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Lesson 108: Synchronous Optical Network

A standard for high-speed communications over fiber optic cable brings relief to telcos and customers.

The phenomenal growth of the Internet as a place of commerce and information exchange has led to more and more traffic traveling over wide area links. If you talk to some of the larger service providers like MCI and UUNET, you will hear tales of how network size is doubling every few months due to the vast amount of electronic traffic coming and going from customers' sites.

Although most of the traffic clogging the Internet is still data, we're starting to see a mixture of voice, video, and other multimedia applications vying for precious bandwidth. For some time, most companies were content with leased 56Kbit/sec or T-1 lines, and in rare instances a company required T-3 (45Mbits/sec) pipes. Although T-1 still fulfills most companies' needs, service providers that have to aggregate multiple T-1s and provide connections across the country or around the world have needed more transport capacity.

That much-needed bandwidth has come in the form of Synchronous Optical Network (SONET), a broadband transmission standard. It provides an optical signal format for the high-speed transfer of data, video, and other types of information across great distances without regard to the specific services and applications it supports.

HIGH-SPEED NETWORK

SONET was first conceived of in the mid-1980s, when the telecommunications industry and various standards bodies-including CCITT, ANSI, IEEE, and EIA-determined the need for a fiber optic-based standard that could handle much

more than just voice at gigabit-per-second rates. Before then, fiber optic products from different manufacturers were not compatible with each other, forcing carriers to do business with only one fiber supplier. In addition, the connections between various networks could be tricky if products from more than one vendor were being used.

Before SONET standards were developed and started becoming widely implemented, an older infrastructure, known as the North American Digital Hierarchy (NADH), was the primary Physical layer used by asynchronous T-1 lines (see [Table 1](#)).

Using NADH, telephone company central offices were able to send DS-1 signals, which break down into 24 64Kbit/sec segments (or DS-0 signals), over copper T-1 lines. But, thousands or even tens of thousands of voice and data transmissions can occur simultaneously. When this happens, the only viable option is fiber optic cabling. The NADH infrastructure still exists and continues to be widely used, even with a lack of standards and inherent bandwidth limitations, but eventually SONET will become the primary transport vehicle.

In general, copper lines are fine for transmitting voice and data. However, as the number of such transmissions over a single piece of copper cabling increases, bandwidth becomes limited. Fiber optic cabling brings much more bandwidth to the picture. An analog line on the local loop provides just 4KHz of bandwidth for voice, while a single optical fiber can carry 3Gbits/sec. (While you cannot directly compare analog bandwidths with digital bit rates, the best current analog modem technologies can deliver only 56Kbits/sec over an analog phone line.) Fiber also comes in two varieties, multimode and single-mode, giving customers the option of using this medium over the LAN or over a distance of several kilometers.

In addition to the advantages of using fiber optic cabling, going with a synchronous transmission method such as SONET offers several advantages over the asynchronous T-1 line. Synchronous transmissions support bandwidth (or circuit) provisioning, which allows providers to have control over individual DS-0, DS-1, and DS-3 channels. This ability allows the provider to add more channels to meet traffic demand and then remove them when they are no longer needed.

Synchronous transmission environments also allow customers to do real-time routing around nodes that are experiencing a lot of traffic. Customers can reconfigure routes without having

to end voice and other sessions. Another benefit of synchronous transmission includes the ability for service providers to conduct automatic testing and maintenance of network performance. This is accomplished through overhead channels that are tacked onto the transmission itself. These channels can perform automated functions such as maintenance, testing, and issuance of reports.

BUILDING BLOCKS

The basic foundation of SONET consists of groups of DS-0 signals (64Kbits/sec) that are multiplexed to create a 51.84Mbit/sec signal, which is also known as STS-1 (Synchronous Transport Signal). STS-1 is an electrical signal rate that corresponds to the Optical Carrier line rate of OC-1, SONET's building block (see [Table 2](#)).

Subsequent SONET rates are created by interleaving (at the byte level) STS-1 signals to create a concatenated, or linked, signal. For example, three STS-1 frames can form an STS-3 frame (155Mbits/sec). Rates above STS-3 can be created by either directly multiplexing STS-1 signals or by byte-interleaving STS-3 signals.

This ability to use direct multiplexing is an improvement over the NADH scheme, which doesn't always allow it because the signals that need to be multiplexed to get a higher signal rate are asynchronous to each other and could be operating at slightly different frequencies.

With NADH, signals can't just leap from DS-1 to DS-3; instead, a two-step process must be taken, which involves adding overhead to the transmission. This often leads to loss of integrity, making it difficult to create higher signal rates.

If the OC-3 and OC-12 rates look suspiciously like the rate for two particular flavors of ATM, it's no coincidence. ATM at the 155Mbit/sec and 622Mbit/sec rates was designed specifically to use SONET as the transport mechanism, and in fact, you cannot run higher bit rate ATM over anything except SONET. Because OC-3 has the same line rate as 155Mbits/sec and OC-12 has the same rate as 622Mbits/sec, many people erroneously equate them.

A designation of OC-3 simply means the SONET pipe itself is operating at a data rate of 155Mbits/sec. The pipe could be transporting 155Mbit/sec ATM, but because SONET is independent of the service it carries, the service could be FDDI, ISDN, or SMDS. The same applies to OC-12, but when

you see the designation OC-12c, it means the bandwidth capacity is actually a concatenation of several smaller pipes instead of a single 622Mbit/sec ATM connection. For example, bandwidth capacity might consist of four OC-3 signals. (For more on high-speed ATM, see "ATM in the Fast Lane," July 1997, page 48.) Initially, SONET was defined only up to the OC-48 level, but now we're hearing talk of OC-192 (almost 10Gbits/sec).

Just because the basic level of SONET starts at 51Mbits/sec doesn't mean lower bit rate asynchronous signals are ignored. The basic STS-1 frame contains 810 DS-0s, 783 of which are used for sending data (including slower asynchronous signals) and 27 of which are overhead. The overhead in this case is information concerning framing, errors, operations, and format identification.

Signals with speeds below STS-1, such as DS-1 and the European E-1 (2.048Mbits/sec) can be accommodated by dividing the STS-1 payload into smaller segments that are known as Virtual Tributaries (VTs). The lower data rate signals are combined with overhead information, which leads to the creation of Synchronous Payload Envelopes (SPEs). SPEs allow these signals to be transported at high speeds without compromising integrity. Each VT on an STS-1 signal includes its own overhead information and exists as a distinct segment within the signal.

For example, VT-1.5, which is commonly used in North America, supports a line rate of 1.728Mbits/sec. Because this rate is slightly greater than the 1.54Mbit/sec rate of a DS-1 circuit, VT-1.5 is specially designed to carry a DS-1 along with the overhead information discussed above.

TRANSPORT AND TOPOLOGY

The SONET standard includes a definition of a transmission protocol stack (see Figure 1), which solves the operation and maintenance problems often found when dealing with asynchronous networks that have no standardized way of communicating.

The photonic layer is the electrical and optical interface for transporting information over fiber optic cabling. It converts STS electrical signals into optical light pulses (and vice versa, at the receiving end). The section layer transports STS frames over optical cabling. This layer is commonly compared with the Data-Link layer of the OSI model, which also handles framing and physical transfer.

The line layer takes care of a number of functions, including synchronization and multiplexing for the path layer above it. It also provides automatic protection switching, which uses provisioned spare capacity in the event of a failure on the primary circuit.

The highest level, the path layer, takes services such as DS-3, T-1, or ISDN and maps them into the SONET format. This layer, which can be accessed only by equipment like an add/drop multiplexer (a device that breaks down a SONET line into its component parts), takes care of all end-to-end communications, maintenance, and control.

SONET supports several topologies, including point to point, a hub and spoke star configuration, and the ring topology. The ring topology, which is by far the most popular, has been used for years by such network technologies as FDDI and Token Ring and has proven quite robust and fault-tolerant. A SONET ring can contain two pairs of transmit and receive fibers. One pair can be designated as active with the other one functioning as a secondary in case of failure. SONET rings have a "self-healing" feature that makes them even more appealing for connections from one end of the country to another.

PRACTICAL PURPOSES

The telecommunications industry was the driving force behind defining a fiber optic system standard, and so far, SONET has remained the domain of carriers such as MCI, AT&T, Sprint, and WorldCom, all of which continue to send large amounts of voice traffic, but have also experienced a dramatic rise in Internet traffic. In the last year or two, large ISPs, such as UUNET, have installed SONET rings to bring more bandwidth and reliability to congested networks.

For the corporate world, SONET may carry too hefty a price tag to be practical. Companies can call their local carrier and ask about SONET equipment and service, but with an investment of tens or even hundreds of thousands of dollars, even traditional early adopters such as the financial world may pass for now. But, because SONET leverages existing fiber cabling already in use by many companies and brings stability and reliability to wide area networks, the move may not be so painful once providers become more aggressive about pricing.

TABLE 1-NORTH AMERICAN DIGITAL HIERARCHY

RATES

1

Digital signal	No. of 64Kbit/sec channels	Line rate
DS-0	1	64Kbits/sec
DS-1	24	1.54Mbits/sec
DS-2	96	6.31Mbits/sec
DS-3	672	44.74Mbits/sec
DS-4	2,016	39.26Mbits/sec

TABLE 2-SONET LINE RATES

Electrical signal	Optical Carrier line	Line rate
STS-1	OC-1	51.84Mbits/sec
STS-3	OC-3	155.52Mbits/sec
STS-12	OC-12	622.08Mbits/sec
STS-24	OC-24	1.24Gbits/sec
STS-48	OC-48	2.48Gbits/sec
STS-192	OC- ...192	9.95Gbits/sec

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