LESSON 21:
SONET/SDH

Objective

To provide a detailed understanding of the concepts SONET And SDH

Introduction

Before SONET, the first generations of fiber-optic systems in the public telephone network used proprietary architectures, equipment, line codes, multiplexing formats, and maintenance procedures. The users of this equipment—regional Bell operating companies and interexchange carriers (IXCs) in the United States, Canada, Korea, Taiwan, and Hong Kong—wanted standards so that they could mix and match equipment from different suppliers. The task of creating such a standard was taken up in 1984 by the ECSA to establish a standard for connecting one fiber system to another. This standard is called SONET.

SDH was first introduced into the telecommunications network in 1992 and has been deployed at rapid rates since then. It's deployed at all levels of the network infrastructure, including the access network and the long-distance trunk network. It's based on overlaying a synchronous multiplexed signal onto a light stream transmitted over fibre-optic cable. SDH is also defined for use on radio relay links, satellite links, and at electrical interfaces between equipment. The comprehensive SDH standard is expected to provide the transport infrastructure for worldwide telecommunications for at least the next two or three decades.

Sonet

Sonet stands for **S**ynchronous **O**ptical **Net**work, a high speed transmission technology designed to send traffic over fiber optic cable, but now also used over coax. That compares to the older and more well known T-Carrier system, which started in 1963, an inherently slower technique since it was built for copper cables, noisy, error producing, bandwidth limited metallic lines. Like T-1, SONET is a transmission standard, one that carries other protocols to their destination. So circuit switched voice traffic, X.25 network data packets, ATM cells, and TCP/IP based internet traffic all moves over the road that SONET provides. SONET also sports modern network features including bandwidth management, real time monitoring of the system, survivable networking, and universal connectivity. Sound like so much mush? Not really. Nathan Muller says SONET will provide communications transport mechanism for the next three to four decades; all modern telephone companies are building their new networks with it. Read the files below for more information.

SONET is the American National Standards Institute (ANSI) standard for synchronous data transmission on optical media. The international equivalent of SONET is synchronous digital hierarchy (SDH). SONET provides standards for a number of line rates up to the maximum line rate of 39.808 gigabits per second and beyond. SONET is considered to be the foundation for the physical layer of the broadband ISDN (B-ISDN). Asynchronous transfer mode runs as a layer on top of SONET as well as on top of other technologies.

The network defines optical carrier levels and their electrical equivalents, called synchronous transport signals (STS) for fiber optic transmission. The first step in the process involves multiplexing multiple signals by generating the lowest level or base signal, called Synchronous Transport Signal-Level 1 (STS-1).. Its optical carrier counterpart is called OC-1, and it transmits at 51,480 Mb/s. Other levels operate from 155 Mb/s up to 40 Gb/s. The basic network elements include the terminal multiplexer (PTE), a regenerator (as needed for long distance transmissions), an add-drop multiplexer (ADM), for use in point-to-multipoint configurations, wideband digital cross-connects (W-DCS), broadband digital cross-connects, and the digital loop carrier. Together, these elements may be used in a point-to-point, point-to-multipoint (hub), or ring network configuration. Figure 21.1 illustrates a typical hub network configuration.

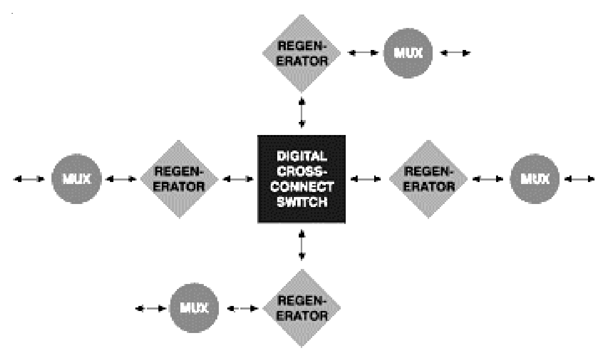

Figure 21.1 – SONET Hub Network

The STS-1 signal is formed from a sequence of repeating frames. The STS-1 frame structure is illustrated in FIG. 21.2. The STS-1 frame structure can be drawn as 90 columns by 9 rows of 8-bit bytes. The order of transmission of the bytes is row by row, from left to right across the columns, with one entire frame being transmitted every 125 ms. The 125 ms frame period supports digital voice signal transport encoded using 1 byte/125 ms=64 kb/s. The first three columns of the STS-1 frame contain section and line overhead bytes. The remaining 87 columns form the STS-1 Synchronous Payload Envelope (SPE). The SPE carries SONET payloads including 9 bytes of path overhead. The STS-1 can carry a clear channel DS3 signal (44.736 Mb/s) or, alternatively, a plurality of lower-rate signals such as DS0, DS1, DS1C, and DS2 by dividing the Synchronous Payload Envelope into a plurality of fixed time slots. For example, 648 DS0 signals fit into the SPE of an STS-1 signal.

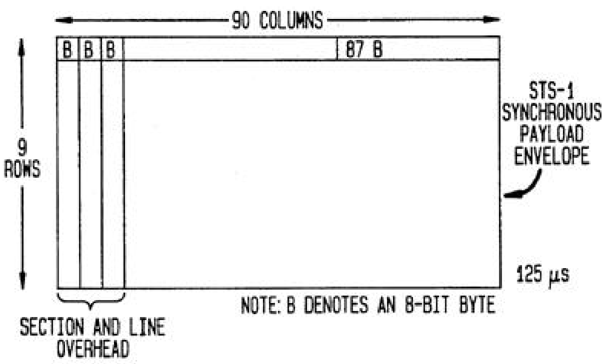

Fig.21.2 STS-1 frame structure

Higher rate SONET signals are obtained by byte interleaving N frame aligned STS-1 signals to form an STS-N signal in accordance with conventional SONET technology. An STS-N signal may be viewed as having a repetitive frame structure, wherein each frame comprises the overhead bits of N STS-1 frames and N synchronous payload envelopes. For example, three STS-1 signals may be multiplexed by a multiplexer into an STS-3 signal. The bit rate of the STS-3 signal is three times the bit rate of an STS-1 signal and the structure of each frame of the STS-3 signal comprises three synchronous payload envelopes and three fields of overhead bits from the three original STS-1 signals. When transmitted using optical fibers, the STS-N signal is converted to optical form and is designated as the OC-N signal.

SONET is the physical transport backbone of B-ISDN. It is a fiber-optic-based networking standard that defines a hierarchy of transmission rates and data-framing formats. It is used as a transmission medium to interconnect carrier-switching offices worldwide, and so forms the structure of the communications networks. SONET is now used as the medium between carrier-switching offices and customers. SONET transmission rates start at 51.4 Mbits/sec and increase in 52-Mbit/sec building blocks.

The increased configuration flexibility and bandwidth availability of SONET provides significant advantages over the older telecommunications system. These advantages include the following:

- reduction in equipment requirements and an increase in network reliabilit
- provision of overhead and payload bytes—the overhead bytes permit management of the payload bytes on an individual basis and facilitate centralized fault sectionalization
- definition of a synchronous multiplexing format for carrying lower level digital signals (such as DS–1, DS–3) and a synchronous structure that greatly simplifies the interface to digital switches, digital cross-connect switches, and add-drop multiplexers
- availability of a set of generic standards that enable products from different vendors to be connected
- definition of a flexible architecture capable of accommodating future applications, with a variety of transmission rates

What Are the Benefits of SONET?

The transport network using SONET provides much more powerful networking capabilities than existing asynchronous systems.

Pointers, MUX/DEMUX

As a result of SONET transmission, the network's clocks are referenced to a highly stable reference point. Therefore, the need to align the data streams or synchronize clocks is unnecessary. Therefore, a lower rate signal such as DS–1 is accessible, and demultiplexing is not needed to access the bitstreams. Also, the signals can be stacked together without bit stuffing.

For those situations in which reference frequencies may vary, SONET uses pointers to allow the streams to float within the payload envelope. Synchronous clocking is the key to pointers. It allows a very flexible allocation and alignment of the payload within the transmission envelope.

Reduced Back-to-Back Multiplexing

Separate M13 multiplexers (DS–1 to DS–3) and fiber-optic transmission system terminals are used to multiplex a DS–1 signal to a DS–2, DS–2 to DS–3, and then DS–3 to an optical line rate. The next stage is a mechanically integrated fiber/multiplex terminal.

In the existing asynchronous format, care must be taken when routing circuits in order to avoid multiplexing and demultiplexing too many times since electronics (and their associated capital cost) are required every time a DS–1 signal is processed. With SONET, DS–1s can be multiplexed directly to the OC–N rate. Because of synchronization, an entire optical signal does not have to be demultiplexed—only the VT or STS signals that need to be accessed.

Optical Interconnect

Because of different optical formats among vendors' asynchronous products, it is not possible to optically connect one vendor's fiber terminal to another. For example, one manufacturer may use 417–Mbps line rate, another 565–Mbps.

A major SONET value is that it allows midspan meet with multivendor compatibility. Today's SONET standards contain definitions for fiber-to-fiber interfaces at the physical level. They determine the optical line rate, wavelength, power levels, pulse shapes, and coding. Current standards also fully define the frame structure, overhead, and payload mappings. Enhancements are being developed to define the messages in the overhead channels to provide increased OAM&P functionality.

SONET allows optical interconnection between network providers regardless of who makes the equipment. The network provider can purchase one vendor's equipment and conveniently interface with other vendors' SONET equipment at either the different carrier locations or customer premises sites. Users may now obtain the OC–N equipment of their choice and meet with their network provider of choice at that OC–N level.

Multipoint Configurations

The difference between point-to-point and multipoint systems was shown previously in Figures 26 and 27. Most existing asynchronous systems are only suitable for point-to-point, whereas SONET supports a multipoint or hub configuration.

A hub is an intermediate site from which traffic is distributed to three or more spurs. The hub allows the four nodes or sites to communicate as a single network instead of three separate systems. Hubbing reduces requirements for back-to-back multiplexing and demultiplexing and helps realize the benefits of traffic grooming.

Network providers no longer need to own and maintain customer-located equipment. A multipoint implementation permits OC–N interconnects or midspan meet, allowing network providers and their customers to optimize their shared use of the SONET infrastructure.

Reduced Cabling and Elimination of DSX Panels

Asynchronous systems are dominated by back-to-back terminals because the asynchronous fiber-optic transmission system architecture is inefficient for other than point-to-point networks. Excessive multiplexing and demultiplexing are used to transport a signal from one end to another, and many bays of DSX–1 cross-connect and DSX–3 panels are required to interconnect the systems. Associated expenses are the panel, bays, cabling, the labor installation, and the inconveniences of increased floor space and congested cable racks.

The corresponding SONET system allows a hub configuration, reducing the need for back-to-back terminals. Grooming is performed electronically, so DSX panels are not used except when required to interface with existing asynchronous equipment.

Enhanced OAM&P

SONET allows integrated network OAM&P in accordance with the philosophy of single-ended maintenance. In other words, one connection can reach all network elements within a given architecture; separate links are not required for each network element. Remote provisioning provides centralized maintenance and reduced travel for maintenance personnel—which translates to expense savings.

Enhanced Performance Monitoring

Substantial overhead information is provided in SONET to allow quicker troubleshooting and detection of failures before they degrade to serious levels.

Introduction To SDH

SDH (Synchronous Digital Hierarchy) is a standard for telecommunications transport formulated by the International Telecommunication Union (ITU), previously called the International Telegraph and Telephone Consultative Committee (CCITT).

The increased configuration flexibility and bandwidth availability of SDH provides significant advantages over the older telecommunications system.

These advantages include:

- A reduction in the amount of equipment
- An increase in network reliability.

The provision of overhead and payload bytes – the overhead bytes permitting management of the payload bytes on an individual basis and facilitating centralized fault sectionalisation. The definition of a synchronous multiplexing format for carrying lower-level digital signals (such as 2 Mbit/s, 34 Mbit/s, 140 Mbit/s) which greatly simplifies the interface to digital switches, digital cross-connects, and add-drop multiplexers. The availability of a set of generic standards, which enable multivendor interoperability.

The definition of a flexible architecture capable of accommodating future applications, with a variety of transmission rates.

In brief, SDH defines synchronous transport modules (STMs) for the fibre-optic based transmission hierarchy.

Before SDH, the first generations of fibre-optic systems in the public telephone network used proprietary architectures, equipment line codes, multiplexing formats, and maintenance procedures. The users of this equipment wanted standards so they could mix and match equipment from different suppliers.

The task of creating such a standard was taken up in 1984 by the Exchange Carriers Standards Association (ECSA) in the U.S. to establish a standard for connecting one fibre system to another. In the late stages of the development, the CCITT became involved so that a single international standard might be developed for fibre interconnect between telephone networks of different countries. The resulting international standard is known as Synchronous Digital Hierarchy (SDH).

Synchronisation of Digital Signals

To correctly understand the concepts and details of SDH, it's important to be clear about the meaning of Synchronous, Plesiochronous, and Asynchronous.

In a set of Synchronous signals, the digital transitions in the signals occur at exactly the same rate. There may however be a phase difference between the transitions of the two signals, and this would lie within specified limits. These phase differences may be due to propagation time delays, or low-frequency wander introduced in the transmission network. In a synchronous network, all the clocks are traceable to one Stratum 1 Primary Reference Clock (PRC). The accuracy of the PRC is better than ±1 in 1011 and is derived from a cesium atomic standard.

If two digital signals are Plesiochronous, their transitions occur at "almost" the same rate, with any variation being constrained within tight limits. These limits are set down in ITU-T recommendation G.811. For example, if two networks need to interwork, their clocks may be derived from two different PRCs. Although these clocks are extremely accurate,

there's a small frequency difference between one clock and the other. This is known as a plesiochronous difference.

In the case of Asynchronous signals, the transitions of the signals don't necessarily occur at the same nominal rate. Asynchronous, in this case, means that the difference between two clocks is much greater than a plesiochronous difference. For example, if two clocks are derived from free-running quartz oscillators, they could be described as asynchronous.

SDH Advantages

The primary reason for the creation of SDH was to provide a long-term solution for an optical mid-span meet between operators; that is, to allow equipment from different vendors to communicate with each other. This ability is referred to as multi-vendor interworking and allows one SDH-compatible network element to communicate with another, and to replace several network elements, which may have previously existed solely for interface purposes. The second major advantage of SDH is the fact that it's synchronous. Currently, most fibre and multiplex systems are plesiochronous. This means that the timing may vary from equipment to equipment because they are synchronised from different network clocks. In order to multiplex this type of signal, a process known as bit-stuffing is used. Bit-stuffing adds extra bits to bring all input signals up to some common bit-rate, thereby requiring multi-stage multiplexing and demultiplexing. Because SDH is synchronous, it allows single-stage multiplexing and demultiplexing.

This single-stage multiplexing eliminates hardware complexity, thus decreasing the cost of equipment while improving signal quality. In plesiochronous networks, an entire signal had to be demultiplexed in order to access a particular channel; then the non-accessed channels had to be re-multiplexed back together in order to be sent further along the network to their proper destination. In SDH format, only those channels that are required at a particular point are demultiplexed, thereby eliminating the need for back-to-back multiplexing. In other words, SDH makes individual channels "visible" and they can easily be added and dropped.

Basic SDH Signal

The basic format of an SDH signal allows it to carry many different services in its Virtual Container (VC) because it is bandwidth-flexible. This capability allows for such things as the transmission of high-speed packet-switched services, ATM, contribution video, and distribution video. However, SDH still permits transport and networking at the 2 Mbit/s, 34 Mbit/s, and 140 Mbit/s levels, accommodating the existing digital hierarchy signals. In addition, SDH supports the transport of signals based on the 1.5 Mbit/s hierarchy.

Table 2. SDH Hierarchy

Bit Rate	Abbreviated	SDH	SDH Capacity
51.84 Mbit/s	51 Mbit/s	STM-0	21 E1
155.52 Mbit/s	155 Mbit/s	STM-1	63 E1 or 1 E4
622.08 Mbit/s	622 Mbit/s	STM-4	252 E1 or 4 E4
2488.32 Mbit/s	2.4 Gbit/s	STM-16	1008 E1 or 16 E4
9953.28 Mbit/s	10 Gbit/s	STM-64	4032 E1 or 64 E4
39813.12 Mbit/s	40 Gbit/s	STM-256	16128 E1 or 256 E4

STM = Synchronous Transport Module

Notes