Communications Technology

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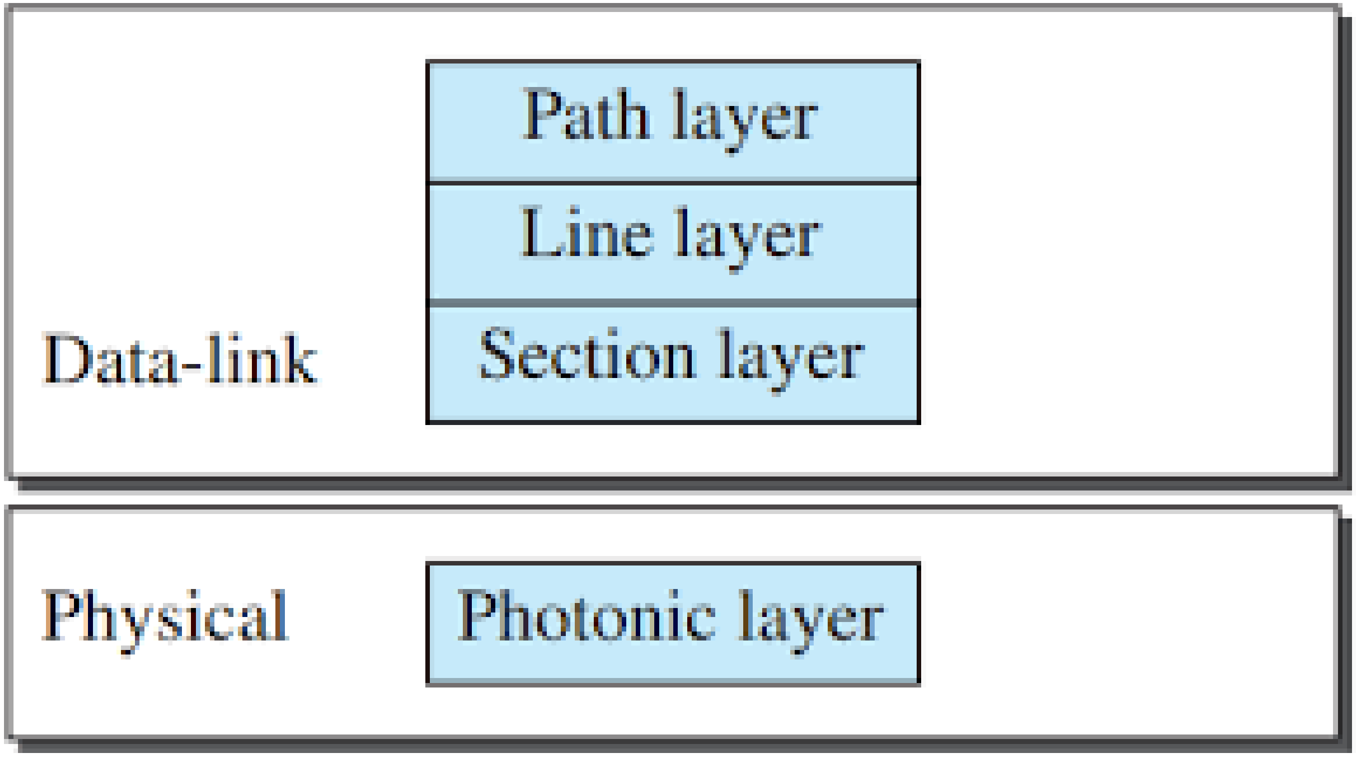
Chapter 2

SONET Network

SONET Layers

The SONET standard includes **four functional layers**: the photonic, the section, the line, and the path layer. They correspond to both the physical and the data link layers . The headers added to the frame at the various layers .


Path layer
Line layer
Section layer
Data-link
Physical
Photonic layer

Path Layer: The path layer is responsible for the movement of a signal from its optical source to its optical destination. At the optical source, the signal is changed from an electronic form into an optical form, multiplexed with other signals, and encapsulated in a frame.

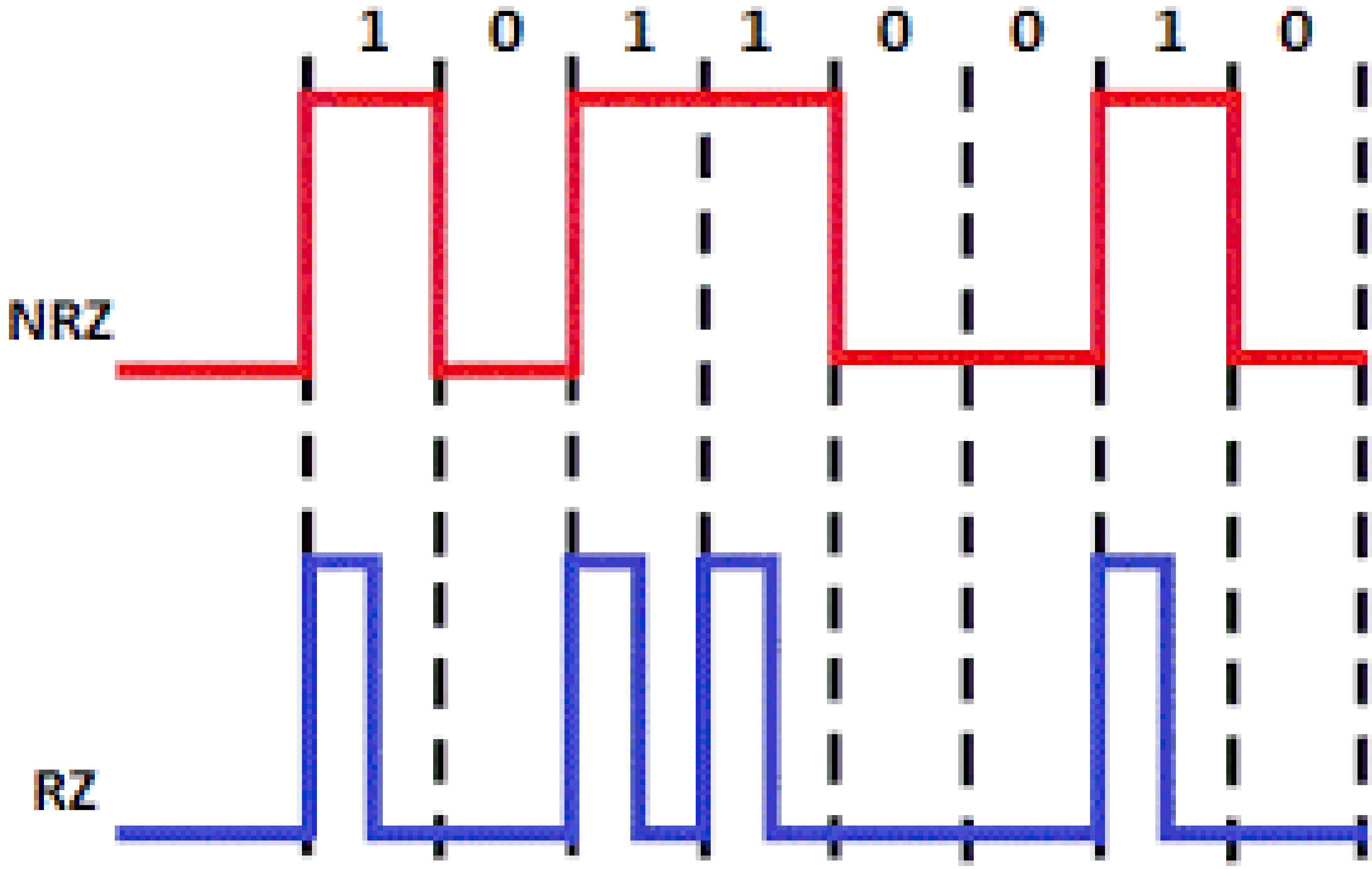
At the optical destination, the received frame is demultiplexed, and the individual optical signals are changed back into their electronic forms. Path layer overhead is added at this layer. STS multiplexers provide path layer functions.

v

Line Layer: The line layer is responsible for the movement of a signal across a physical line. Line layer overhead is added to the frame at this layer. STS multiplexers and add/drop multiplexers provide line layer functions.

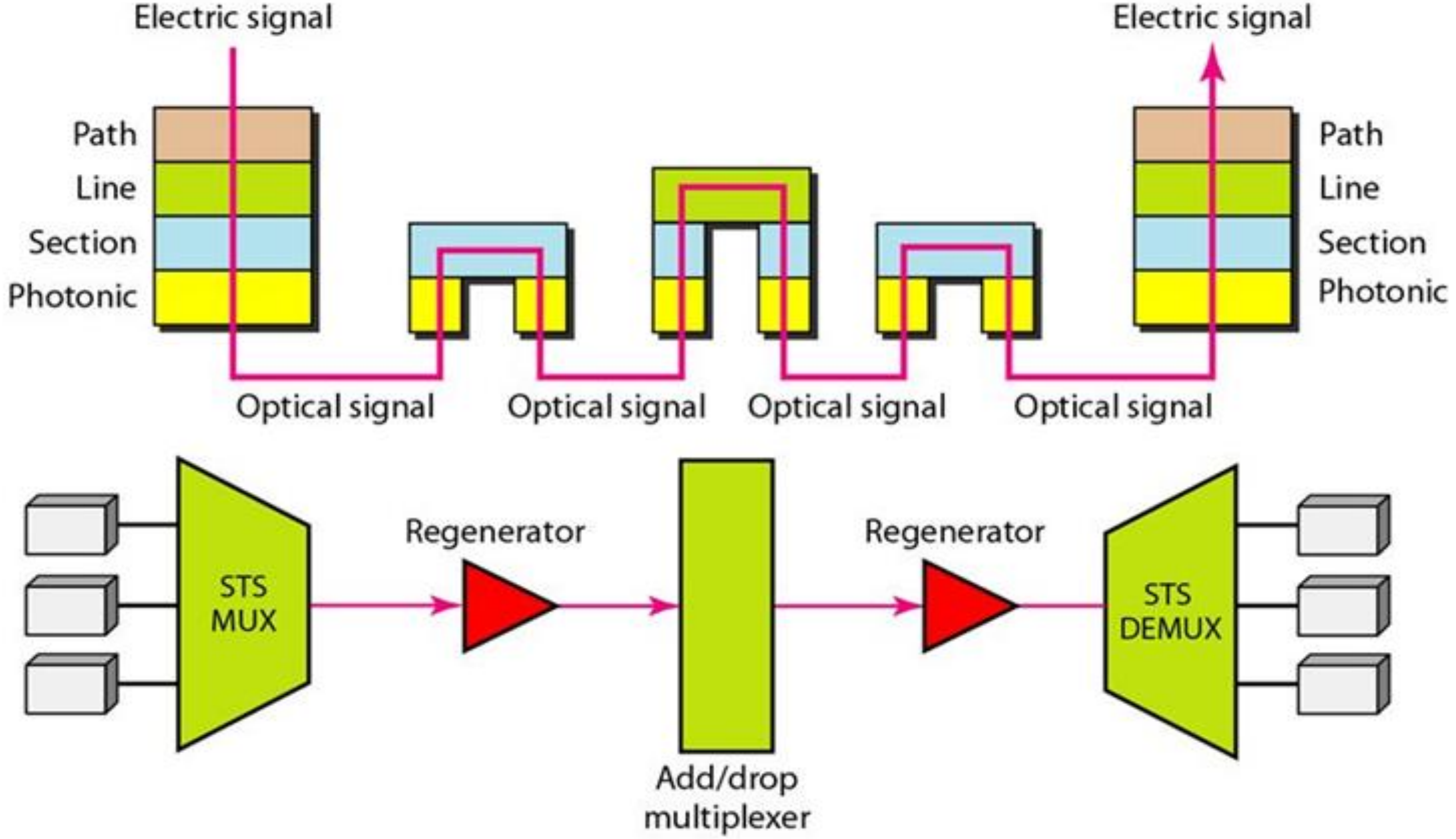
Section Layer: The section layer is responsible for the movement of a signal across a physical section. It handles framing, scrambling, and error control. Section layer overhead is added to the frame at this layer.

Photonic Layer: The photonic layer corresponds to the physical layer of the OSI model. It includes physical specifications for the optical fiber channel, the sensitivity of the receiver, multiplexing functions, and so on. SONET uses **Non Return to Zero (NRZ)** encoding with the presence of light representing 1 and the absence of light representing 0.


1 0 1 1 0 0 1 0
NRZ
RZ

The relationship between the devices used in SONET transmission and the four layers of the standard. As you can see, an STS multiplexer is a four-layer device. An add/drop multiplexer is a three-layer device. A regenerator is a two-layer device.

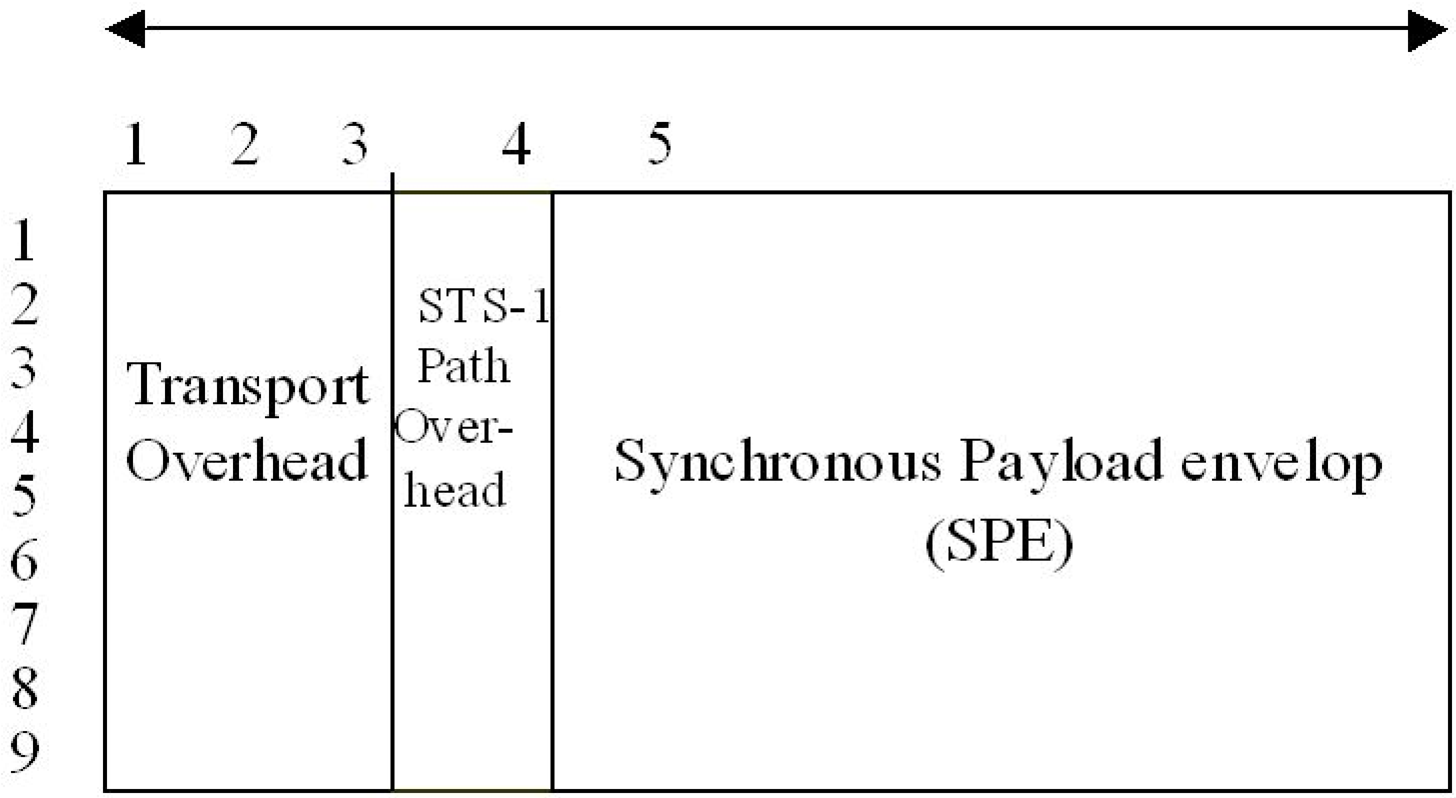
Device–layer relationship in SONET

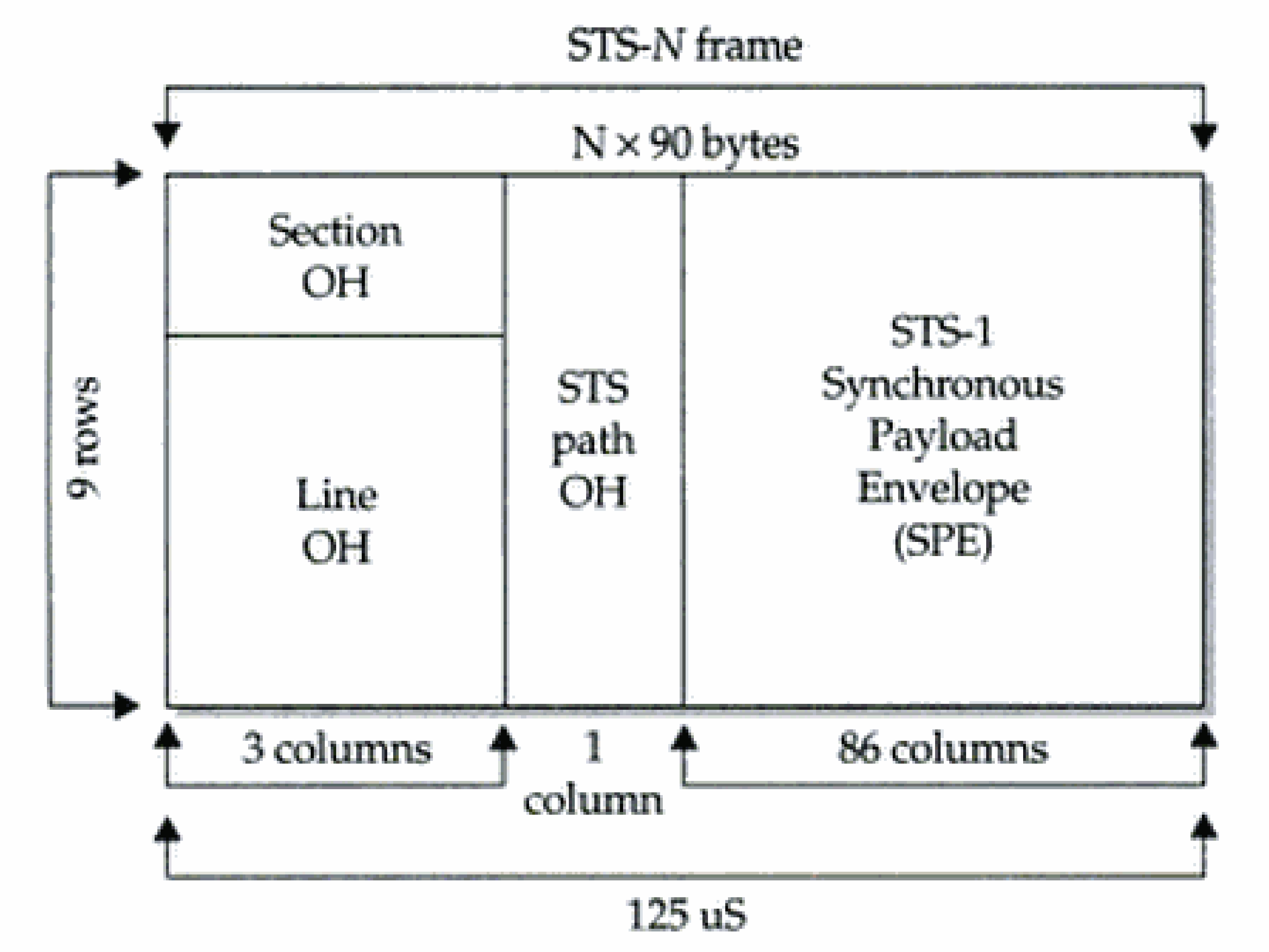


SONET Frames

Each synchronous transfer signal STS-n is composed of 8000 frames. Each frame is a two-dimensional matrix of bytes with 9 rows by 90 x n columns. For example, STS-l frame is 9 rows by 90 columns (810 bytes), and an STS-3 is 9 rows by 270 columns (2430 bytes).

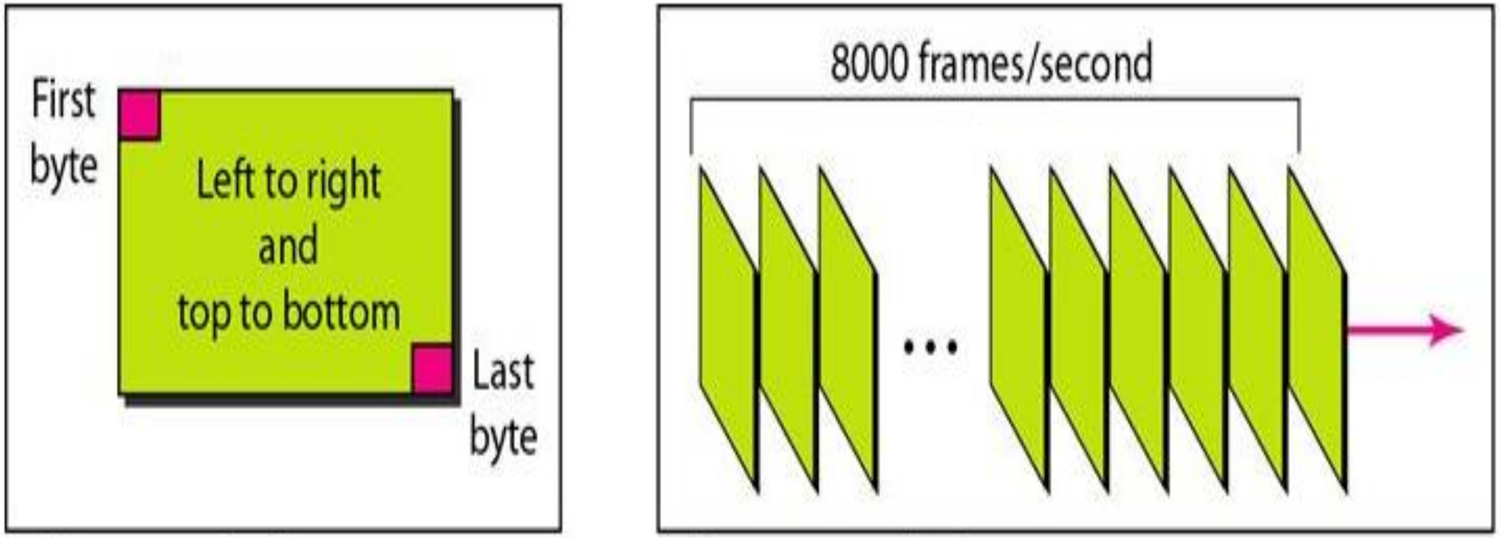
STS – 1 Frame Format




STS-N frame
N × 90 bytes
9 rows
Section OH
Line OH
STS path OH
STS-1 Synchronous Payload Envelope (SPE)
3 columns
1 column
86 columns
125 uS

One of the interesting points about SONET is that each STS-n signal is transmitted at a fixed rate of 8000 frames per second. This is the rate at which voice is digitized. For each frame the bytes are transmitted from the left to the right, top to the bottom. For each byte, the bits are transmitted from the most significant to the least significant (left to right). A SONET *STS-n* signal is transmitted at 8000 frames per second.

STS-1 frames in transition



a. Byte transmission b. Frame transmission

If we sample a voice signal and use 8 bits (l byte) for each sample, we can say that each byte in a SONET frame can carry information from a digitized voice channe1. In other words, an STS-l signal can carry 774 voice channels simultaneously (810 minus required bytes for overhead). Each byte in a SONET frame can carry a digitized voice channel.

Example 1

Find the **data rate of an STS-l signal**.

Solution

STS-l, like other STS signals, sends 8000 frames per second. Each STS-l frame is made of 9 by (l x 90) bytes. Each byte is made of 8 bits.

The data rate of STS-1 =

8000 x 9 x (1 x 90) x 8= 51.840 Mbps

Example 2

Find the **data rate of an STS-3 signal**.

Solution

STS-3, like other STS signals, sends 8000 frames per second.

Each STS-3 frame is made of 9 by (3 x 90) bytes. Each byte is made of 8 bits.

STS-3 data rate =

$$8000 \times 9 \times (3 \times 90) \times 8 = 155.52 \text{ Mbps}$$

Note that in SONET, there is an exact relationship between the data rates of different STS signals. We could have found the data rate of STS-3 by using the data rate of STS-1 (multiply the latter by 3). In SONET, the data rate of an STS-n signal is n times the data rate of an STS-1 signals.

Example 3

What is **the duration of an STS-l frame**?

STS-3 frame?

STS-n frame?

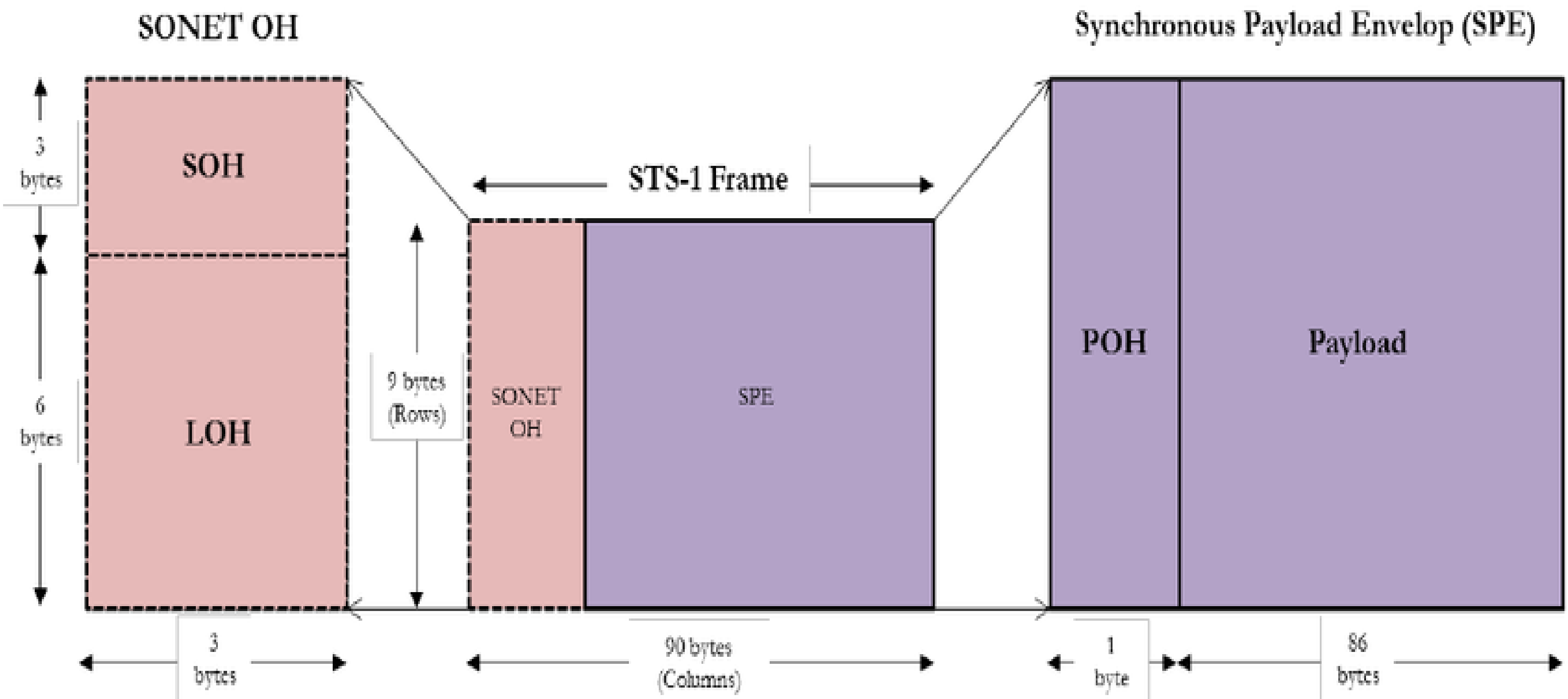
Solution

In SONET, 8000 frames are sent per second.

This means that the duration of an STS-l, STS-3, or STS-n frame is the same and equal to 1/8000 S, or 125 μs. In SONET, the duration of any frame is 125 μs.

STS1 Frame Format

The basic format of an STS-l frame. As we said before, a SONET frame is a matrix of 9 rows of 90 bytes (octets) each, for a total of 810 bytes. The first three columns of the frame are used for section and line overhead. The upper three rows of the first three columns are used for section overhead (SOH). The lower six are line overhead (LOH).



POH – Path Overhead
SOH – Section Overhead
LOH – Line Overhead

The rest of the frame is called the **synchronous payload envelope (SPE).** It contains user data and path overhead (POH) needed at the user data level.

SST1- Frame = 810 bytes.

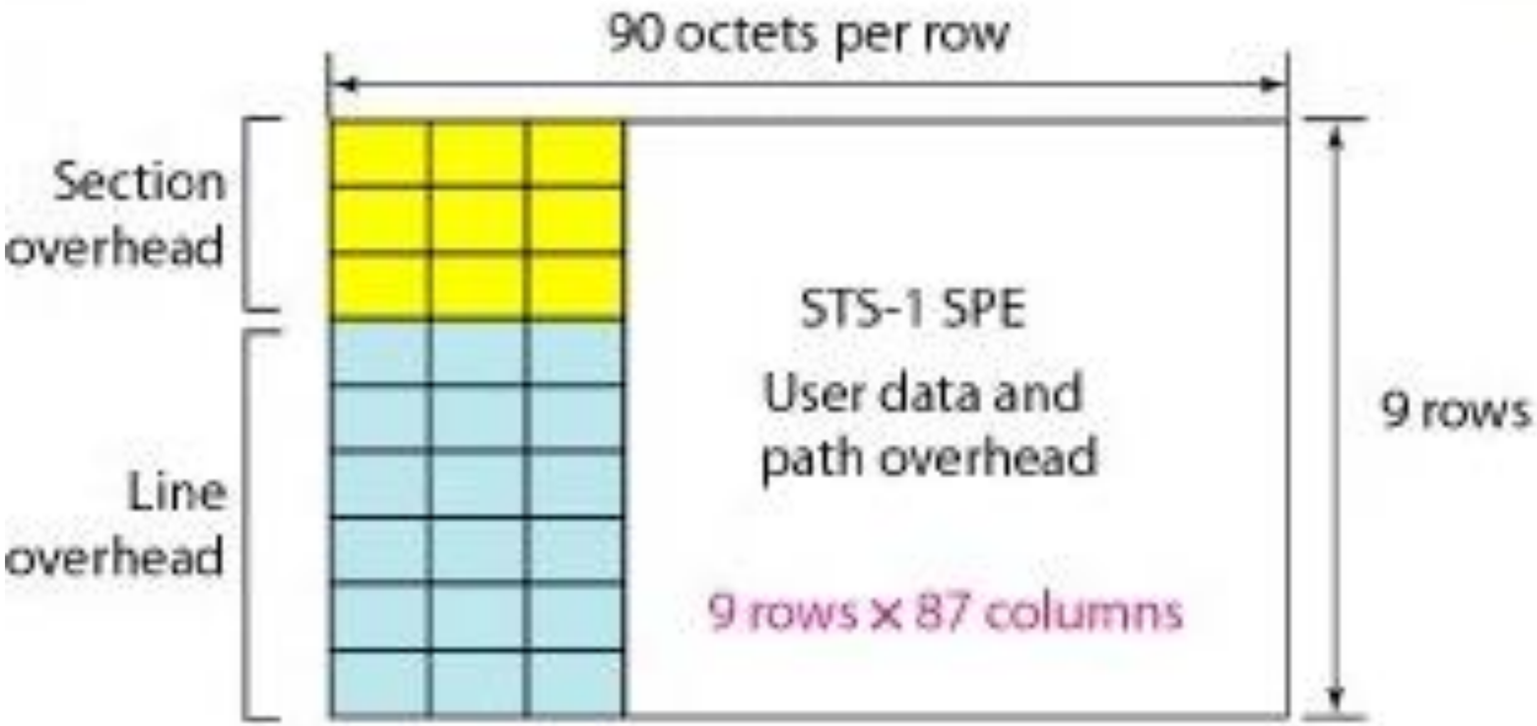
SOH= 3 x 3= 9 bytes.

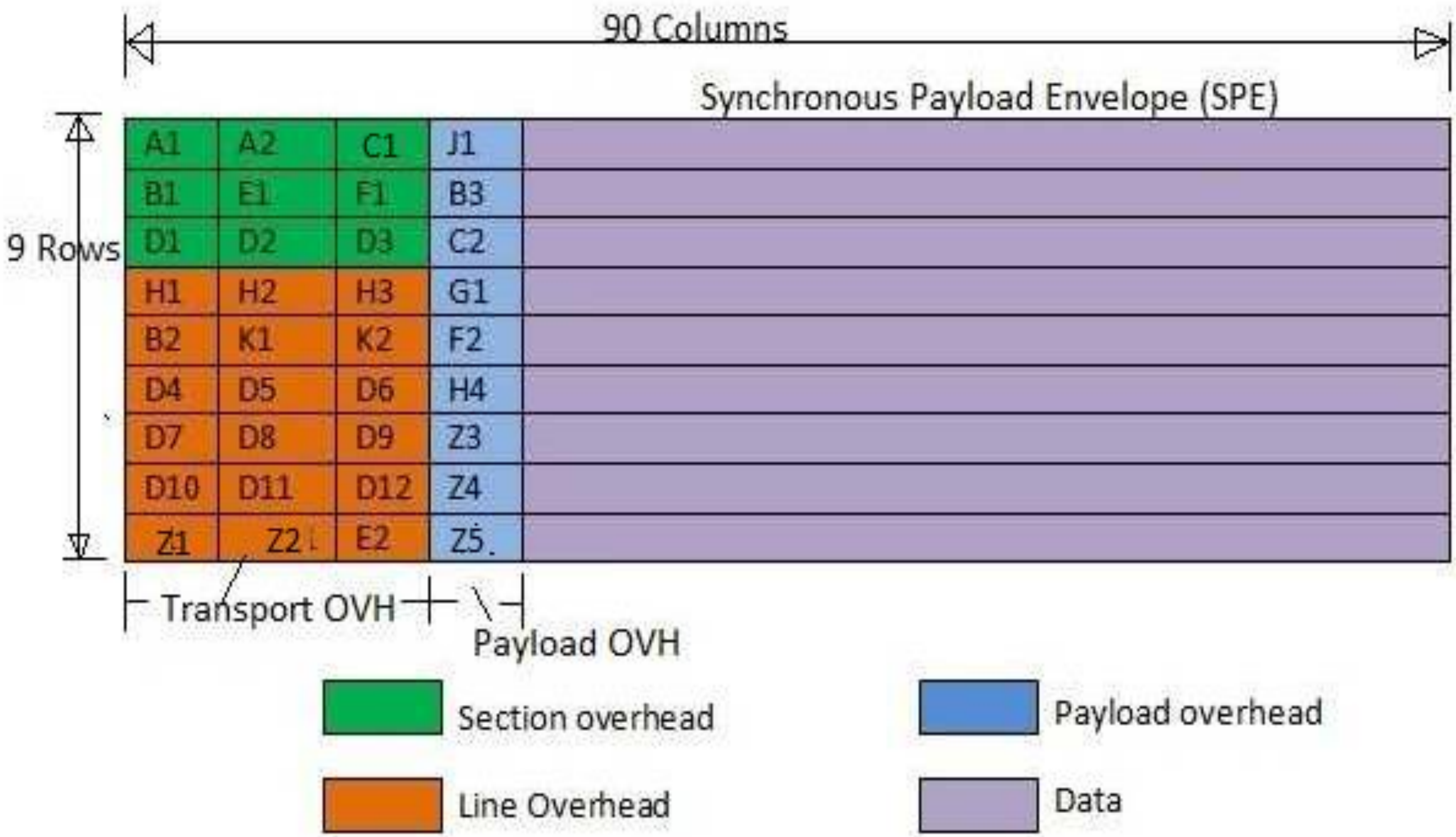
LOH = 6 x 3 = 18 bytes.

POH = 9 x 1= 9 bytes.

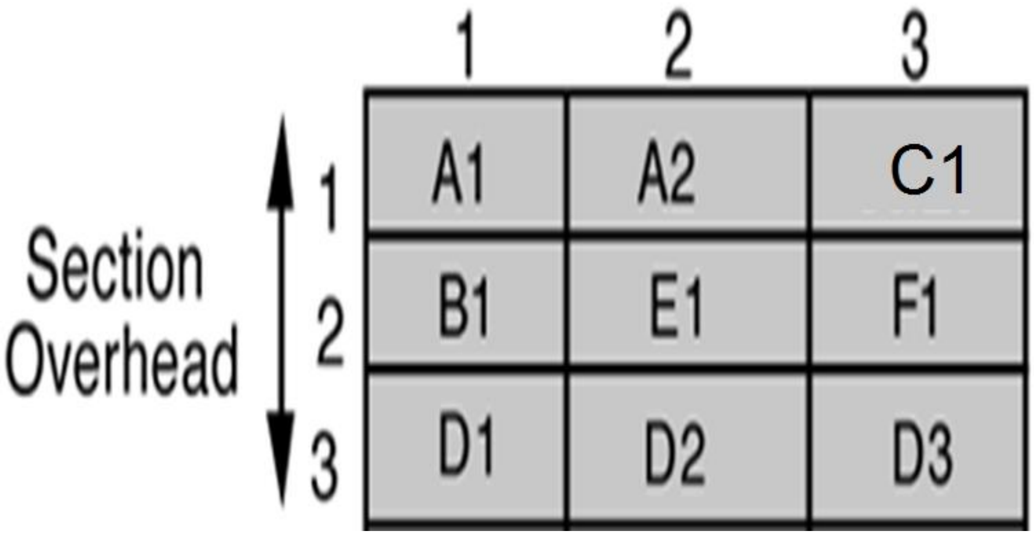
User data for SST1-Frame= 810-(9+18+9)= 774 bytes

= 86 x 9= 774 bytes


90 octets per row
Section overhead
Line overhead
STS-1 SPE
User data and path overhead
9 rows × 87 columns
9 rows


90 Columns
Synchronous Payload Envelope (SPE)
9 Rows
A1 A2 C1 J1
B1 E1 F1 B3
D1 D2 D3 C2
H1 H2 H3 G1
B2 K1 K2 F2
D4 D5 D6 H4
D7 D8 D9 Z3
D10 D11 D12 Z4
Z1 Z2 E2 Z5
Transport OVH
Payload OVH
Section overhead
Payload overhead
Line Overhead
Data

Section Overhead: The section overhead consists of nine octets. The labels, functions, and organization of these octets



- **Alignment bytes (A1 and A2)**. Bytes A1 and A2 are used for framing and synchronization and are called alignment bytes. These bytes alert a receiver that a frame is arriving and give the receiver a predetermined bit pattern on which to synchronize. The bit patterns for these two bytes in hexadecimal are (F628). The bytes serve as a flag.

- **Section parity byte (B1).** Byte B1 is for bit interleaved parity (BIP-8). Its value is calculated over all bytes of the previous frame. In other words, the ith bit of this byte is the parity bit calculated over all ith bits of the previous STS-n frame. The value of this byte is filled only for the first STS-l in an STS-n frame. In other words, although an STS-n frame has n B1 bytes,, only the first byte has this value; the rest are filled with 0s.

- **Identification byte (Cl).** Byte Cl carries the identity of the STS-l frame. This byte is necessary when multiple STS-ls are multiplexed to create a higher-rate STS (STS-3, STS-9, STS-12, etc.). Information in this byte allows the various signals to be recognized easily upon demultiplexing. For example, in an STS-3 signal, the value of the C1 byte is 1 for the first STS-l; it is 2 for the second; and it is 3 for the third.

- **Management bytes (D1, D2, and D3).** Bytes Dl, D2, and D3 together form a 192-kbps channel (3 x 8000 x 8) called the data communication channel. This channel is required for operation, administration, and maintenance (OA&M) signaling.
- **Order wire byte (E1).** Byte El is the order wire byte. Order wire bytes in consecutive frames form a channel of 64 kbps (8000 frames per second times 8 bits per frame). This channel is used for communication between regenerators, or between terminals and regenerators.

- **User's byte (F1)**. The F1 bytes in consecutive frames form a 64-kbps channel that is reserved for user needs at the section level.

Section overhead is recalculated for each SONET device (regenerators and multiplexers).

Line Overhead: Line overhead consists of 18 bytes. The labels, functions, and arrangement of these bytes.

Line Overhead

	1	2	3
4	H1	H2	H3
5	B2	K1	K2
6	D4	D5	D6
7	D7	D8	D9
8	D10	D11	D12
9	Z1	Z2	E2

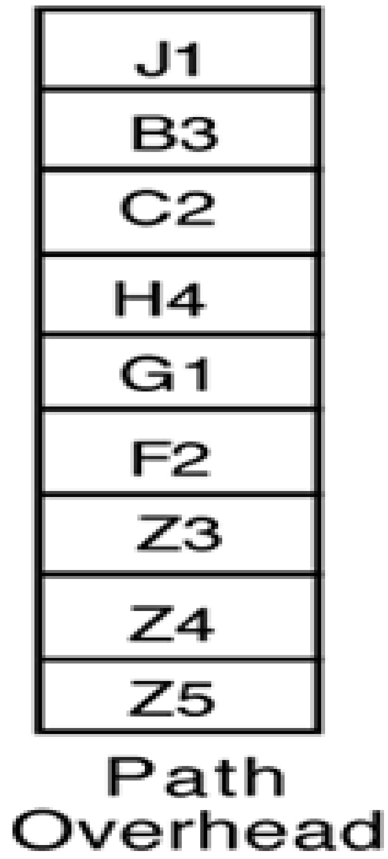
- **Line parity byte (B2).** Byte B2 is for bit interleaved parity. It is for error checking of the frame over a line (between two multiplexers). In an STS-n frame, B2 is calculated for all bytes in the previous STS-I frame and inserted at the B2 byte for that frame. In other words, in a STS-3 frame, there are three B2 bytes, each calculated for one STS-I frame. Contrast this byte with B1 in the section overhead.

- **Data communication channel** bytes (D4 to D12). The line overhead D bytes (D4 to D12) in consecutive frames form a 576-kbps channel that provides the same service as the D1-D3 bytes (OA&M), but at the line rather than the section level (between multiplexers).
- **Order wire byte (E2)**. The E2 bytes in consecutive frames form a 64-kbps channel that provides the same functions as the E1 order wire byte, but at the line level.

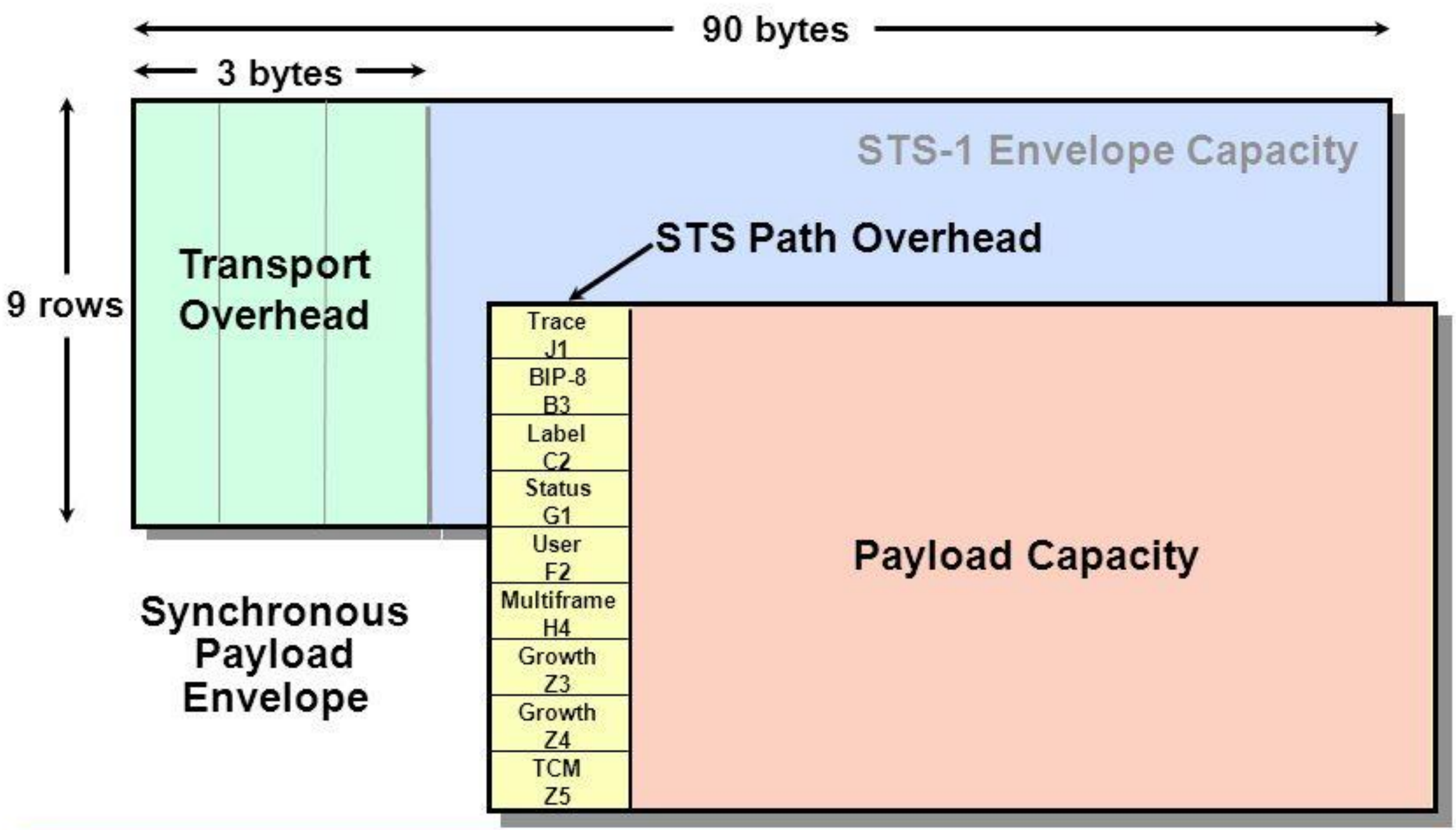
- **Pointer bytes (H1, H2, and H3)**. Bytes H1, H2, and H3 are pointers. The first two bytes are used to show the offset of the SPE in the frame; the third is used for justification.
- **Automatic protection switching bytes (K1 and K2)**. The K1 and K2 bytes in consecutive frames form a I28-kbps channel used for automatic detection of problems in line-terminating equipment.
- **Growth bytes** (Z1 and Z2). The Z1 and Z2 bytes are reserved for future use.

The synchronous payload envelope (SPE) contains the user data and the overhead related to the user data (path overhead). One SPE does not necessarily fit it into one STS-l frame; it may be split between two frames. This means that the path overhead, the leftmost column of an SPE, does not necessarily align with the section or line overhead. The path overhead must be added first to the user data to create an SPE, and then an SPE can be inserted into one or two frames.

Path overhead: It consists of 9 bytes. The labels, functions, and arrangement of these bytes.



STS-1 SPE path overhead



- **Path parity byte (B3).** Byte B3 is for bit interleaved parity, like bytes Bland B2, but calculated over SPE bits. It is actually calculated over the previous SPE in the stream.
- **Path signal label byte (C2)**. Byte C2 is the path identification byte. It is used to identify different protocols used at higher levels (such as IP or ATM) whose data are being carried in the SPE.

- **Path user channel byte (F2).** The F2 bytes in consecutive frames, like the F1 bytes, form a 64-kbps channel that is reserved for user needs, but at the path level.
- **Path status byte (G1)**. Byte GI is sent by the receiver to communicate its status to the sender. It is sent on the reverse channel when the communication is duplex.

- **Multiframe indicator (H4).** Byte H4 is the multiframe indicator. It indicates payloads that cannot fit into a single frame. For example, virtual tributaries can be combined to form a frame that is larger than an SPE frame and need to be divided into different frames.
- **Path trace byte (J1).** The J1 bytes in consecutive frames form a 64-kbps channel used for tracking the path. The J1 byte sends a continuous 64-byte string to verify the connection. The choice of the string is left to the application program. The receiver compares each pattern with the previous one to ensure nothing is wrong with the communication at the path layer.

- **Growth bytes (Z3, Z4, and Z5)**. Bytes Z3, Z4, and Z5 are reserved for future use.

Path overhead is only calculated for end-to-end (at STS multiplexers). Overhead Summary compares and summarizes the overheads used in a section, line, and path

Table *SONETISDH rates*

Byte Function	*Section*	*Line*	*Path*
Alignment	A1,A2		
Parity	B1	B2	B3
Identifier	CI		C2
OA&M	DI-D3	D4-DI2	
Order wire	EI		
User	FI		F2
Status			Gl
Pointers		HI-H3	H4
Trace			11
Failure tolerance		KI,K2	
Growth (reserved for future)		ZI, Z2	Z3-Z5

Example 4

What is the user data rate of an STS-l frame (without considering the overheads)?

Solution

The user data part in an STS-I frame is made of 9 rows and 86 columns. So we have

STS-l user data rate

= 8000 x 9 x 1 x 86=49.536Mbps

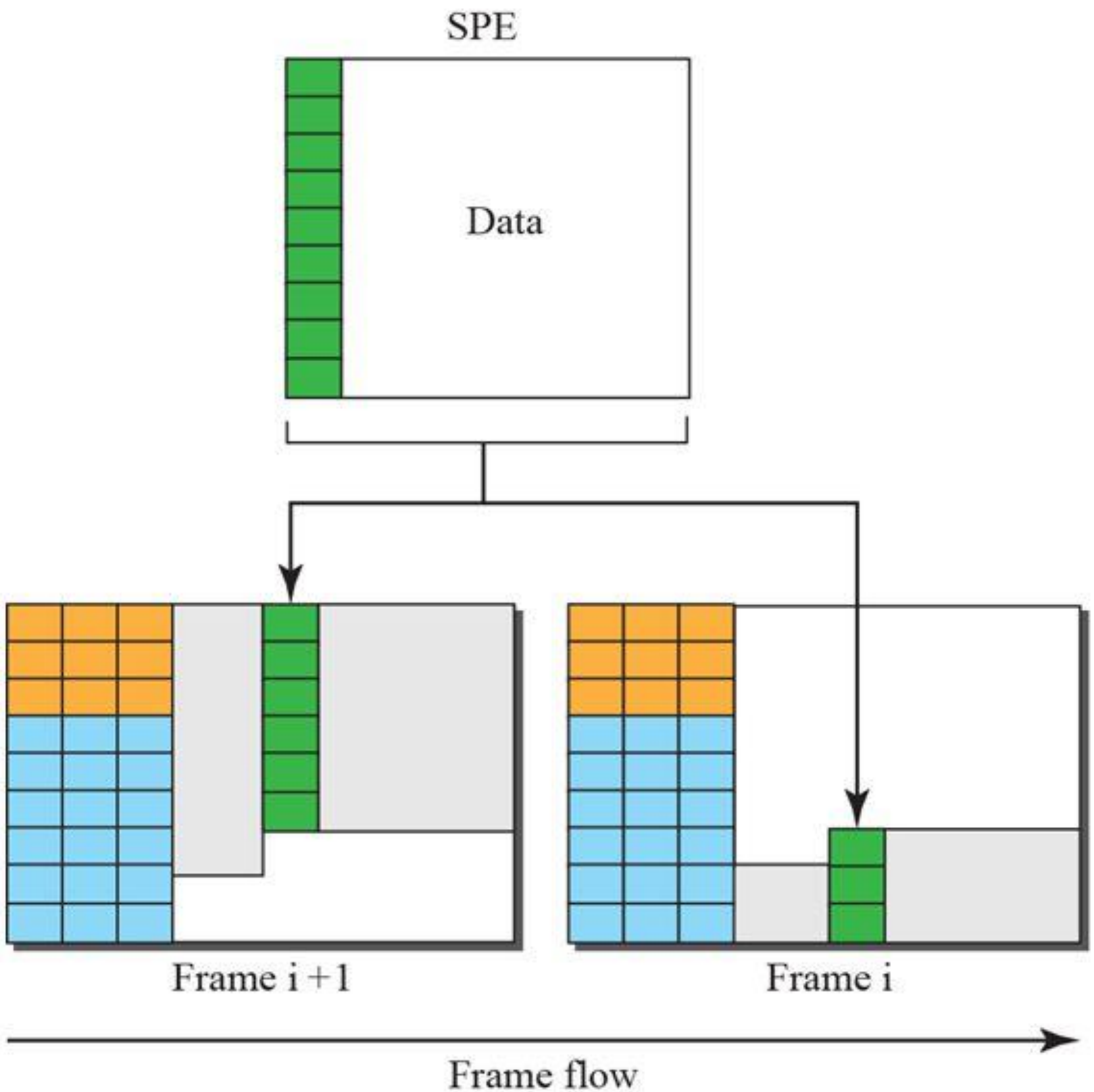
Encapsulation

SPE needs to be encapsulated in an STS-1 frame.

Encapsulation may create two problems that are handled elegantly by SONET using pointers (H1 to H3).

Offsetting: SONET allows one SPE to span two frames, part of the SPE is in the first frame and part is in the second. This may happen when one SPE that is to be encapsulated is not aligned time-wise with the passing synchronized frames. SPE bytes are divided between the two frames. The first set of bytes is encapsulated in the first frame; the second set is encapsulated in the second frame.

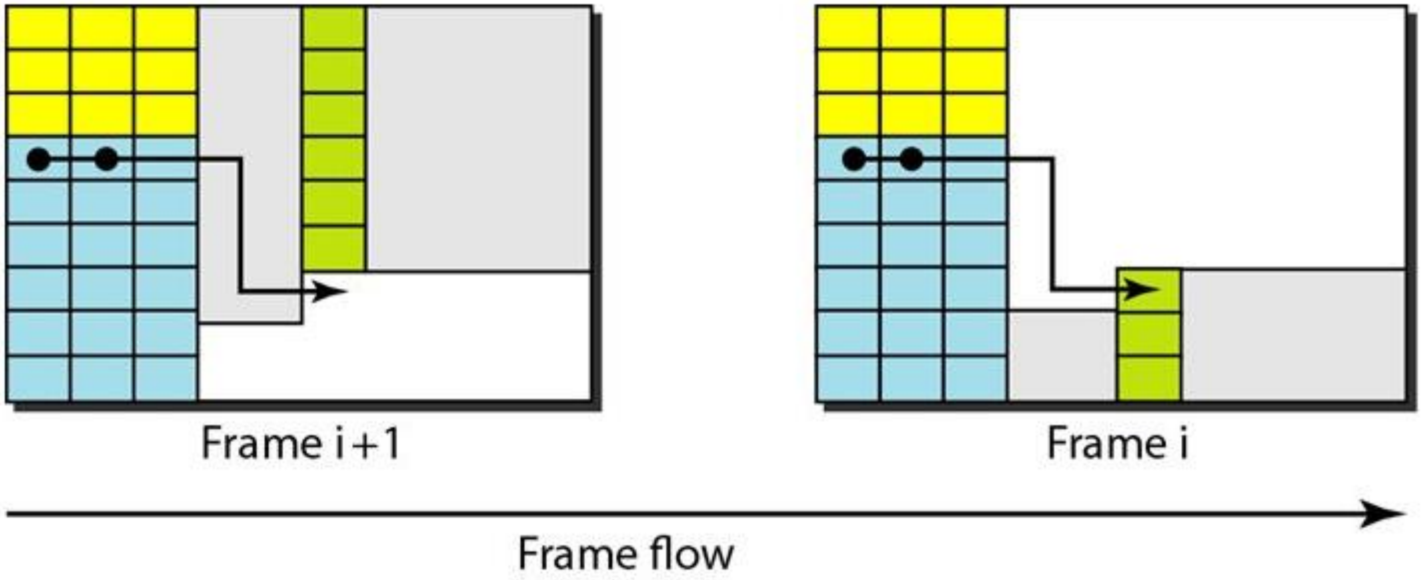
Offsetting of SPE related to frame boundary



The figure also shows the path overhead, which is aligned with the section/line overhead of any frame. The question is, How does the SONET multiplexer know where the SPE starts or ends in the frame? The solution is the use of pointers H1 and H2 to define the beginning of the SPE; the end can be found because each SPE has a fixed number of bytes. SONET allows the offsetting of an SPE with respect to an STS-l frame.

To find the beginning of each SPE in a frame, we need two pointers H1 and H2 in the line overhead. Note that these pointers are located in the line overhead because the encapsulation occurs at a multiplexer. These 2 bytes point to the beginning of the SPEs. Note that we need 2 bytes to define the position of a byte in a frame; a frame has 810 bytes, which cannot be defined using 1 byte.

The use of H1 and H2 pointers to show the start of an SPE in a frame



Example 5

What are the values of H1 and H2 if an SPE starts at byte number 650?

Solution

The number 650 can be expressed in four hexadecimal digits as 028A. This means the value of H1 is 02 and the value of H2 is 8A.

$(650)_{10} = (0000001010001010)_2 = (028A)_{16}$

Justification: Now suppose the transmission rate of the payload is just slightly different from the transmission rate of SONET. First, assume that the rate of the payload is higher. This means that occasionally there is 1 extra byte that cannot fit in the frame. In this case, SONET allows this extra byte to be inserted in the H3 byte. Now, assume that the rate of the payload is lower. This means that occasionally 1 byte needs to be left empty in the frame. SONET allows this byte to be the byte after the H3 byte.