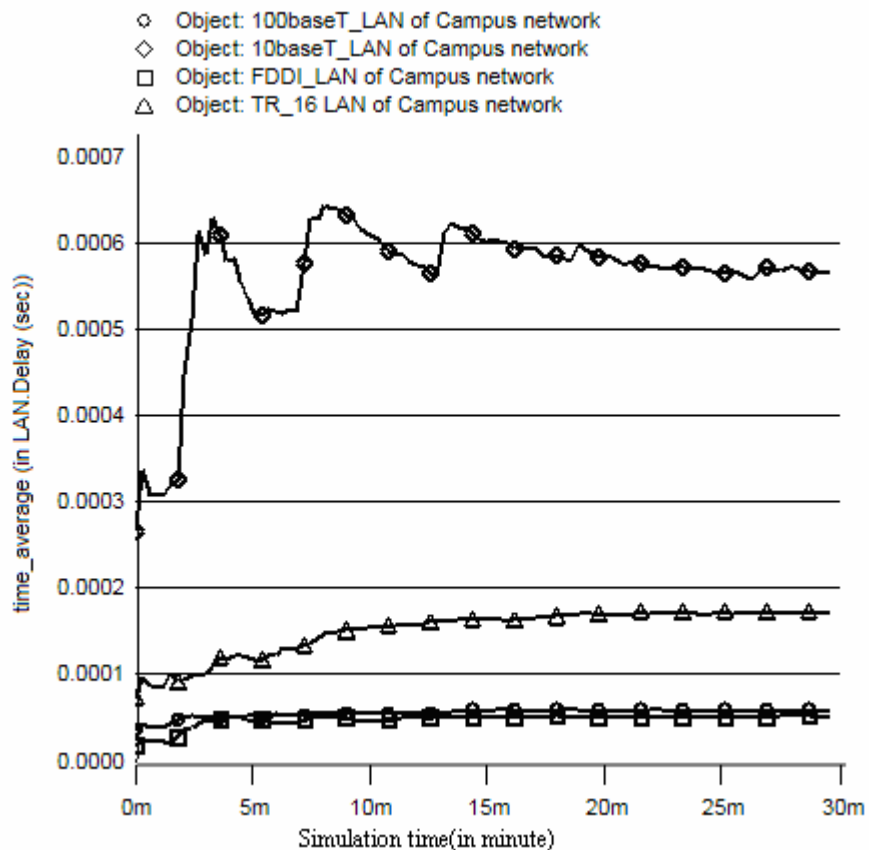


Figure4.2-LAN delay of different LANs

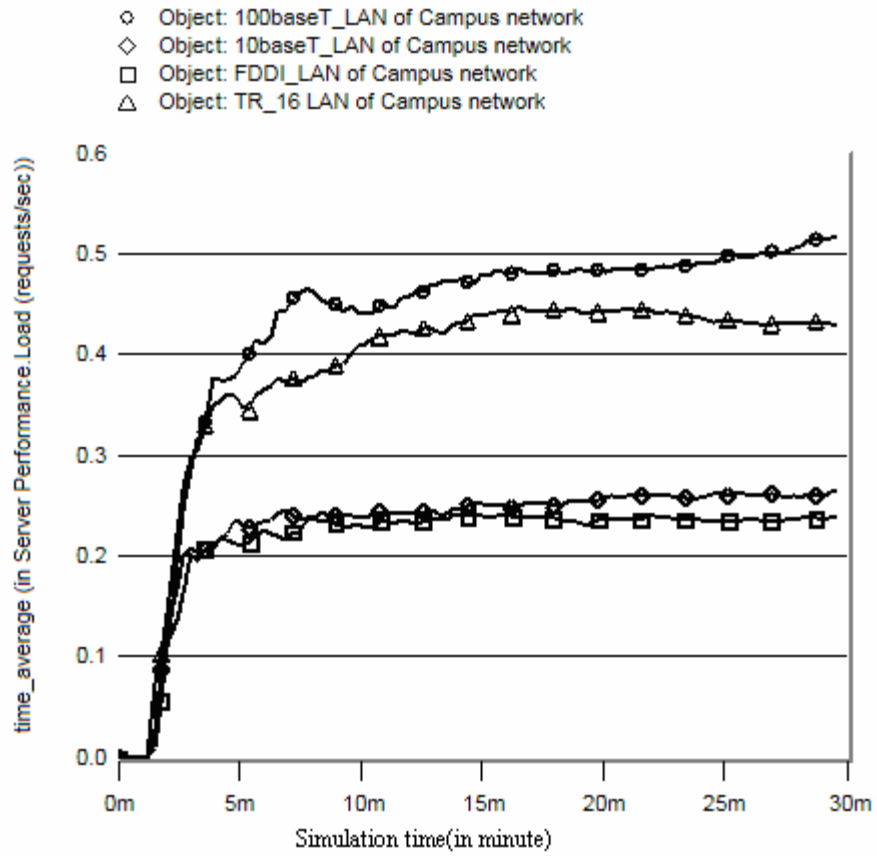


Figure 4.3 - Server performance load (request/sec)

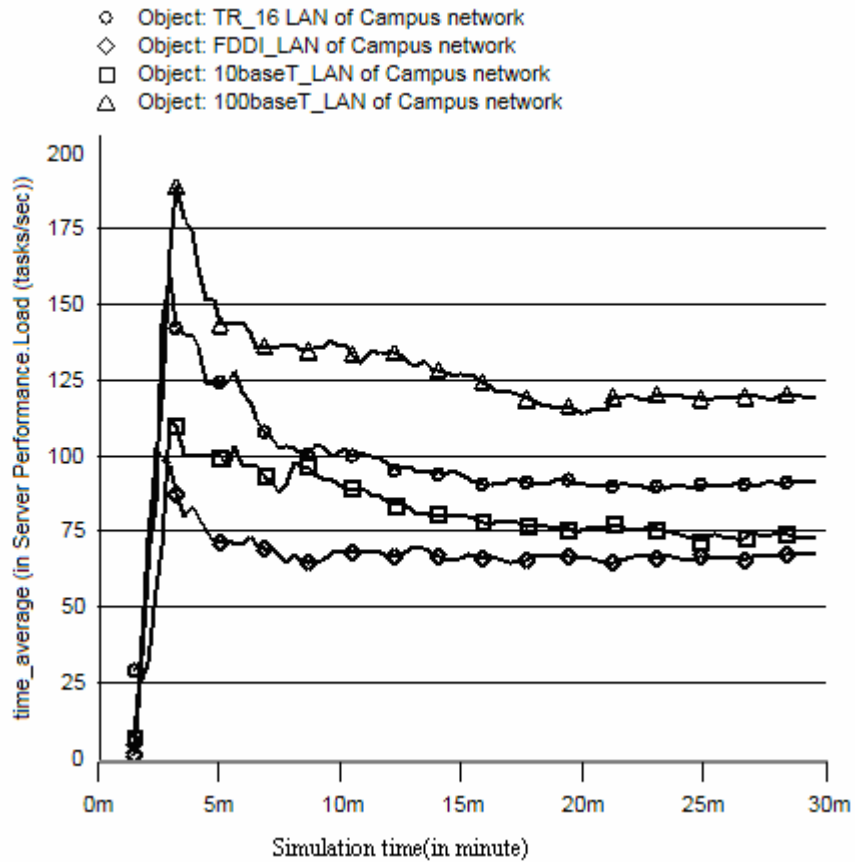


Figure 4.4 –Server performance load (tasks/sec)

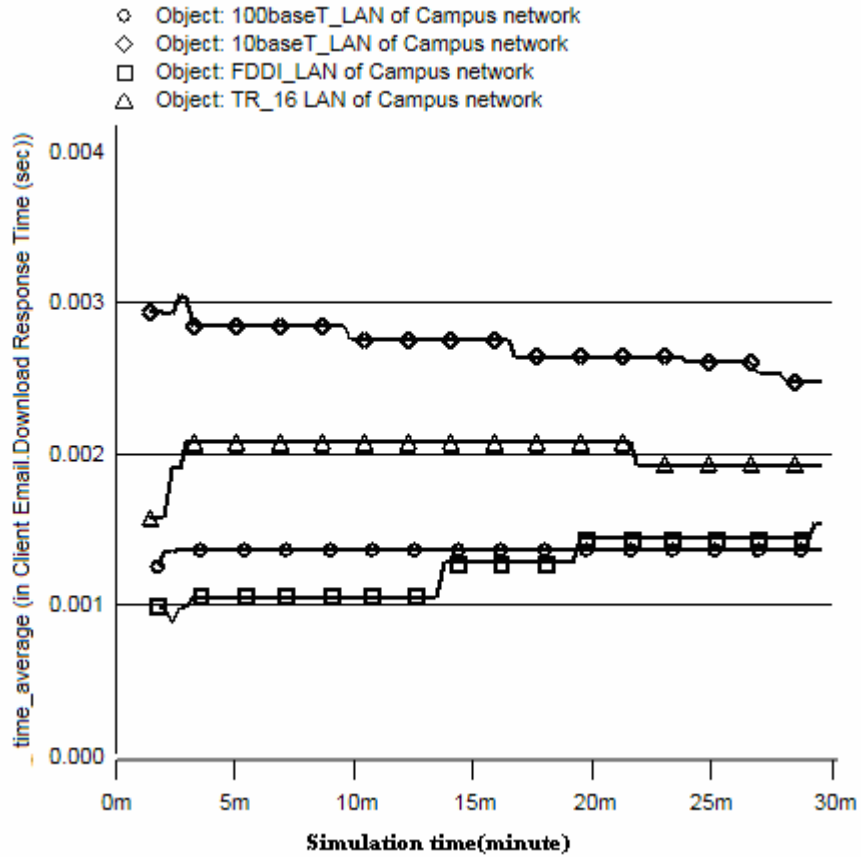


Figure 4.5 - Client e-mail response time

This simulation was designed to explore the effects of different LANs within the wide area network which is a SONET based data communication network.

Figure (4.2) shows the result of LAN Delay. The time average of the LAN delay in the FDDI based LAN is around 0.05 milliseconds and is the lowest when compared to the other three LAN delay. It shows that it is more efficient to route the data within a FDDI based LAN in comparison to other type of LANs like 10base-T, 100base-T and Token ring based LAN.

Figures (4.3) & (5.4) show the results of server performance in term of load (request/sec) and load (tasks/sec) for different types of LANs. Server performance measures the time taken for the server to process a request from the workstations. The

average time taken for the server to respond back to the workstations requests in FDDI based LAN is lowest among the four LANs.

Figure (4.5) shows the results of client e-mail download response time. Client e-mail download response time provides a good measure of time experienced to send a mail from one workstation to another workstation. The average time taken for sending a mail to the workstations in FDDI based LAN is lowest among the four LANs.

### **4.3.2 COMPARISON OF THE EFFECTS OF DIFFERENT LANS**

All the results obtained from Figures (4.2) to (4.5), demonstrate the effects of the different LANs in SONET based wide area network presented in this scenario. From the results obtained from Figure (4.2), the FDDI based LAN experiences the lowest LAN delay amongst all other LANs available in the network. The 10baseT LAN has higher LAN delay. It shows that a FDDI based LAN is the most efficient network to route data over the DCN.

As shown in Figures (4.3) & (4.4) which are showing the server performance, the FDDI based LAN network has the lowest average time taken for the server to respond back to the workstations requests. For comparison, the other LANs have higher load (request/sec) when the server processes the workstation's requests. This shows that the server is most efficient in processing the data when the workstation requests are routed via FDDI based LANs in the DCN as compared to either a 10baseT LAN or Token ring based LAN.

## **4.4 CONCLUSION**

In this chapter, a wide area network is designed which consists different types of local area networks such as 10baseT-LAN, 100baseT-LAN, Token ring LAN and FDDI (fiber distributed data interface) based LAN for optimal performance. Finally, on comparing all performance parameter, LAN delay and e-mail response time we can conclude that FDDI based LAN achieves better performance among all types of LANs and is the least obtrusive on network oper

#### 5.1 INTRODUCTION

This chapter provides a summary of the findings of the study which has done so far. Included in the summary are conclusions from observations made during the execution of this study. Suggestions for future and follow-on work are also presented.

#### 5.2 OUTCOME OF RESEARCH

This thesis project has provided the author with many learning opportunities regarding the G.7712 ITU-T standard and its usefulness and presence in the telecommunication industry. The first objective of this study is, to evaluate the routing protocols in the SONET based data communication network to facilitate moving towards an IP DCN. By modeling and simulating the two routing protocols (open shortest path first and routing information protocol) in the DCN using OPNET IT Guru, the overall results demonstrated that OSPF is the protocol most suited for the DCC network based on its performance. It also supports the decision of G.7712 in specifying the use of IP protocol architecture for the DCC network.

The second objective of this thesis is, to study the usefulness of data compression in fast speed and slow speed SONET data communication network. By modeling and simulating fast speed and slow speed network in OPNET IT Guru, we observe the overall result that although the throughput between the switch and the client using compression is less than the throughput between the switch and the client that is not using the compression, the response time for the client using compression is higher. In other words, the client loses more time for the compression and decompression processes than it gains from the transmission of the smaller frames. So it can be observed that there is no need to

transmit the compressed data in the high speed network because it transmits uncompressed data to higher speed than the compressed data as compression and decompression of data takes relatively more time. But it is also observed that data compression improves the throughput of the high speed network which is the main advantage of data compression.

Wide Area Network (WAN) is a computer network that covers a broad area. So WANs are used to connect LANs and other types of networks together, so that users and computers in one location can communicate with users and computers in other locations. The third objective of this thesis is to evaluate the performance of different types of LANs in wide area network. There are various types of LANs to which a wide area network can be connected such as 10BaseT, 100BaseT, Token Ring based LANs and FDDI based LANs etc. By modeling and simulating the wide area network connected with various LANs in OPNET IT Guru, the overall result demonstrate that FDDI based LAN achieves better performance among all types of LANs and is the least obtrusive on network operations.

### **5.3 FUTURE RESEARCH AREAS**

The results of this research can be construed as accurate in so far as one acknowledges the myriad assumptions and simplifications. Further research should be conducted with more realistic representations of the target network by modeling the SONET network using the models found in the OPNET WDM Guru.

In addition, a test network can be setup in the laboratory once the actual SONET hardware and software have arrived and the network analysis tool can be installed into the SONET network management system to analyze the results. The test scenarios generated in this study could be reproduced and actual traffic data obtained from the SONET DCN tested can be used to compare with the OPNET analysis performed in this study.

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