**WHAT IS SDH?**

SDH (Synchronous Digital Hierarchy) is an international standard for high speed telecommunication over optical/electrical 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 1991. 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 70's, and was based on the Pulse Code Modulation (PCM) method.

In the early 80'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 44 Mbps or 56 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**

[Diagram showing 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.

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 \( \frac{46}{10} \) Kbps in PDH to \( \frac{1.5}{4} \) - \( \frac{2}{4} \) Mbps in SDH.

SDH/SONET Vs. PDH rates
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:
standards

- SDH has been standardized by ITU-T in 1989.
- In November 1990, the first SDH standards were approved.
- In 1991, the CCITT (International Consultative Committee on Telephony & Telegraphy) had published in its "Blue book" recommendations G.707, G.807 & G.907 covering the SDH standards.

G.707 - Digital Hierarchy Bit Rates
G.703 - Physical/Electrical Characteristics of Hierarchical Digital Interfaces
G.707 - SDH Bit Rates
G.708 - Network Node Interface for the SDH
G.709 - Synchronous Multiplexing Structure
G.709 - Protocol Suites for Q Interfaces for Management of Transmission Systems
G.707 - (Formerly G.smux-1) Structure of Recommendations on
SDH Elements

The most common SDH elements are:

**Terminal Multiplexer**

- **E1-E4** to **STM-N**
- **STM-M**

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.

**Regenerator**

- **STM-N**

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.

**Add And Drop Multiplexer (ADM)**

- **STM-N**
- **STM-N**
- **E1-E4**
- **STM-M**

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.

**Synchronous Digital Cross Connect**

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.

SDH Topologies

### Linear Bus (Chain)

![Linear Bus (Chain) Diagram]

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

### Ring

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

### Mesh

![Mesh Diagram]

The mesh topology allows even the most paranoid network manager to sleep well at nights because of the flexibility and redundancy that it gives.
The Star topology is used for connecting far and less important sites to the network.

Usage of SDH elements in SDH Topologies

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

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.

**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 - ٢٨٤٠ Mbit/Sec
- E٢ - ٨٤٤ Mbit/Sec
- E٣ - ٤٣٨٦٣ Mbit/Sec
- E٤ - ٩٣١٤٦٢ Mbit/Sec

The En is the result of multiplication 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 \( \mathrm{En} \).  

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 E\(^1\) or E\(^3\) is used.  

In order to transmit E\(^1\) (a very common data rate) we need roughly one level of multiplexing, this means that the indication bits indicate that the following stuff bits are data. This is the reason why \( \mathrm{En} \).  

Further more there is no inband management in the PDH protocol if we need to know the status of E\(^1\) of the multiplexers, or if we need to change the route of E\(^1\) 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:  

- STM\(^1\) - 51.84 Mbit/Sec  
- STM\(^1\) - 154.5 Mbit/Sec  
- STM\(^1\) - 5.0 Gbit/Sec  
- STM\(^1\) - 1.0 Gbit/Sec  
- Etc. \( \cdots \)

In order to have the ability to connect a low rate PDH stream (E\(^1\), E\(^3\) 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.  

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 E\(^1\) (\( \cdots \)) into the STM-n frame we have to create a TU\(^{\mathrm{1}}\) stream which is a low rate stream that is synchronized to the SDH network clock. The TU\(^{\mathrm{1}}\) is composed of the E\(^1\) data, indication bits, stuffing bits, management bits and a direct pointer to the E\(^1\) frame.  

The TUG\(^{\mathrm{1}}\) is a structure that can be composed of \( \mathrm{TU}^{\mathrm{1}}\)'s (\( \mathrm{E}^{1}\)'s), or \( \mathrm{TU}^{\mathrm{1}}\)'s (\( \mathrm{T}^{1}\)'s), or \( \mathrm{TU}^{\mathrm{1}}\) (\( \mathrm{T}^{1}\)). 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 \(^t\) TUG-\(^s\) into \(^1\) VC-\(^r\) or into \(^1\) TUG-\(^r\) and so on according to the flow chart.

This method of multiplexing allow us to directly map the \(T^{1}, T^{2}, T^{3}\) (American standards) and the \(E^{1}, E^{2}, E^{3}\) (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 without 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.

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**SDH Frame Structure**

The STM-n frame structure is best represented as a rectangle of \(9 \times N\). The first \(9\) 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 \(A^{1}A^{2}\) are transmitted.

The multiplexing method of \(t\) STM-n streams into a STM-nx\(^t\) is an interleaving of the STM-n streams to produce the STM-nx\(^t\) stream. The method is shown in the next picture for producing STM-\(^4\) from \(4\) STM-\(^1\) streams.

![Diagram showing multiplexing](image)

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.
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 using the graphics from those sources was granted.
- "Synchronous Digital Hierarch (SDH)" by Marconi.
- "SDH - Three little words" by Ericsson.