LNCT GROUP OF COLLEGES

Name of Faculty: Rahul Sharma/ Prashant Chaturvedi/ Abhinav Bhargava/ Sunny Jain/ Dr Mukul Shrivastava

Designation: Assistant Professor

Department: EC

Subject: Data Comm EC 603

Unit: IV

Topic: Sonet

To satisfy the requirements of ever increasing data rate for diverse applications, ANSI developed a standard known as Synchronous Optical Network (SONET) by utilizing the enormous bandwidth of optical fiber. Another very similar standard developed by ITU-T is known as Synchronous Digital Hierarchy (SDH). It is a synchronous TDM system controlled by a master clock, which adds predictability. The comprehensive SONET/synchronous digital hierarchy (SDH) standard is expected to provide the transport infrastructure for worldwide telecommunications for at least the next two or three decades.

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 reliability.
- 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

In brief, SONET defines optical carrier (OC) levels and electrically equivalent synchronous transport signals (STSs) for the fiber-optic–based transmission hierarchy.

Synchronization of Digital Signals

To understand the concepts and details of SONET correctly, it is important to follow the meaning of *synchronous, asynchronous, and plesiochronous*. 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 delays or jitter introduced into the transmission network. In a synchronous network, all the clocks are traceable to one primary reference clock (PRC).

If two digital signals are plesiochronous, their transitions occur at almost the same rate, with any variation being constrained within tight limits. For example, if two networks must interwork, their clocks may be derived from two different primary reference clocks (PRCs). Although these clocks are extremely accurate, there is a 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 do not 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.

Basic SONET Signal

SONET defines a technology for carrying many signals of different capacities through a synchronous, flexible, optical hierarchy. This is accomplished by means of a byte-interleaved multiplexing scheme. Byte interleaving simplifies multiplexing and offers end-to-end network management.

The first step in the SONET multiplexing process involves the generation of the lowest level or base signal. In SONET, this base signal is referred to as synchronous transport signal–level 1, or simply STS–1, which operates at 51.84 Mbps. Higher-level signals are integer multiples of STS–1, creating the family of STS–N signals in Table 1. An STS–N signal is composed of N byte-interleaved STS–1 signals. This table also includes the optical counterpart for each STS–N signal, designated optical carrier level N (OC–N).

Table 4.3.1 Synchronous transport signals and optical carriers

STS	OC	Raw (Mbps)	SPE (Mbps)	User (Mbps)
STS-1	OC-1	51.84	50.12	49.536
STS-3	OC-3	155.52	150.336	148.608
STS-9	OC-9	466.56	451.008	445.824
STS-12	OC-12	622.08	601.344	594.432
STS-18	OC-18	933.12	902.016	891.648
STS-24	OC-24	1244.16	1202..688	1188.864
STS-36	OC-36	1866.23	1804.032	1783.296
STS-48	OC-48	2488.32	2405.376	2377.728
STS-192	OC-192	9953.28	9621.604	9510.912

Why Synchronize?

In a synchronous system such as SONET, the average frequency of all clocks in the system will be the same (synchronous) or nearly the same (plesiochronous). Every clock can be traced back to a highly stable reference supply. Thus, the STS–1 rate remains at a nominal 51.84 Mbps, allowing many synchronous STS–1 signals to be stacked together when multiplexed without any bit-stuffing. Thus, the STS–1s are easily accessed at a higher STS–N rate.

Low-speed synchronous virtual tributary (VT) signals are also simple to interleave and transport at higher rates. At low speeds, DS–1s are transported by synchronous VT–1.5 signals at a constant rate of 1.728 Mbps. Single-step multiplexing up to STS–1 requires no bit stuffing, and VTs are easily accessed.

Pointers accommodate differences in the reference source frequencies and phase wander and prevent frequency differences during synchronization failures.

Synchronization Hierarchy

Digital switches and digital cross-connect systems are commonly employed in the digital network synchronization hierarchy. The network is organized with a master-slave relationship with clocks of the higher-level nodes feeding timing signals to clocks of the lower-level nodes. All nodes can be traced up to a primary reference source, a Stratum 1 atomic clock with extremely high stability and accuracy. Less stable clocks are adequate to support the lower nodes.

Synchronizing SONET

The internal clock of a SONET terminal may derive its timing signal from a building integrated timing supply (BITS) used by switching systems and other equipment. Thus, this terminal will serve as a master for other SONET nodes, providing timing on its outgoing OC–N signal. Other SONET nodes will operate in a slave mode called loop timing with their internal clocks timed by the incoming OC–N signal. Current standards specify that a SONET network must be able to derive its timing from a Stratum 3 or higher clock.

Physical Configuration and Network Elements

Three basic devices used in the SONET system are shown in Fig. 4.3.1. Functions of the three devices are mentioned below:

- Synchronous Transport Signal (STS) multiplexer/demultiplexer: It either multiplexes signal from multiple sources into a STS signal or demultiplexes an STS signal into different destination signals.
- Regenerator: It is a repeater that takes a received optical signal and regenerates it. It functions in the data link layer.
- Add/drop Multiplexer: Can add signals coming from different sources into a given path or remove a desired signal from a path and redirect it without demultiplexing the entire signal.

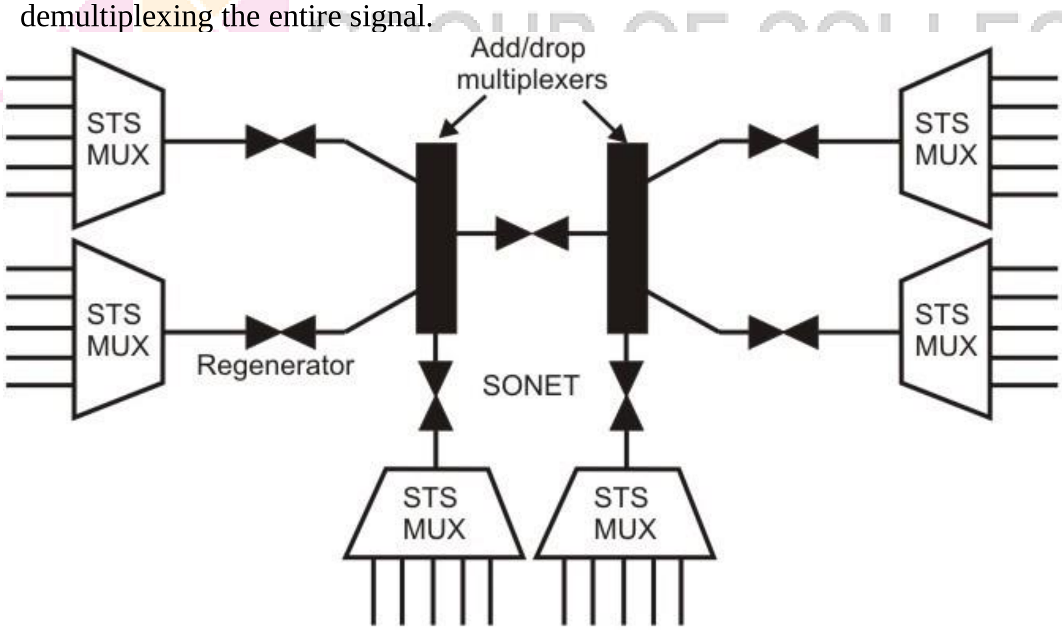


Figure 4.3.1 Devices used in the SONET system

Section, Line and paths

A number of electrical signals are fed into an STS multiplexer, where they are combined into a single optical signal. Regenerator recreates the optical signal without noise it has picked up in transit. Add/Drop multiplexer reorganize these signals. A section is an optical link, connecting two neighboring devices: multiplexer to multiplexer, multiplexer to regenerator, or regenerator to regenerator. A line is a portion of network between two multiplexers: STS to add/drop multiplexer, two add/drop multiplexer, or two STS multiplexer. A Path is the end-to-end portion of the network between two STS multiplexers, as shown in Fig. 4.3.2.

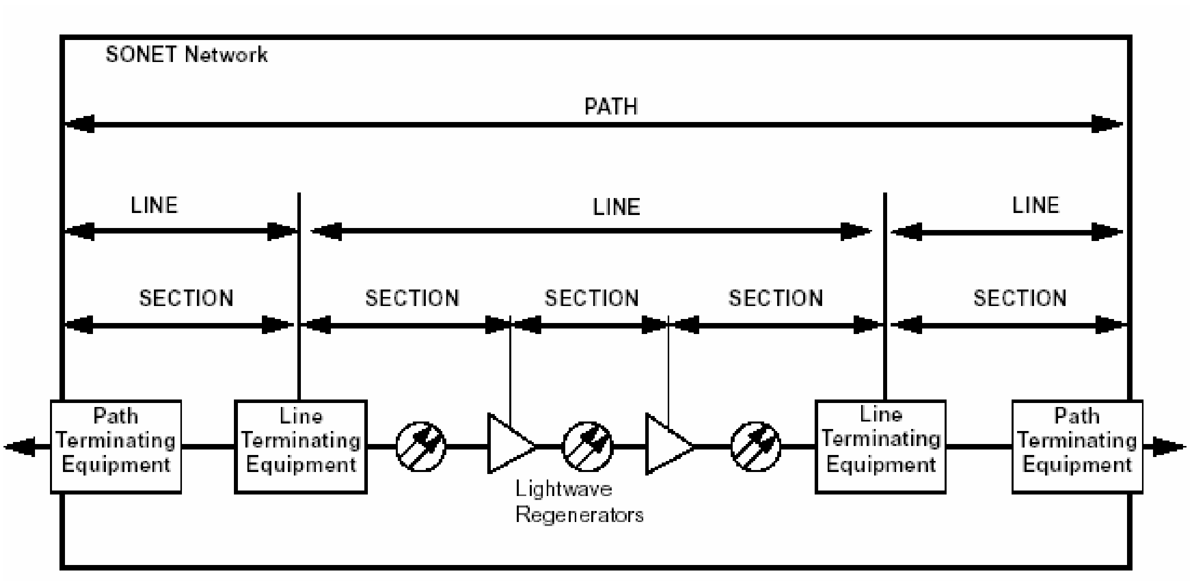


Figure 4.3.2 Section, line and path in a SONET network

"WORKING TOWARDS BEING THE BEST"

SONETtwork Elements

Terminal Multiplexer

The path terminating element (PTE), an entry-level path-terminating terminal multiplexer, acts as a concentrator of DS–1s as well as other tributary signals. Its simplest deployment would involve two terminal multiplexers linked by fiber with or without a regenerator in the link. This implementation represents the simplest SONET link (a section, line, and path all in one link; see Figure 4.3.3).

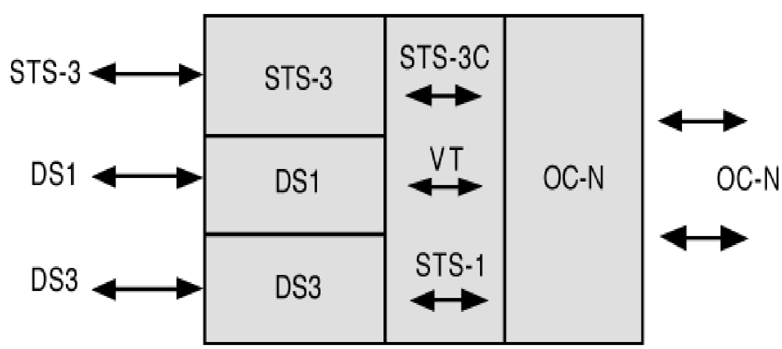


Figure 4.3.3 Terminal Multiplexer

Regenerator

A regenerator is needed when, due to the long distance between multiplexers, the signal level in the fiber becomes too low. The regenerator clocks itself off of the received signal and replaces the section overhead bytes before retransmitting the signal. The line overhead, payload, and POH are not altered (see Figure 4.3.4).

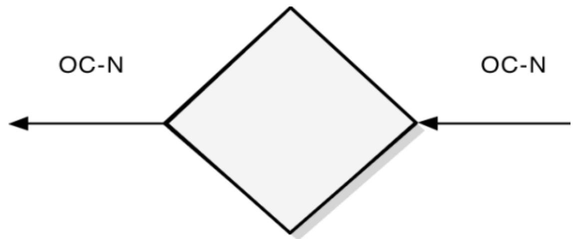


Figure 4.3.4 Regenerator

Add/Drop Multiplexer (ADM)

A single-stage multiplexer/demultiplexer can multiplex various inputs into an OC–N signal. It can add signals coming from different sources into a given path or remove a desired signal from a path and redirect it without demultiplexing the entire signal, as shown in Fig. 4.3.5. Instead of relying on timing and bit positions, add/drop multiplexer uses header information such as addresses and pointers to identify individual streams.

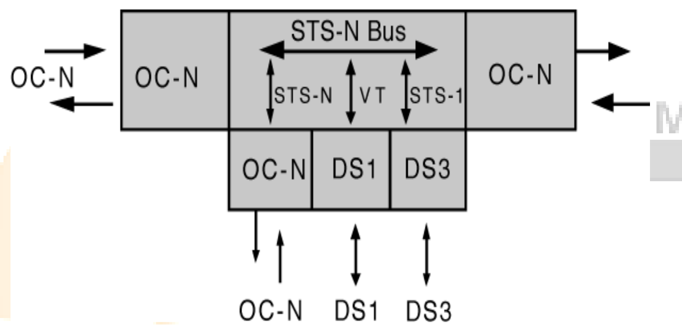


Figure 4.3.5 Add/drop Multiplexer

In rural applications, an ADM can be deployed at a terminal site or any intermediate location for consolidating traffic from widely separated locations. Several ADMs can also be configured as a survivable ring. SONET enables drop and repeat (also known as drop and continue)—a key capability in both telephony and cable TV applications. With drop and repeat, a signal terminates at one node, is duplicated (repeated), and is then sent to the next and subsequent nodes.

The add/drop multiplexer provides interfaces between the different network signals and SONET signals. Single-stage multiplexing can multiplex/demultiplex one or more tributary (DS–1) signals into/from an STS–N signal. It can be used in terminal sites, intermediate (add/drop) sites, or hub configurations. At an add/drop site, it can drop lower-rate signals to be transported on different facilities, or it can add lower-rate signals into the higher-rate STS–N signal. The rest of the traffic simply continues straight through.

Wideband Digital Cross-Connects

A SONET cross-connect accepts various optical carrier rates, accesses the STS–1 signals, and switches at this level. It is ideally used at a SONET hub as shown in Fig. 4.3.6. One major difference between a cross-connect and an add/drop multiplexer is that a cross-connect may be used to interconnect a much larger number of STS– 1s. The broadband cross-connect can be used for grooming (consolidating or segregating) of STS–1s or for broadband traffic management. For example, it may be used to segregate high-bandwidth from low-bandwidth traffic and send it separately to the high-bandwidth (e.g., video) switch and a low-bandwidth (voice) switch. It is the synchronous equivalent of a DS–3 digital cross-connect and supports hubbed network**.** **architecture**

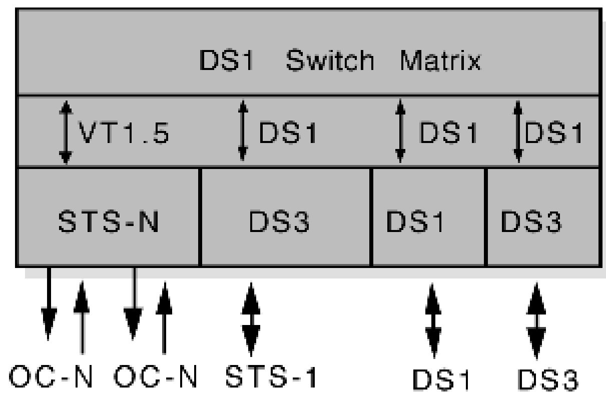


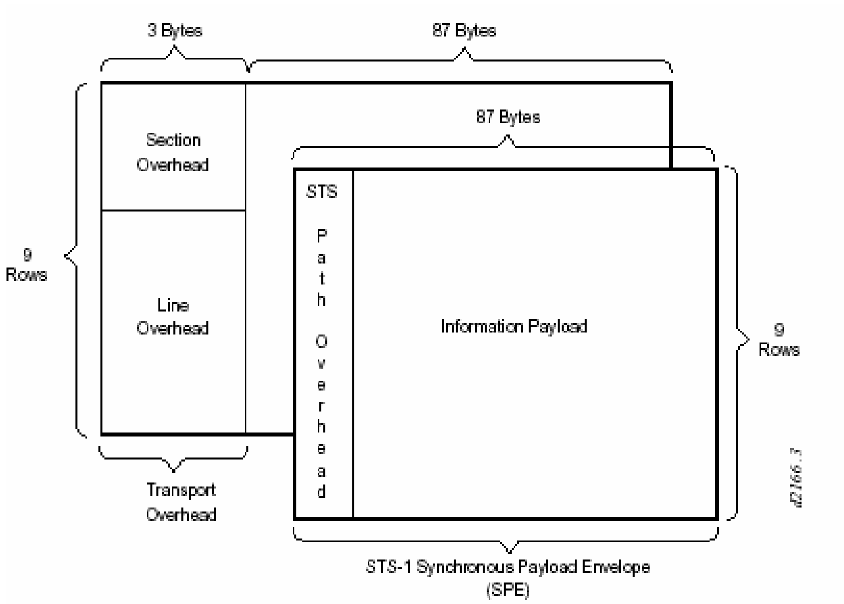
Figure 4.3.6 Wideband digital cross-connect

Frame Format Structure

SONET uses a basic transmission rate of STS–1 that is equivalent to 51.84 Mbps. Higher-level signals are integer multiples of the base rate. For example, STS–3 is three times the rate of STS–1 (3 x 51.84 = 155.52 Mbps). An STS–12 rate would be 12 x 51.84 = 622.08 Mbps. SONET is based on the STS-1 frame. STS-1 Frame Format is shown in Fig. 4.3.7.

- STS-1 consists of 810 octets
  - 9 rows of 90 octets
  - 27 overhead octets formed from the first 3 octets of each row
    - 9 used for section overhead
    - 18 used for line overhead
  - 87x9 = 783 octets of payload
    - one column of the payload is path overhead - positioned by a pointer in the line overhead
  - Transmitted top to bottom, row by row from left to right
- STS-1 frame transmitted every 125 us: thus a transmission rate of 51.84 Mbps.

The synchronous payload envelope can also be divided into two parts: the STS path overhead (POH) and the payload. Transport overhead is composed of section overhead and line overhead. The STS–1 POH is part of the synchronous payload envelope. The first three columns of each STS–1 frame make up the transport overhead, and the last 87 columns make up the SPE. SPEs can have any alignment within the frame, and this alignment is indicated by the H1 and H2 pointer bytes in the line overhead.



OVERHEAD

Figure 4.3.7 STS1 Frame format

SONET overhead is not added as headers or trailers as we have seen in other protocols. Instead, SONET inserts overhead at a variety of locations in middle of the frame. The meaning s and location of these insertions are discussed below. The overhead information has several layers, which will also be discussed in this section.

SONET Layers: SONET defines 4 layers, namely photonic layer, Section layer, Line layer and Path layer. The photonic layer is the lowest and performs the physical layer activities while all other 3 layers correspond to Data link layer of OSI model. The photonic layer includes physical specifications for the optical fiber channel, the sensitivity of the receiver, multiplexing functions and so on. It uses NRZ encoding.

- **Section Layer and Overhead:** This layer is responsible for movement of a signal across a physical section. It handles framing, scrambling, and error control. Section overhead which is added in this layer contains 9 bytes of the transport overhead accessed, generated, and processed by section-terminating equipment.

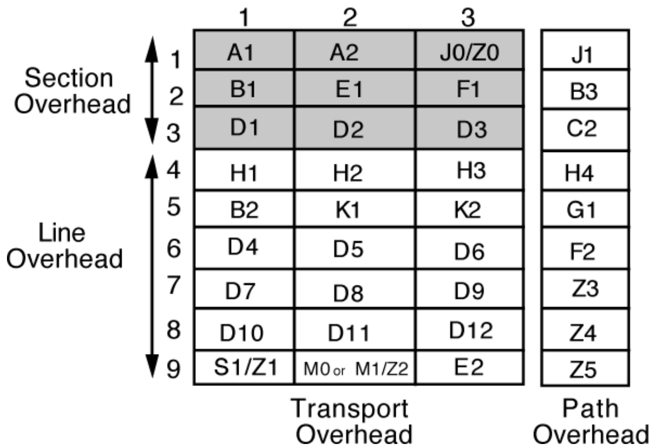


Figure 4.3.8 Section Overhead

This overhead supports functions such as the following:

- performance monitoring (STS–N signal)
- local orderwire
- data communication channels to carry information for OAM&P
- framing

Let's discuss these overhead bytes in a bit more detail.

Let's discuss these overhead bytes in a bit more detail.

Framing bytes (A1, A2)—These two bytes indicate the beginning of an STS–1 frame. These are used for framing and synchronization. These Bytes are also called as **Alignment Bytes**

Section trace (J0)/section growth (Z0)—This is also known as **Identification Byte.** It carries a unique identifier for STS1 frame. This byte is necessary when multiple STS1 frames are multiplied to create higher rate STS. Information in this byte allows the various signals to de-multiplex easily.

Parity byte (B1) —This is a for bit-interleaved parity (even parity), BIP used to check for transmission errors over a regenerator section. Its value is calculated over all bits of the previous STS–N frame after scrambling then placed in the B1 byte of STS–1 before scrambling. Therefore, this byte is defined only for STS–1 number 1 of an STS–N signal

Orderwire byte (E1)—This byte is allocated to be used as a local orderwire channel for voice communication between regenerators, hubs, and remote terminal locations.

User channel byte (F1)—This byte is set aside for the users' purposes. It terminates at all section-terminating equipment within a line. It can be read and written to at each section-terminating equipment in that line.

Data communications channel (DCC) bytes or Management byte (D1, D2, D3)—Together, these 3 bytes form a 192–kbps message channel providing a message-based channel for OAM&P between pieces of section-terminating equipment. The channel is used from a central location for alarms, control, monitoring, administration, and other communication needs. It is available for internally generated, externally generated, or manufacturer-specific messages.

- **Line Layer and Overhead:** This layer is responsible for the movement of a signal across a physical line. STS multiplexer and add/drop multiplexers provide line layer functions. Line overhead contains 18 bytes of overhead accessed, generated, and processed by line-terminating equipment.

This overhead supports functions such as the following:

- locating the SPE in the frame
- multiplexing or concatenating signals
- performance monitoring
- automatic protection switching
- line maintenance

Line overhead is found in rows 4 to 9 of columns 1 to 9

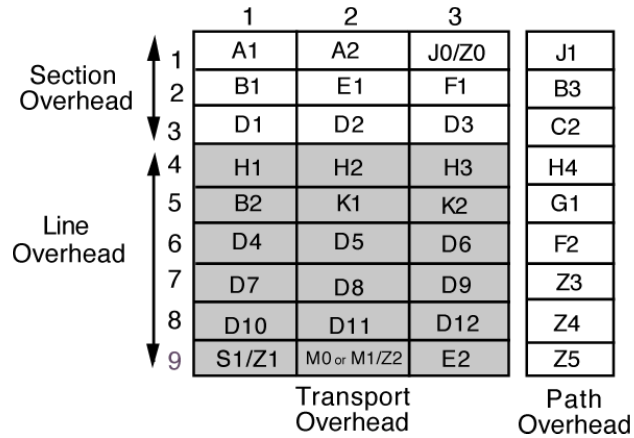


Figure 4.3.9 Line Overhead

Let's discuss these overhead bytes in a bit more detail.

STS payload pointer (H1 and H2)—Two bytes are allocated to a pointer that indicates the offset in bytes between the pointer and the first byte of the STS SPE. The pointer bytes are used in all STS–1s within an STS–N to align the STS–1 transport overhead in the STS–N and to perform frequency justification. These bytes are also used to indicate concatenation and to detect STS path alarm indication signals (AIS–P).

Pointer action byte (H3)—The pointer action byte is allocated for SPE frequency justification purposes. The H3 byte is used in all STS–1s within an STS–N to carry the extra SPE byte in the event of a negative pointer adjustment. The value contained in this byte when it is not used to carry the SPE byte is undefined.

Line bit-interleaved parity code (BIP–8) byte (B2)—This parity code byte is used to determine if a transmission error has occurred over a line. It is even parity and is calculated over all bits of the line overhead and STS–1 SPE of the previous STS–1 frame before scrambling. The value is placed in the B2 byte of the line overhead before scrambling. This byte is provided in all STS–1 signals in an STS–N signal.

Automatic protection switching (APS channel) bytes (K1, K2)—These 2 bytes are used for protection signaling between line-terminating entities for bidirectional automatic protection switching and for detecting alarm indication signal (AIS–L) and remote defect indication (RDI) signals.

Line Data communications channel (DCC) bytes (D4 to D12)—These 9 bytes form a 576–kbps message channel from a central location for OAM&P information (alarms, control, maintenance, remote provisioning, monitoring, administration, and other communication needs) between line entities. They are available for internally generated, externally generated, and manufacturer-specific messages. A protocol analyzer is required to access the line–DCC information.

Synchronization status (S1)—The S1 byte is located in the first STS–1 of an STS–N,

and bits 5 through 8 of that byte are allocated to convey the synchronization status of the network element.
Growth (Z1)—The Z1 byte is located in the second through Nth STS–1s of an STS–N (3 <= N <= 48) and are allocated for future growth. Note that an OC–1 or STS–1 electrical signal does not contain a Z1 byte.
STS–1 REI–L (M0)—The M0 byte is only defined for STS–1 in an OC–1 or STS–1 electrical signal. Bits 5 through 8 are allocated for a line remote error indication function (REI–L, formerly referred to as line FEBE), which conveys the error count detected by an LTE (using the line BIP–8 code) back to its peer LTE.
STS–N REI–L (M1)—The M1 byte is located in the third STS–1 (in order of appearance in the byte-interleaved STS–N electrical or OC–N signal) in an STS–N (N >= 3) and is used for a REI–L function.
Growth (Z2)—The Z2 byte is located in the first and second STS–1s of an STS–3 and the first, second, and fourth through Nth STS–1s of an STS–N (12 <= N <= 48). These bytes are allocated for future growth. Note that an OC–1 or STS–1 electrical signal does not contain a Z2 byte.
Orderwire byte (E2)—This orderwire byte provides a 64–kbps channel between line entities for an express orderwire. It is a voice channel for use by technicians and will be ignored as it passes through the regenerators.

Virtual Tributaries and Pointers

- *Virtual Tributary*

SONET is designed to carry broadband payloads. Current digital hierarchy data rates are lower than STS1, so to make SONET backward compatible with the current hierarchy its frame design includes a system of **Virtual Tributaries (VTs)**. A virtual tributary is a partial payload that can be inserted into an STS1 and combined with other partial payloads to fill out the frame. Instead of using 86 payload columns of an STS1 frame for data from one source, we can sub-divide the SPE and call each component as a VT.

- *Pointers*

SONET uses a concept called pointers to compensate for frequency and phase variations. Pointers allow the transparent transport of synchronous payload envelopes (either STS or VT) across plesiochronous boundaries (i.e., between nodes with separate network clocks having almost the same timing). The use of pointers avoids the delays and loss of data associated with the use of large (125-microsecond frame) slip buffers for synchronization.

Pointers provide a simple means of dynamically and flexibly phase-aligning STS and VT payloads, thereby permitting ease of dropping, inserting, and cross-connecting these payloads in the network. Transmission signal wander and jitter can also be readily minimized with pointers. STS–1 pointers (H1 and H2 bytes) are the ones which allow the SPE to be separated from the transport overhead. The pointer is simply an offset value that points to the byte where the SPE begins.

- **VT Mappings**

There are several options for how payloads are actually mapped into the VT. Locked-mode VTs bypass the pointers with a fixed byte-oriented mapping of limited flexibility. Floating mode mappings use the pointers to allow the payload to float within the VT payload. There are three different floating mode mappings—asynchronous, bit- synchronous, and byte-synchronous.

VT Type	Bit Rate (Mbps)	Size of VT
VT 1.5	1.728	9 rows, 3 columns
VT 2	2.304	9 rows, 4 columns
VT 3	3.456	9 rows, 6 columns
VT 6	6.912	9 rows, 12 columns

Figure 4.3.10 VTs

To accommodate mixes of different VT types within an STS–1 SPE, the VTs are grouped together. An SPE can carry a mix of any of the seven groups. The groups have no overhead or pointers; they are just a means of organizing the different VTs within an STS–1 SPE. Because each of the VT groups is allocated 12 columns of the SPE, a VT group would contain one of the following combinations:

- Four VT1.5s (with 3 columns per VT1.5)
- Three VT2s (with 4 columns per VT2)
- Two VT3s (with 6 columns per VT3)

LNCT GROUP OF COLLEGES "WORKING TOWARDS BEING THE BEST"

Que 1. What is Sonet ? Explain its working principle.

Que2. Write short notes on SONET.

"WORKING TOWARDS BEING THE BEST"