DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THEORIES AND APPLICATIONS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) SYSTEMS

by

Şahin KARAKELLE

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İZMİR

THEORIES AND APPLICATIONS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) SYSTEMS

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Şahin KARAKELLE

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We have read the thesis entitled **"THEORIES AND APPLICATIONS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) SYSTEMS"** completed by **ŞAHİN KARAKELLE** under supervision of **ASSIST. PROF. DR. Reyat YILMAZ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Reyat YILMAZ

Supervisor

Assist. Prof. Dr. Yavuz ŞENOL

(Jury Member)

Prof. Dr. Alp Kut

(Jury Member)

Prof.Dr. Ayşe OKUR

Director

Graduate School of Natural and Applied Sciences

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Şahin KARAKELLE

THEORIES AND APPLICATIONS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) SYSTEMS

ABSTRACT

The evolution of networks in telecommunications has brought on the importance of communication technologies to obtain high performance transportation networks. Nowadays, The Synchronous Digital Hierarchy multiplex technology is generally well suitable for the optical communications network solution in utility public communication systems.

Highly standardized Scynchronous Digital Hierarchy defines for modern multiplexer technology, though it provides support for investments and protocols as well. Integrated management features make Scynchronous Digital Hierarchy networks very reliable, which ensure fast and high availability times, as well as quick reconfiguration in faults.

In this thesis, we evaluated the Bit Error Rate (BER) performances of Synchronous Digital Hierarchy System with an interconnected multi ring architecture overlaid over an optical mesh network. Firstly, we tested the Bit Error Rate (BER) in the introduced path over the real Synchronous Digital Hierarchy System onto a digital transmission center in Türk Telekom İzmir. In the second part of the study the whole Scynchronous Digital Hierarchy Communication System is computer simulated and than the Bit Error Rate (BER) of the System is determinated. It is shown that the simulation results are very close to the evaluated test results.

Keywords: Optical networks, synchronous digital hierarchy, multi ring synchronous digital hierarchy networks, ber performans in synchronous digital hierarchy networks, BER performans

EŞZAMANLI SAYISAL HİYERARŞİK SİSTEMLERİN TEORİSİ VE UYULAMALARI

ÖZ

Telekomünikasyon ağlarının evrimi, yüksek performanslı iletişim ağları elde etmek için iletişim teknolojilerni önemli hale getirdi. Bu zamanda, Senkron Sayısal Hiyerarşik çoklayıcı teknolojisi ulusal haberleşme sistemlerinde optik ağ çözümü için en uygun çözümdür.

Yüksek dereceli standardize Senkron Sayısal Hiyerarşi, yetki ve protokoller için destek olmakla birlikte modern çoklama teknolojisi için tanımlanmıştır. Entegre yönetim özellikleri, Senkron Sayısal Hiyerarşi ağları çok güvenilir yapmaktadır. Senkron Sayısal Hiyerarşi ağlar, arızalarda hızlı yeniden yapılanma, hızlı ve yüksek kullanılabilirlik sürelerini temin etmektedir.

Bu tezde öncelikle, Türk Telekom İzmir merkezinde optik ağlar üzerinde çalışan Senkron Sayısal Hiyerarşi Sistemleri üzerinde tanımlı data devresinin hata ölçüm testleri yapılmıştır. İkinci bölümünde, Senkron Sayısal Hiyerarşi Sistemleri üzerinde tanımlı kanal için bilgisayar similasyonu yapıldı ve sistemin hatası hesaplandı. Simülasyon sonuçları ve test sonuçlarının birbirine çok yakın olduğu görülmüştür.

Anahtar kelimeler: Optik şebekeler, eş zamanlı sayısal hiyerarşi, çoklu halka eşzamanlı sayısal hiyerarşi şebekeler, eşzamanlı sayısal hiyerarşi şebekelerde BER performansı, BER performans

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CHAPTER ONE
INTRODUCTION

Today’s transport networks must manage with ever increasing traffic by the highcapacity and reliable systems. The request is increased by many different factors. The quick growth of the internet, voice, and data services consumes large amounts of bandwidth. There are also increasing technological developments on the finance, education, industry, medicine and government intranet applications. All these factors grow for bandwidth in networks. Optical fiber transmission is an important role in carrying high bit rates traffic.

Optical fibers can transmit higher bit rates than copper cables. Thus, it is preferred for transmission in long distance. The transmission cost was reduced the past years with the optical technology in transmission network. The widespread use of optical fibers prefers reduced the cost in today’s networks.

Before optical fibers, coaxial cables were used. The fibers provide more bandwidth than the coaxial cables. In the mid 80’s years, telecom operators needed a high capacity transmission system. After than Plesiochronous Digital Hierarchy (PDH) systems were used in transmission networks. In Plesiochronous Digital Hierarchy transmission systems, Time Division Multiplexing (TDM) technology is used to multiplex lower order bit rates.

Over the last 100 years, communications networks have developed from analog telephone system to the modern digital network. These digital networks are needed to carry large amounts of data at high rates. These digital networks provide for fast communications and improved quality of service.

Until 1990s, Synchronous Digital Hierarchy (SDH) transmission system were started to be used with Plesiochronous Digital Hierarchy systems by telecom operators. Synchronous Digital Hierarchy Transmission Systems is used to multiplex higher order bit rates. Today, the used transmission rates in telecommunication networks are 10 Gb/s and 40 Gb/s. Today's, Synchronous Digital Hierarchy prefered in digital transport networks on the optical cable. The Synchronous Digital Hierarchy in digital networks provides for flexible, economic and compatible solution for optical transmission. One of the advantages of Synchronous Digital Hierarchy networks is the low bit error rates that are reached. Very times improvement in bit error rate can be achieved when changing from coax or twisted pair.

Another technology has been deployed since 1990s. It is called Wavelength Division Multiplexing (WDM). Wavelength Division Multiplexing transmission Systems use multiplexing multiple optical channels on a single fiber at different wavelengths. It has become preferred transmission technology in long distance. Today's Dense Wavelength Division Multiplex (DWDM) systems can multiplex 16, 32, 64, 80, and 96 channels. Wavelength Division Multiplexing is widely used in point-to-point configurations in long distance backbone architectures.

In this thesis, we studied the Synchronous Digital Hierarchy and Synchronous Digital Hierarchy Network. We provides a brief introduction to modern telecommunication networks. We focus on network layout, and performance analysis. In Synchronous Digital Hierarchy networks, point to point connections are widely replaced by ring structures. A ring network connected alternatively paths between two nodes. When a failure happens on a link, the traffic is rerouted over the paths on the reserved capacity of the ring. This is called as ring protection. The ring Protection is most popular in Synchronous Digital Hierarchy Network. A simplified technical description of Synchronous Digital Hierarchy technology and characterization of protection mechanisms is given. We describe the basic functionality of modern telecommunication networks. We provide some technical background. We provide information helping to understand the working methods of a telecommunication network.

This thesis with the configuration of Synchronous Digital Hierarchy networks, Synchronous Digital Hierarchy technology is described in more detail. We focus on security mechanisms protecting networks provided services and ensure further transmission in the case of component failures. We discuss difficulties of Synchronous Digital Hierarchy, and multi layer networks.

In addition, in this thesis, The Bit Error Rate is monitored. The Bit Error Rate of the Synchronous Digital Hierarchy system is found by simulating and measuring. Bit Error Rate monitoring plays an important role in measuring the quality of service transported by a network. Thus, performance analysis plays a fundamental role in a Synchronous Digital Hierarchy Framer.

In Chapter 2, background information about multiplexing techniques are given. This chapter also examines the multiplexing hierarchies. In Chapter 3, the Synchronous Digital Hierarchy structure and network systems are presented. This chapter focus on the Synchronous Digital Hierarchy multiplexer. In Chapter 4, we have introduced the tested real Synchronous Digital Hierarchy system and the simulated model. The Bit Error Rate of both system are introduced. Finally, conclusions are presented in Chapter 5.

CHAPTER TWO
INFORMATION OF TRANSMISSION SYSTEMS

In this chapter, the evolution towards the transmission system on digital multiplex will be discussed. We present the transmission hierarchy from PDH to Synchronous Digital Hierarchy.

Multiplexer is very important to modern telecommunications. Since the year 1874, Thomas Edison made the first multiplexed transmissions over a telegraph line. Multiplexer technology has invented a way to use single communication link first in telegraph, telephony and later on in video. It separate for point to point communication. Multiplexer technology has brought important financial for network companies.

We also discuss Synchronous Digital Hierarchy network, ring architectures, and protection. Finally, we discuss a literature survey.

2.1 Tramission History

Analog voltage travels over copper wire end to end invented in the circa 1900. Telephony Multiplexing use in the circa 1918, and Carrier System used Frequency Division Multiplexing (FDM). Voice Signal arrives at destination after amplification and filtering to 4 KHz. Later, science people developed group (12 channels), supergroups (60 channels), and master groups (900 channels) for Analog Trunks of the Public Switching Telephone Network (PSTN).

The Digitalization started in 1963 Time Division Multiplexing (TDM) carrier system for the PSTN in 1963, Voice signal filtered to 4 KHz at input to digital network. Idea SONET (Synchronous Optical NETwork) coined in 1988. ITU version coined Synchronous Digital Hierarchy standardization at the 1987. The Synchronous Optical Network is an ANSI (US) standard, but the Synchronous Digital Hierarchy is an ITU-T Europe standard for high speed telecommunication.

Today's Synchronous Digital Hierarchy is very important multiplexing in digital taransmission network.

2.2 Tramission Structure

For high speed networks, to use the optical cable, digital transmission systems, switching, and routing. The new technology Synchronous Digital Hierarchy has become the preferred transmission technology for point to point connections.

The Synchronous Digital Hierarchy classic transport protocol transfers many telephone channels on the fiber cable, which uses fiber as seen in Figure 2.1 (Winch, 1998; Cisco Systems, 2000; ITU, 2009).

Figure 2.1 Classic fiber optic transport.

Basic multiplexer is a device that has input signals and one output signals. Input signals combine inside a multiplexer, and one signal sent with communication link. The receiving of the link separate the combined signal back to the original signals. They support wire communication like copper pairs, coaxial cables, optical fibers, and wireless communication like radio. Moreover, multiplexed signals could be analogical or digital.

2.3 Frequency Division Multiplexing

Frequency Division Multiplexing (FDM) agree multiplexing technique for transmission. Frequency Division Multiplexing is transmitting analog information over cable or wireless link. The entire frequency bandwidth of the communications link is separated into smaller bands, each incoming signal. The signals transmit over the same link, but each signal has a different portion of the frequency spectrum.

A simple Frequency Division Multiplexing example is seen with three standard 300 to 3400 Hz voice signals as seen in Figure 2.2. Each voice signal is modulated with a different channel carrier frequency. In order to successfully, the same signal take demodulation in the receiving end of the link. The carrier frequencies must be losed the bandwidths of the input signals. There is reserved 4 kHz spectrum from the same wire pair for every voice channel (Cisco Systems, 2000; Freeman, 1999).

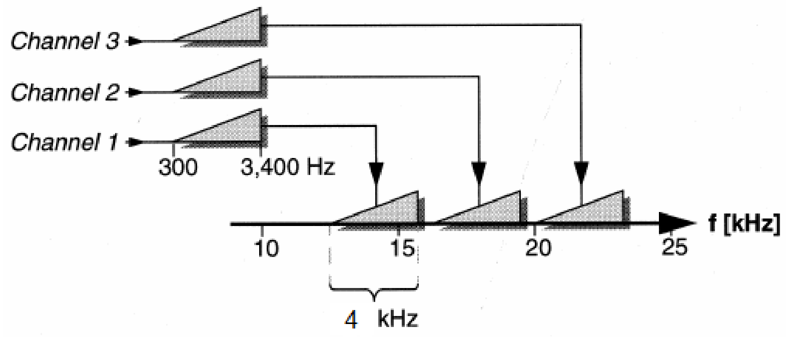

Figure 2.2 Frequency division multiplexing for three channels.

The Frequency Division Multiplexing was first multiplexing technique, and it was used first in telegraphy in the 1800s. It development in the 1900s the methods of telephone transmission. It possible to use same wire for transmission of up to 24 telephone signals. Nevertheless, It use coax cable and radio network for transmission of up to 300, 900, and 1800 telephone signals. Frequency Division Multiplexing is common technique in cable TV and in radio networks.

2.4 Time Division Multiplexing

Time Division Multiplexing (TDM) is the basic digital multiplexing technique for transmission of digital information. Time Division Multiplexing transmission system was introduced in the 1960s, to need for voice telephony. In Time Division Multiplexing, the common transmission link is divided into time slots. Each time slot is sequentially assigned for input channels, as seen in Figure 2.3. The time slots must be framed in order to separate in the receiving. One time slot and some bits in frame use to synchronization (Winch, 1998; Freeman, 1999).

Each time slot has third slot time and the original signal, seen from the Figure 2.3. The capacity of the common link is three times that of each original channel. Time Division Multiplexing allows into a higher order, that link can be combined another links with wider bandwidth. The higher bit rate is the amount of four rate of links with three voice channels by multiplexing (Winch, 1998; Freeman, 1999).

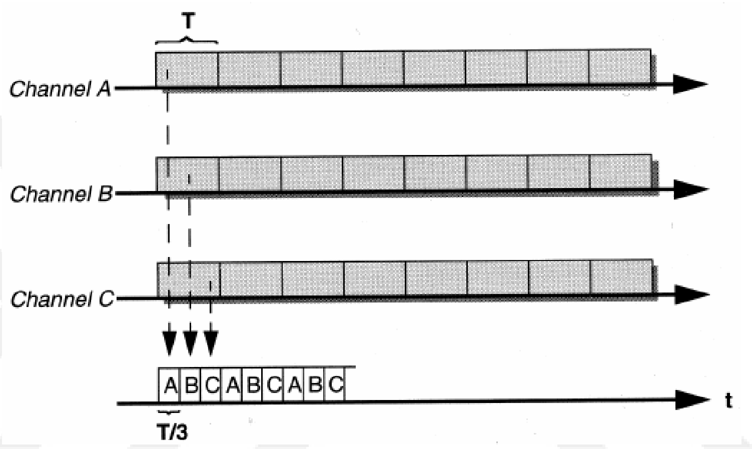

Figure 2.3 Time division multiplexing with three channels.

It found to use the same transmission by signals in binary form Pulse Code Modulation (PCM). The Pulse Code Modulation samples from the analog voice signal. First, it is at the rate of 8000 samples per second. Each value is 8 bits, a 64 kbit/s digital signal. Finally, digital values are coded into a binary pattern that represents the original analogue signal. The overall bandwidth to 32·64 kbit/s =2048 kbit/s. The first level of the digital transmission hierarchy established by International Telecommunication Union. This signal sended in the far end of the transmission link (Winch, 1998; Freeman, 1999).

Today's, Time Division Multiplexing use in video streaming, telephone traffic, and multimedia applications. This type is more efficient than Frequency Division Multiplexing standard, because it provides to transmit more subchannels in the same transmission link. In addition, TDM can be combined with other multiplexing techniques e.g. to carry multiple voice conversations on each channel.

2.5 Plesiochronous Digital Hierarchy

Plesiochronous digital hierarchy is all the Time Division Multiplexing, which are higher bit rates. If we want higher rates, we can mux together tributaries signals. We can demux the Multiplexing signals.

European Conference of Postal and Telecommunications Administrations (CEPT) set E-carrier system. it has been seted by International Telecommunication Unit (ITU-T). E-carrier system used to in the World except USA, Canada and Japan. T-carrier used to in North America, and J-carrier used to in Japan. These three carrier systems are form the basis of Plesiochronous Digital Hierarchies (PDH).

Table 2.1. presents the Plesiochronous Digital Hierarchies transmission rates in Europe, in North America, in Japan. The first level signal E1 is 2048 kbit/s, the second level signal E2 involved four 2048 kbit/s, the third level signal E3 involved four 8448 kbit/s, the fourth level signal E4 involved four 34368 kbit/s kbit/s in Europen Standard (Winch, 1998; Freeman, 1999; JDSU, n.d.).

Table 2.1 Different plesiochronous digital hierarchies.

Level	Signal	CEPT (kb/s)	Signal	N.A.(kb/s)	Signal	Japan (kb/s)
0	(--*30)	64	(--*24)	64	(--*24)	64
1	E1 (*4)	2048	T1 (*4)	1544	J1 (*4)	1544
2	E2 (*4)	8448	T2 (*7)	6312	J2 (*5)	6312
3	E3 (*4)	34368	T3 (*6)	44736	J3 (*3)	32064
4	E4	139264	T4	274176	J4	97728

At the Plesiochronous Digital Hierarchies in Europen Standard, high capacity transmission networks are E.1 to E.4 on a hierarchy of digital multiplexed signals. The basic building block is the primary rate of 2.048 Mb/s (E.1). This could be made up of 30 x 64 Kb/s voice channels. This would be multiplexed up to a higher rate for high capacity transmission. Four signals at the primary rate can be multiplexed up to the secondary rate. Four signals at the secondary rate can be multiplexed up to the third-rate. Finally, four signals at the third-rate can be multiplexed up to the fourth-rate. The 139264 kb/s rate represents 64 x 2048 kb/s signals, and 1920 multiplexed voice channels. The Plesiochronous Digital Hierarchies multiplexing structure in Europen, as seen from the Figure 2.4 (Winch, 1998; JDSU, n.d.).

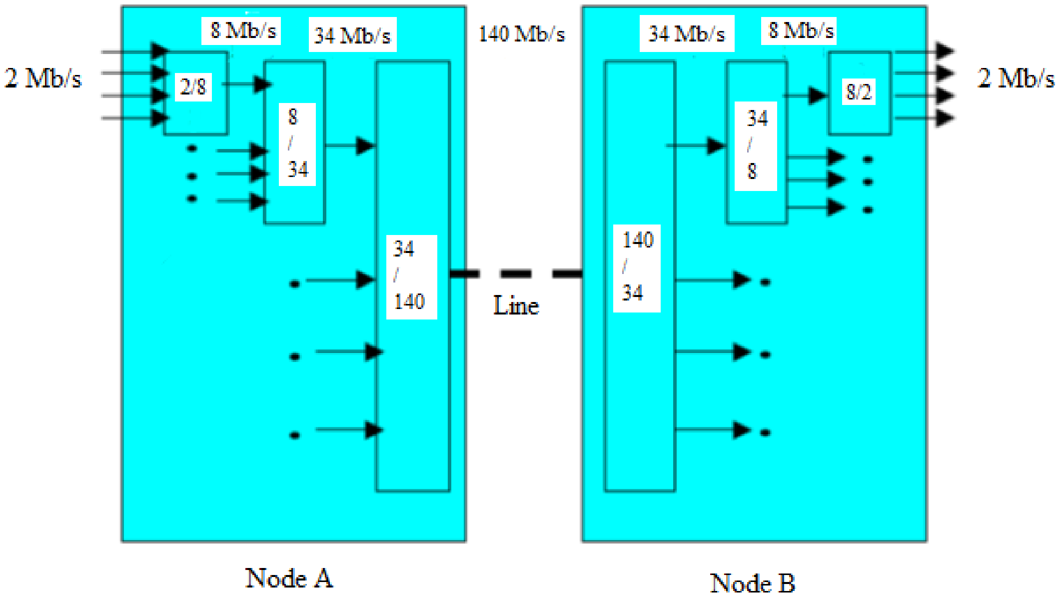

Figure 2.4 Plesiochronous digital hierarchies multiplexing structure.

2.6 Synchronous Digital Hierarchy

Synchronous Digital Hierarchy is a standard for high speed and high capacity optical telecommunication networks. It is a synchronous digital transport system purposed at economic, simple and flexible telecommunications network. It can be used in all of the communication application areas. Synchronous Digital Hierarchy designed for cost effective, flexible telecoms networking, advanced network management and maintenance capabilities.

Synchronous Digital Hierarchy provides physical framework for broadband applications in National Communication Network, ATM and IP. However, It can transport high level applications directly. Hence, SDH transmission can be taked into as a pipe, which transports low or high rate application traffic, such as ATM, IP, PDH, in the form of packages (Winch, 1998; Freeman, 1999).

The basic unit of Synchronous Digital Hierarchy is the Synchronous Transfer Modüle (STM) level one. It procures transmission rate of 155 Mbit/s. So the following rates are 622 Mbit/s for STM-4, 2,5 Gbit/s for STM-16, and 10 Gbit/s for STM-64.

Teh Synchronous transport module N frame structure is submited in Figure 2.5. The general STM-1 frame is form 2430 (270 * 9) bytes of information. Three main areas of the STM frame are payload, AU pointer and section overhead (SOH). The payload is formed by one VC-4, either one 140 Mbit/s PDH signal or combination of lowe level signals (ITU,1997; ABB, 2007; JDSU, n.d.).

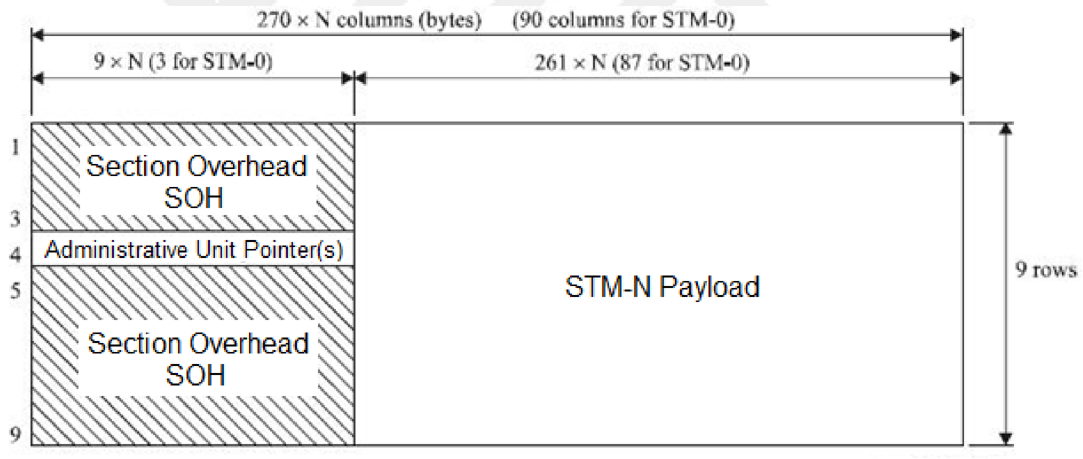

Figure 2.5 STM-N frame structure.

2.7 Dense Wavelength Division Multiplexing

The Dense Wavelength Division Multiplexing (DWDM) is for high speed networks, to use the optical switching and routing, the new technology. It has become the preferred transmission technology for point to point connections. The Dense Wavelength Division Multiplexing permissions combining many channels onto a single fiber to classic transport protocol, which uses fiber and Synchronous

Digital Hierarchy as seen in Figure 2.6, each channel is transmitted on a different optic color signal. The Dense Wavelength Division Multiplexing is used with less separation 0,1–5 nm. It was possible to transmit wavelength at a rate of 2,5 Gbit/s or 10 Gbit/s in the same fiber (Winch, 1998; Cisco Systems, 2000; ITU, 2009).

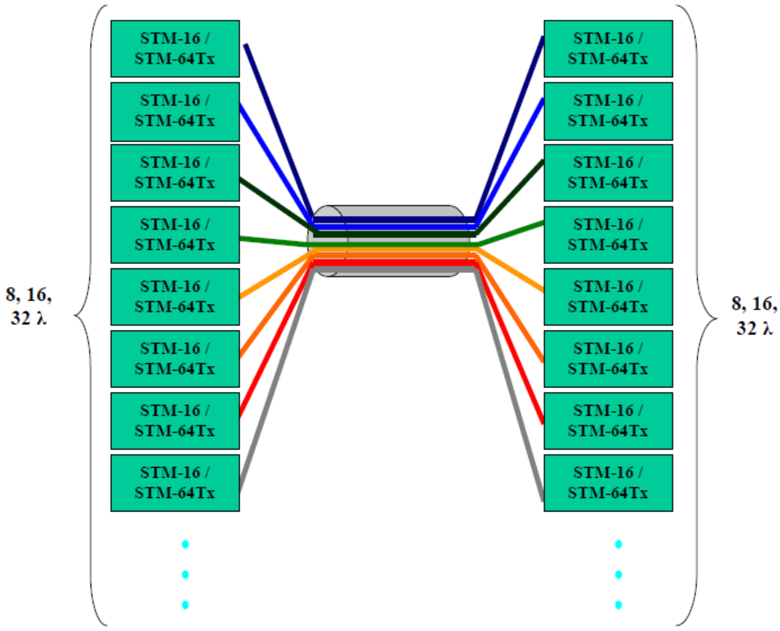

Figure 2.6 The dense wavelength division multiplexing.

While 8, 16, 32 or more traffic channels can be transmitted per fiber in Dense Wavelength Division Multiplex (DWDM). A Dense Wavelength Division Multiplex backbone network consist an optical mesh network. The Dense Wavelength Division Multiplex is used for routing wavelength or optical pass though for optical channels. It carry traffic from node to another node.

CHAPTER THREE
SYNCHRONOUS DIGITAL HIERARCHY SYSTEMS

In this chapter, the evolution synchronous digital hierarchy system on digital multiplex will be discussed. We present the synchronous digital hierarchy, configuration, multiplexing structure, in the telephone network.

3.1 What is Synchronous Digital Hierarchy?

The Synchronous Digital Hierarchy is an international standard for high speed telecommunication, which can transport digital signals in variable capacities over optical/electrical networks. The demand for transmission capacity and higher order transmission rates has rapidly expanded in the telephone network. Since Operators introduced digital transmission into the telephone network in the 1990's. Similar and compatible this standards used with fiber optics, radio link, and satellite.

The first Synchronous Digital Hierarchy standards were finded by the ITU-T in November 1988. Recommendations G707, G708 and G709 were announced in the CCITT Blue Book in 1989. They define the rate, frame and multiplexing processes in the high rate international telecommunication network standard.

3.2 Synchronous Digital Hierarchy Configuration

The Synchronous Digital Hierarchy Configuration is formed Synchronous Transport Module (STM) Multiplexer, Add/Drop Multiplexer, Regenerator pieces over the telephone network. Synchronous Transport Module Multiplexer multiplexes and de-multiplexes signals from multiple sources, that is formed path terminating equipment and maps user payload into standard frame.

Add/Drop Multiplexer adds signals from different sources or removes. Regenerator is repeatered thin signal for signal quality. The Synchronous Digital Hierarchy transmitted higher order rates in the telephone network. The basic configuration in the telephone network is presented in Figure 3.1 (Winch, 1998; Freeman, 1999; Cisco Systems, 2000; ABB, 2007).

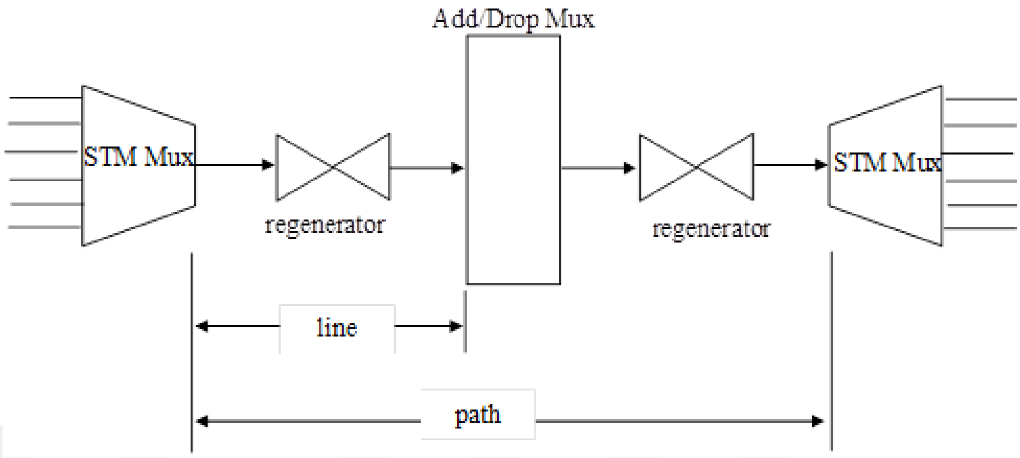

Figure 3.1 The snchronous digital hierarchy configuration.

The Synchronous Digital Hierarchy architecture is formed three layers. First, Physical layer is linear optical fiber or ring, and regenerators. Second, Line layer is link between the Synchronous Digital Hierarchy muxes, and Add/Drop Multiplexers. Third, Path layer is end-to-end path of client data or tributaries.

3.3 Synchronous Transmission

The Synchronous Digital Hierarchy Multiplexer is backbone synchronous transmission in the telecommunication network. The Synchronous Digital Hierarchy Multiplexer provides physical framework for broadband applications. It can act as transport higher level applications directly.

The Synchronous Digital Hierarchy transmission can be taked into as a pipe, which carries lower rate application traffic, such as ATM, IP or PDH, in the form of packages. The Synchronous Digital Hierarchy transmission provides physical infrastructure for the optical parameters, types of cables and light sources.

The basic unit of The Synchronous Digital Hierarchy is the Synchronous Transfer Module (STM-1) level one frame. Transmission rate of Synchronous Transfer Module-1 is 155 Mbit/s. The other most important used Synchronous Transfer Module rates are 622 Mbit/s for STM-4, 2.5 Gbit/s for STM-16 and 10 Gbit/s for STM-64.

The Synchronous Digital Hierarchy defines a full set of transmission rates, which are presented in Table 3.1 (Winch, 1998; Freeman, 1999; ABB, 2007; Cisco Systems, 2000).

Table 3.1 Synchronous digital hierarchy transmission rates.

SDH	Optical Carrier	Rate (Mb/s)
STM-1	OC-3	155.520
STM-3	OC-9	466.560
STM-4	OC-12	622.080
STM-6	OC-18	933.120
STM-8	OC-24	1244.160
STM-12	OC-36	1866.230
STM-16	OC-48	2488.320
STM-32	OC-96	4976.640
STM-64	OC-192	9953.280

3.4 Synchronous Multiplexing Structure

The Synchronous Digital Hierarchy multiplexing structure is based on standard sized container (C) and virtual containers (VC). They can be as the traffic packages in the Synchronous Digital Hierarchy pipe. They are seted inside a synchronous transport module (STM) frame for the actual transport. The Synchronous Digital Hierarchy multiplexing route in Europe defined by European Telecommunications Standards Institute (ETSI) is seen in Figure 3.2 (Winch, 1998; Freeman, 1999; ABB, 2007; JDSU, n.d.).

In Synchronous Digital Hierarchy, there are three basic virtual containers VC-12, VC-3 and VC-4. Each virtual containers corresponding is a certain tributary signal level. These levels are equivalent to the PDH transmission levels. The signal rates are 2 Mbit/s for VC-12, 34 Mbit/s for VC-3 and 140 Mbit/s for VC-4. Virtual containers can be packaged into a higher order virtual container. VC-4 can contain three VC-3s, 63 VC-12s, or combinations of the above within the overall capacity of VC-4.

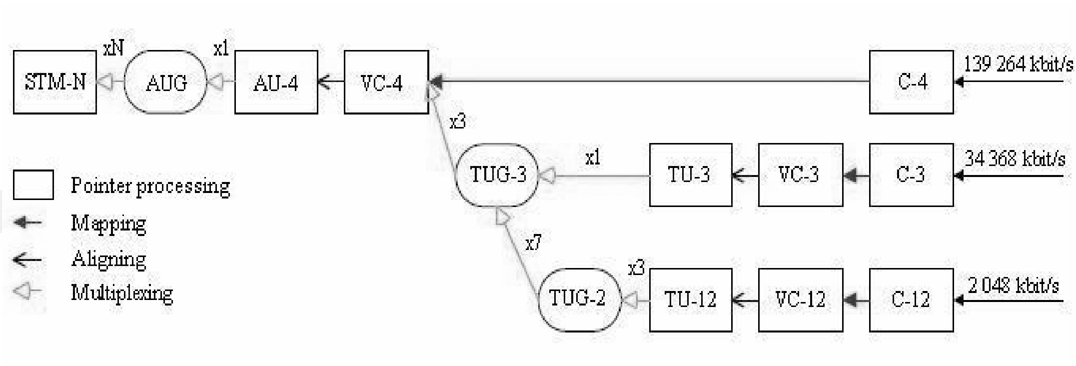

Figure 3.2 Typical SDH multiplexing route.

As seen from the Figure 3.2, each lower order virtual container is aligned inside a tributary unit (TU) with a pointer indicating and packed into tributary unit groups (TUGs). TUGs are then multiplexed into a higher order VC-4, which is aligned inside administrative unit (AU-4) and packed into administrative unit group (AUG). This operation used to the transport and management of the signals across the network (Winch, 1998; Freeman, 1999; ABB, 2007; ITU, 1997).

3.5 Synchronous Transport Module

The Synchronous Transport Module (STM) frame is based very important of the Synchronous Digital Hierarchy multiplexing structure. The Synchronous Transport Module (STM) can be as the traffic packages in the Synchronous Digital Hierarchy pipe. The STM-1 frame is based level one in the Synchronous Digital Hierarchy multiplexing structure.

The STM-1 frame comprises 2430 (270 * 9) bytes of synchronous digital hierarchy information. There are three main areas of the STM-1 frame. These are payload, AU pointer, and section overhead (SOH). The payload is formed by one VC-4, three VC-3, and twenty one VC-12. It contains either one 140 Mb/s PDH signal, three 34 Mb/s PDH signal, twenty one 2 Mb/s PDH signal combination of lower level signals. The starting point of the VC-4 is stored into the AU pointer for to indicate the virtual containers within the STM payload.

STM-N frame structure is formed N unit from STM-1 frame, and multi multiplex of lower level PDH signals. Basic STM-N frame structure is seen in Figure 3.3 (Winch, 1998; Freeman, 1999; Cisco Systems, 2000; ABB, 2007, ITU, 1997).

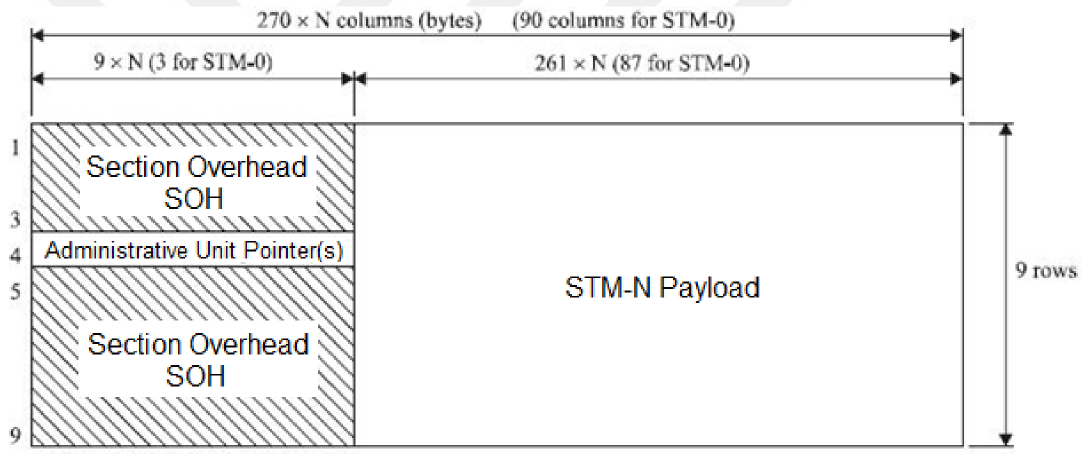

Figure 3.3 STM-N frame structure

The section overhead is divided into regenerator section overhead (RSOH), and multiplex section overhead (MSOH). They provide dedicated management channels. It is used for communication between adjacent network elements, for synchronization, transmission quality measurement, remote access, service and section failure detection as automatic protection switching (APS).

The Payload supports the transportation container of specific tributary signals. The contents of the container carried by the truck represent the real value. This

Payload is analogous or digitals to customer traffic, being carried by the container within an STM-1 frame.

The Section Overhead actually gets the contents of the truck to it's destination is the tractor unit. The Section Overhead carried analogous or digitals to the network maintenance and management capability by the STM frame in the Synchronous Digital Hierarchy. It is Section OverHead as SOH. The SOH is part Multiplexer Section Overhead (MSOH) and Regenerator Section Overhead (RSOH).

The section overhead distributes with transport of an STS-N frame across the physical medium. It is responsible for framing, section error monitoring, and communicating between section terminating equipment. Content of STM-1 section overhead defined by ITU-T is shown in Table 3.2. Description for individual bytes is listed from below (Winch, 1998; Freeman, 1999; Cisco Systems, 2000; ABB, 2007).

Table 3.2 STM-1 section overhead.

RSOH	A1	A1	A1	A2	A2	A2	J0	res	res
	B1	m	m	E1	m		F1	res	res
	D1	m	m	D2	m		D3		
	AU pointer(s)								
MSOH	B2	B2	B2	K1			K2		
	D4			D5			D6		
	D7			D8			D9		
	D10			D11			D12		
	S1					M1	E2		

- A1 and A2 framing bytes always uses equal numbers of A1 = 11110110 and A2 = 00101000.
- B1, B2 parity checks for error detection, B1 interleaved parity, B2s for muxed STM-N.

- D1, D2 and D3 messaging channels, 192 kbit/s communication channel (DCC) for the regenerator section in SDH. From D4 to D12 are reserved for the DCC of the multiplex section with bandwidth of 576 kbit/s. DCCs are used for network management.
- E1, E2 order wire voice channels. E1 is 64 kbps from regenerator to regenerator. E2 is 64 kbps from line mux to line mux.
- F1 user channel, 64 kbps for user purposes.
- J0 regenerator section trace.
- K1, K2 APS signaling channels.
- M1 Multiplex section remote error indication.
- m, media dependent.
- res, reserved for national use.
- S1, 5–8 of S1 byte are allocated for Synchronization Status Messages (SSM).

Transport Overhead is constituted byte in the transport overhead of a Synchronous Digital Hierarchy frame has a specific purpose such as frame synchronization, error detection, or remote defect indication (OpenCon Systems, 2003; ABB, 2007).

The tributary signals are all synchronous, higher STM transmission rates can be gotten by byte interleaving. However, STM-16 signal can be multiplexed either directly from sixteen STM-1 signals. To maintain the signal structure, STM-N signals must be N byte interleaved (Winch, 1998; ABB, 2007).

3.6 Higher Synchronous Digital Hierarchy Rates

STM-1 has nine different columns of transport overhead. RS overhead is three rows and nine columns. Pointer overhead is one row and nine columns. MS overhead is five rows and nine 9 columns. Synchronous Payload Envelope (SPE) is nine rows and two hundred sixty one columns.

The principle for the Synchronous Digital Hierarchy transmission signal frame is the bytes (8-bit). The frame structure is transmitted byte-by-byte from left to right and from top to bottom. After one row is transmitted and the next row will follow. After than one frame is completed and the next frame will start.

The sample frequency to be 8000 frames per second for all levels in STM hierarchy in ITU-T defines. STM-1 rate is 9 rows x 270 columns x 8 bits x 8000 frames per second = 155.52 Mb/s. STM-4 rate is 9 rows x (270 x 4) columns x 8 bits x 8000 frames per second = 622 Mb/s. STM-16 rate is 9 rows x (270 x 16) columns x 8 bits x 8000 frames per second = 2488.320 Mb/s. STM-64 rate is 9 rows x (270 x 64) columns x 8 bits x 8000 frames per second = 9953.280 Mb/s. The multiplication STM-N has 9*N rows and 270*N columns. The Synchronous Digital Hierarchy rates increase by multiplication STM-N. The STM signals can carry Synchronous Digital Hierarchy or Plesynchronous Digital Hierarchy tributaries (Winch, 1998; Freeman, 1999; Cisco Systems, 2000; ABB, 2007).

In the Multiplexing**,** an AUG contain a VC-4 with an E4 or it contain 3 AU-3s each with a VC-3s with an E3. The AU pointer points to the AUG and inside the AUG are 3 pointers to the AU-3s. Lower rate STMs can be combined into higher rate STMs. AUGs can be combined into STMs. AUs can be combined into AUGs. TUGs can be combined into high order VCs. Lower rate TUs can be combined into TUGs.

3.7 The Synchronous Digital Hierarchy Network Topologies

The Synchronous Digital Hierarchy results from Synchronous Optical Network is an international standard for high speed communication over optical networks. It can transport digital signals in variable capacities. Telecommunication Operators introduced digital transmission into the communication network in the 1990's. For transmission capacity and higher order transmission rates has increased in the communication network.

The Synchronous Digital Hierarchy is based on optical fiber transmission links in order to take advantage of the high bandwidth. It is compatible with the existing Plesynchronous Digital Hierarchy equipments.

A Synchronous Digital Hierarchy network element can be configured as point to point links Terminal Multiplexer (TM), Add and Drop Multiplexer (ADM), Digital Cross Connect (DXC), Rings and Multi Rings topologies, or Mesh topologies.

3.7.1 Terminal Multiplexer

In linear networks, There creates two terminal multiplexer elements in point to point links as shown in Figure 3.4. This network elements structure can be protected or unprotected. In case of a failure, two extra fibers are needed to be reserved for protection in protected links (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

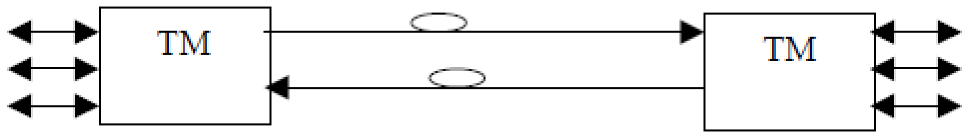

Figure 3.4 A point to point link with Terminal Multiplexer.

3.7.2 Add and Drop Multiplexer

In linear networks, Add and Drop Multiplexer nodes are connected in a linear form where two terminal multiplexers create at both ends as shown in Figure 3.5. This topology procures drop and insert capability to all network elements (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

There may be protected or unprotected this communication networks, , setting two or four fiber connections between two Add and Drop Multiplexers. Two fiber are working and other two serving as a backup pair.

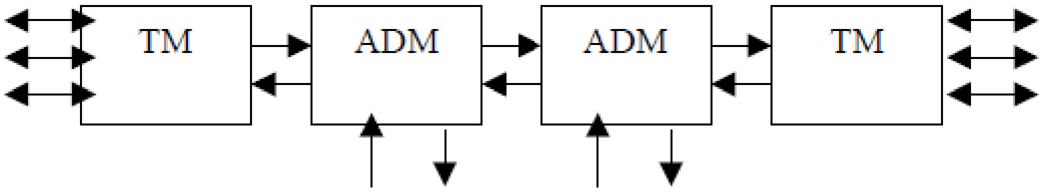

Figure 3.5 A linear add and drop multiplexer network.

3.7.3 Digital Cross Connects

Digital Cross Connects (DXCs) are usually used in the backbone communication network or at the gateway nodes backbone communication networks. They are bigger capacity systems than an Add and Drop Multiplexer. In the Digital Cross Connects, signals can be switched between tributaries, or between two lines.

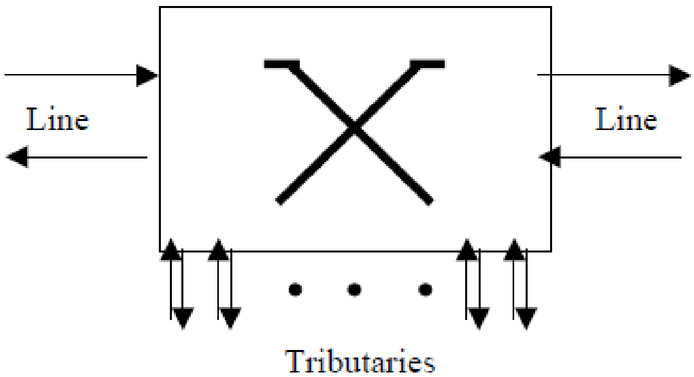

Figure 3.6 The digital cross connects equipment.

The Digital Cross Connect nodes are connected in a switch form where as shown in Figure 3.6. Digital Cross Connections contains mapping of the interconnections between different channels. It is used to route each tributary signal up to the virtual container. A large network system, many cross connections must be created one by one. The complex network topology used protection schemes in the network system. The Cross Connection is the most difficult of the configuration (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

3.7.4 Ring Topology

In communication networks, two fibers are used for protection between two Add and Drop Multiplexers. The rings are used topology, they procure an alternate path to communicate between two nodes, as shown in the Figure 3.7 (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

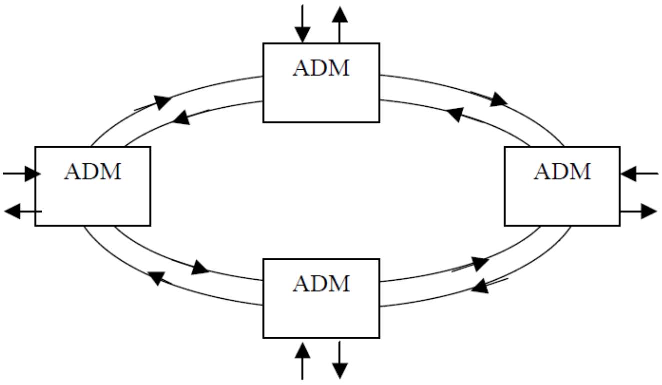

Figure 3.7 A ring network of SDH network.

A two fiber ring can operate as a unidirectional ring or a bidirectional ring. Two fiber or four fiber protection can be selected in ring architecture. In unidirectional rings, traffic is limited to one fiber, the second fiber works as the protection fiber. In a bidirectional ring, traffic is sent on both fibers, the both fibers is reserved for backup.

3.7.5 Multi Ring Topology

Two or more rings can be connected between many nodes a multi ring topology as seen in Figure 3.8. In this topology, each ring has their ring protection mechanisms. The traffic path is protected between many nodes in case of a node failure or cut fiber (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

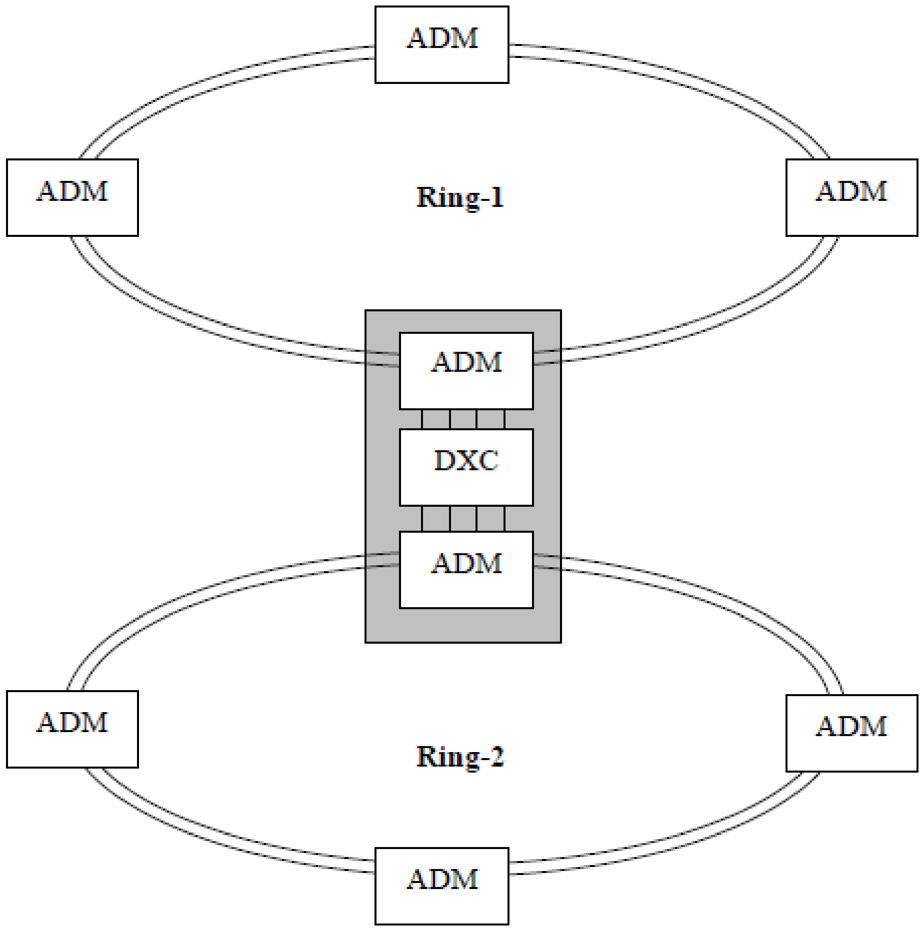

Figure 3.8 A multi ring topology of SDH network.

3.7.6 Mesh Topology

Another type of the Synchronous Digital Hierarchy network is the mesh architecture.

The mesh architecture is genarally used in the communication network as shown in Figure 3.9. This rings are often preferred in practice, because of their simpler and faster switching mechanism (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

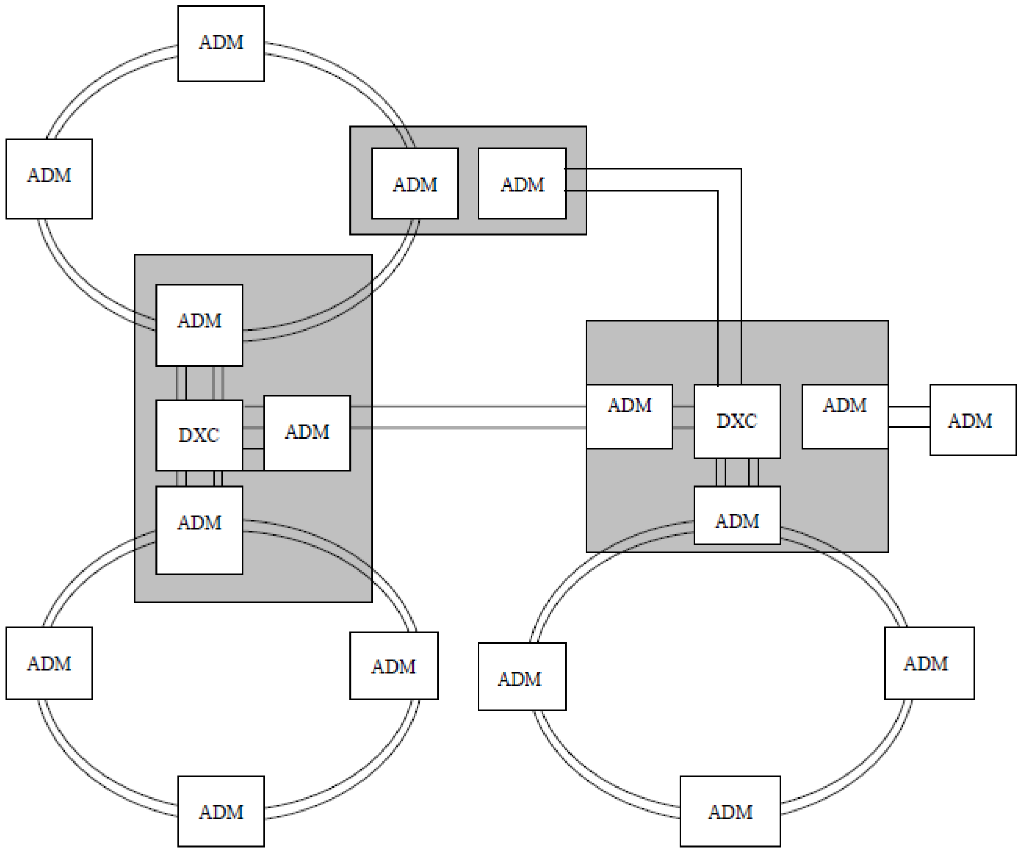

Figure 3.9 A mesh topology of SDH network.

3.8 Synchronization

The Synchronous requires consummate synchronization between in the network node elements. The network elements has a stable internal quartz crystal clock as a default timing source. Primary reference clock (PRC) source is preferred. This clock of stability can be generated only by atomic clocks, such as the global positioning system (GPS).

In Synchronous Digital Hierarchy networks, the timing sources can be precedenced by using synchronization status messaging (SSM). The quality level of source is distributed to the network. The synchronization status messaging byte is in the section overhead of the STM frame.

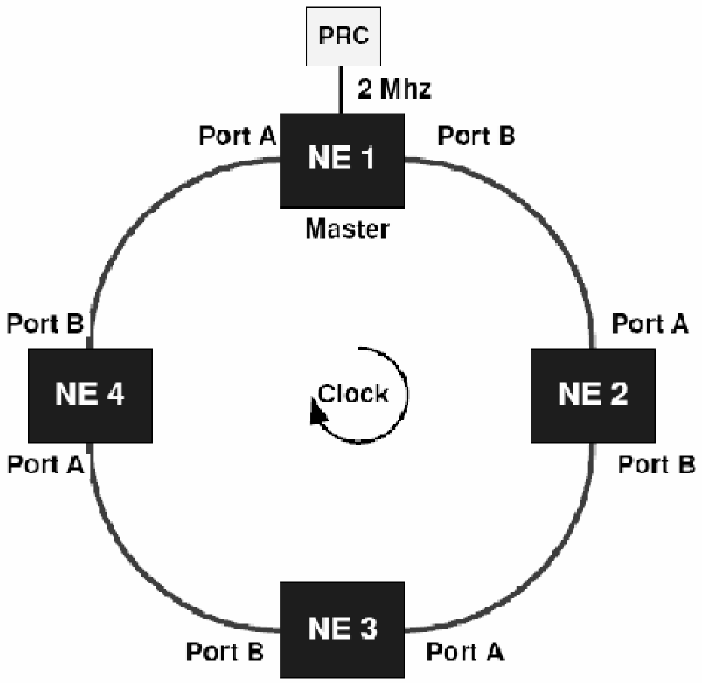

Figure 3.10 An example of network synchronization.

An example of synchronization in a ring network as shown in Figure 3.10. PRC is setted the highest priority level, from which the other network elements derive their clock directly or indirectly (Cisco Systems, 2000; ABB, 2007; JDSU, n.d.).

3.9 Network Management

Network management system is the most important features that can offer. The management messages can be sent over the connection together with operational data. The STM frame procures centralized remote management for network elements. In managment system, data communication channels (DCC) are presented for transport management data between network elements in each STM frame. These channels are very convenient from the maintenance external management communication network (OpenCon Systems, 2003; ABB, 2007; JDSU, n.d.).

In Synchronous Digital Hierarchy network, data communication channels messages are routed as packets by the central units. The data communication channels can be accessed from each network node. All the network can be managed from different locations with the management messages in the data communication channels.

Structure of the network management messages is standard for all the producer firm in telecommunication systems. The same management system permits to supervise multiplexer equipment from different vendors.

In the management system, bit error rate and alarms are monitored with management system in the synchronous digital hierarchy network. And, alarms of synchronous digital hierarchy system are supervised to detect synchronization faults, signal losses, and other changes.

The synchronous digital hierarchy network supports simple network management protocol standard. It constructs connection to higher level network management systems with process control server (Cisco Systems, 2000; OpenCon Systems, 2003; ABB, 2007; JDSU, n.d.).

3.10 The Synchronous Digital Hierarchy Protection Mechanisms

Protection mechanisms are performed to reduce the harm caused by failure of communication network elements. The network elements failure can have for various reasons in the network. This for various reasons are as loss signal, break down equipments, physical destruction of a fiber, or harmed of synchronous clock.

Therefore, Protection mechanisms are worked in the communication network system. The routing requirements of protection demands could be fulfilled an obligation for original path, or original equipments. In this way, the communication is provide traffic in the network.

There are different concepts in the protection mechanisms of synchronous digital hierarchy network. 1:1 protection concept is used in practice. Alternative routing paths can be protected by backup paths. Each protected routing path dedicated replacement path. The disadvantage of this protection mechanism is the large amount of reserve capacity, that has to be provided. 1:N protection model is more economic and the need for reserve capacity.

A different concept is used by 1+1 protection. The demand signal is duplicated and routed along paths. The recive location, it has to procure to receive both signals and to choose the better one. The disadvantage of this protection method is taransmit signal togather links all the time.

The different concepts are used by rings protection. The ring protection types are as follows 2f-MS-SPRing, 4f-MS-SPRing, and 2f-SNCP in Europe. This ring protection types are full traffic protected, and more expensive protected methods, that are very importent for uninterrupted communication. There are several transport synchronous digital hierarchy network architectures. Ring, Multi Ring, and Mesh structures are on hand for traffic protecting optical transmission networks.

The synchronous digital hierarchy technology presents standardized protection mechanisms. The system provide transmit protection that network failures are detected before a loss of service. These protection mechanisms can be divided into all the traffic between workin path and protecting path.

The path higher quality is chosen to be the working path, while the other one is devoted to the protection. In event of a failure in the working path, the receiving will switch to use the protecting path.

In disagreement to the path protection, section protection veils overall to the highest level STM traffic. Multiplex section protection is worried as protection between two neighboring network nodes. It can be accomplished in different routes (Cisco Systems, 2000; ABB, 2007).

3.10.1 Linear 1:1 Protection

In 1:1 linear protection mechanism, there are one card for each card at protection system. Network traffic is continued uninterupted after protection switching. The 1:1 linear protection mechanism seen as Figure 3.11 (ABB, 2007; Cisco Systems, 2000; JDSU, n.d.).

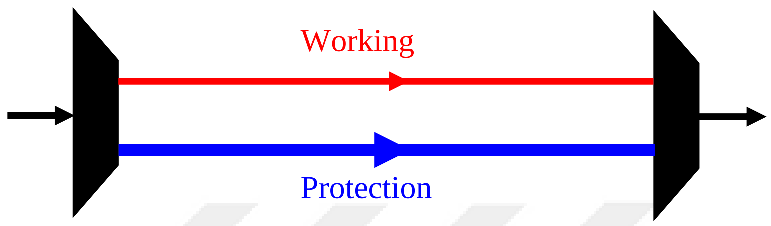

Figure 3.11 A 1:1 linear protection mechanism.

In 1:1 linear protection mechanism, the traffic is only sent the working link, but in event of failure, it must switch to use the protecting link. In this case, protecting link can be used to carry high priority traffic.

3.10.2 Linear 1:N Protection

There are one card for N card at this protection system.

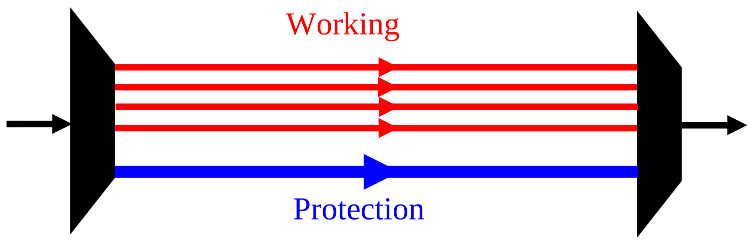

Figure 3.12 A 1:N linear protection mechanism.

The system perform 1 protection channel for every N working channels. One protection link can protect N multiple working links, which is reserved as 1:N this protection mechanism. Structure of 1:N linear protection mechanism seen as Figure 3.11 (Cisco Systems, 2000; JDSU, n.d.).

3.10.3 Linear 1+1 Protection

In 1+1 linear multiplex section protection mechanism, the signal of concurrent sending is permanent route. In the each a failure on the working link of network, the bridge is switching for selective receiving. Typical 1+1 protection mechanism presented in Figure 3.12 (Cisco Systems, 2000; JDSU, n.d.).

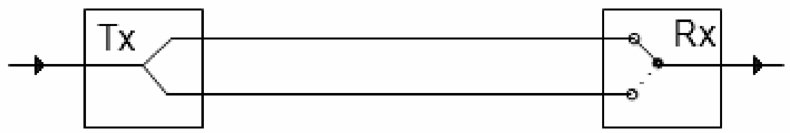

Figure 3.13 A 1+1 linear protection system

In 1+1 linear multiplex section protection mechanism, the traffic of communication network between two node is transmitted duplicated links. Normally, the working link is used for the communication traffic, but in the each a failure on the working link of network, the receiving communication network element selects the protection link to be switched for the communication traffic.

3.10.4 Ring Protection Mechanisms

The rings of synchronous digital hierarchy are included all the nodes and protection mechanisms. In the rings detect failures, it is used reserved channels rapidly for reroute traffic. Every normal path has a protection path.

The ring protection types are as 2f-MS-SPRing, 4f-MS-SPRing, and 2f-SNCP in Europe. This synchronous digital hierarchy network architectures propose more developed functionalities, require high capacity, easy management, have limited flexibility, being economical, and fast restoration.

MS-SPRing architecture performs traffic routing function electrically in the synchronous digital hierarchy equipment of nodes. The neighbor nodes are responsible for the protection switching action in the failures. In the MSSPRing communication network mechanisms, protocol of synchronous digital hierarchy restricts the number of nodes in a ring.

MS-SPRing architecture have two type rings, one type 2-fiber rings that are shown in Fig. 2.13, other type 4-fiber rings that are shown in Fig. 2.14 (Cisco Systems, 2000; JDSU, n.d.).

3.10.5 Two Fiber Ring

Two fiber ring architecture is used two fiber in the communication network. Switching criteria for protection is communication quality of each channel from loss signal and system alarms.

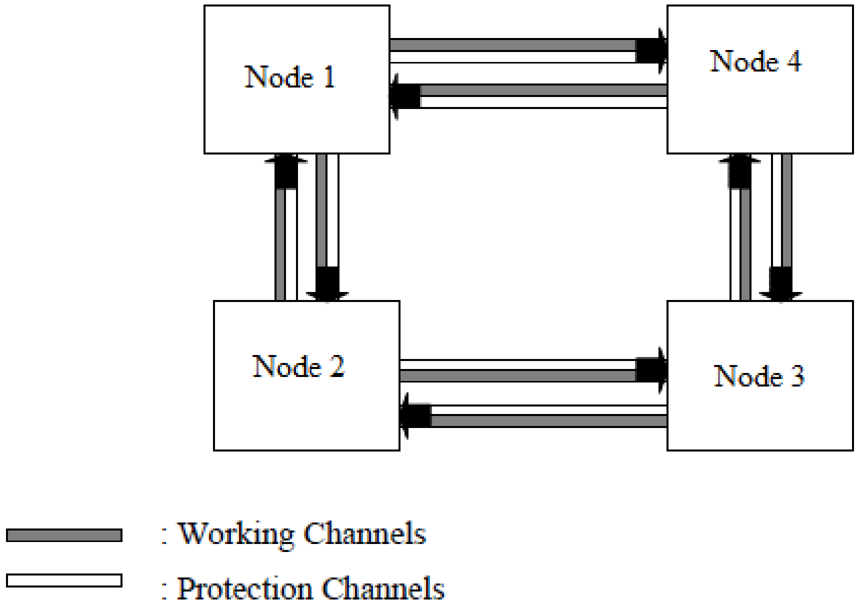

Figure 3.14 Two-fiber MS-SPRing.

Multiplex section protection offers protection to the traffic between nodes in the system alarms. This traffic is lost if one of the nodes not transmit. After than, ring network used another route, limitation in multiplex section protection is the working fiber and the protecting fiber. Multiplex section protection can be practiced to rings, which welcomes these limitations.

Principle of 2-fiber MS-SPRing protecting is shown in Figure 3.13. This protection architecture uses half of the capacity for working traffic, and reserves the other half of the capacity for protection. In the protection mechanism, it uses both of the fibers to carry working traffic and reserved for Protection (Cisco Systems, 2000; JDSU, n.d.).

3.10.6 Four Fiber Ring

Four fiber ring architecture is used two fiber in the communication network. Switching criteria for protection is communication quality of each channel from loss signal and system alarms. 4-fiber MS-SPRing protecting is shown in Figure 3.14 (Cisco Systems, 2000; JDSU, n.d.).

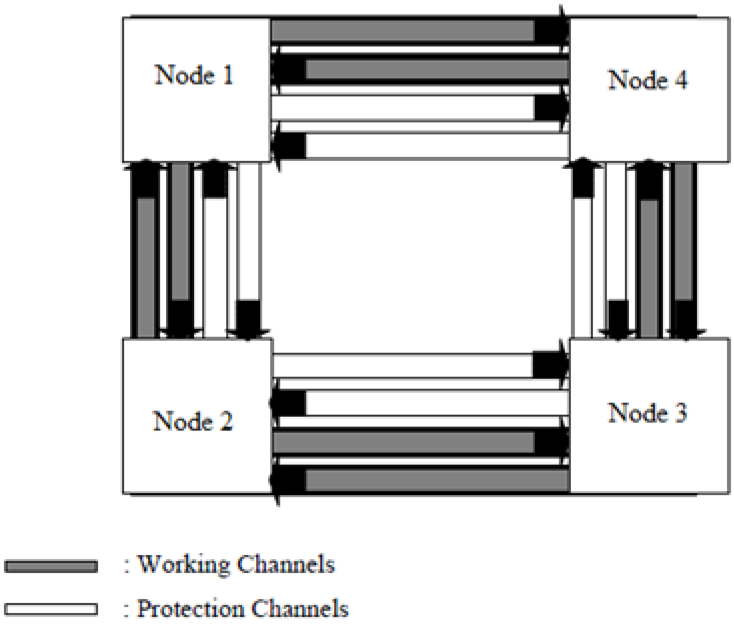

Figure 3.15 Four fiber multiplex section protection.

This system offers protection to the traffic between nodes in the system alarms. Traffic of network is lost if one of the nodes not transmit. This time, the network used another route. The multiplex section protection is the working fiber and the protecting fiber.

This protection architecture uses full of the capacity for working traffic, and full reserves of the capacity for protection. In the protection mechanism, it uses four fibers to carry working traffic and reserved for Protection.

3.10.7 Subnetwork Connection Protection

Useful another path protection is subnetwork connection protection (SNCP). In subnetwork connection protection, the network is divided interconnected subnetworks, subnetwork has internal path protection. Switching between the working and protecting path can be alarms of the end node.

Principle of subnetwork connection protection is shown in Figure 3.15. In normal state, between two node, signal is sent via two different routes. Damage of the main route, receiving is switched to the protecting route (Cisco Systems, 2000; JDSU, n.d.).

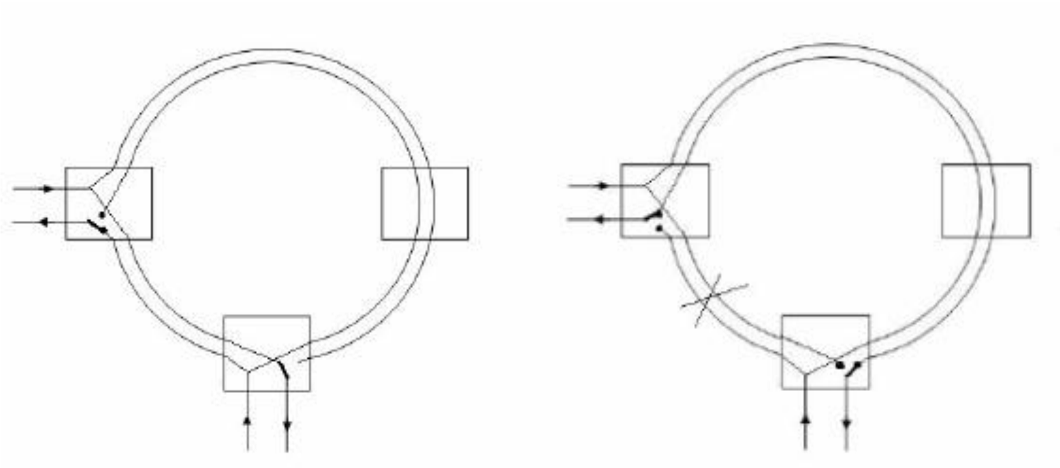

Figure 3.16 Subnetwork connection protection.

CHAPTER FOUR
PERFORMANCE ANALYSIS

In the Optical Communication System, the operational of the Synchronous Digital Hierarchy Systems, such as Network Managment System must be very reliable and continuously available. It is important to ensure that the critical applications are not blocked by general and less crucial applications. Before utilizing Synchronous Digital Hierarchy network to transport these realtime signals and application data, some performance must be considered. In addition, Synchronous Digital Hierarchy system design and network configuration can be more difficult. It can be seen that Synchronous Digital Hierarchy systems are for the most part to have long coexistence with Optical Network technology.

The high capacity fiber optical links are specified as the communications system that can deliver the requested bandwidth. The optical fiber network can be integrated into the other network. The fiber optical links provide long transmission distances without the need for repeaters. The high costs and long time to install and repair, the advantages make optical fibers the most important communications network.

In the Synchronous Digital Hierarchy, the response time for protection switching is defined by the ITU-T standards, which has been considered as very fast compared to other competing options. The high performance of the Synchronous Digital Hierarchy in optical network is the most important communications network.

In the thesis, Bit Error Rate is focused in the digital channel of the Synchronous Digital Hierarchy Systems and optical channel of the Optical Transmission Network. In Digital Transmission Network, the number of bit errors is the number of received bits of a data stream over a communication channel, that has been altered due to distortion, interference, noise or bit synchronization errors. The Bit Error Rate (BER) is the number of bits in error divided by the total number of transferred bits during a worked time (Fyath, Al-mfrji, 2008; Sadeque, 2002).

$$\text{Bit Error Rate (BER)} = \frac{\textit{Number of bit in error}}{\textit{Total number of transfered bits}}$$

In the thesis, Bit Error Rate calculation is made with two method. First method, the BER performance is measured in the active Synchronous Digital Hierarchy Systems in the İzmir Türk Telekom. Second method, the BER performance is simulated in the computer by MATLAB programme.

4.1 Bit Error Rate of Synchronous Digital Hierarchy System

The built test system is visualized in Figure 4.1. The system was performed within the limits of available equipment at the testing environment of optical network. The testing system consisted of Synchronous Digital Hierarchy Rings in İzmir Türk Telekom. It is used empty path over Synchronous Digital Hierarchy Network.

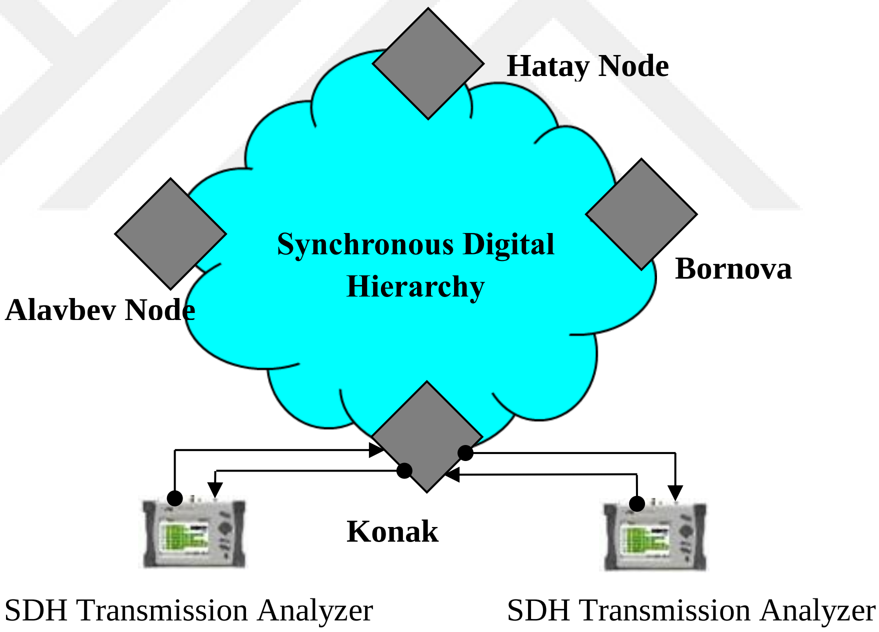

Figure 4.1 Bit error rate test system overview.

Each Node of Synchronous Digital Hierarchy Network were equipped with units for teleprotection, telephone, serial data and Ethernet traffic, as well as termination units for STM-1 traffic. For the management connections, RS-232 and LAN connections were established to nodes, and DCC channel was also used to the remote configuration and management operations. This section presents test results to assess the performance of transmission link incorporating the Synchronous Digital Hierarchy Network over Optical Network. Konak-Alaybey 155 Mb/s, STM1 BER Test Results (Pattern 2^23-1 ITU, Measuring time is 3 minutes) :

Rx (dBm)	B3 BER
-35.2	2.07E-09
-35.1	3.73E-09
-35.0	2.07E-09
-34.9	3.70E-09
-34.8	2.00E-09
-34.7	1.55E-09
-34.6	1.81E-09
-34.5	6.65E-10
-34.4	4.06E-10
-34.3	1.85E-10
-34.2	2.96E-10
-34.1	3.70E-11
-34.0	1.11E-10

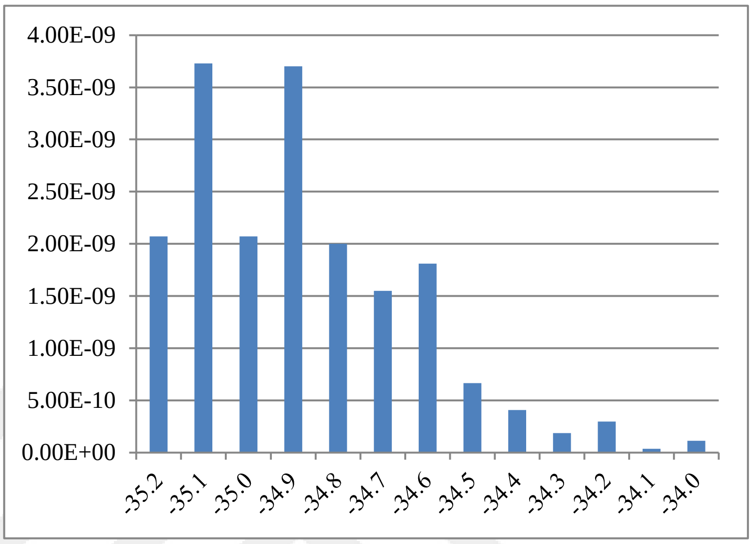

Figure 4.2 BER test results of Konak-Alaybey 155 Mb/s STM1.

Konak-Bornova 155 Mb/s, STM1 BER Test Results (Pattern 2^23-1 ITU, Measuring time is 60 secont) :

Rx (dBm)	B3 BER
-34.65	1.66E-09
-34.6	1.88E-09
-34.5	1.11E-09
-34.4	6.65E-10
-34.3	3.33E-10
-34.2	6.65E-10
-34.1	1.11E-10
-34.0	1.11E-10
-33.9	2.22E-10
-33.85	2.22E-10

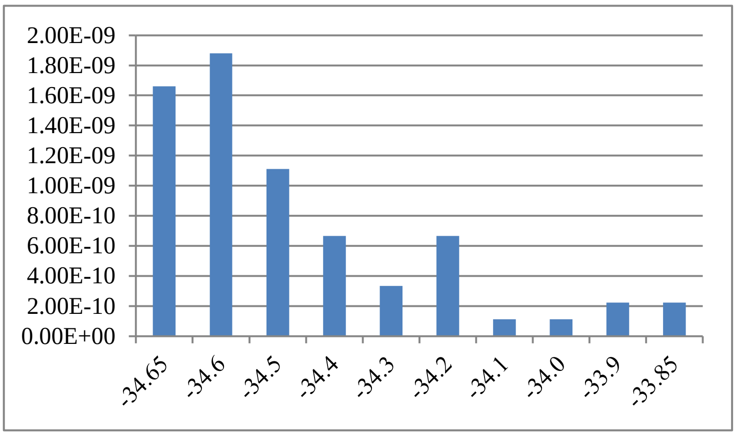

Figure 4.3 BER test results of Konak-Bornova 155 Mb/s STM1.

Konak-Hatay 155 Mb/s, STM1 BER Test Results (Pattern 2^23-1 ITU, Measuring time is 30 secont) :

Rx (dBm)	B3 BER
-34.85	2.44E-09
-34.8	2.44E-09
-34.7	1.55E-09
-34.6	2.66E-09
-34.5	1.33E-09
-34.4	2.00E-09
-34.3	8.87E-10
-34.2	6.65E-10
-34.1	4.43E-10
-34.0	4.43E-10
-33.95	2.22E-10

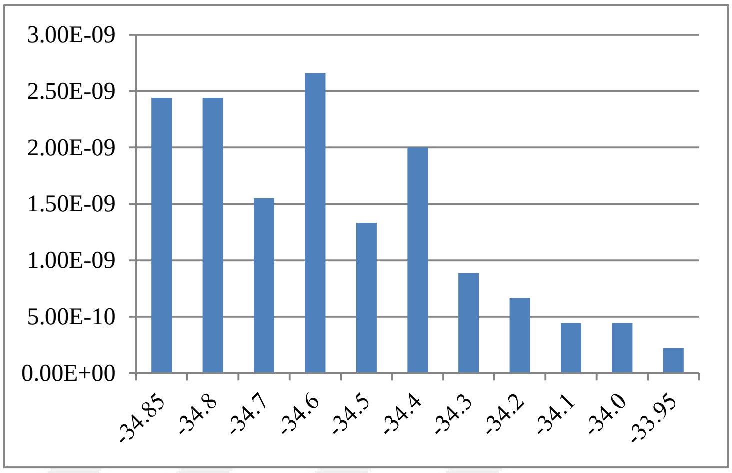

Figure 4.4 BER test results of Konak-Hatay 155 Mb/s STM1.

This section presents test results to assess the together performance of Konak-Hatay, Konak-Bornova, and Konak-Alaybey transmission links with variable time in the Synchronous Digital Hierarchy Network over Optical Network. Konak-Hatay, Konak-Bornova, and Konak-Alaybey 155 Mb/s STM1 BER Test Results (Pattern 2^23-1 ITU, Rx (dBm): -35.0):

Time	Hatay	Bornova	Alaybey
1s	0	0	0
5s	1.33E-09	1.33E-09	1.33E-09
10s	6.65E-10	6.65E-10	1.33E-09
30s	2.22E-10	2.22E-10	2.44E-09
1m	4.43E-10	1.48E-10	1.66E-09
2m	1.66E-10	1.66E-10	1.77E-09
3m	1.48E-10	2.96E-10	2.07E-09

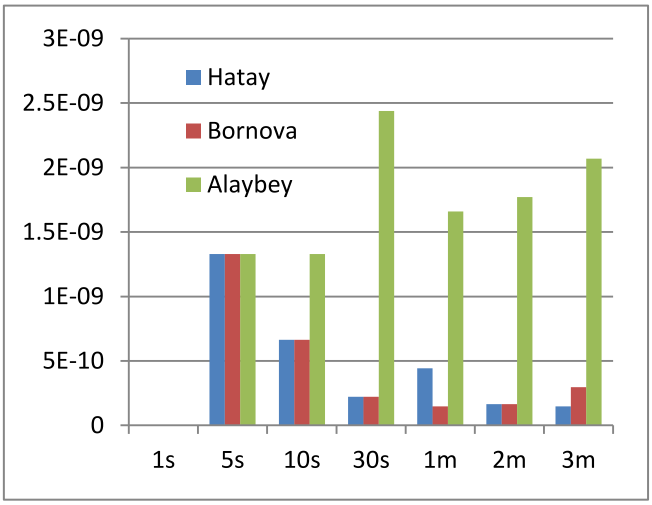

Figure 4.5 BER test results of Konak-Hatay 155 Mb/s STM1.

This section presents test results to assess the performance of Konak-Bornova, transmission links with injection errors in the Synchronous Digital Hierarchy Network over Optical Network.

S/N	8k	10k	12k	14k	16k
BER	8.04E-05	9.84E-06	1.00E-06	9.99E-08	9.97E-09

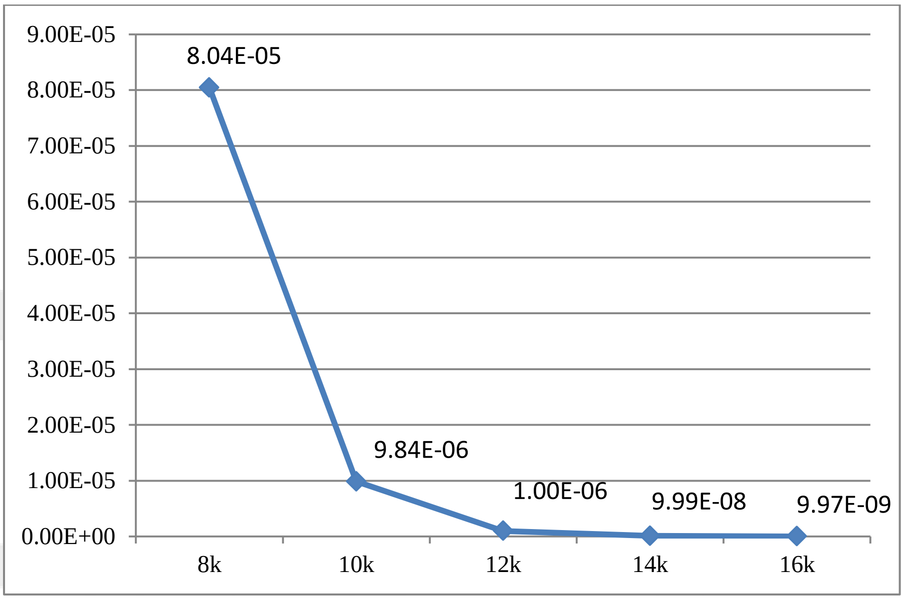

Figure 4.6 BER test results of Konak-Bornova 155 Mb/s STM1 with variable time.

4.2 The Performance of Simulated System

In the digital communications over optical network, the communication industry continues to grow, the applications of communication techniques continue to grow as well. This growth, has ripened an increasing need to seek methods of analyzing the performance of digital communication using the computer softwares.

BER has been analyzed for different values of digital or optical communication channels. The goal of our analysis is presented the performance of various communication channels in terms of their error probability. Simulink tool presents the simplified environment for the simulation of communication systems in general.

The performance of each communication is measured by calculating its probability of error with assumption. The Calculation Systems are operating with this additive white gaussian noise for communication system.

The Simulink, developed by the Math Works, is an environment for multi domain for dynamic and embedded systems. It procures an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement. It test a variety of timevarying systems, including communications, controls, and signal processing. With Simulink, we build models by dragging and dropping blocks from the library browser onto the graphical editor and connecting them with lines.

In this simulation, the generic files are used together with simulink to simulate the BER graphs. First, the simulation is done by running the MATLAB file, the output values are stored in the workspace, the MATLAB file is typed under the command window and it is run. Finally, BER graph are obtained once the simulation is completed. The additive white Gaussian channel block appends white gaussian noise to a input signal. When the input signal, this block appends gaussian noise and does output signal. The scheme of digital Transmission channel for BER performance are shown in Figure 4.7 (Sadeque, 2002).

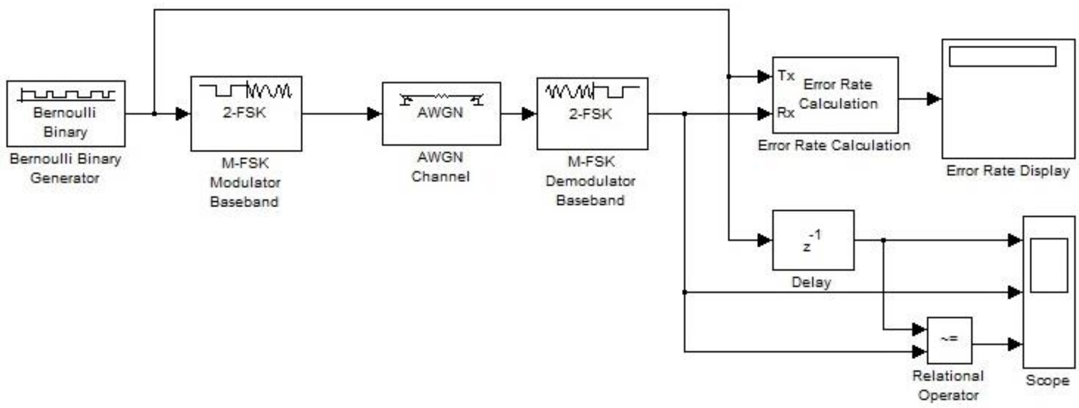

Figure 4.7 A simulation model for digital transmission channel.

The simulink analysis and simulations using MATLAB tool shows that the BER for digital transmission channel scheme decreases with values of Eb/No. It is observed from the simulation curves and the sumulink analysis of the signals. It is seen that higher order techniques exhibit higher error rates. The BER performance result for digital transmission channels are shown in Figure 4.8 (Sadeque, 2002).

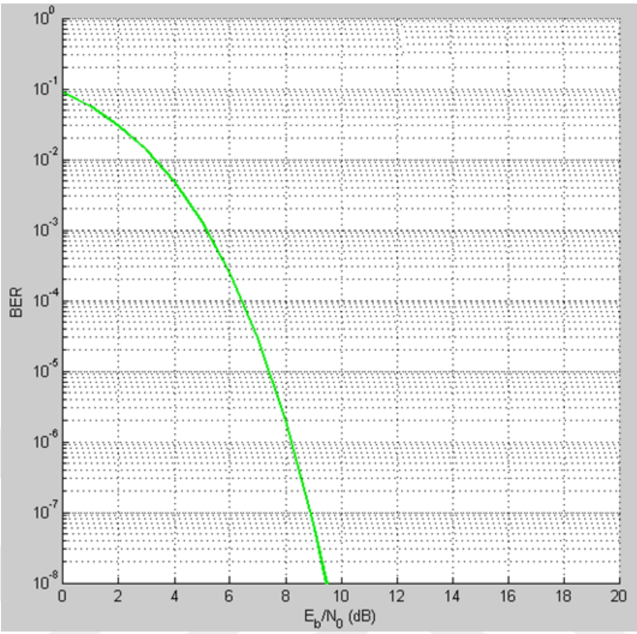

Figure 4.8 BER simulink result of digital transmission channel.

CHAPTER FIVE
CONCLUSION

The Synchronous Digital Hierarchy multiplex technology is generally well suitable for the optical communications network solution in utility public communication systems. Highly standardized Scynchronous Digital Hierarchy defines for modern multiplexer technology, though it provides support for investments and protocols as well. Integrated management features make Scynchronous Digital Hierarchy networks very reliable, which ensure fast and high availability times, as well as quick reconfiguration in faults.

The Scynchronous Digital Hierarchy multiplex equipments makes possible to integrate the telecomunnication, protection and control operations with administrative data into different public communication network. The Scynchronous Digital Hierarchy multiplex equipments has versatile interfaces for very applications as well as for standard telecommunication services. The developing of this technology in transmision increase the importance of the network protection design and system maintenance. The important technology can be used multi layer solutions, and can be used for obtaining solutions with the best performance.

In this thesis, we consider the best performance for the Scynchronous Digital Hierarchy over optical fiber network. Scynchronous Digital Hierarchy ring networks are installed today in the public network and they have several advantages. We study the Scynchronous Digital Hierarchy over optical network such that all resilience functions are performed by the ring protection.

Performance analysis of Scynchronous Digital Hierarchy networks has been studied extensively in the literature. We have tested path in ring selection ring over different network topologies, and we obtained the cost effective at different steps on the network. We have simulated the bit error rate monitoring circuit, which designed as my thesis Project. It will aid in the operation and maintenance of Scynchronous Digital Hierarchy over high speed optical networks. Finally, this thesis has helped all of us for better understanding of the Scynchronous Digital Hierarchy technologies, higher performance, and managment of communication system.

In this thesis, we evaluated the Bit Error Rate (BER) performances of Synchronous Digital Hierarchy System with an interconnected multi ring architecture overlaid over an optical mesh network. Firstly, we tested the Bit Error Rate (BER) in the introduced path over the real Synchronous Digital Hierarchy System onto a digital transmission center in Türk Telekom İzmir. In the second part of the study the whole Scynchronous Digital Hierarchy Communication System is computer simulated and than the Bit Error Rate (BER) of the System is determinated. It is shown that the simulation results are very close to the evaluated test result.

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