Communications Technology

Dr./ Ahmed Mohamed Rabie

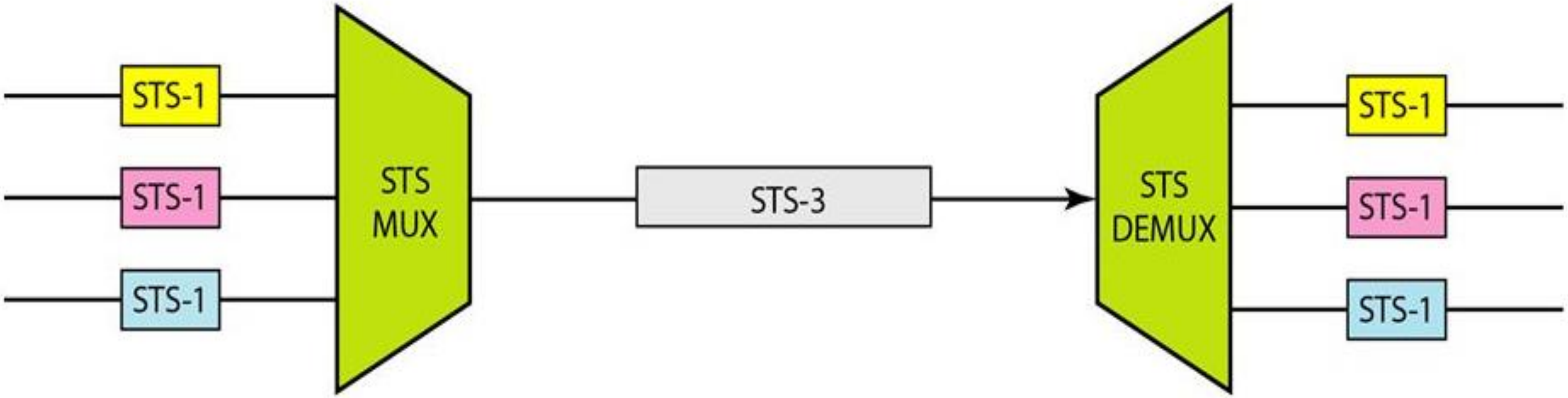
Chapter 2

SONET Network

STS Multiplexing

In SONET, frames of lower rate can be synchronously time-division multiplexed into a higher-rate frame. For example, three STS-l signals (channels) can be combined into one STS-3 signal (channel), four STS-3s can be multiplexed into one STS-12, and so on, Multiplexing is synchronous TDM, and all clocks in the network are locked to a master clock to achieve synchronization. In SONET, all clocks in the network are locked to a master clock.

STS multiplexing/demultiplexing

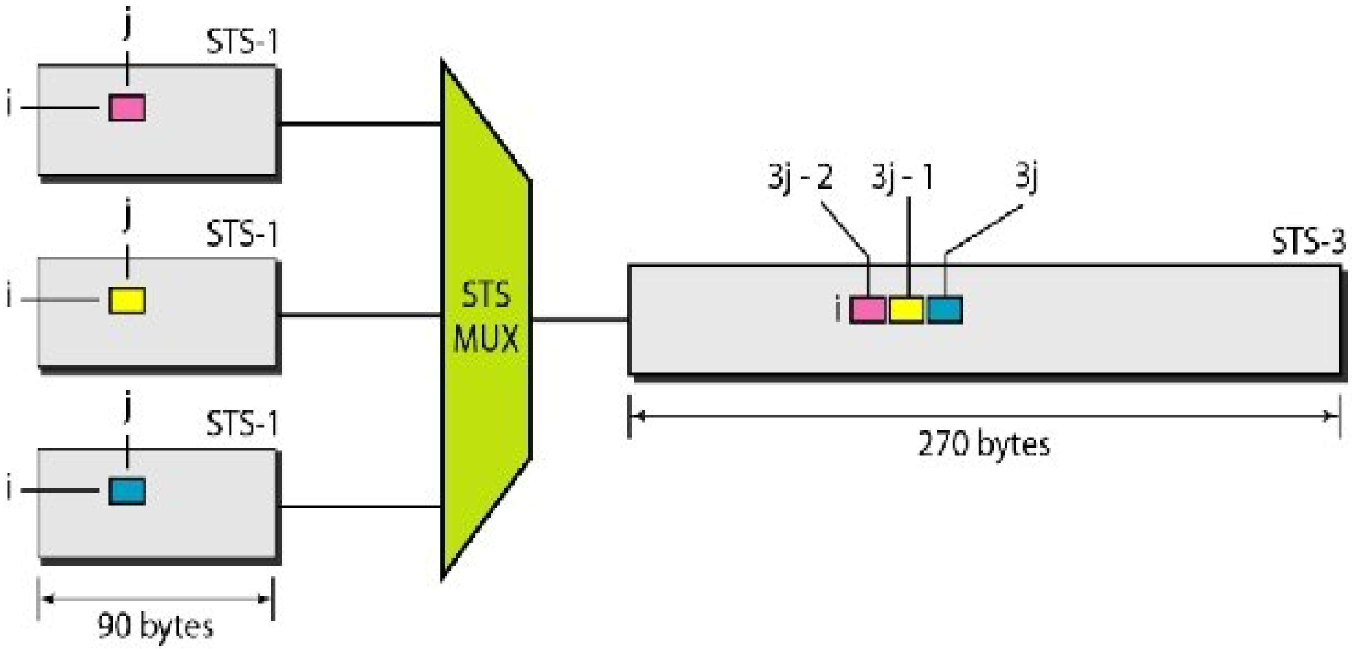


We need to mention that multiplexing can also take place at the higher data rates. For example, four STS-3 signals can be multiplexed into an STS-12 signal. However, the STS-3 signals need to first be demultiplexed into 12 STS-l signals, and then these twelve signals need to be multiplexed into an STS-I2 signal.

Byte Interleaving: Synchronous TDM multiplexing in SONET is achieved by using byte interleaving. For example, when three STS-1 signals are multiplexed into one STS-3 signal, each set of 3 bytes in the STS-3 signal is associated with 1 byte from each STS-1 signal.

V

Byte interleaving

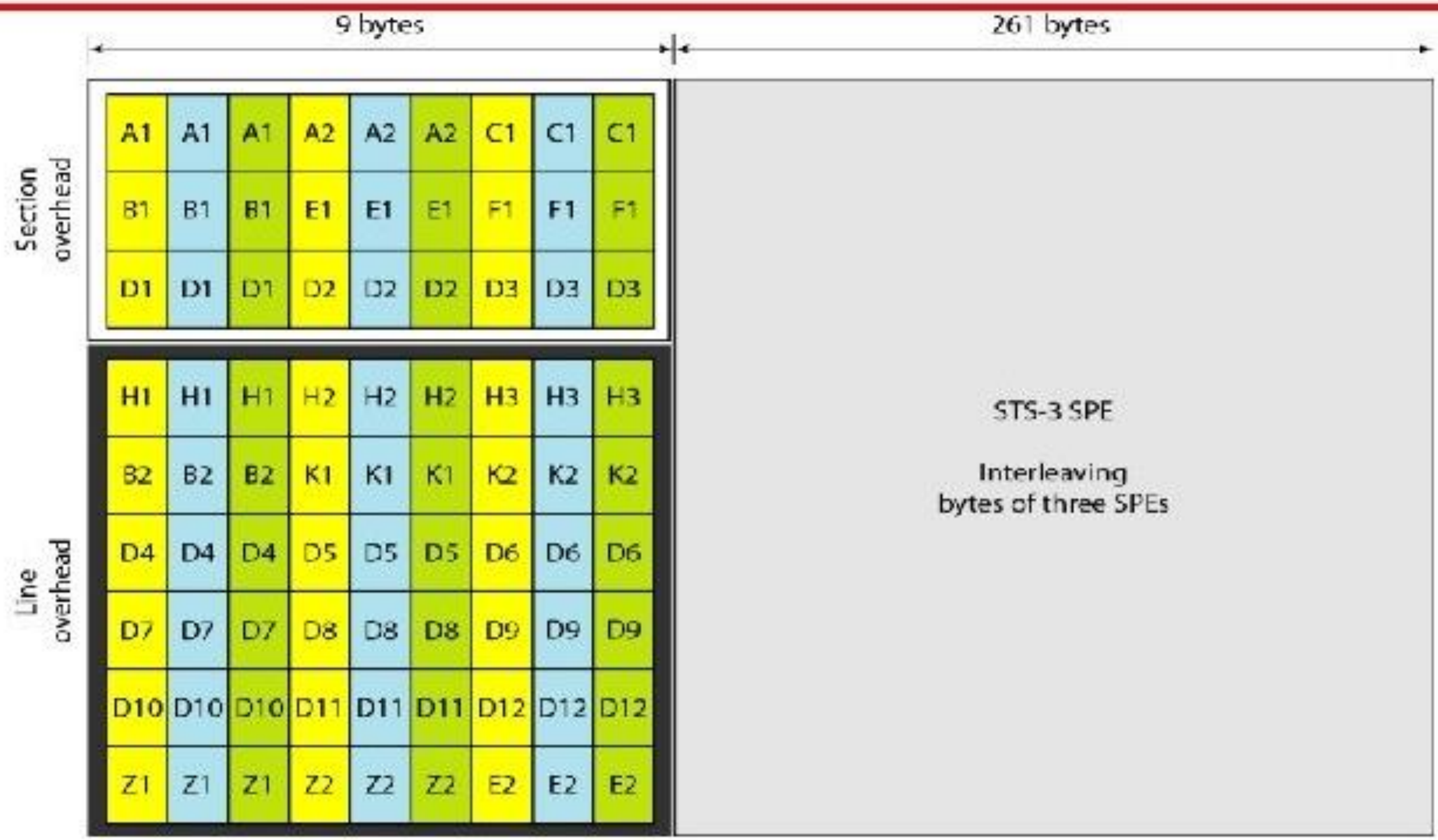


Note that a byte in an STS-1 frame keeps its row position, but it is moved into a different column. The reason is that while all signal frames have the same number of rows (9), the number of columns changes. The number of columns in an STS-n signal frame is n times the number of columns in an STS-1 frame. One STS-n row, therefore, can accommodate all n rows in the STS-1 frames.

Byte interleaving also preserves the corresponding section and line overhead. As the figure shows, the section overheads from three STS-1 frames are interleaved together to create a section overhead for an STS-1 frame. The same is true for the line overheads. Each channel, however, keeps the corresponding bytes that are used to control that channel. In other words, the sections and lines keep their own control bytes for each multiplexed channel.

This interesting feature will allow the use of add/drop multiplexers. As the figure shows, there are three Al bytes, one belonging to each of the three multiplexed signals. There are also three A2 bytes, three B1 bytes, and so on.

An STS-3 frame



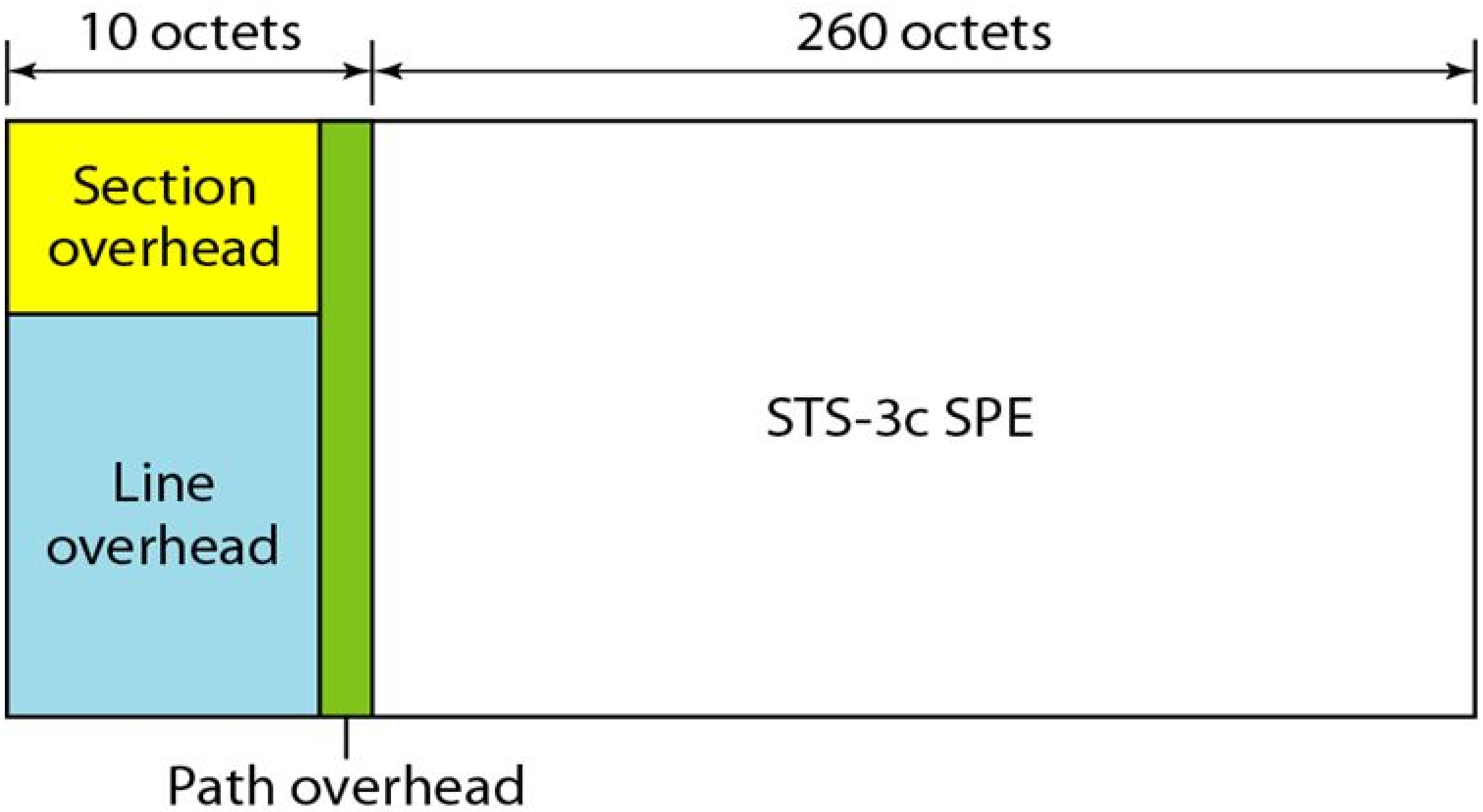
Demultiplexing here is easier than in the statistical TDM because the demultiplexer, with no regard to the function of the bytes, removes the first A1 and assigns it to the first STS-1, removes the second A1, and assigns it to second STS-l, and removes the third Al and assigns it to the third STS-I. In other words, the demultiplexer deals only with the position of the byte, not its function.

What we said about the section and line overheads does not exactly apply to the path overhead. This is because the path overhead is part of the SPE that may have splitted into two STS-1 frames. The byte interleaving, however, is the same for the data section of SPEs.

The byte interleaving process makes the multiplexing at higher data rates a little bit more complex. How can we multiplex four STS-3 signals into one STS-12 signal?. This can be done in two steps: First, the STS-3 signals must be demultiplexed to create 12 STS-l signals. The 12 STS-l signals are then multiplexed to create an STS-12 signal.

Concatenated Signal: In normal operation of the SONET, an STS-n signal is made of n multiplexed STS-1 signals. Sometimes, we have a signal with a data rate higher than what an STS-1 can carry. In this case, SONET allows us to create an STS-n signal which is not considered as n STS-l signals; it is one STS-n signal (channel) that cannot be demultiplexed into n STS-l signals. To specify that the signal cannot be demultiplexed, the suffix c (for concatenated) is added to the name of the signal.

A concatenated STS-3c signal



For example, STS-3c is a signal that cannot be demultiplexed into three STS-l signals. However, we need to know that the whole payload in an STS-3c signal is one SPE, which means that we have only one column (9 bytes) of path overhead. The used data in this case occupy 260 columns.

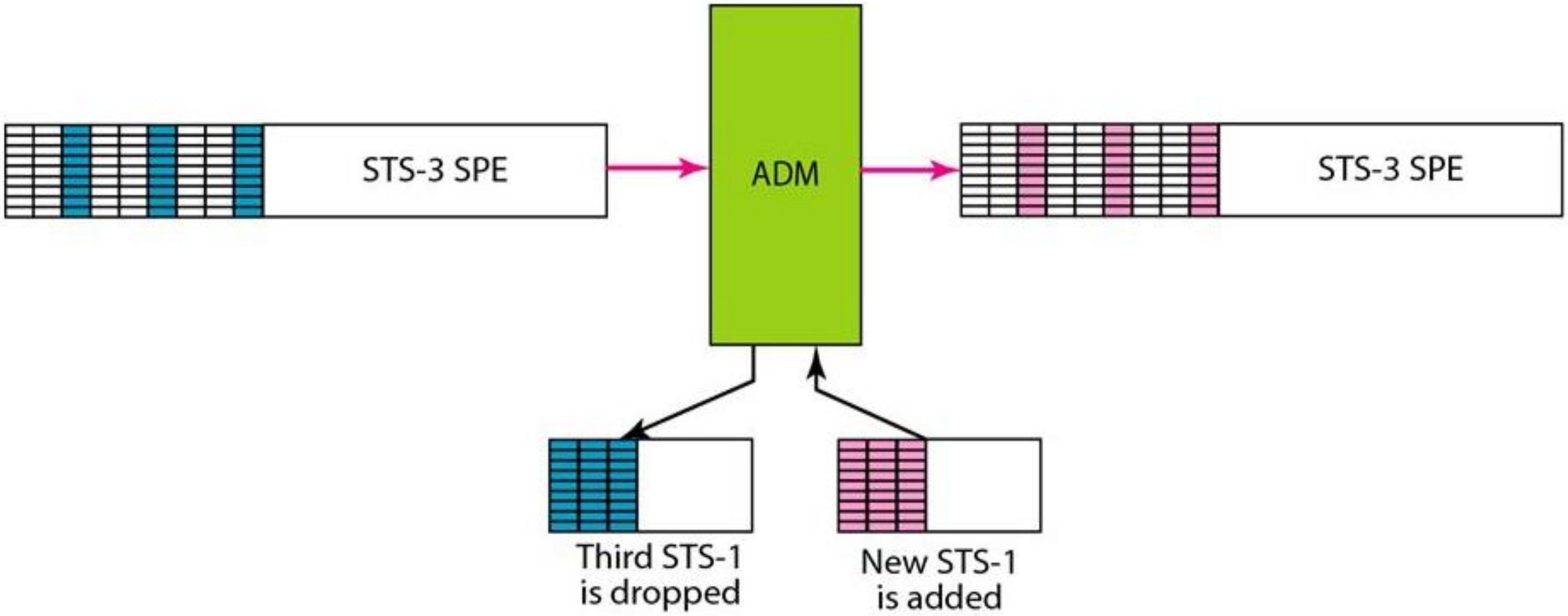
Concatenated Signals Carrying ATM Cells: An ATM network is a cell network in which each cell has a fixed size of 53 bytes. The SPE of an STS-3c signal can be a carrier of ATM cells. The SPE of an STS-3c can carry 9 x 260 =2340 bytes, which can accommodate approximately 44 ATM cells, each of 53 bytes. An STS-3c signal can carry 44 ATM cells as its SPE.

Add/Drop Multiplexer

Multiplexing of several STS-1 signals into an STS-n signal is done at the STS multiplexer (at the path layer). Demultiplexing of an STS-n signal into STS-1 components is done at the STS demultiplexer. In between, however, SONET uses add/drop multiplexers that can replace a signal with another one. We need to know that this is not demultiplexing/multiplexing in the conventional sense.

An add/drop multiplexer operates at the line layer. An add/drop multiplexer does not create section, line, or path overhead. It almost acts as a switch, it removes one STS-1 signal and adds another one. The type of signal at the input and output of an add/drop multiplexer is the same (both STS-3 or both STS-12, for example). The add/drop multiplexer (ADM) only removes the corresponding bytes and replaces them with the new bytes (including the bytes in the section and line overhead).

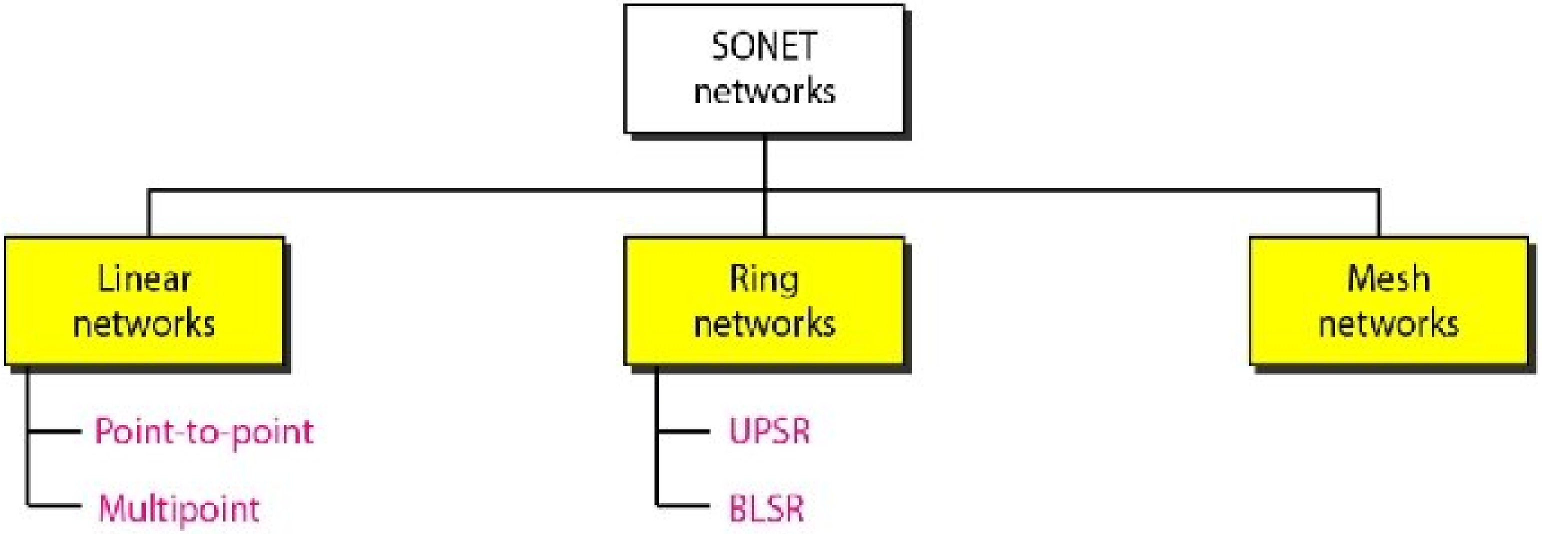
Dropping and adding STS-1 frames in an add/drop multiplexer



SONET Network

Using SONET equipment, we can create a SONET network that can be used as a high-speed backbone carrying loads from other networks such as ATM or IF. We can roughly divide **SONET networks** into three categories: linear, ring, and mesh networks.

Taxonomy of SONET networks

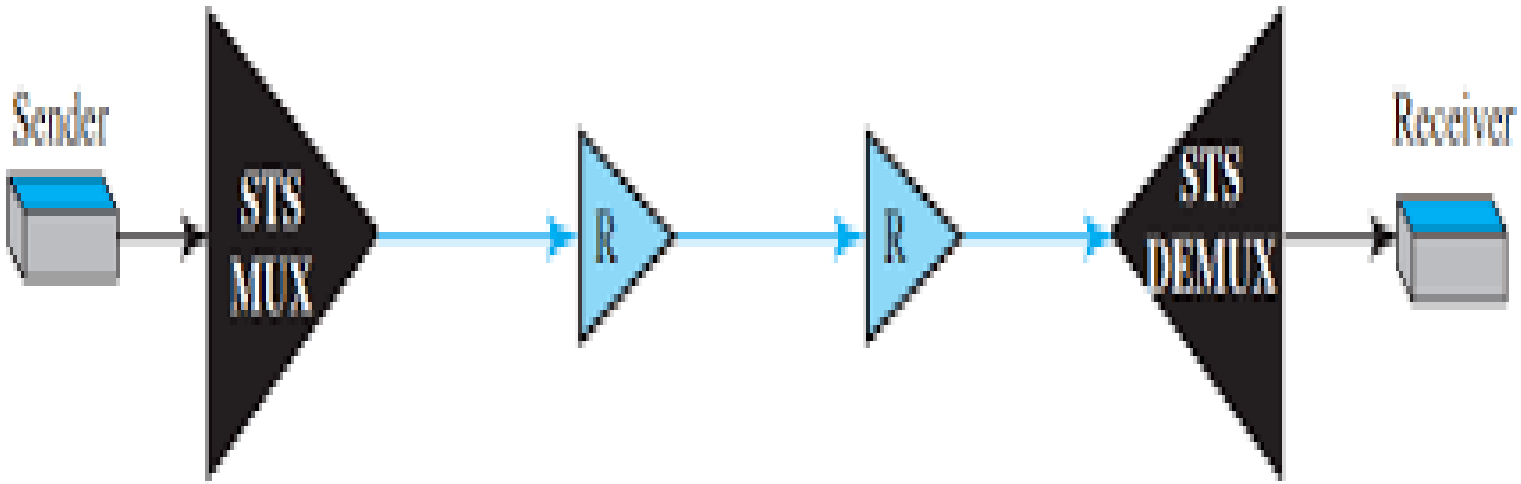


Linear Network

1- Linear Networks: A linear SONET network can be point-to-point or multipoint.

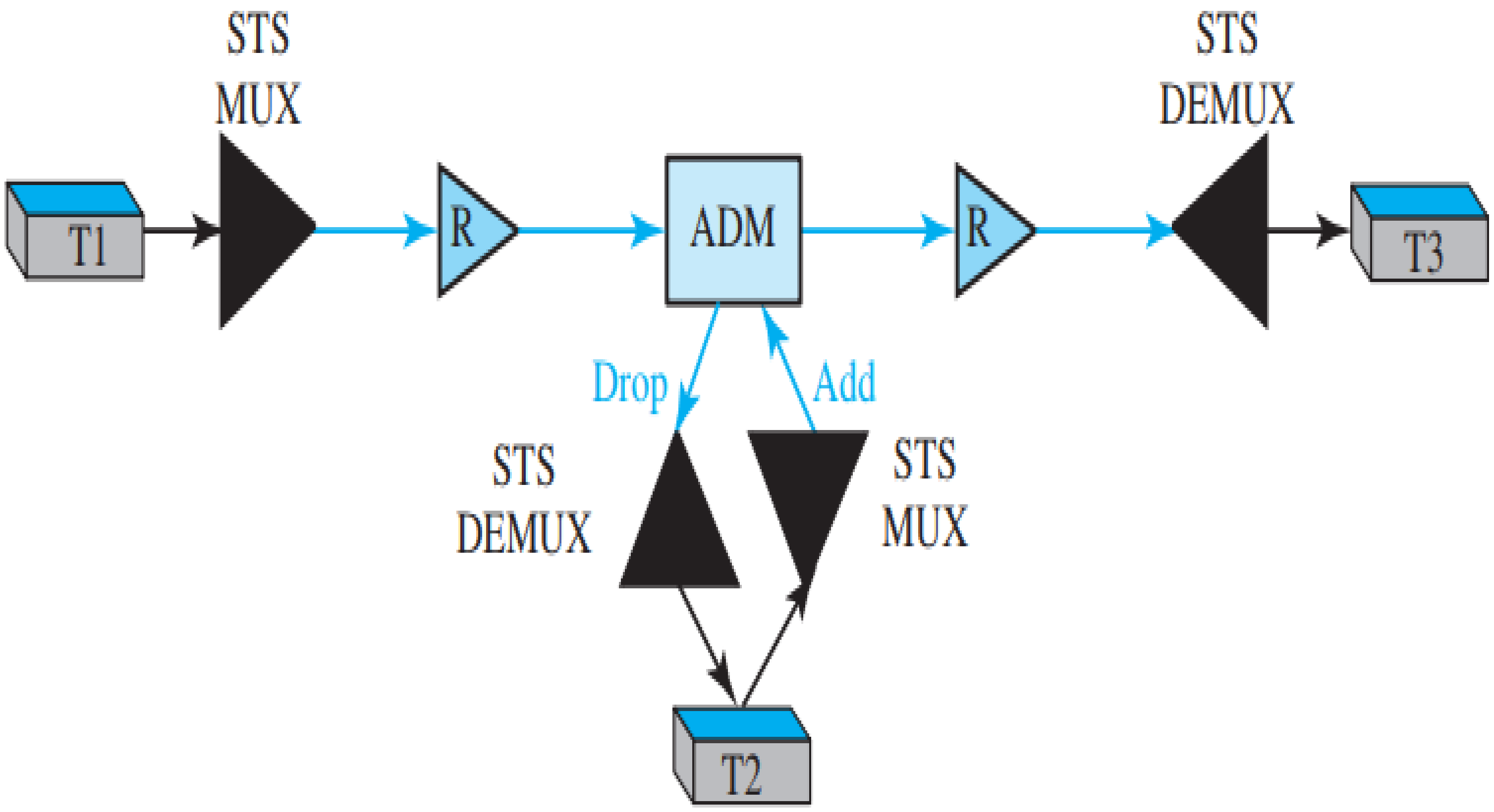
- Point-to-Point Network: A point-to-point network is normally made of an STS multiplexer, an STS demultiplexer, and zero or more regenerators with no add/drop multiplexers. The signal flow can be unidirectional or bidirectional, although Figure shows only unidirectional for simplicity.

Point-to-Point



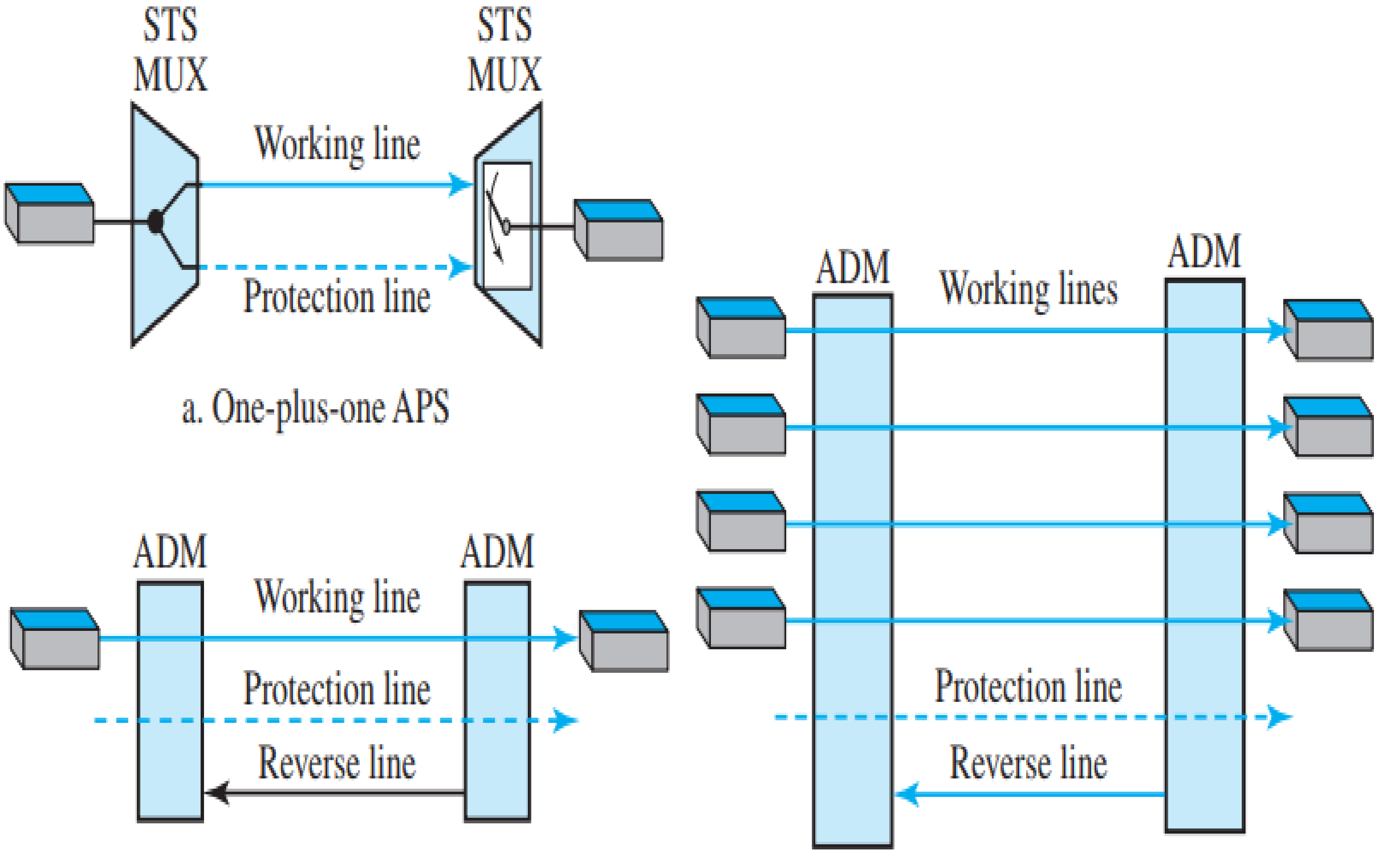
- Multipoint Network: A multipoint network uses ADMs to allow the communications between several terminals. An ADM removes the signal belonging to the terminal connected to it and adds the signal transmitted from another terminal. Each terminal can send data to one or more downstream terminals. Figure shows a unidirectional scheme in which each terminal can send data only to the downstream terminals, but the a multipoint network can be bidirectional, too.

Multipoint



In Figure, Tl can send data to T2 and T3 simultaneously. T2, however, can send data only to T3. The figure shows a very simple configuration; in normal situations, we have more ADMs and more terminals.

To create protection against failure in linear networks, SONET defines **automatic protection switching (APS)**. APS in linear networks is defined at the line layer, which means the protection is between two ADMs or a pair of STS multiplexer/demultiplexers. The idea is to provide redundancy; a redundant line (fiber) can be used in case of failure in the main one. The main line is referred to as the work line and the redundant line as the protection line. Three schemes are common for protection in linear channels: one-plus-one, one-to-one, and one-to-many.



a. One-plus-one APS

b. One-to-one APS

c. One-to-many APS

- **One-Plus-One APS** In this scheme, there are normally two lines: one working line and one protection line. Both lines are active all the time. The sending multiplexer sends the same data on both lines; the receiver multiplexer monitors the line and chooses the one with the better quality. If one of the lines fails, it loses its signal, and, of course, the other line is selected at the receiver. Although, the failure recovery for this scheme is instantaneous, the scheme is inefficient because two times the bandwidth is required. Note that one-plus-one switching is done at the path layer.

- **One-to-One APS** In this scheme, which looks like the one-plus-one scheme, there is also one working line and one protection line. However, the data are normally sent on the working line until it fails. At this time, the receiver, using the reverse channel, informs the sender to use the protection line instead. Obviously, the failure recovery is slower than that of the one-plus-scheme, but this scheme is more efficient because the protection line can be used for data transfer when it is not used to replace the working line. Note that the one-to-one switching is done at the line layer.

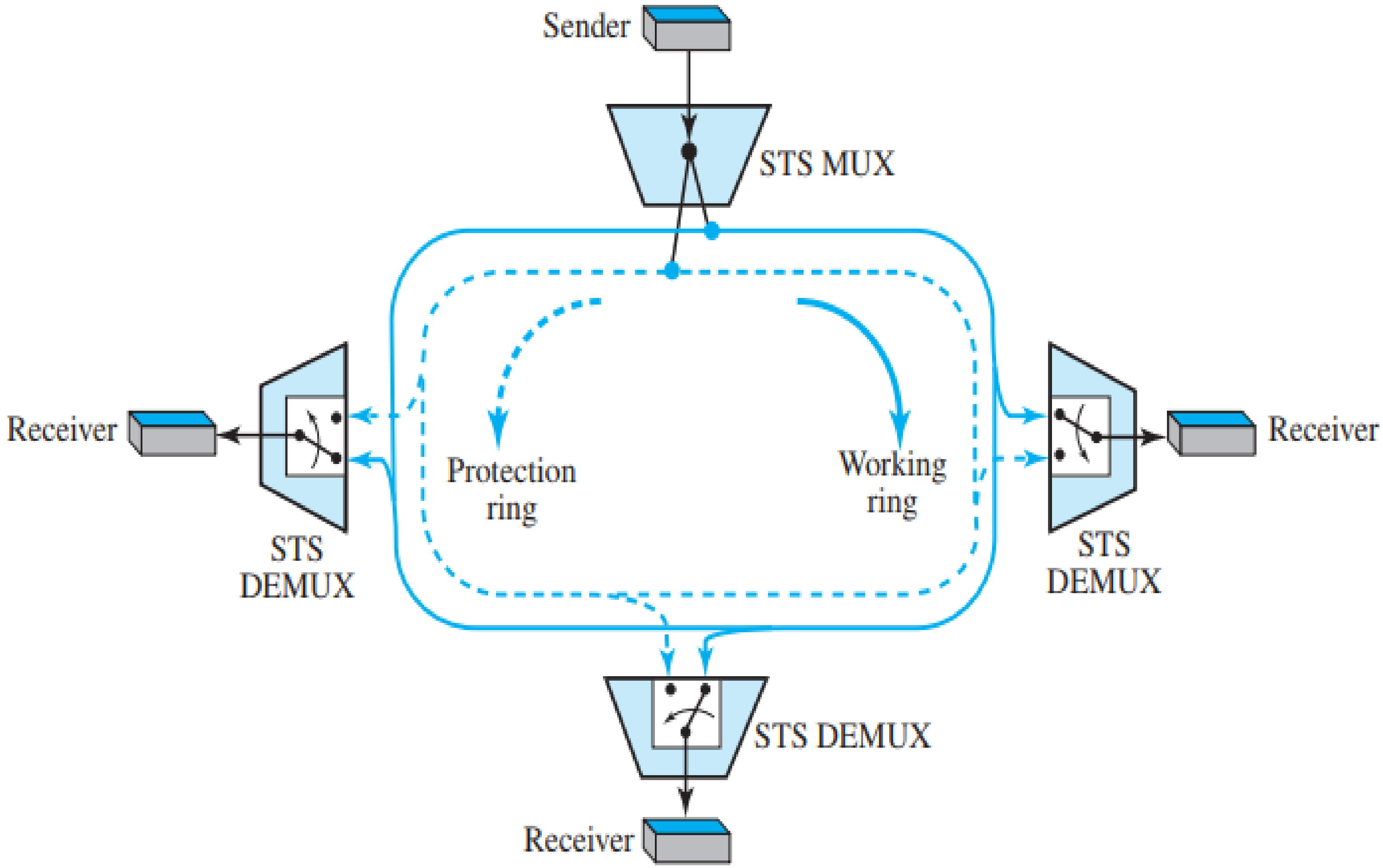
- **One-to-Many APS** This scheme is similar to the one-to-one scheme except that there is only one protection line for many working lines. When a failure occurs in one of the working lines, the protection line takes control until the failed line is repaired. It is not as secure as the one-to-one scheme because if more than one working line fails at the same time, the protection line can replace only one of them. Note that one-to-many APS is done at the line layer.

Ring Network

2- Ring Networks: ADMs make it possible to have SONET ring networks. SONET rings can be used in either a unidirectional or a bidirectional configuration. In each case, we can add extra rings to make the network self-healing, capable of self-recovery from line failure.

- **Unidirectional Path Switching Ring** A unidirectional path switching ring (UPSR) is a unidirectional network with two rings: one ring used as the working ring and the other as the protection ring. The idea is similar to the one-plus-one APS scheme. The same signal flows through both rings, one clockwise and the other counterclockwise. It is called **UPS**, because monitoring is done at the path layer.

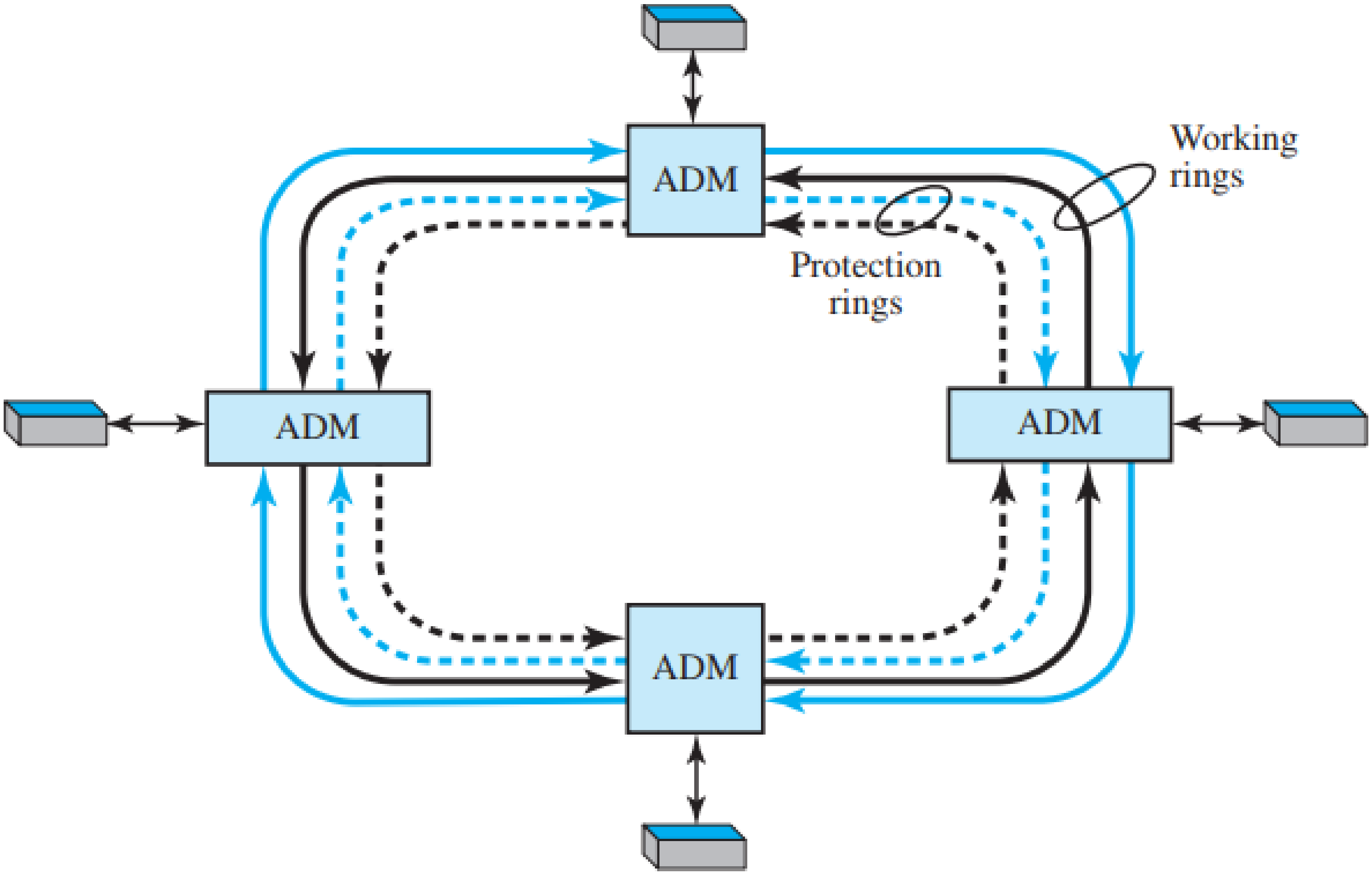
A node receives two copies of the electrical signals at the path layer, compares them, and chooses the one with the better quality. If part of a ring between two ADMs fails, the other ring still can guarantee the continuation of data flow. UPSR, like the one-plus-one scheme, has fast failure recovery, but it is not efficient because we need to have two rings that do the job of one. Half of the bandwidth is wasted. Figure shows a UPSR network.



unidirectional path switching ring

Although we have chosen one sender and three receivers in the figure, there can be many other configurations. The sender uses a two-way connection to send data to both rings simultaneously; the receiver uses selecting switches to select the ring with better signal quality. We have used one STS multiplexer and three STS demultiplexers to emphasize that nodes operate on the path layer.

- **Bidirectional Line Switching Ring:** Another alternative in a SONET ring network is bidirectional line switching ring (BLSR). In this case, communication is bidirectional, which means that we need two rings for working lines. We also need two rings for protection lines. This means BLSR uses four rings. The operation, however, is similar to the one-to-one APS scheme.

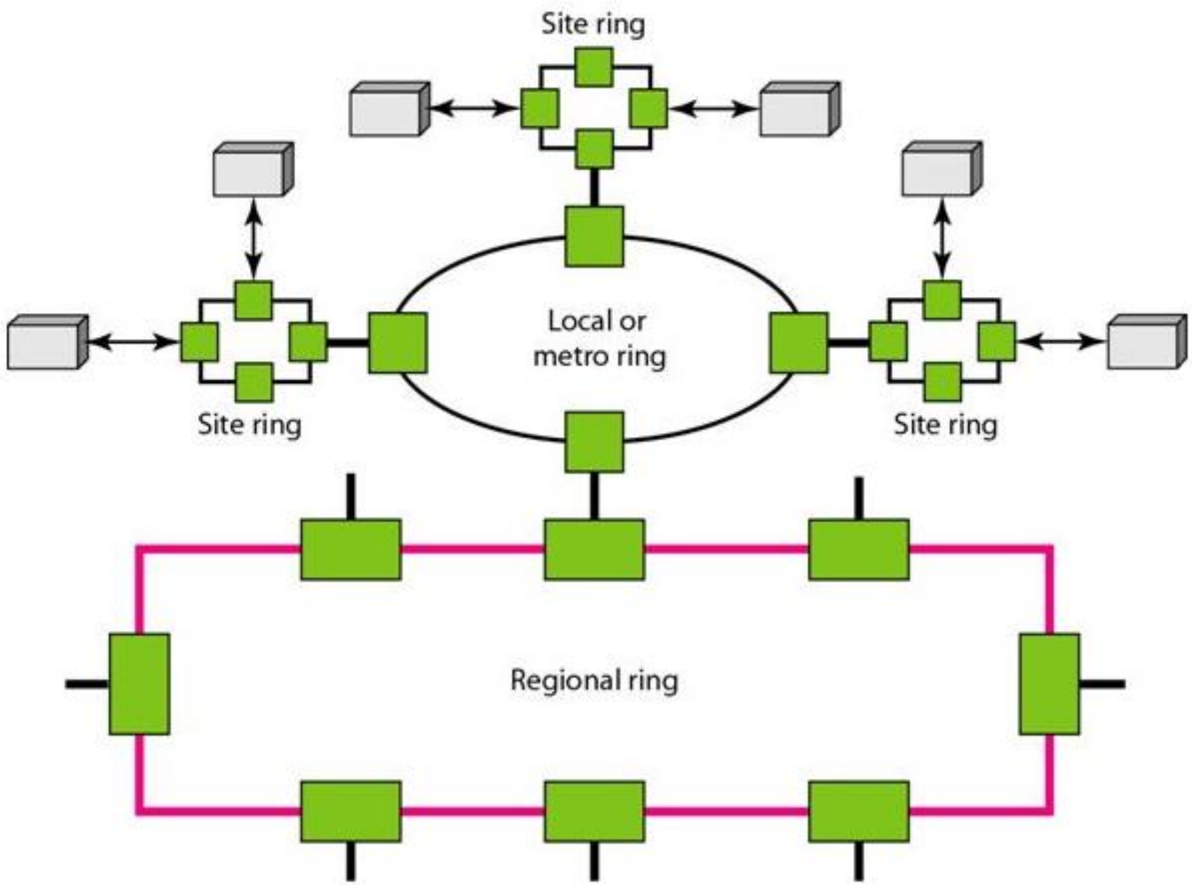


bidirectional line switching ring

If a working ring in one direction between two nodes fails, the receiving node can use the reverse ring to inform the upstream node in the failed direction to use the protection ring. The network can recover in several different failure situations. Note that the discovery of a failure in BLSR is at the line layer, not the path layer. The ADMs find the failure and inform the adjacent nodes to use the protection rings. Figure shows a BLSR ring.

Combination of Rings: SONET networks today use a combination of interconnected rings to create services in a wide area. For example, a SONET network may have a regional ring, several local rings, and many site rings to give services to a wide area. These rings can be UPSR, BLSR, or a combination of both. Figure shows the idea of such a wide-area ring network.

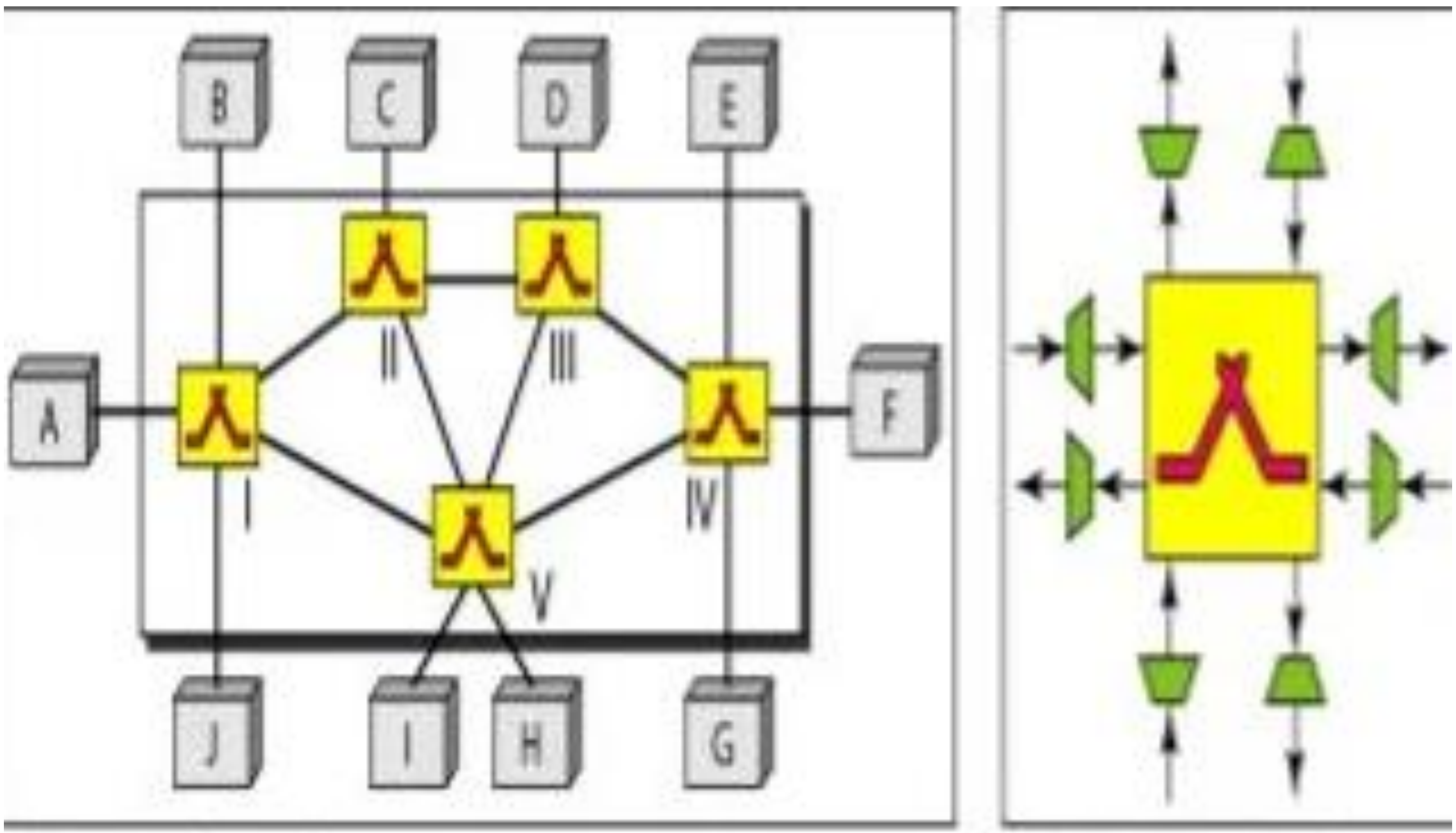
A combination of rings in a SONET network



Mesh Network

Mesh Networks: One problem with ring networks is the lack of scalability. When the traffic in a ring increases, we need to upgrade not only the lines, but also the ADMs. In this situation, a mesh network with switches probably give better performance. A switch in a network mesh is called a cross-connect. A cross-connect, like other switches we have seen, has input and output ports.

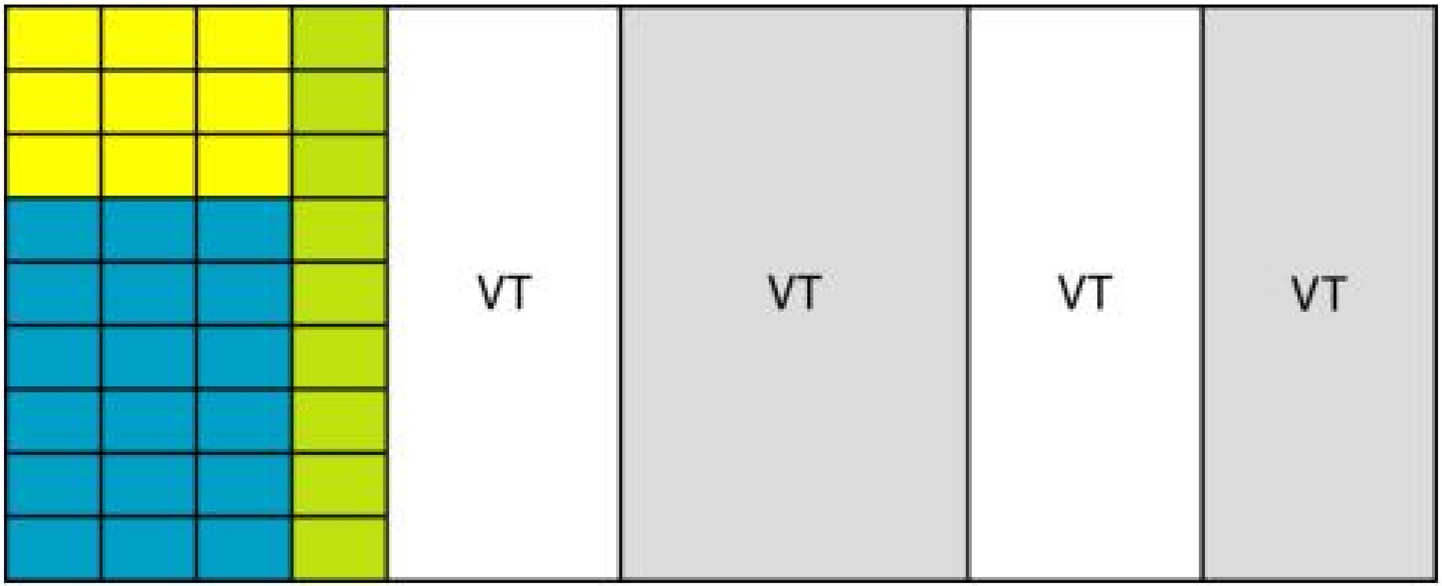
In an input port, the switch takes an OC-n signal, changes it to an STS-n signal, demultiplexes it into the corresponding STS-1 signals, and sends each STS-1 signal to the appropriate output port. An output port takes STS-1 signals coming from different input ports, multiplexes them into an STS-n signal, and makes an OC-n signal for transmission. Figure shows a mesh SONET network, and the structure of a switch.



a. SONET mesh network   b. Cross-connect switch

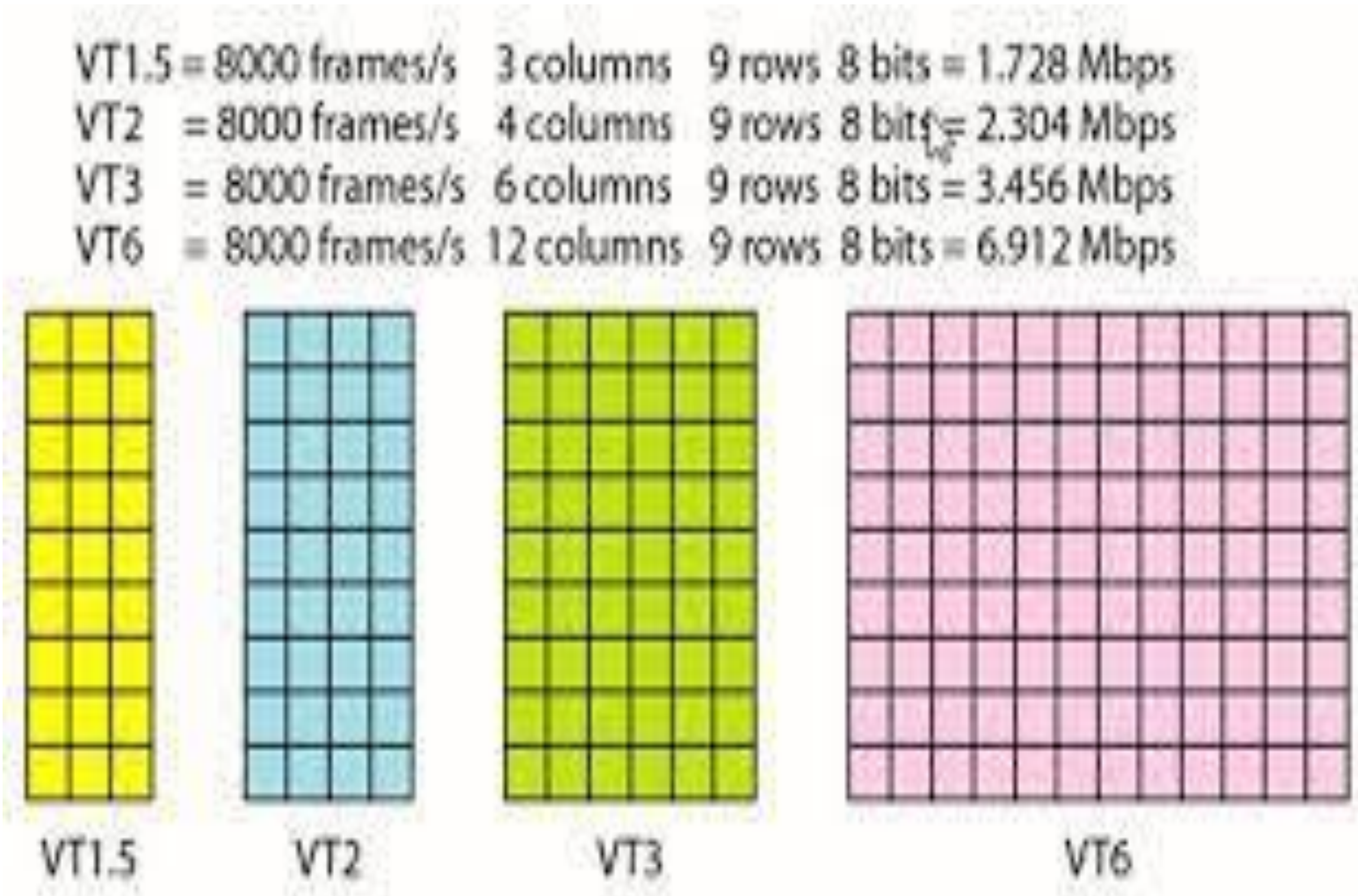
Virtual Tributaries

SONET is designed to carry broadband payloads. Current digital hierarchy data rates (DS-1 to DS-3), however, are lower than STS-l. To make SONET backward-compatible with the current hierarchy, its frame design includes a system of **virtual tributaries (VTs)**. A virtual tributary is a partial payload that can be inserted into an STS-1 and combined with other partial payloads to fill out the frame. Instead of using all 86 payload columns of an STS-1 frame for data from one source, we can subdivide the SPE and call each component a VT.


VT
VT
VT
VT

Types of VTs: Four types of VTs have been defined to accommodate existing digital hierarchies. Notice that the number of columns allowed for each type of VT can be determined by doubling the type identification number (VT1.5 gets three columns, VT2 gets four columns, etc.).

- VT1.5 accommodates the U.S. DS-1 service (1.544 Mbps).
- VT2 accommodates the European CEPT-l service (2.048 Mbps).
- VT3 accommodates the DS-1C service (fractional DS-l, 3.152 Mbps).
- VT6 accommodates the DS-2 service (6.312 Mbps).


VT1.5 = 8000 frames/s 3 columns 9 rows 8 bits = 1.728 Mbps
VT2 = 8000 frames/s 4 columns 9 rows 8 bits = 2.304 Mbps
VT3 = 8000 frames/s 6 columns 9 rows 8 bits = 3.456 Mbps
VT6 = 8000 frames/s 12 columns 9 rows 8 bits = 6.912 Mbps
VT1.5
VT2
VT3
VT6

When two or more tributaries are inserted into a single STS-1 frame. they are interleaved column by column. SONET provides mechanisms for identifying each VT and separating them without demultiplexing the entire stream.

SONET Benefits

The most common **advantages of SONET optical network** include the following:

- Lower cost of equipment for transmitting signals over vast distances while maintaining their quality.
- A higher level of network connectivity.
- Increased efficiency irrespective of the type of traffic being transmitted
- Smoother connectivity between different network service providers or Telecom carriers.

- This technology comes with a highly flexible architecture making it compatible with current as well as legacy systems.
- One of the biggest advantages of the SONET optical network is that it offers easy multiplexing as well as de-multiplexing features.
- Resources need not be present on-site to look after the operational requirements as this can work efficiently in a remote operating environment as well.
- SONET offers standard optical interference and out of band management systems.