WHAT IS SDH ?

SDH (Synchronous Digital Hierarchy) is an international standard for high speed
telecommunication over optical/electical networks which can transport digital signals
in variable capacities. It is a synchronous system which intend to provide a more flexible , yet simple
network infrastructure.

SDH (and its American variant- SONET) emerged from standard bodies somewhere around ١٩٩٠.
these two standards create a revolution in the communication networks based on optical fibers ,
in their **cost** and **performance**.

---

before SDH

The development of digital transmission systems started In the early ٧٠s , and was based on
the Pulse Code Modulation (PCM) method.

In the early ٨٠'s digital systems became more and more complex , yet there was huge
demand for some features that were not supported by the existing systems.
The demand was mainly to high order multiplexing through a hierarchy of increasing bit
rates up to ١٤٠ Mbps or ٥٦٥ Mbps in Europe.
The problem was the high cost of **bandwidth** and digital devices. The solution that was
created then , was a multiplexing technique , allowed for the combining of slightly
non synchronous rates, referred to as **plesiochronous***, which lead to the term plesiochronous digital
hierarchy (PDH).

*plesiochronous **-** "almost synchronous , because bits are stuffed into the frames as padding and the
                  calls location varies slightly - jitters - from frame to frame".

multiplexing with PDH
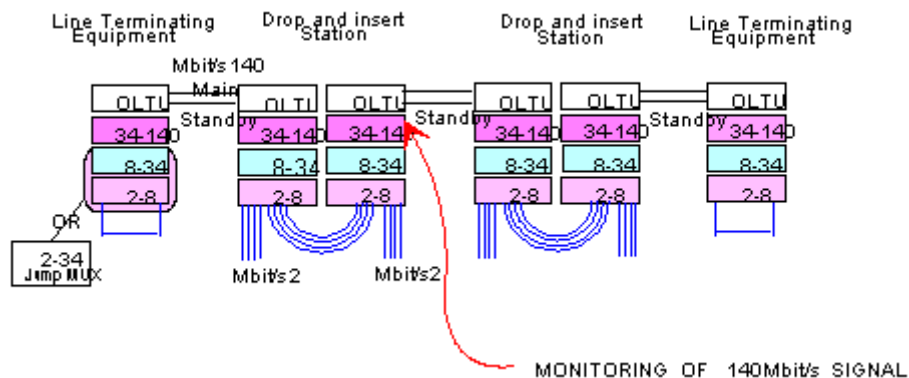
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why using SDH ?

Although PDH was A breakthrough in the digital transmission systems , it has a lot of weaknesses :

- No world standard on digital format (three incompatible regional standards - European, North american and Japanese).
- No world standard for optical interfaces. Networking is impossible at the optical level.
- Rigid asynchronous multiplexing structure.
- Limited management capability.

Because of PDH disadvantages, It was obvious That a new multiplexing method is needed. The new method was called SDH.

multiplexing with SDH

Mbit's Alternative routing via Ring Topology155

Management of Mbit's Traffic2
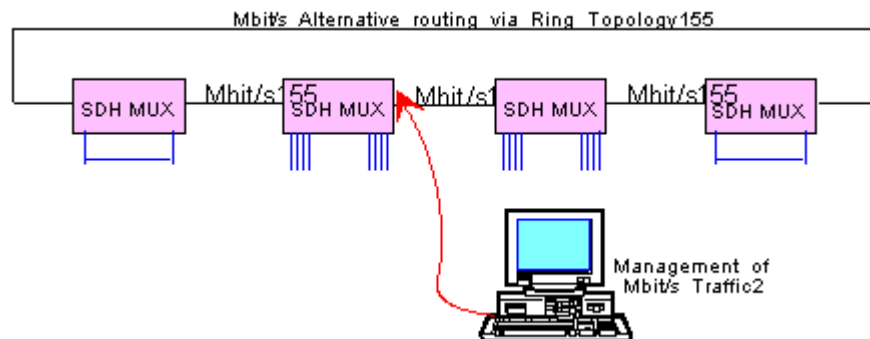
SDH has a lot of advantages:

- First world standard in digital format.
- First optical Interfaces.
- Transversal compatibility reduces networking cost. Multivendor environment drives price down
- Flexible synchronous multiplexing structure .
- Easy and cost-efficient traffic add-and-drop and cross connect capability.
- Reduced number of back-to-back interfaces improve network reliability and serviceability.
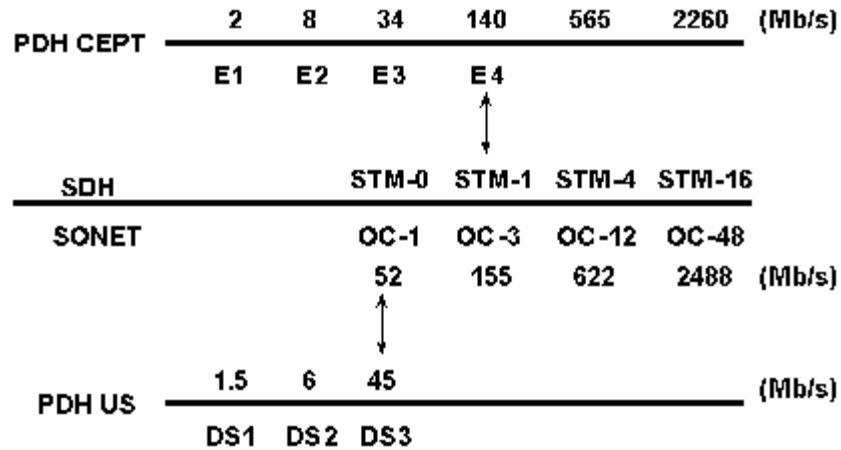- Powerful management capability.

- New network architecture. Highly flexible and survivable self healing rings available.
- Backward and forward compatibility: Backward compatibility to existing PDH
  Forward compatibility to future B-ISDN, etc.

The following Graph Shows the differences between PDH and SDH Prices:
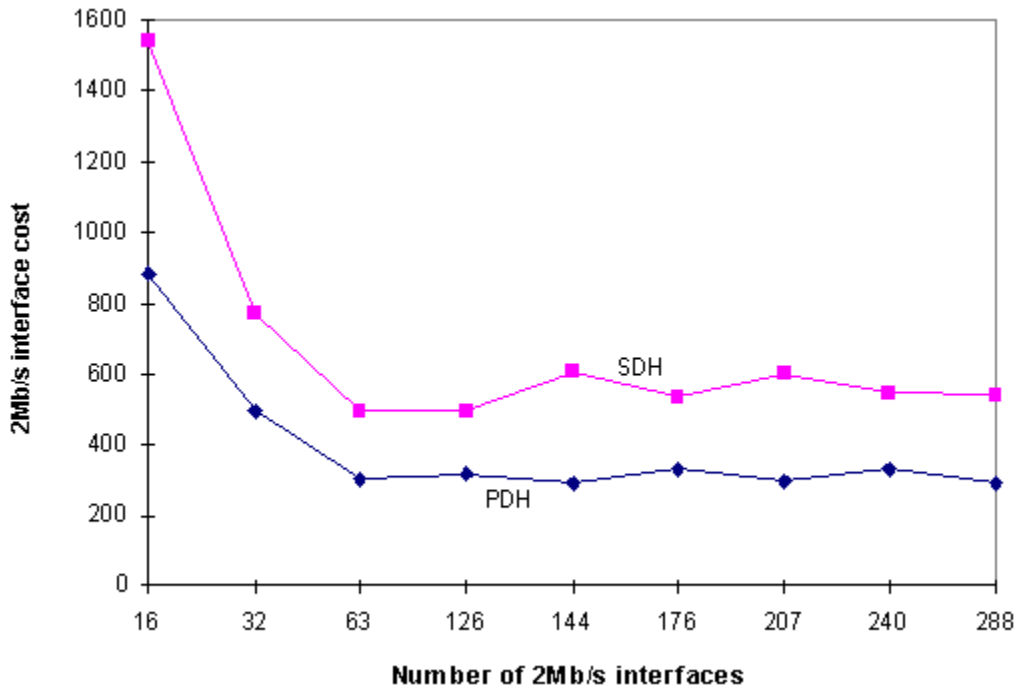
SDH is based on byte interleaving and not bit interleaving , as PDH was based on.
The bit rate increased from ٦٤ Kbps in PDH to ١.٥ - ٢ Mbps in SDH.

SDH/SONET Vs. PDH rates

PDH CEPT   2   8   34   140   565   2260   (Mb/s)

E1   E2   E3   E4

SDH   STM-0   STM-1   STM-4   STM-16

SONET   OC-1   OC-3   OC-12   OC-48

     52   155   622   2488   (Mb/s)

PDH US   1.5   6   45   (Mb/s)

DS1   DS2   DS3

when do we use SDH ?

- When networks need to increase capacity , SDH simply acts as a means of increasing transmission capacity.
- When networks need to improve flexibility , to provide services quickly or to respond to new change more rapidly.
- when networks need to improve survivability for important user services.
- when networks need to reduce operation costs , which are becoming a heavy burden .

layers model of SDH

the following scheme describes the different layers of SDH , according to the OSI model :

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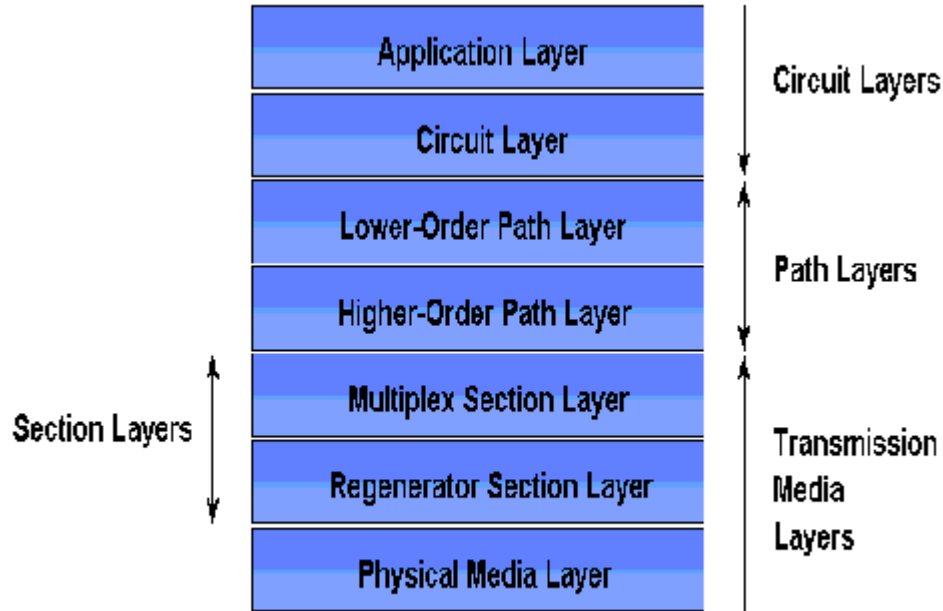
standards

- **SDH has been standardized by ITU-T in ١٩٨٨.**
- **In November ١٩٨٨ the first SDH standards were approved.**
- **In ١٩٨٩ , the CCITT (International Consultative Committee on Telephony & Telegraphy) had published in its "Blue book" recommendations G.٧٠٧ , G.٧٠٨ & G.٧٠٩ covering the SDH standards.**

G.٧٠٢ - Digital Hierarchy Bit Rates
G.٧٠٣ - Physical/Electrical Characteristics of Hierarchical Digital
       Interfaces
G.٧٠٧ - SDH Bit Rates
G.٧٠٨ - Network Node Interface for the SDH
G.٧٠٩ - Synchronous Multiplexing Structure
G.٧٧٣ - Protocol Suites for Q Interfaces for Management of
       Transmission Systems
G.٧٨١ - (Formerly G.smux-١) Structure of Recommendations on
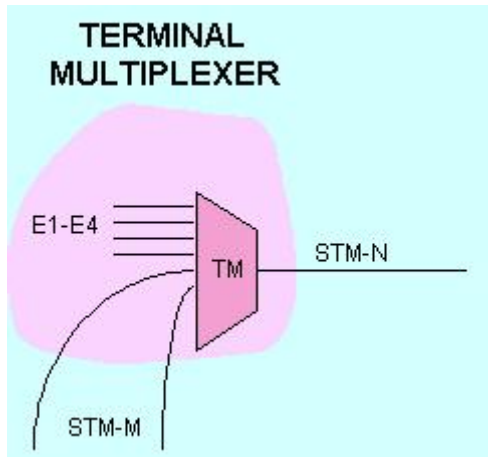
Multiplexing Equipment for the SDH
G.٧٨٢ - (Formerly G.smux-٢) Types and General Characteristics
   of SDH Multiplexing Equipment
G.٧٨٣ - (Formerly G.smux-٣) Characteristics of SDH Multiplexing
   Equipment Functional Blocks
**G.٧٨٤ - (Formerly Gsmux-٤) SDH Management**

SDH Elements

The most common SDH elements are :

The terminal multiplexer is used to multiplex local tributaries (low rate) to the stm-N (high rate) aggregate. The terminal is used in the chain topology as an end element.

The regenerator is used to regenerate the (high rate) stm-N in case that the distance between two sites is longer than the transmitter can carry.

The Add And Drop Multiplexer (ADM) passes the (high rate) stm-N through from his one side to the other and has the ability to drop or add any (low rate) tributary. The ADM used in all topologies.
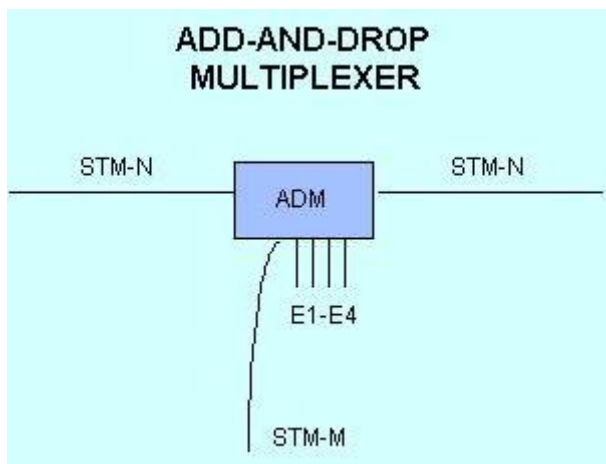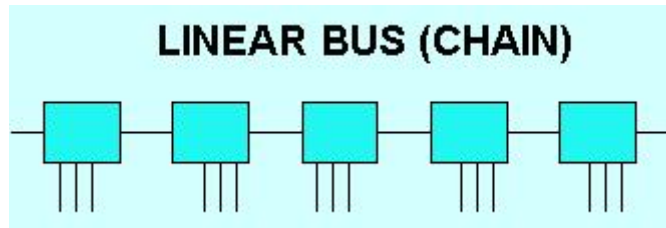

The synchronous digital cross connect receives several (high rate) stm-N and switches

any of their (low rate) tributaries between them. It is used to connect between several topologies.
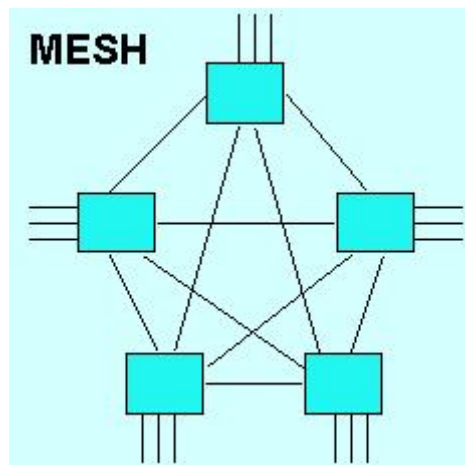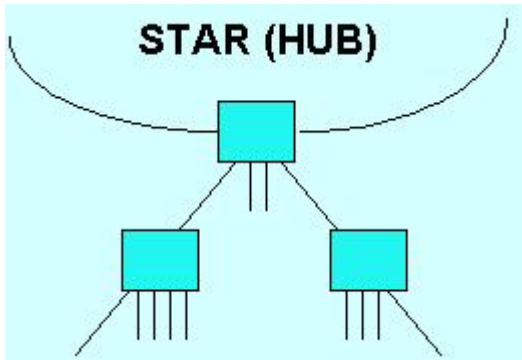
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SDH Topologies

The linear bus (chain) topology used when there is no need for protection and the demography of the sites is linear.

The ring topology is the most common and known of the sdh topologies it allows great network flexibility and protection.

The mesh topology allows even the most paranoid network manager to sleep well at nights because of the flexibility and redundancy that it gives.
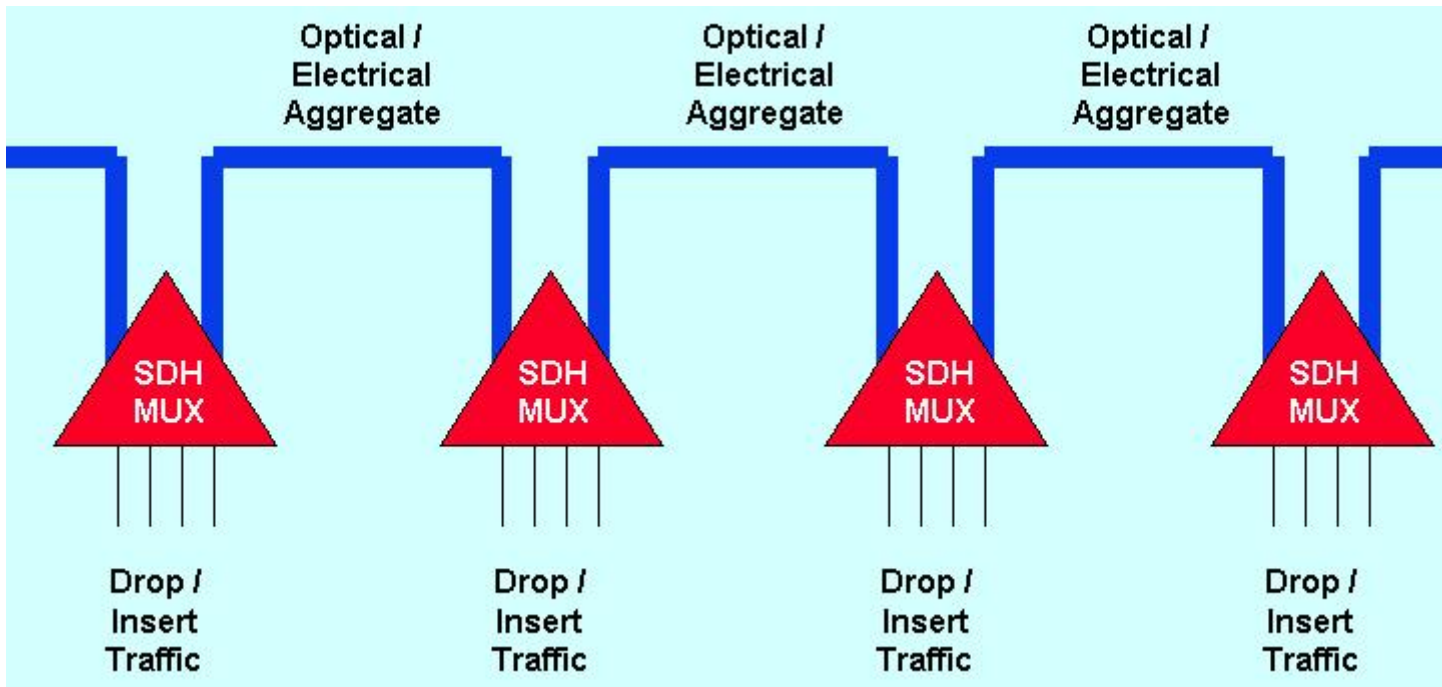
STAR (HUB)

The Star topology is used for connecting far and less important sites
to the network.

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The Terminal multiplexer can be used to connect two sites in a high rate
connection .

Optical / Electrical Aggregate — SDH MUX — Drop / Insert Traffic

The Add And Drop Multiplexer (ADM) is used to build the chain topologies in the above picture.
At the ends of the chain usually a Terminal Multiplexer is connected.

The Add And Drop Multiplexer (ADM) is used to build the ring topology.
At each site we have the ability to add & drop certain tributaries.

SDH Protection

The SDH gives the ability to create topologies with protection for the data transferred.
Following are some examples for protected ring topologies.
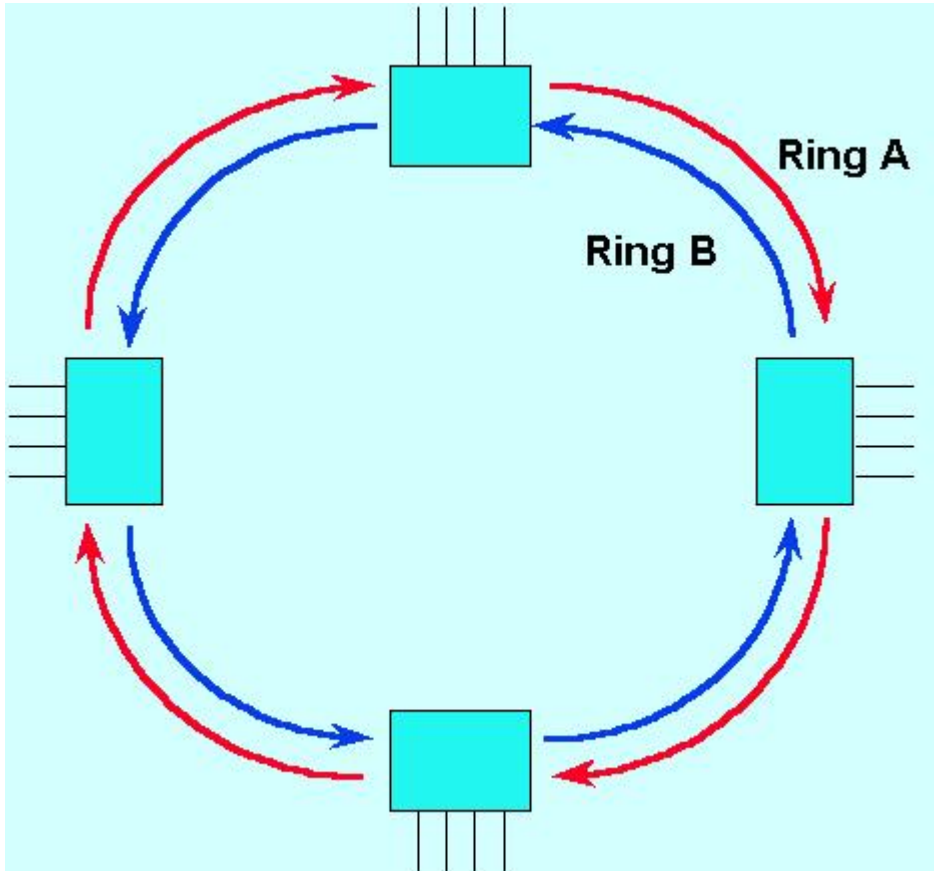
At this picture we can see Dual Unidirectional Ring . The normal data flow is
according to ring A (red). Ring B (blue) carries unprotected data which is lost in
case of breakdown or it carries no data at all.
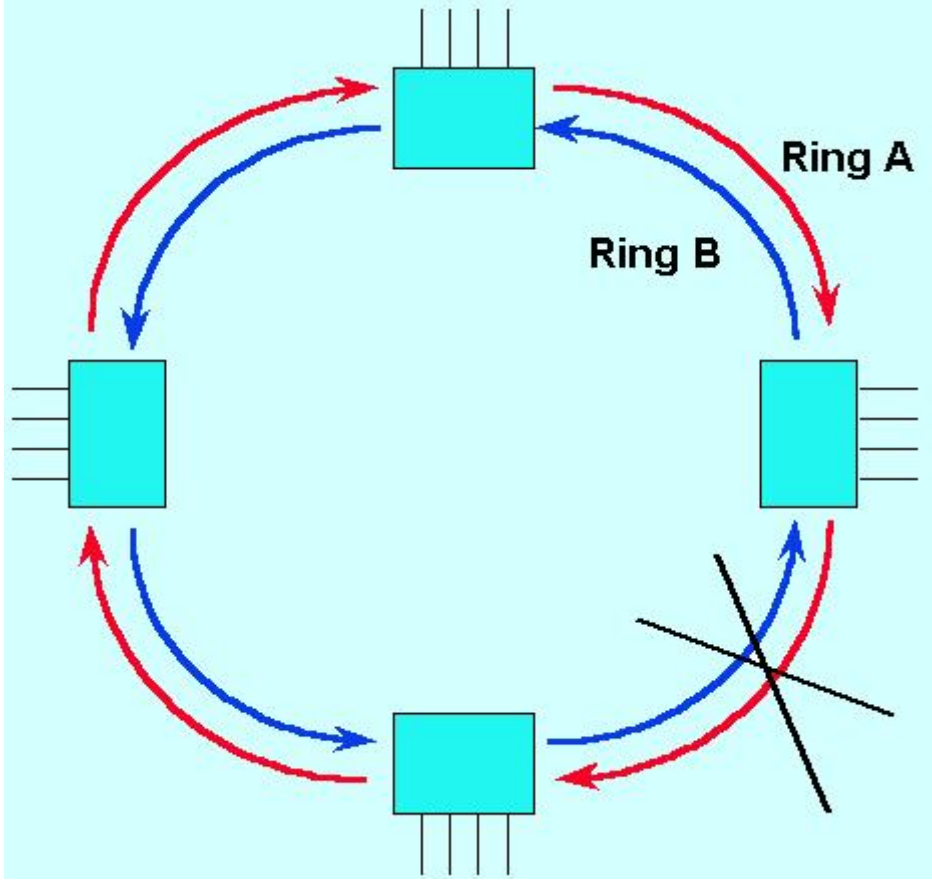
In case of breakdown rings A & B become one ring without the broken segment.

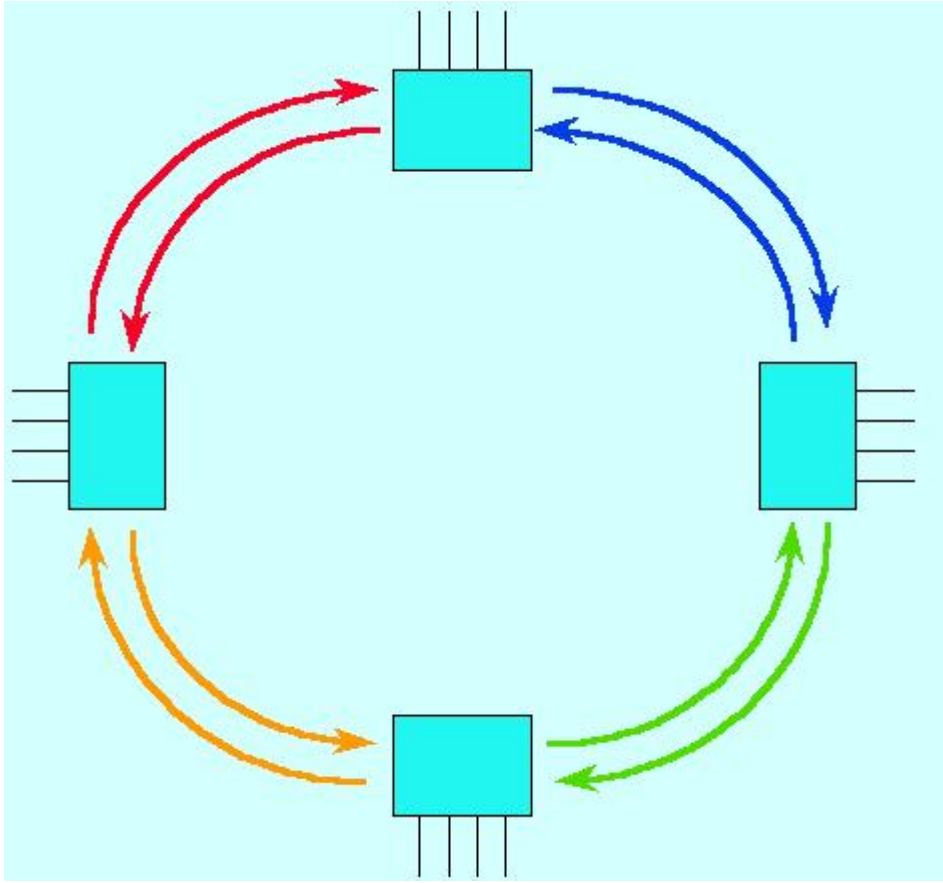The Bi-directional Ring allows data flow in both directions. For example if data from one of the sites has to reach a site which is next to the left of the origin site it will flow to the left instead of doing a whole cycle to the right.
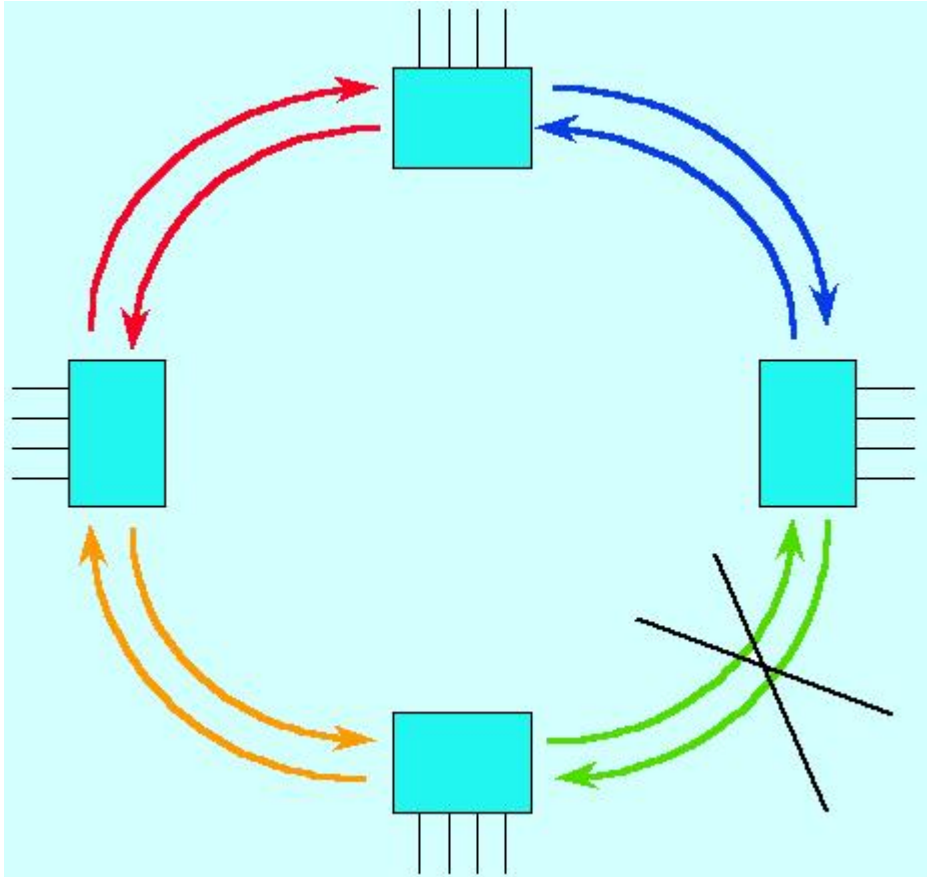
In case of breakdown some of the data is lost and the important data is switched. For example if data from a site should flow to its destination through the broken segment, it will be switched to the other side instead.

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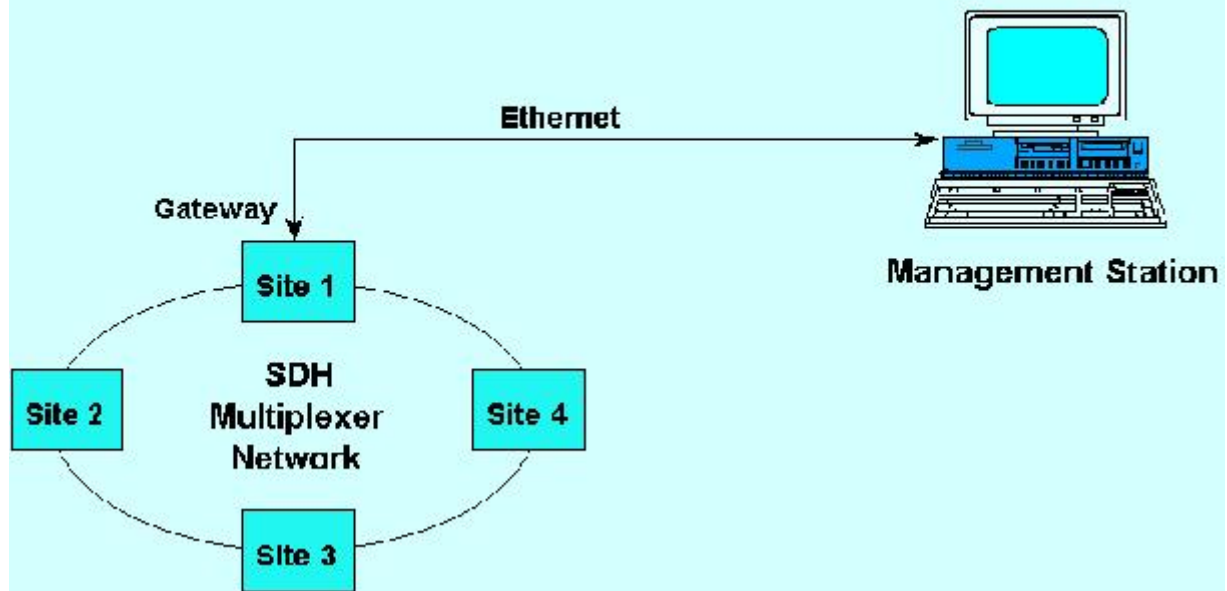

SDH Management

SDH has enhanced management capabilities :

- Alarm/Event Management
- Configuration Management
- Performance Management
- Access and Security Management

Depicted above is a Management Station connected to a SDH ring through site ١ which contains the gateway element. The Gateway elements receives the status of all the other elements in the net through the special fields that exists in the SDH protocol (in band).

SDH vs. PDH

Few years ago the common way to build a backbone network that supplies broadband communication to the suppliers (BT, Bezeq etc.) was a PDH network. The topology of a PDH network is the Mesh topology where every multiplexer in each site worked with its own clock. In order to synchronize between two multiplexers that works together, usually the transmission was made according to the local clock and the reception was made according to the recovered clock that was recovered from the received data. The PDH contains ٤ basic bit rates:

- E١ - ٢.٠٤٨ Mbit/Sec
- E٢ - ٨.٤٤٨ Mbit/Sec
- E٣ - ٣٤.٣٦٨ Mbit/Sec
- E٤ - ١٣٩.٢٦٤ Mbit/Sec

The En is the result of multiplextion of ٤ En-١.

The fact that each of the multiplexers transmits according to its own clock creates a problem when we need to multiplex several transmitted data streams, the problem is that we can't decide which clock to choose for the multiplexing. If we will choose a fast clock we will not have enough data to put in the frame from a slower incoming data stream (we will get empty spaces in the frame), from the other hand if we will choose a slow clock the data at the faster incoming stream will be lost.

This problem was solved with a **stuffing** algorithm, which is implemented by using a fast clock, that allows transmission of indication bits and stuff bits. In case that the data is slower then "expected", the

indication bits indicate that the following stuff bits are "garbage" and if the data is faster then "expected" the indication bits indicate that the following stuff bits are data. This is the reason why ٤ * En-١ < En.


There are two common ways to connect between two PDH sites. The first is by Radio Frequency (RF) and the other is by Electrical Signal over copper cable. since we cant afford to many cables or frequencies
usually E٣ or E٤ is used.
In order to transmit E١ (a very common data rate) we need ٢ or ٣ levels of multiplexing, this means that in a full E٤ constellation ١+٤+١٦=٢٥ multiplexers are needed.
Further more there is no inband management in the PDH protocol if we need to know the status of ١ of the multiplexers, or if we need to change the route of ١ of the trails we have to go to the site or build an
outside network that allows us to manage the PDH network.

In the latest years a new protocol was defined, this new protocol was aimed to provide all the PDH capabilities and solve some of the PDH weaknesses that are mentioned above. This new protocol is the SDH.
The SDH network works with a single central clock that synchronizes all the elements in the network.
The SDH contains the following bit rates:

- STM١ - ١٥٥ Mbit/Sec
- STM٤ - ٦٢٢ Mbit/Sec
- STM١٦ - ٢.٥ Gbit/Sec
- STM٦٤ - ١٠ Gbit/Sec
  - Etc.

In order to have the ability to connect a low rate PDH stream (E١, E٣ etc.), an improved **stuffing** algorithm is used.
The SDH protocol enables transmitting any of the PDH bit rates directly by mapping it to the STM-n frame, that gives the user the flexibility to transmit any configuration of tributary rates using only one multiplexing element, depicted bellow the difference between the SDH network element and the PDH network elements that need to transmit different tributary rates.
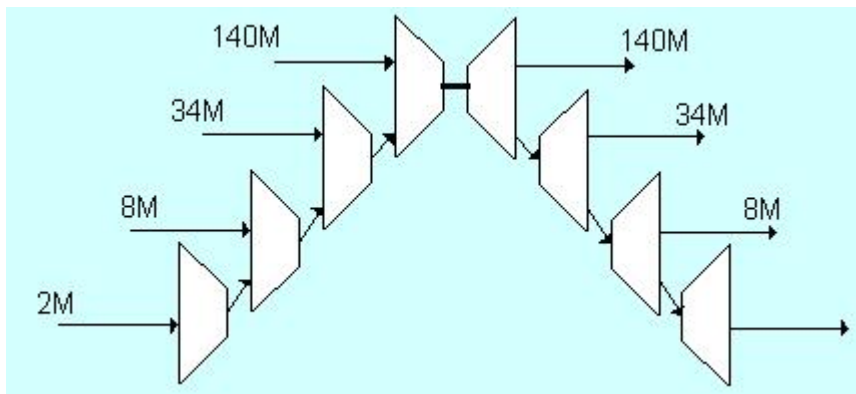
PDH network elements.

The inband management functionality enables the SDH network manager to receive information about the quality of service, the damaged elements (if there are any) and gives the manager the option to change the network configuration from a remote site. In order to be able to do the same things with the PDH network, one should build another separated network for the management and the remote control.

The ability to multiplex any of the standard bit rates into the STM-n frame is possible due to the complicated containers structure of the STM-n frame as depicted bellow.

In order to map an E١(٢.٠٤٨ Mbit/Sec) into the STM-n frame we have to create a TU-١٢ stream which is a low rate stream that is synchronized to the SDH network clock. The TU-١٢ is composed of the E١ data, indication bits, stuffing bits, management bits and a direct pointer to the E١ frame.
The TUG-٢ is a structure that can be composed of ٣ TU-١٢s (٣ E١s), or ٤ TU-١١s (٤ T١s), or ١ TU-٢ (١ T٢). This structure gives the STM

frame its flexibility to multiplex different rates directly into the STM-n frame (impossible in the PDH protocol). The next stage is mapping ٧ TUG-٢s into ١ VC-٣ or into ١ TUG-٣ and so on according to the flow chart.

This method of multiplexing allow us to directly map the T١, T٢, T٣ (American standards) and the E١, E٢, E٣, E٤ (European standards) into the STM-n frame.

Each time we map lower rate streams into a higher rate structure we add pointers to a fixed point in the lower rate streams, so we can directly extract the relevant information with out demultiplexing the all high rate stream.

When stuffing is needed the pointer to the fixed location is changed according to the direction of the stuffing, this is the improvement of stuffing algorithm used in the PDH .
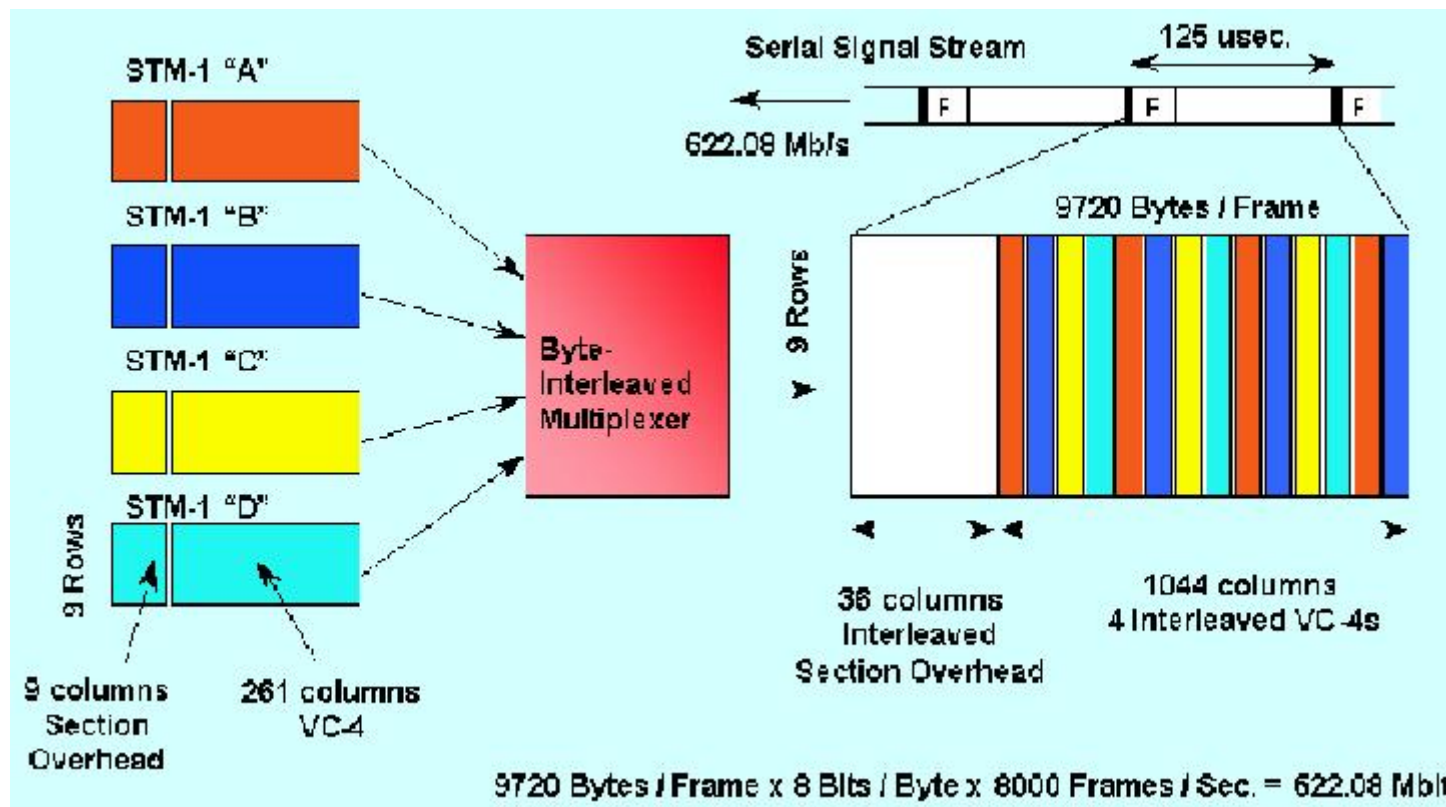

SDH Frame Structure

The STM-n frame structure is best represented as a rectangle of ٩ x ٢٧٠xN.
The ٩xN first columns are the frame header and the rest of the frame is the inner structure data (including the data, indication bits, stuff bits, pointers and management).

The STM-n frame is usually transmitted over an optical fiber. The frame is transmitted row by row (first is transmitted the first row then the second and so on). At the beginning of each frame a synchronized bytes A١A٢ are transmitted .

The multiplexing method of ٤ STM-n streams into a STM-nx٤ is an interleaving of the STM-n streams to produce the STM-nx٤ stream. The method is shown in the next picture for producing STM-٤ from ٤ STM-١ streams.
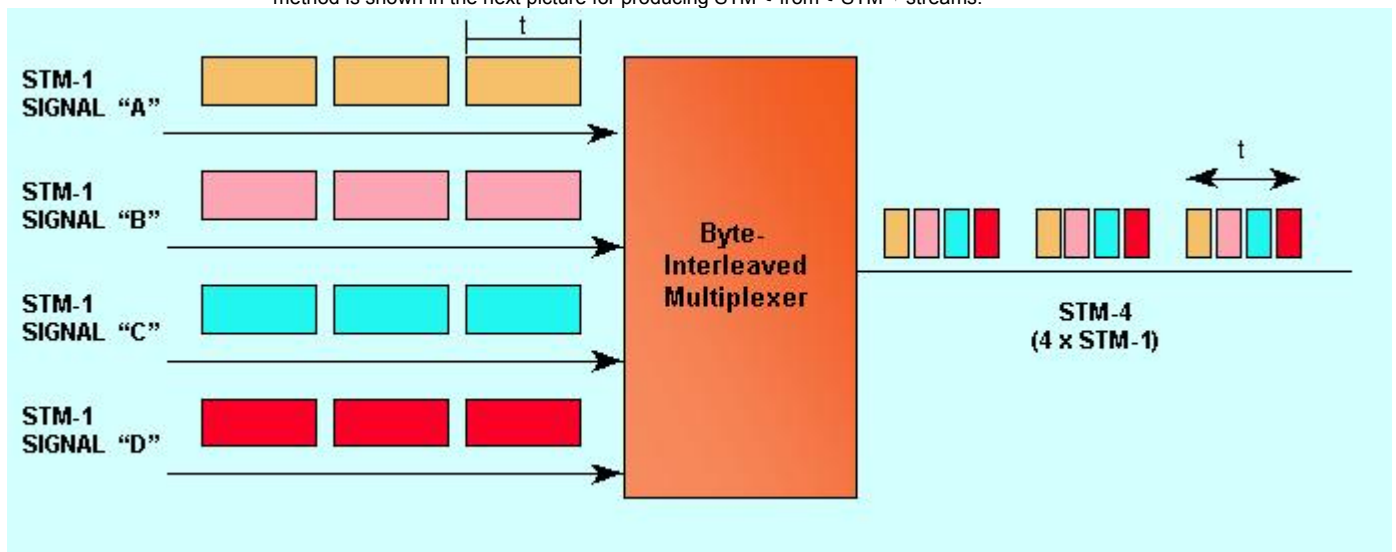
After interleaving we get a higher order stream that in its rectangular form all the low order STM streams are placed as its columns which makes it easier to find each of them in the bigger frame.

STM-1 "A"

STM-1 "B"

STM-1 "C"

STM-1 "D"

9 Rows

9 columns
Section
Overhead

261 columns
VC4

Byte-
Interleaved
Multiplexer

Serial Signal Stream

125 usec.

622.08 Mb/s

9720 Bytes / Frame

9 Rows

36 columns
Interleaved
Section Overhead

1044 columns
4 Interleaved VC-4s

9720 Bytes / Frame x 8 Bits / Byte x 8000 Frames / Sec. = 622.08 Mb/s

SDH - In the future

The modern lifestyle requires high speed communication applications.
SDH provides large bandwidth that can meet the needs of this applications.
Here are some of the needs and there solutions.

Future of the private circuits

Demands:

- **In the future there will be an increasment in the demand for private circuits (leased line traffic) and the associated capacity increase in the trunk network.**
- **Mega stream services will be available for end users.**

SDH solution:

- **SDH networks have flexible routing ability for circuit protection thus allowing rapid circuit reallocation and high circuit availability.**

Future of the Broadband ISDN

Demands:

- **Growing demand for non voice broadband services which require a variable bandwidth such as video signal transmission, video conferencing, remote data base access and high speed multimedia file transfer.**

SDH solution:

- **ATM has been chosen by CCITT to be the target transfer mode for B-ISDN services, ATM cells can be easily transported in the SDH frame.**

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References :

- Most of the references to this Tutorial are taken from ECI Technology Seminars Center and ECI Virtual Training Center.Permission for useing the graphics from those sources was granted.
- The ITU-T standards G.٧٠١ - G.٧٠٨ (particulary the G.٧٠٧ standard).
- "Synchronous Digital Hierarch (SDH)" by Marconi.
- "SDH - Three little words" by Erricsson