Introduction To SDH

SDH (Synchronous Digital Hierarchy) is a standard for telecommunications transport formulated by the International Telecommunication Union (ITU), previously called the International Telegraph and Telephone Consultative Committee (CCITT).

SDH was first introduced into the telecommunications network in 1992 and has been deployed at rapid rates since then. It's deployed at all levels of the network infrastructure, including the access network and the long-distance trunk network. It's based on overlaying a synchronous multiplexed signal onto a light stream transmitted over fibre-optic cable. SDH is also defined for use on radio relay links, satellite links, and at electrical interfaces between equipment.

The comprehensive 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 SDH provides significant advantages over the older telecommunications system. These advantages include:

- A reduction in the amount of equipment and an increase in network reliability.
- The provision of overhead and payload bytes – the overhead bytes permitting management of the payload bytes on an individual basis and facilitating centralised fault sectionalisation.
- The definition of a synchronous multiplexing format for carrying lower-level digital signals (such as 2 Mbit/s, 34 Mbit/s, 140 Mbit/s) which greatly simplifies the interface to digital switches, digital cross-connects, and add-drop multiplexers.
- The availability of a set of generic standards, which enable multi-vendor interoperability.
- The definition of a flexible architecture capable of accommodating future applications, with a variety of transmission rates.

In brief, SDH defines synchronous transport modules (STMs) for the fibre-optic based transmission hierarchy.

Background

Before SDH, the first generations of fibre-optic systems in the public telephone network used proprietary architectures, equipment line codes, multiplexing formats, and maintenance procedures. The users of this equipment wanted standards so they could mix and match equipment from different suppliers.

The task of creating such a standard was taken up in 1984 by the Exchange Carriers Standards Association (ECSA) in the U.S. to establish a standard for connecting one fibre system to another. In the late stages of the development, the CCITT became involved so that a single international standard might be developed for fibre interconnect between telephone networks of different countries. The resulting international standard is known as Synchronous Digital Hierarchy (SDH).

Synchronisation of Digital Signals

To correctly understand the concepts and details of SDH, it's important to be clear about the meaning of Synchronous, Plesiochronous, and Asynchronous.

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 time delays, or low-frequency wander introduced in the transmission network. In a synchronous network, all the clocks are traceable to one Stratum 1 Primary Reference Clock (PRC). The accuracy of the PRC is better than ± 1 in 10^{11} and is derived from a cesium atomic standard.

If two digital signals are **Plesiochronous**, their transitions occur at "almost" the same rate, with any variation being constrained within tight limits. These limits are set down in ITU-T recommendation G.811. For example, if two networks need to interwork, their clocks may be derived from two different PRCs. Although these clocks are extremely accurate, there's a small frequency difference between one clock and the other. This is known as a plesiochronous difference.

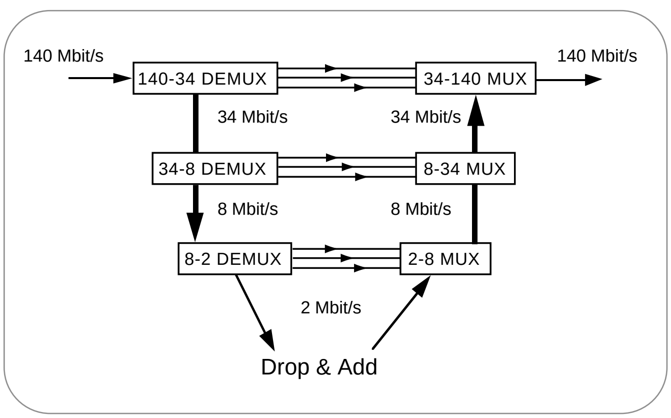
In the case of **Asynchronous** signals, the transitions of the signals don't necessarily occur at the same nominal rate. Asynchronous, in this case, means that the difference between two clocks is much greater than a plesiochronous difference. For example, if two clocks are derived from free-running quartz oscillators, they could be described as asynchronous.

SDH Advantages

The primary reason for the creation of SDH was to provide a long-term solution for an optical mid-span meet between operators; that is, to allow equipment from different vendors to communicate with each other. This ability is referred to as multi-vendor interworking and allows one SDH-compatible network element to communicate with another, and to replace several network elements, which may have previously existed solely for interface purposes.

The second major advantage of SDH is the fact that it's synchronous. Currently, most fibre and multiplex systems are plesiochronous. This means that the timing may vary from equipment to equipment because they are synchronised from different network clocks. In order to multiplex this type of signal, a process known as bit-stuffing is used. Bit-stuffing adds extra bits to bring all input signals up to some common bit-rate, thereby requiring multi-stage multiplexing and demultiplexing. Because SDH is synchronous, it allows single-stage multiplexing and demultiplexing. This single-stage multiplexing eliminates hardware complexity, thus decreasing the cost of equipment while improving signal quality.

In plesiochronous networks, an entire signal had to be demultiplexed in order to access a particular channel; then the non-accessed channels had to be re-multiplexed back together in order to be sent further along the network to their proper destination. In SDH format, only those channels that are required at a particular point are demultiplexed, thereby eliminating the need for back-to-back multiplexing. In other words, SDH makes individual channels "visible" and they can easily be added and dropped.



▶ ***Figure 1.*** *PDH multiplexing by steps, showing add/drop function.*

Plesiochronous Digital Hierarchy (PDH)

Traditionally, digital transmission systems and hierarchies have been based on multiplexing signals which are plesiochronous (running at almost the same speed). Also, various parts of the world use different hierarchies which lead to problems of international interworking; for example, between those countries using 1.544 Mbit/s systems (U.S.A. and Japan) and those using the 2.048 Mbit/s system.

To recover a 64 kbit/s channel from a 140 Mbit/s PDH signal, it's necessary to demultiplex the signal all the way down to the 2 Mbit/s level before the location of the 64 kbit/s channel can be identified. PDH requires "steps" (140-34, 34-8, 8-2 demultiplex; 2-8, 8-34, 34-140 multiplex) to drop out or add an individual speech or data channel (see Figure 1). This is due to the bit-stuffing used at each level.

Limitations of PDH Network

The main limitations of PDH are:

- Inability to identify individual channels in a higher-order bit stream.
- Insufficient capacity for network management;
- Most PDH network management is proprietary.
- There's no standardised definition of PDH bit rates greater than 140 Mbit/s.
- There are different hierarchies in use around the world. Specialized interface equipment is required to interwork the two hierarchies.

Basic SDH Signal

The basic format of an SDH signal allows it to carry many different services in its Virtual Container (VC) because it is bandwidth-flexible. This capability allows for such things as the transmission of high-speed packet-switched services, ATM, contribution video, and distribution video. However, SDH still permits transport and networking at the 2 Mbit/s, 34 Mbit/s, and 140 Mbit/s levels, accommodating the existing digital hierarchy signals. In addition, SDH supports the transport of signals based on the 1.5 Mbit/s hierarchy.

Transmission Hierarchies

Following ANSI's development of the SONET standard, the ITU-T undertook to define a standard that would address interworking between the 2048 kbit/s and 1554 kbit/s transmission hierarchies. That effort culminated in 1989 with ITU-T's publication of the Synchronous Digital Hierarchy (SDH) standards.

Tables 1 and 2 compare the Non-synchronous and Synchronous transmission hierarchies.

Table 1. Non-Synchronous, PDH Hierarchy

Signal	Digital Bit Rate	Channels
E0	64 kbit/s	One 64 kbit/s
E1	2.048 Mbit/s	32 E0
E2	8.448 Mbit/s	128 E0
E3	34.368 Mbit/s	16 E1
E4	139.264 Mbit/s	64 E1

Table 2. SDH Hierarchy

Bit Rate	Abbreviated	SDH	SDH Capacity
51.84 Mbit/s	51 Mbit/s	STM-0	21 E1
155.52 Mbit/s	155 Mbit/s	STM-1	63 E1 or 1 E4
622.08 Mbit/s	622 Mbit/s	STM-4	252 E1 or 4 E4
2488.32 Mbit/s	2.4 Gbit/s	STM-16	1008 E1 or 16 E4
9953.28 Mbit/s	10 Gbit/s	STM-64	4032 E1 or 64 E4
39813.12 Mbit/s	40 Gbit/s	STM-256	16128 E1 or 256 E4

STM = Synchronous Transport Module