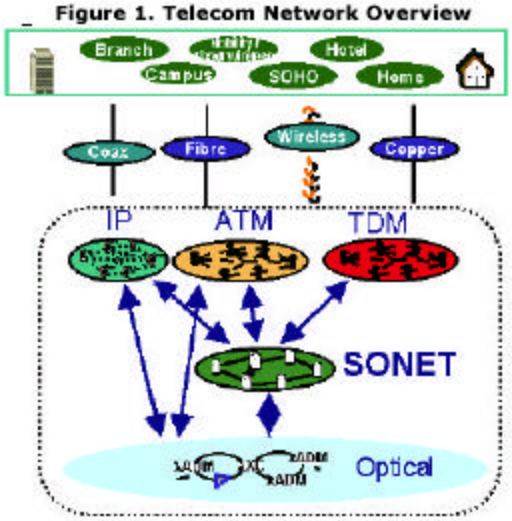
Synchronous Optical Network (SONET) Transmission

Definition

Synchronous optical network (SONET) offers cost-effective transport both in the access area and core of the network. For instance, telephone or data switches rely on SONET transport for interconnection.
The optical layer provides the foundation of transport services for both metro and long-haul applications. It also directly supports data services. The optical layer is now evolving to provide the same level of sophistication that has been achieved with synchronous transmission, such as performance monitoring and network resilience (i.e., the ability to recover quickly from a link being cut). Thus, the SONET layer will remain for some time. *Figure 1* illustrates the access, switching, packet multiservice, SONET, and optical layers in the telecommunications network.

Figure 1. Telecom Network Overview



Overview

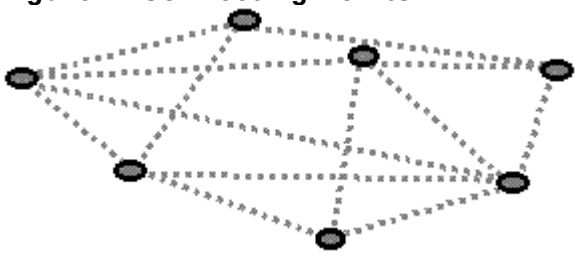
The objective of this tutorial is to clarify what SONET is, what it does, and what benefits it offers.

Topics

1. Transport Network Role

If each data switch, telephone exchange, or radio terminal is known as a point, then a transport network is something that enables these points to be connected so that traffic can be carried (see *Figure 2*). However, merely providing a set of links between sites is not sufficient; a robust and economic network is required.

Figure 2. Connecting Points

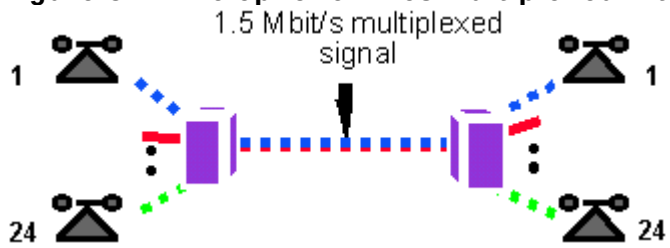


SONET is particularly adapted to address resilience, which is the ability of the network to cope with the loss of a link or node and still provide alternative routes for the transport of traffic. Services generally require a resilient network.

2. Multiplexing

Multiplexing enables one physical medium to carry multiple signals. A transport network is a set of links between sites. To put more than one call on each link is to give each call a time slot (a place in a schedule) and transmit several calls simultaneously. This process is known as time division multiplexing (TDM). With multiplexing, the end users have the illusion of being on their own private links. Transmission systems that are designed according to North American rules work with groups of 24 telephone calls (see *Figure 3*).

Figure 3. 24 Telephone Lines Multiplexed into a 1.5 Mbps Signal

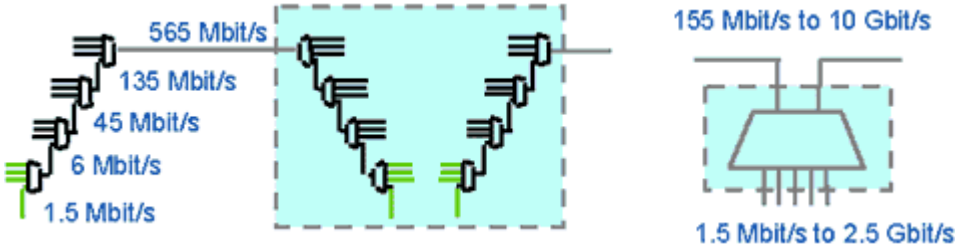


With SONET, multiplexing is TDM, not statistical. Hence, there is no concept of congestion or priority in SONET. The traffic flowing in and out of a node is exactly equal; there is no peak rate. A pipe of a certain size is given and is there whether data flows or not.

3. Asynchronous Hierarchy: Comparison with SONET

SONET provides the ability to access traffic at a node without the need for complex packing and unpacking of the various signals. This is a result of the fact that each node is synchronized to a central clock, unlike asynchronous digital hierarchy. *Figure 4* shows how much equipment is required for asynchronous digital hierarchy to accomplish the same task as a SONET network element.

Figure 4. Asynchronous Digital Hierarchy versus SONET



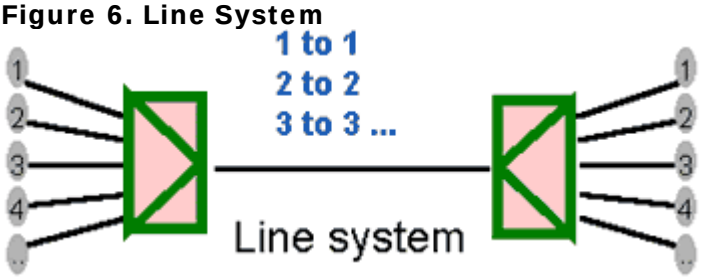
4. Types of Network Elements

The role of a transmission network is to connect points. This can be done in two ways: via a fixed point-to-point connection (exemplified by asynchronous digital hierarchy) or via a flexible network that allows connection changes and fast responses to new connection requests (see *Figure 5*).

Figure 5. Point-to-Point and Flexible Connections

The equipment formerly implemented a point-to-point connection called a terminal multiplexer (MUX) or line system (see *Figure 6*). A terminal MUX offers fixed connections between end-user termination points. Note that this was the only type of equipment available for asynchronous transmission, the technological predecessor to SONET.

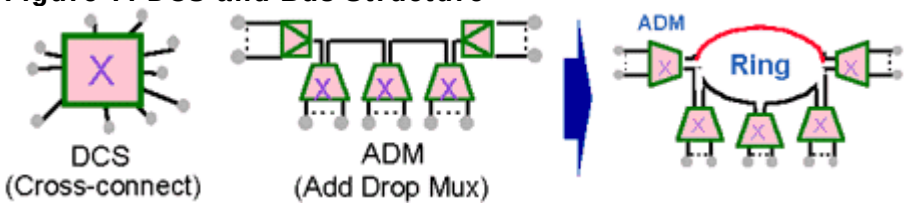
Figure 6. Line System



The other type of connection is made through a flexible network. This can be implemented using cross-connects or bus structures.

A digital cross-connect (DCS) is a piece of equipment that provides flexible connections between its termination points. Similarly, a bus structure provides flexible connections between the termination points of the elements making up the network. The bus route has “bus stops” known as add/drop multiplexers (ADMs) that provide the traffic with the flexibility to jump on or off or remain in place (see *Figure 7*).

Figure 7. DCS and Bus Structure



Network survivability is a key issue addressed by SONET. Networks are designed to cater for node and link failure.

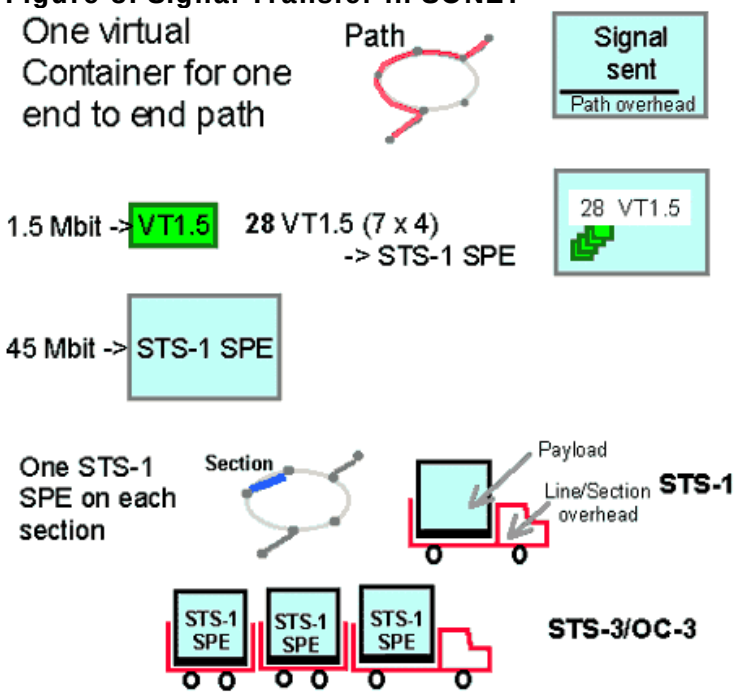
In the case of a point-to-point network, link resilience can be introduced by duplicating the link. Maximum protection is achieved if these two links are separately routed.

In the case of flexible network implemented with a cross-connect, the cross-connect is the major point of vulnerability, and a design with several cross-connects may be needed to achieve the degree of availability needed. However, with a bus structure, resilience can be achieved by adding an extra link to the network to make up a ring (see *Figure 7*). Now two alternative routes can be offered for a connection.

5. SONET Hierarchy

Figure 8 illustrates how signals are carried in SONET. First, SONET packages a signal into containers. It then adds the section overhead so that the signal and the quality of transmission are all traceable. The containers have two names depending on size: virtual tributary (VT) or a synchronous payload envelope (SPE). The path overhead contains data to control the facility (end to end) such as for path trace, error monitoring, far-end error, or virtual container (VC) composition.

Figure 8. Signal Transfer in SONET



SONET traffic is packaged in VCs and transported in synchronous transport vehicles or signals (STS). An STS exists on each section (i.e., the link between two nodes). An STS is made up of the payload and extra information called the line or section overhead. This line/section overhead contains data to control the node-to-node transmission (protection switching, error monitoring), and, in addition, provides extra channels (network management and maintenance phone link).

The SONET line transmission rates are 51, 155, and 622 Mbps; 2.5 Gbps; and 10 Gbps. Line signals can be optical or electrical. Electrical signals are used for short distances (e.g., between shelves in a rack) for interconnections of equipment on the same site. Electrical signals are sent on copper wires, while optical signals used for longer distances (from 40 km) require optical fibers.

SONET is an American National Standards Institute (ANSI) standard for North America, while synchronous digital hierarchy (SDH) is the standard for the rest of world. With many customers requiring international circuits, it is not uncommon to come across references to SDH. *Table 1* demonstrates the various rates (note the different names used at transport level for SDH and SONET). First common transport rate is at 155 Mbps; SONET transport starts at 51 Mbps (28 T1).

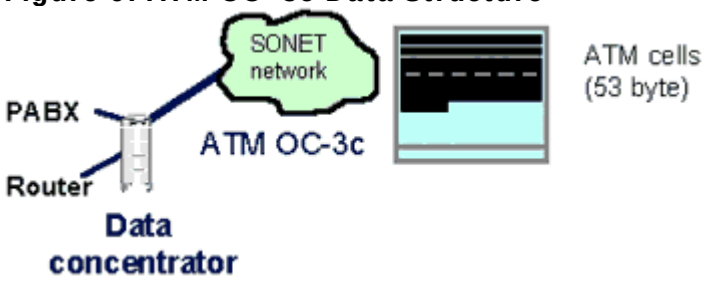
Table 1. SONET/SDH Transmission Rates

	PDH North America		PDH Europe		SDH		SONET	
Bit Rate (Mbps)	Name	Bit Rate (Mbps)	Name	Bit Rate (Mbps)	Container	Transport	Container	Transport
10,000						STM–64		STS/OC–192
2,500						STM–16		STS/OC–48
622						STM–4		STS/OC–12
155						STM–1		STS/OC–3
140			E4	140	VC4			
51								STS/OC–1
45	DS–3/T3	45				STS–1 SPE		
34			E3	34	VC3			
8			E2	8				
6	DS–2/T2	6				VT6—not really used		
2			E1	2	VC12			
1.5	DS–1/T1	1.5					VT1.5	
0.064	DS0/T0	0.064	E0	0.064				

6. Structure to Carry Data

An asynchronous transfer mode (ATM) optical carrier (OC)–3c does not have the structure with the VTs, described earlier. It is simply filled with cells. The *c* stands for concatenated and means that the truck trailers on the OC–3 are seen as one. Data equipment using SONET rates greater than 155 Mbps tend to require concatenated containers. Backbone network elements at 2.5 and 10 Gbps must support this type of data structure (see *Figure 9*).

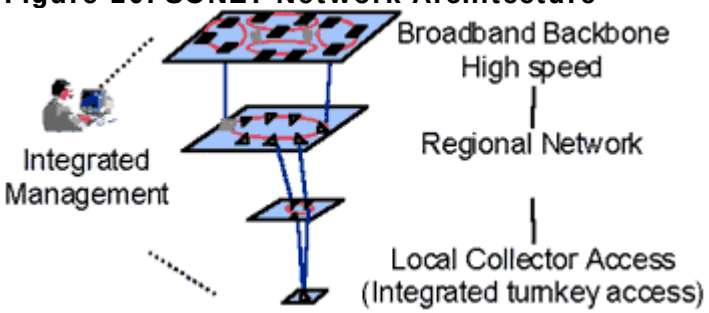
Figure 9. ATM OC–3c Data Structure



7. SONET Network Architecture

SONET is not a simple replacement for asynchronous digital hierarchy. It is a network in its own right (i.e., reconfigurable, with embedded switches and centralized management that allow automated processes). See *Figure 10*.

Figure 10. SONET Network Architecture



SONET benefits are delivered through functionality. A transport network is hierarchical as a road network, comprised of small roads, medium-sized roads, and highways for long distance:

- Collector rings provide the network interface for all access applications, including local offices, private automatic branch exchange (PABX), access multiplexers, wireless base stations, and ATM terminals. In some instances, a SONET multiplexer is located in the customer premises and provides direct service (T1 leased line, for instance).

- The bandwidth-management function routes, grooms, and consolidates traffic between the collectors and backbone networks. It ensures that backbone synchronous transport signal (STS–1) switch processing element (SPE) are filled to the maximum.

- The high-speed backbone transport function provides reliable and economical long-distance transport.

SONET Features

- network management
- protection
- bandwidth management
- network simplification
- mid-fibre meet

SONET Benefits

- increased revenues
- improved services
- differentiated services
- survivable network
- reduced operating cost
- centralized management
- reduced capital investment

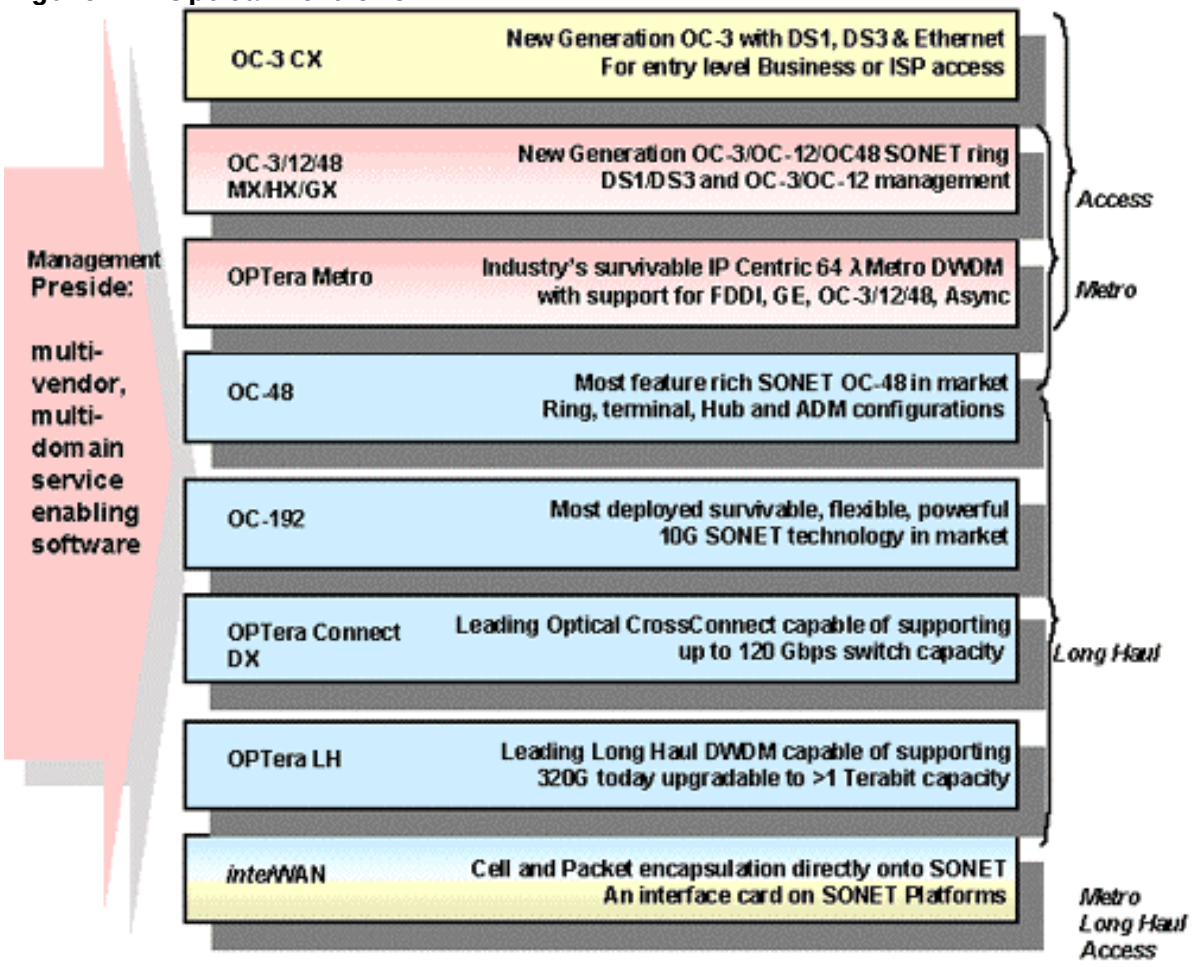
8. When Is a Separate SONET Layer Needed?

When assessing the need for SONET, certain parameters must be acknowledged. If any of the following are required, SONET is necessary:

- reliable transmission

- ultrafast protection mechanisms
- extensive monitoring
- fastest transmission speeds (10 Gbps)
- long-distance transmission (>120 km)
- multiplexing scalability (1.5 Mbps to 10 Gbps)
- global reach (optical amplifiers and regenerators)
- optical layer integration

Figure 11. Optical Portfolio



Self-Test

1. Synchronous optical network offers cost-effective transport in the access area but not the core of the network.

    a. true

    b. false

2. With SONET, the traffic flowing in and out of a node is exactly equal.

    a. true

    b. false

3. With SONET, multiplexing is _____.

    a. statistical

    b. TDM

4. Asynchronous digital hierarchy uses a _____ connection.

    a. point-to-point

    b. flexible

5. A terminal MUX is the only type of equipment available for _____ transmission.

    a. synchronous

    b. asynchronous

6. Maximum link resilience is achieved if the link and its duplicate are routed _____.

    a. separately

    b. together

7. _____ is the standard for North America, while _____ is the standard for the rest of the world.

    a. SONET; SDH

    b. SDH; SONET

8. The c in OC–3c stands for _____.

   a. carrier

   b. cellular

   c. concatenated

   d. cyclic

9. SONET is a simple replacement for asynchronous digital hierarchy.

   a. true

   b. false

10. Which of the following functions provide(s) the network interface for all access applications?

    a. bandwidth-management

    b. backbone transport

    c. collector rings

Correct Answers

1. Synchronous optical network offers cost-effective transport in the access area but not the core of the network.

   a. true

   b. false

   See Definition.

2. With SONET, the traffic flowing in and out of a node is exactly equal.

   a. true

   b. false

   See Topic 2.

3. With SONET, multiplexing is _____.

   a. statistical

b. TDM

See Topic 2.

4. Asynchronous digital hierarchy uses a _____ connection.

a. point-to-point

b. flexible

See Topic 4.

5. A terminal MUX is the only type of equipment available for _____ transmission.

a. synchronous

b. asynchronous

See Topic 4.

6. Maximum link resilience is achieved if the link and its duplicate are routed _____.

a. separately

b. together

See Topic 4.

7. _____ is the standard for North America, while _____ is the standard for the rest of the world.

a. SONET; SDH

b. SDH; SONET

See Topic 5.

8. The c in OC–3c stands for _____.

a. carrier

b. cellular

c. concatenated

d. cyclic

See Topic 6.

9. SONET is a simple replacement for asynchronous digital hierarchy.

a. true

b. false

See Topic 7.

10. Which of the following functions provide(s) the network interface for all access applications?

a. bandwidth-management

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c. collector rings

See Topic 7.

Glossary

ADM
add/drop multiplexer

ANSI
American National Standards Institute

ATM
asynchronous transfer mode

DCS
digital cross-connect

MUX
multiplexer

OC
optical carrier

PABX
private automatic branch exchange

SDH
synchronous digital hierarchy

SONET
synchronous optical network

SPE
synchronous payload envelope

STS
synchronous transport signal

TDM
time division multiplexing

VC
virtual container

VT
virtual tributary