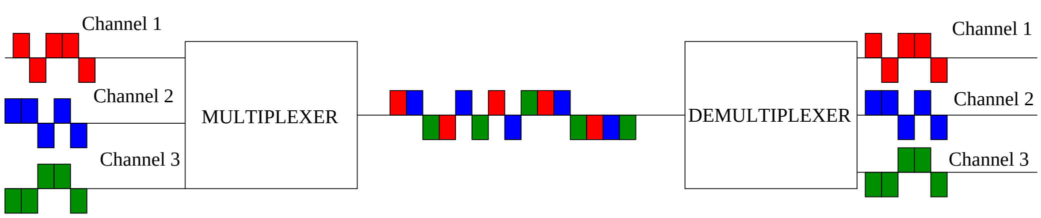
SONET/SDH

SONET is an acronym for **Synchronous Optical Network**. SONET is widely used in telephone network and is one of the first large scale optical transmission systems Digital information is sent through optical fibers using a LED or a laser source. However, most of data processing, switching etc. are done electronically. SONET is primarily used in the North America while Europe and Japan use a modified version, called the **Synchronous Digital Hierarchy (SDH).** SONET arose out of a need to find a solution of the problem of inter-operability among various vendors and technologies that existed in sixties and seventies.

Multiplexing :
In telecommunication, the phrase **multiplexing** is used to denote the process of combining two or more channels into a single channel. For instance, in encoding a video stream, we need to multiplex audio and video on single channel. One of the ways of doing it is known as **time division multiplexing**. The basic idea of the process is as follows.
Suppose we have three individual users in Mumbai who wish to send low stream data to three users in Delhi. Assigning physical lines for each will be expensive and such expense would grow exponentially with increasing number of users. If instead, we used a higher bit rate channel, we could use different time slots for the different data set. The figure below illustrates how this is achieved.
In sixties, the International Telecommunication Union (ITU) defined what is now known as a T-1 carrier. The analog voice data was digitized by sampling at a rate which is twice that of the maximum frequency component in the signal. This is known as **Pulse Code Modulation (PCM).** The T-1 standard was an universal agreement on a sampling rate of 8 kHz and a channel rate of 64 kilo-bit per second. The single voice channel is known as DS-0 signal (DS= Digital Signal). Thus, if we return back to the example of three users, with each transmitting at a rate of 64 kbps, we could transmit them as a sequential stream of data over a single channel capable of transmitting at 192 kbit/sec.



The way to achieve this is to divide the high rate channel into a series of time slots and the time slots could be assigned to the invividual data stream.

Example :

The T-1 line (T= Transmitted) is a channel capable of transmitting at a speed of 1.544 Mbit/sec. The voice is sampled at 8 kbits/sec, so that the time occupied by a bit is 125μs. The interval is subdivided into 24 time slots with each time slot coding 8 bits of data for a channel. Thus in each 125 μs there are 192 bits. Adding one bit to mark the beginning, there are 192 bits transmitted in 125 μs which gives the speed to be 1.544 Mbits/sec. The signal formed by interleaving 24 DS-0 signal is known as DS-1 signal and the corresponding transmitted signal is T-1. Proceeding further, four DS-1 signals are interleaved to give a 6.3 Mbit/sec DS-2 signal (transmitted as T-2) and seven DS-2 give rise to a 45 Mbit/sec DS-3 transmitted over a T-3 line.

Asynchronous, Plesiochronous and Synchronous Systems : Electrical signals which are used in transmission use system clocks which are very accurate. Generally, they use clocks which are based on natural frequency of vibration of some crystals, such as quartz crystals. Though such clocks are accurate, there can be differences between different clocks used by different systems and such clocks are not synchronised. Such systems are called **asynchronous**.

A plesiochronous system also uses different clocks but they are accurate to within a specified tolerance. Thus the clocks have phase differences. **Plesiochronous Digital Hierarchy (PDH)** was the most commonly used digital transmission system before the advantage of SDH. To accommodate delays between different clocks, extra bit(s), known as **justification bits** may be added to the multiplexed stream. This is known as **bit stuffing**. These bits will have to discarded while demultiplexing.

The disadvantage of PDH is that at higher speeds, it does not allow adding or dropping channels without having to first demultiplexing the channels. For instance, consider a service provider who has to provide a 2 Mbps line to a customer from his bandwidth of 155 Mbps.He has to locate and identify frames in the 2 Mb line. For this, the service provider will have to first demultiplex the line into its 64 kbps constituents, add the customer and remultiplex the system. The Digital telephone hierarchy for the North America and Europe is shown in the following table. Japan uses a scheme which is close to that of Europe but is not identical with it. The data rates are in Mbit/sec.

North America	Europe
0.064 (DS0)	0.064
1.544 (DS1)	2.048 (E1)
6.312 (DS2)	8.448 (E2)
44.736 (DS3)	34.368 (E3)
139.264 (DS4)	139.264 (E4)

Principle of SONET/SDH

- In a synchronous device the clock transitions occur precisely at the same rate. All signal transitions are fixed with reference to a very accurate atomic clock (such as Cs clock), called **Primary Reference Clock (PRC).** The accuracy of such a clock is one part in 10^{11} or better. The advantage of a synchronous system is that multiple signals can be stacked without any need for bit stuffing.
- In SDH, data from different sources are multiplexed in a way that the channels have fixed locations with respect to the framing byte.
- As the location is fixed, it is not necessary to demultiplex while dropping a single channel from the stream.

The basic signal of SONET is synchronous transport signal, called **STS-1** which operates at 51.84 Mbit/sec. After conversion to optical signals, STS- 1 is known as optical carrier, or **OC-1**. The higher level signals are multiples of STS-1 signal and operate at multiples of base frequency. Thus STS-3 (or its optical equivalent OC-3) operates at a bit rate of 155.52 Mbps interleaving frames from three STS-1 signals. This STS-3/OC-3 is the base signal for SDH and is known as the synchronous transport module or **STM-1**. The hierarchy for SONET/SDH hiherarchy is shown in the following table.

Signal Name			Data Rate
SONET	**SDH**	**Optical**	(Mbps)
STS-1	–	OC-1	51.84
STS-3	STM-1	OC-3	155.52
STS-12	STM-4	OC-12	622.08
STS-48	STM-16	OC-48	2488.32
STS-192	STM-64	OC-192	9953.28
STS-768	STM-256	OC-768	$\sim$40 Gbps

Each rate is an exact multiple of the lower rate ensuring that the hierarchy is synchronous. The network hierarchy is organized in a master-slave relationship with the lower level nodes receiving time signal from the higher level nodes. All clock level can be traced back to the primary reference clock (PRC), which is very stable.

FRAMES IN SONET

As the bit rate of information is moving at very fast rate, a convention has to be applied distinct digital channels that have been multiplexed together can be distinguished. SONET uses the concept of **framing** to achieve this.

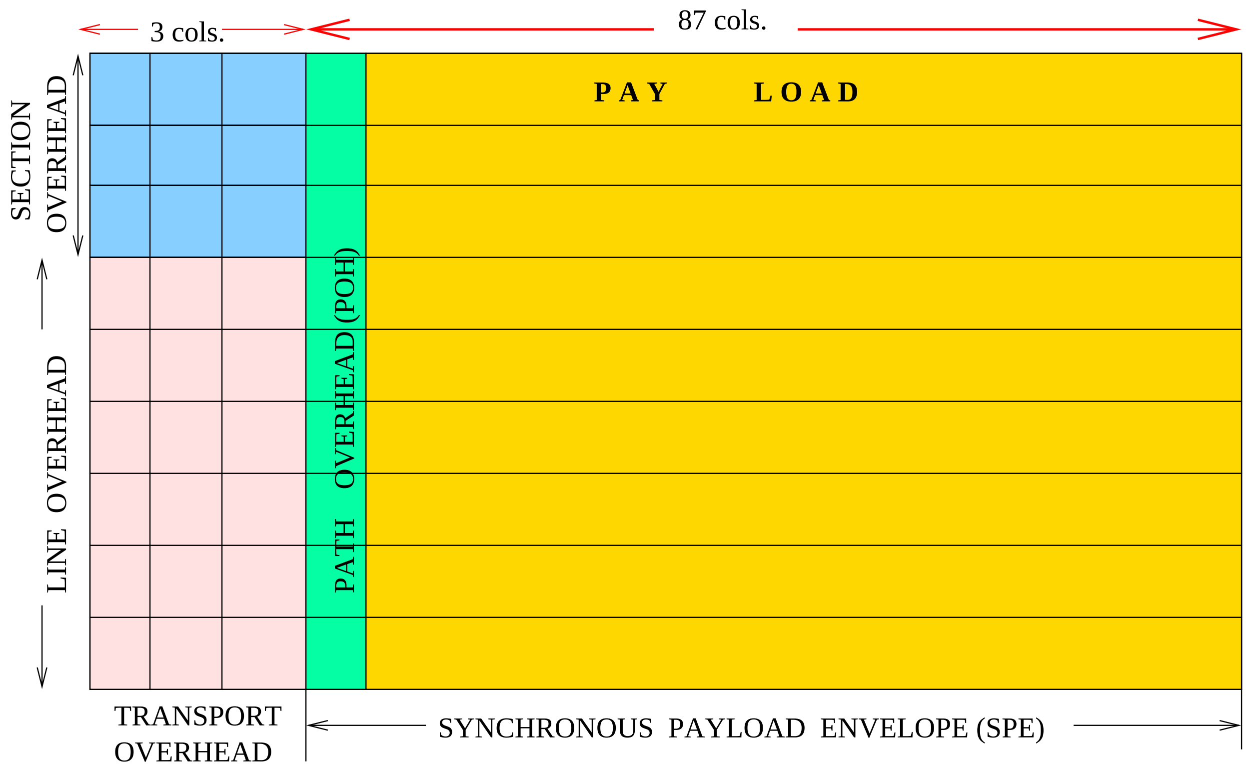
A framing bit can be thought of as a pointer or an address. As the line is moving fast, it would be easy to skew it a little to left or to right and the information would then get out of sequence. The extra bit of information creates a locator for the system.

SONET organizes data into 810-byte blocks called **frames**. The bytes are arranged as a two dimensional array of 9 rows and 90 columns. The data transmission is serial, i.e. starting with the extreme left byte (first row, first column) we proceed to right, byte by byte, and reach the 90th element on the first row. The next byte assessesd is the first column of the second row and so on. Frames are sampled at the rate of 8000 frames per second, i.e., one frame is transmitted every 125 micro second. This determines the speed to be as follows :

$$\begin{aligned} 8000 \times 810 &= 6,480,000 \text{ bytes/sec} \\ &= 6.48 \times 10^6 \times 8 \text{ bits/sec} \\ &= 51.84 \text{ Mb/sec} \end{aligned}$$

If one compares the above data rates with that given earlier for the telephone hierarchy, one observes that the SONET/SDH rates are about 10% higher. This is because of **overheads** required to administer and monitor signal transmission.

The frame has two main constituents. Each row has 3 bytes of transport overheads and and 87 bytes of payload. Thus there are $9 \times 3 = 27$ bytes of transport overheads and $9 \times 87 = 783$ payload bytes. Payload is the traffic that is transported through the SONET network.

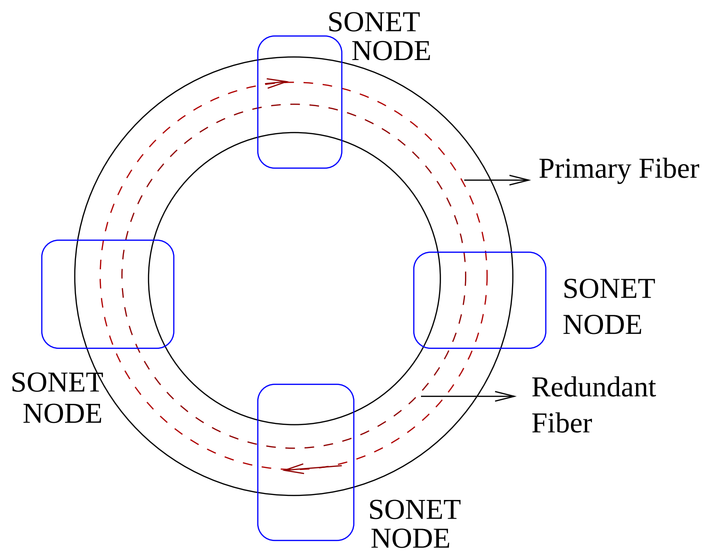


Path overhead :
Out of the 783 bytes of payload, which occupy 87 columns, only 756 bytes in 84 columns actually carry payload capacity of STS-1. The first column, consisting of 9 bytes, is known as **Path overhead (POH)**. POH is transported point to point with the payload till the latter is demultiplexed. It carries service provider information and monitors end-to-end transport of the payload. Columns 30 and 59 are not used for payload.
Transport overheads :
Out of the 27 transport overheads, 9 bytes are **section overhead** and the remaining 18 bytes are **line overhead**. Transport overhead provides transport information. The section overhead contains information required for communicating between successive network elements in the network, such as, repeaters. It also provides a voice communication channel for maintenance personnel.
The line overhead contains information to monitor line performance. This overhead provides for the following functions:

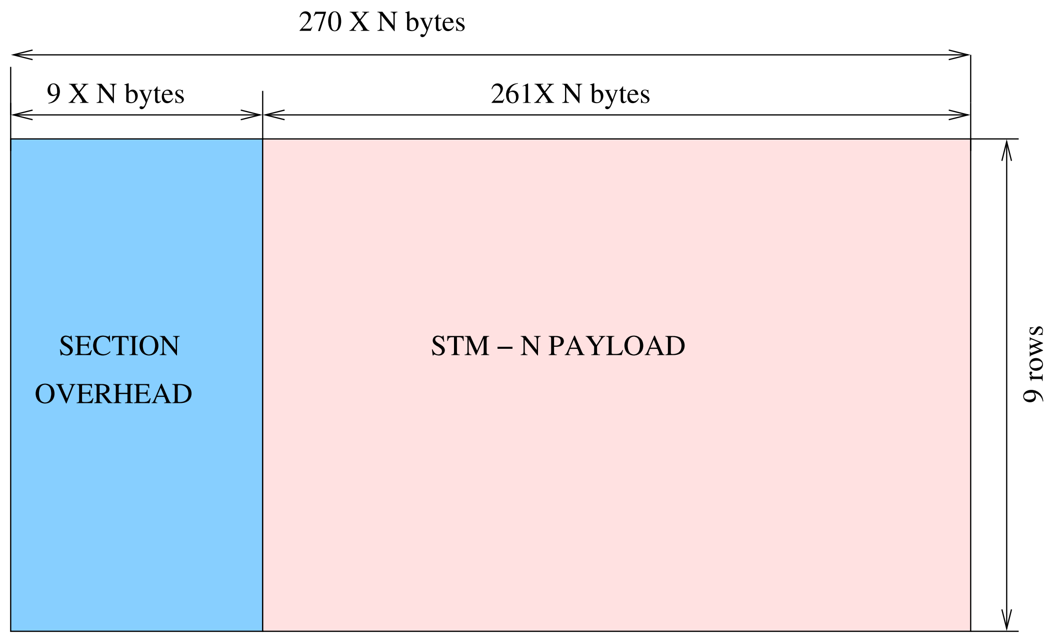
- line performance monitoring and line maintenance

- automatic protection switching
- multiplexing signals

SONET Topology :
SONET and SDH standards specify that the network topology be in the form of a ring. The ring contains fiber redundancies which allow traffic both unidirectionally and bidirectionally. In case of an accidental snapping of a fiber, the multiplexers can reroute the traffic along an alternate path using redundant fibers.



The SDH frame format is based on the synchronous transport module STM-1. The frame is organized in 9 rows and 270 columns consisting of 2430 bytes.



Out of the above $9 \times 9 = 81$ bytes are section overheads while the remaining 2349 bytes form the payload. The higher rate frames are multiples of STM-1 and are labelled STM-N.