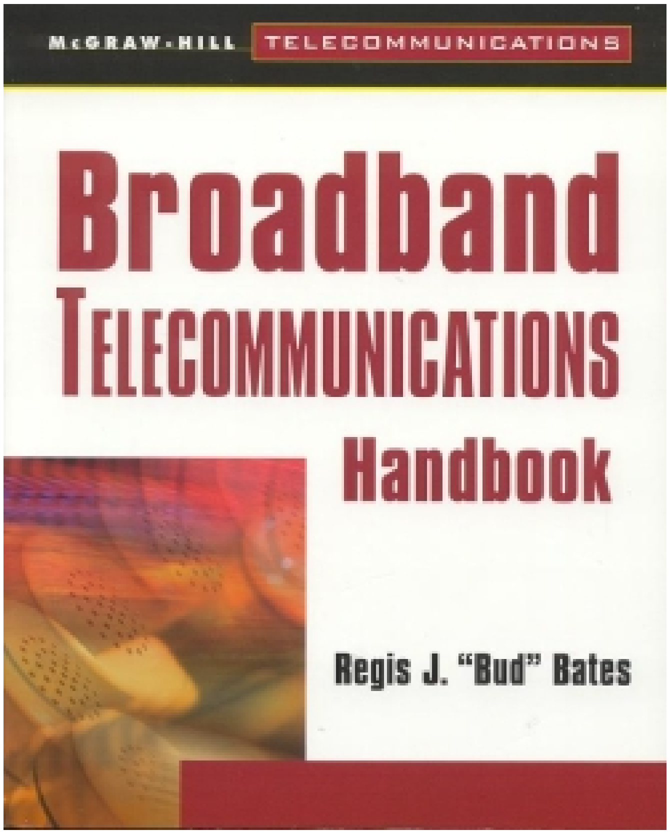
FURTHER READING:

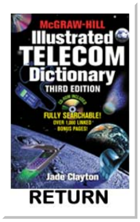
As a preview for further reading, the following reference has been provided from the pages of the book below:

Title: Broadband Telecommunications Handbook
Author: Regis J. “Bud” Bates
Publisher: McGraw-Hill

ISBN: 0071346481



Introduction



Synchronous Optical Network (SONET) is a standard developed by the *Exchange Carriers Standards Association* (ECSA) for ANSI. This standard defines an optical telecommunications transport for U.S. Telecommunications. SONET standards provide an extensive set of operational parameters for optical transmission systems throughout the industry. The North American industry uses the SONET specifications, whereas the rest of the world uses a close "cousin" defined as *Synchronous Digital Hierarchy* (SDH). Between the two sets of standards, the industry attempted to define the roles of transport for the telecommunications providers using optical fibers as the transport medium.

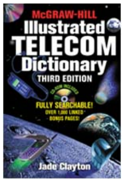
SONET provides more, though. It defines a means to increase throughput and bandwidth through a set of multiplexing parameters. These roles provide certain advantages to the industry, such as the following:

- Reduced equipment requirements in the carriers' network
- Enhanced network reliability and availability
- Conditions to define the overhead necessary to facilitate managing the network better
- Definitions of the multiplexing functions and formats to carry the lower level digital signals (such as DS-1, DS-2, and DS-3)
- Generic standards encouraging interoperability between different vendors' products
- A flexible means of addressing current as well as future applications and bandwidth usage

SONET defines the *Optical Carrier* (OC) levels and the electrical equivalent rates in the *Synchronous Transport Signals* (STS) for the fiber-based transmission hierarchy.

Background Leading to SONET Development

Prior to the development of SONET, the initial fiber-based systems used in the PSTN were all highly proprietary. The proprietary nature of the products included the following:



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1. Equipment
2. Line coding
3. Maintenance
4. Provisioning
5. Multiplexing
6. Administration

The carriers were frustrated with the proprietary products because of interoperability problems, sole-source vendor solutions (which held the carriers hostage to one vendor), and cost issues. These carriers approached the standards committees and demanded that a set of operational standards be developed that would allow them to mix and match products from various vendors. In 1984 a task force was established to develop such a standard. The resultant standard became SONET.

Synchronizing the Digital Signals

SONET involves the synchronization of the digital signals arriving at the equipment. Keeping in mind that the signals may be introduced in one of three ways, it is important to attempt to get everything on a common set of clocking mechanisms. In digital transmission, the normal way of synchronizing traffic is to draw a common clocking reference. In the hierarchy of clocking, systems use a stratum clocking architecture. The stratum references in North America come in a four-level architecture. These are shown in Table 27-1.

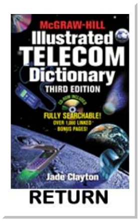
In a set of synchronous signals, the digital transitions in the signals occur at the same rate. There may be a phase difference between the transitions in the two signals, but this would be in specified ranges and limits. The phase differences can be the result of delay in systems, jitter across the link, or other transmission impairments. In a synchronous environment, all the clocks are traceable back to a common reference clock (the Primary Reference Clock).

If two signals are almost the same, they are said to be plesiochronous. Their transitions are close (or almost the same) and variations are contained within strict limits. The clocking between the two different sources, although accurate, may be operating at a different rate.

Table 27-1

Summary of clocking systems

Stratum Reference	Location Used	Accuracy
1	Primary Reference drawn from a GPS or the National Reference Atomic clock	± 1 pulse in 10^{11}
2	Toll Offices (Class 1–4)	± 1.6 pulses in 10^{8}
3	End Offices (Class 5)	± 4.6 pulses in 10^{6}
4	Customer Equipment (Multiplexer, Channel Bank, and so on)	± 32 pulses in 10^{6}



Finally, if two signals are randomly generated and do not occur at the same rate, they are said to be asynchronous. The difference between two clocks is much greater, possibly running from a free running clock source.

Any one of these signals, synchronous, plesiochronous, or asynchronous, may arrive at a SONET multiplexer to be formulated and transmitted across the network. SONET defines the means of synchronizing the traffic for transmission.

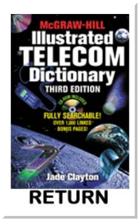
The SONET Signal

SONET defines a technique to carry many signals from different sources and at different capacities through a synchronous, optical hierarchy. The flexibility and robustness of SONET are some of its strongest selling points. Additionally, in the past many of the high-speed, multiplexing arrangements (DS-2 and DS-3) used bit interleaving to multiplex the data streams through the multiplexers. SONET uses a byte-interleaved multiplexing format. This is a strong point because it keeps the basic DS-0 intact throughout the network, making it easier to perform diagnostics and troubleshooting. Byte interleaving simplifies the process and provides better end-to-end management.

The base level of a SONET signal is called the *Synchronous Transport Signal Level1* (STS-1), operating at 51.84 Mbps. The first step in using the SONET architecture is to create the STS-1. Other levels exist in multiples of the STS-n to create a full family of transmission speeds. The SONET hierarchy is shown in Table 27-2.

Table 27-2

Summary of electrical and optical rates for SONET



The SONET hierarchy

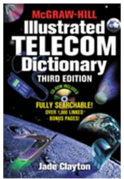
Electrical Signal	Optical Value	Speed	Capacity
STS-1	OC-1	51.84 Mbps	28 DS-1 or 1 DS-3
STS-3	OC-3	155.520 Mbps	84 DS-1 or 3 DS-3
STS-12	OC-12	622.08 Mbps	336 DS-1 or 12 DS-3
STS-24	OC-24	1.244 Gbps	672 DS-1 or 24 DS-3
STS-48	OC-48	2.488 Gbps	1344 DS-1 or 48 DS-3
STS-192	OC-192	9.95Gbps	5376 DS-1 or 192 DS-3

Other rates exist, but these are the most popularly implemented

Why Bother Synchronizing?

In the past, transmission systems have been primarily asynchronous. Each terminal device in the network was independently timed. In a digital synchronous transmission system, clocking is all-important. Clocking uses a series of pulses to keep the bit rate constant and to help recover the ones and zeros from the data stream. Because these past clocks were independently timed, large variations occurred in the clock rate, making it extremely difficult (if not impossible) to extract and recover the data. A DS-1 operates at 1.544 Mbps ± 150 pps, whereas a DS-3 operates at 44.736 Mbps ±1789 pps. These differences mean that one DS-1 may be transmitting at up to 300 pps different than the other (assuming that DS-1 is at –150 pps and the second one is at +150 pps). The differences can make it difficult to derive the actual data across a common receiver.

Back in the section on the T-carriers (Chapter 26), we discussed the asynchronous method of multiplexing a DS-3. In that section we saw that four DS-1s were bit interleaved together to form a DS-2, and that bit stuffing occurred. From there, seven DS-2s were bit interleaved together to form the DS-3, but there were several possible steps where bit stuffing occurred at the multiplexing point. The stuff bits were random occurring in seven of 18 frames, causing confusion in delivering and demultiplexing the signal. Moreover, when a problem occurs on a DS-3 using the M13 Asynchronous Multiplexing technique, the entire DS-3 must be demultiplexed to find the problem. This is inefficient.



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Therefore, the method of synchronously multiplexing in a SONET architecture provides for better efficiency and problem resolution. Using SONET, the average frequency of all the clocks will be the same. Every clock can be traced back to a common reference, which is highly reliable and stable. Bit stuffing can be eliminated in the preparation of the STS-1 signal; therefore, the lower-speed signals are more readily accessible. The benefits outweigh the possible overhead associated with the SONET multiplexing scheme. In SONET, the hierarchy of clocking follows the master-slave clocking architecture. Higher level (stratum 1) clocks will feed the timing across the network to lower level devices. Any jitter, phase shifts, or drifting by the clocks can be accommodated through the use of pointers in the SONET overhead. The internal clock in a SONET multiplexer may also draw its timing from a *Building Integrated Timing System* (BITS) used by switching systems and other devices. This terminal will then serve as the master for other SONET nodes downstream, providing timing on its outgoing signal. The receiving SONET equipment will act in a slave mode (loop timing) with their internal clocks timed by the incoming signal. The standard specifies that SONET equipment must be able to derive its timing at a stratum level 3 or above.

The SONET Frame

SONET also defines a frame format in which to produce the basic rate of 51.84 Mbps (the STS-1). Each of the additions to the multiplexing rates is a multiple of the STS-1. The basic format consists of a frame that is 80 bytes (columns) wide and 9 bytes high (rows). The basic STS-1 signal is then applied into this 810-byte frame. The frame is shown in Figure 27-1. The frame will occur 8,000 times per second. If we calculate the math on this we have the following:

810 bytes × **8 bits/byte** × **8000 frames/sec** = **51.84 Mbps**

Overhead

From the 810-byte frame, overhead is allowed in several ways to handle the *Operations, Administration, Maintenance, and Provisioning* services (*OAM&P*).