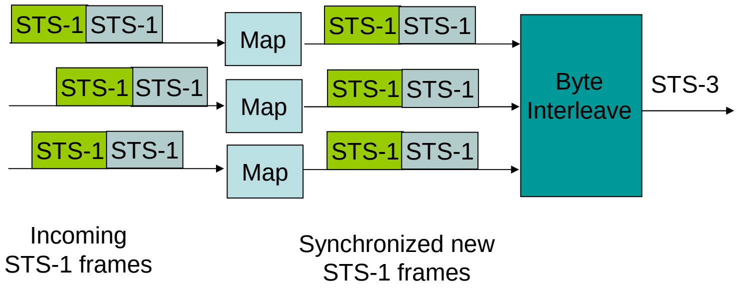
SONET Frame Structure

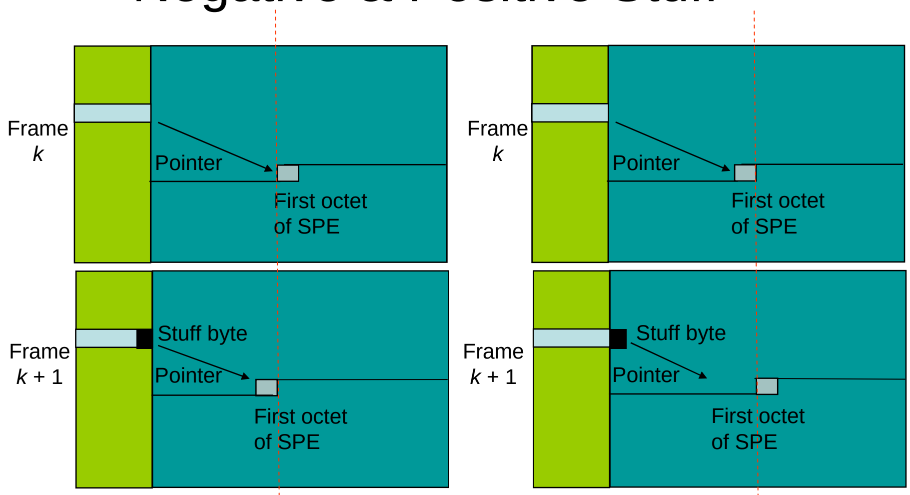


- When n STS-1 signals are multiplexed, they are first synchronized to the clock of the multiplexer. Need to be done at the boundary of SONET. In the SONET, we assume all streams are synchronized.

SONET Frame Structure

- Negative byte stuffing:
  When the payload stream is faster than the frame rate, H_3 is used to transmit an extra SPE byte from time to time. The H_1H_2 pointer is decreased by one in the next frame.
- Positive byte stuffing:
  When the payload stream is slower than the frame rate, the byte immediately follows the H_3 byte is used as a stuff byte (byte with dummy information) from time to time. The H_1H_2 pointer is increased by one in the next frame.

Negative & Positive Stuff



(a) Negative byte stuffing
Input faster than output
Send extra byte in H3 to catch up

(b) Positive byte stuffing
Input is slower than output
Stuff byte to fill gap

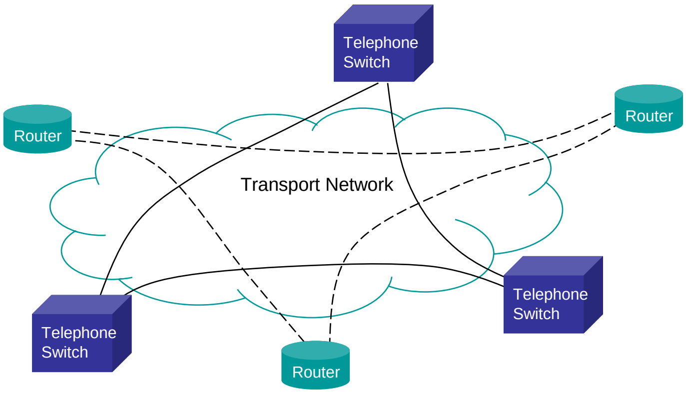
Speed Mapping

1. Virtual tributary: *84* = *7* groups of *12* columns in a SPE.
   – Each group is a virtual tributary.
   – *12 x 9 x 8000 x 8 = 6.912 Mbps*
   – Can accommodate *4 T1* signals. *4 x 1.544 < 6.912*
2. a single SPE can handle one DS3 signal. (*44.736 Mbps*)
3. concatenated STS-1 frames
   – E.g. STS-3C., carries only one column of path overhead.
   – So:
     - STS-3C: *87 x 3 – 1 = 260 columns of user data.*
     - STS-3: *86 x 3 = 258 columns of user data.*

4.3 Transport Networks

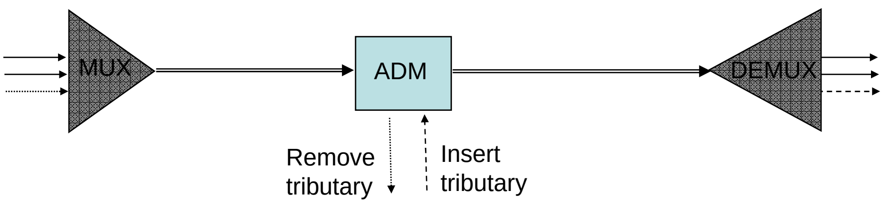
- Transport Network:
  - Form the backbone of multiple, independent networks.
  - Need to be designed to be very resilient with respect to faults.

  1 STS-1 = 783 voice calls; 1 OC-48 = 32000 voice calls



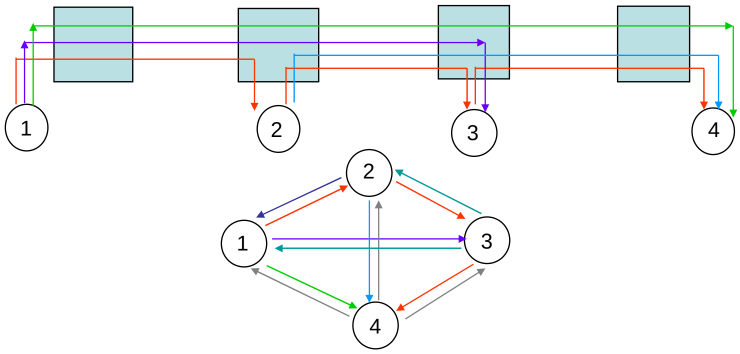
4.3.1 SONET Networks

- “Asynchronous” multiplexing systems (prior to SONET): requires the entire multiplexed stream to be de-multiplexed to access a single tributary.
- SONET: add-drop multiplexer (ADM)
  - can insert and extract tributary streams without disturbing tributary streams that are in transit.



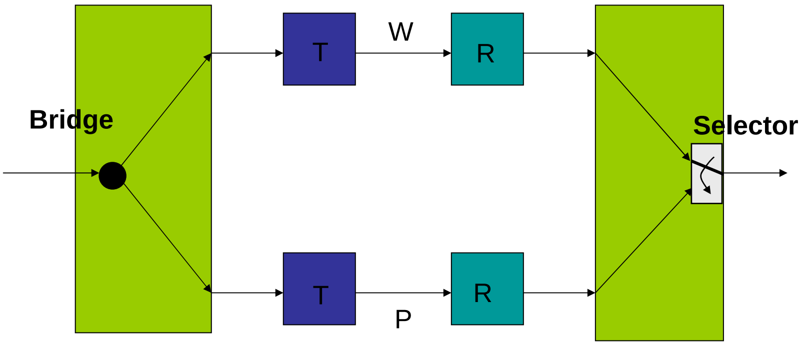
Linear SONET Networks

- Linear SONET Networks.
  - Fig 4.18. (a). (b)
    - (a) Physically linear topology
    - (b) logically: fully connected mesh
  - SONET ADMS can be used to create different “Virtual” topologies



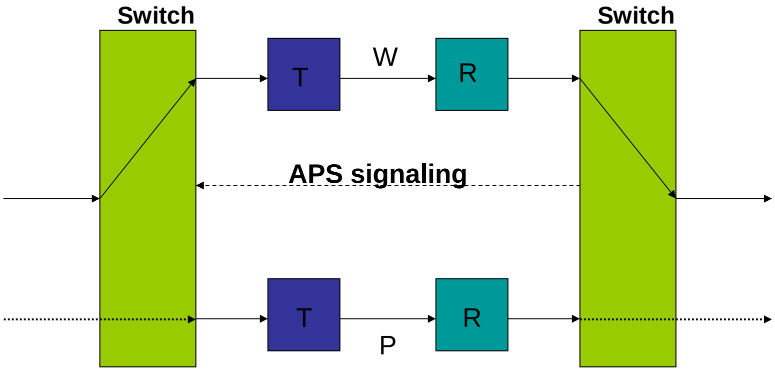
Automatic Protection Switching

- Provide linear protection against failures at the line layer
- Fig 4.19: A working line and a protection line
  - Operate in parallel to provide 1+1 (one plus one) linear APS protection
  - inefficient: use twice the bandwidth



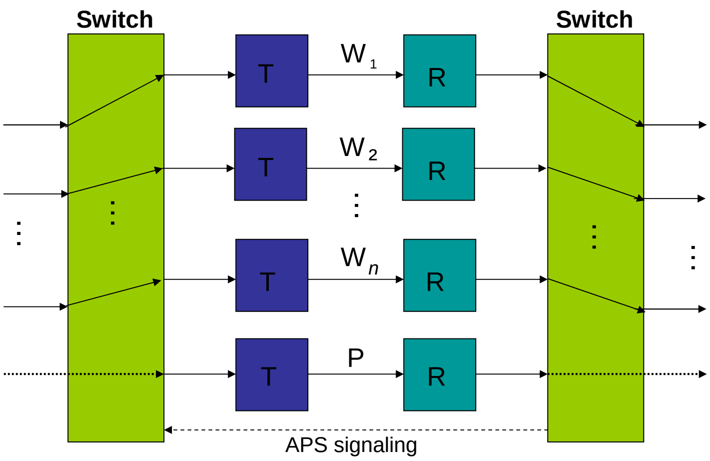
Automatic Protection Switching

– Fig 4.20: 1:1 linear APS protection (one for one)
  - The signal is only transmitted in the working line during normal operation. the protection line can be used to carry extra traffic
  - The extra traffic is pre-empted when there is a failure. Need more time to recover from failure than 1+1. but more efficient in bandwidth usage.



Automatic Protection Switching

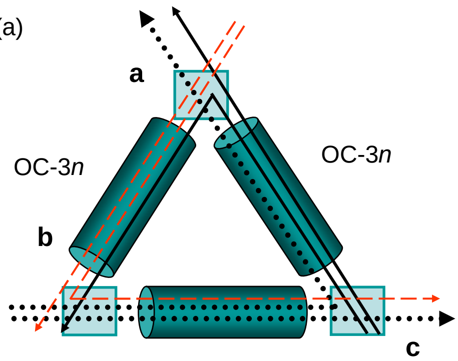
– Fig 4.21: 1:n linear APS protection



Ring Networks

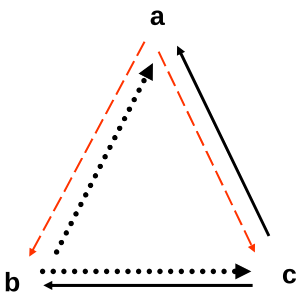
– Fig 4.22: ring topology networks
– Fig 4.23: logically fully connected topology.
– Self-healing rings: line level, path level

(a)



Three ADMs connected in physical ring topology

(b)

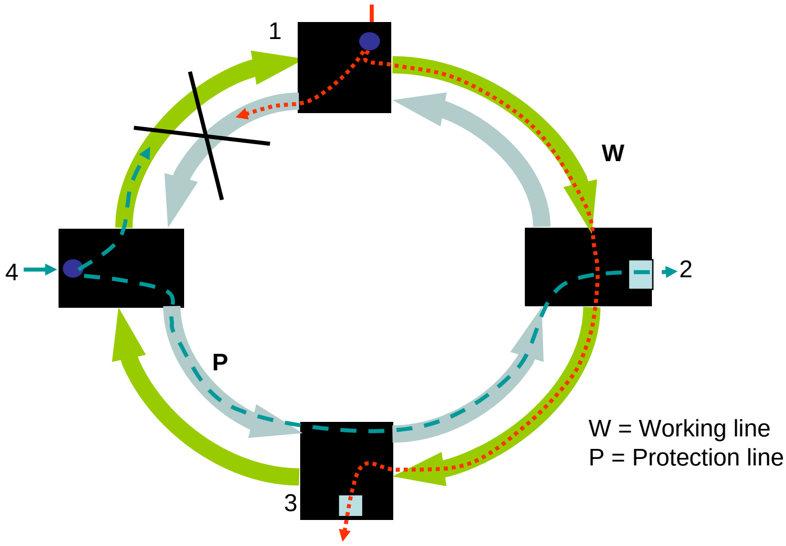


Logical fully connected topology

Ring Networks

- UPSR: unidirectional path switched ring provides protection at the path level
  - Fig 4.24: two-fiber ring.
    - Working traffic: clockwise
    - Protection traffic: counter clockwise
  - 1+1 protection at path level
  - Each exit node monitors the two received path signals and selects the better one
  - Fast path protection but inefficient in bandwidth usage. Used widely in the lower speed rings in the access portion of networks

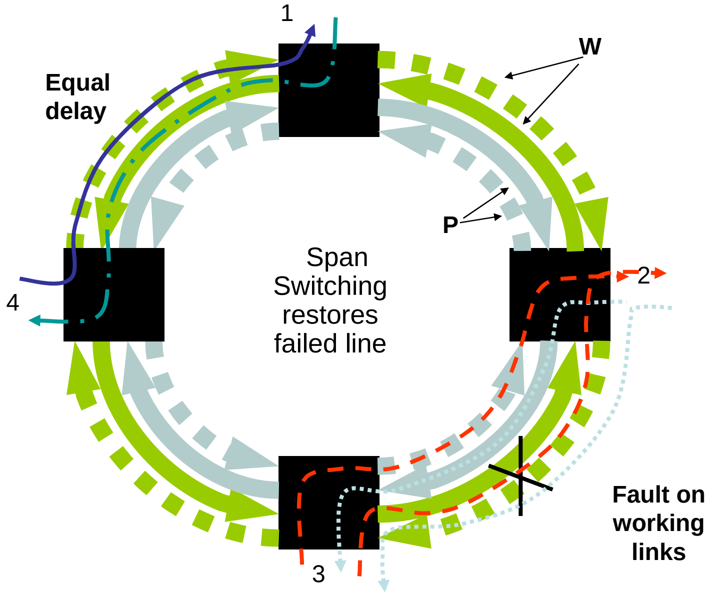
UPSR path recovery



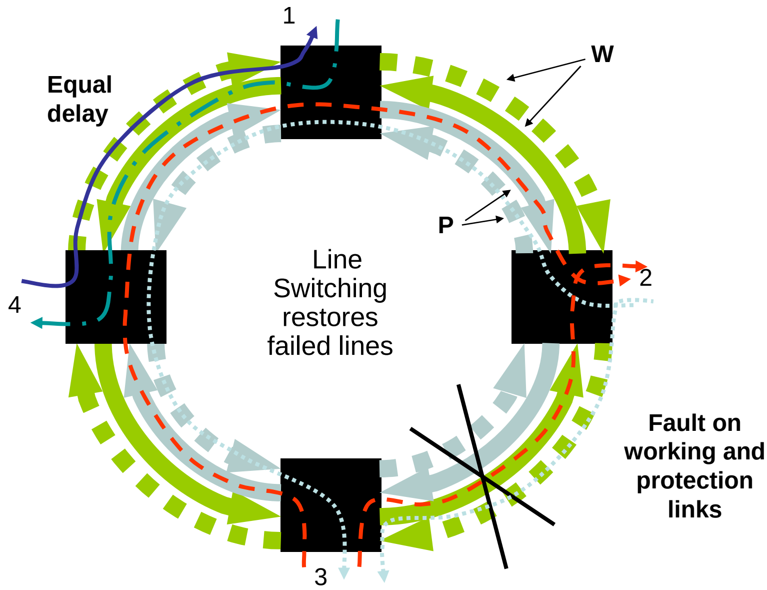
Ring Networks

- BLSR: bidirectional line switched ring provides protection at the line level
  - Adjacent ADMs are connected by a working fiber pair and a protection fiber pair
  - Fig 4.27: the working pair fails between node 2 and 3
    $\Rightarrow$ switch both working channels to the protection channels span switching
  - Fig 4.28: both working pair and protection pair fail.
    Use the protection pair in the direction away from the failure ring switching
  - More efficient than UPSR: traffic can be routed along the shortest path, the protection fibers can be used to carry extra traffic when no failures.
  - BLSR is preferred in high-speed backbone networks
  - Disadvantage: requires complex signalling

BLSR Span Switching



BLSR Ring Switching

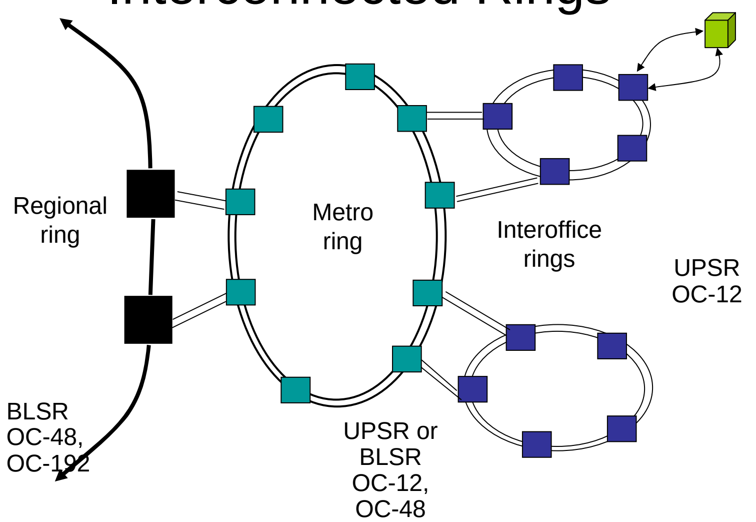


Interconnected ring networks

- Fig 4.29
- To provide protection against faults, rings may be interconnected using matched inter-ring gateways:
  primary gateway
  secondary gateway
- Ring networks are difficult to manage in as environment of rapid growth. To increase the capacity of a single span in a ring. All the ADMs have to be upgraded.

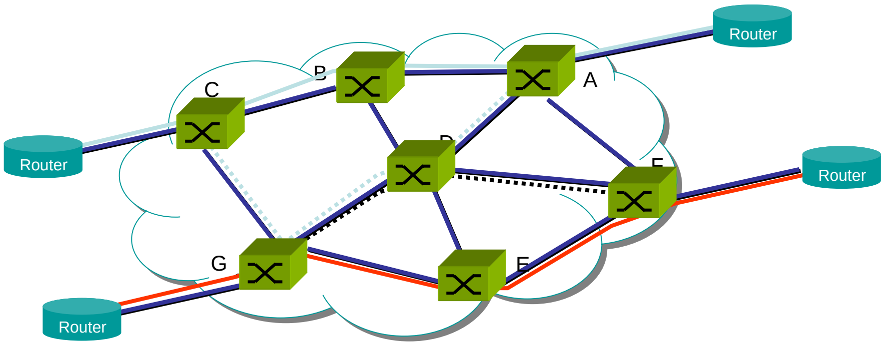
Managing 1 ring is simple; Managing many rings is very complex

Backbone Networks consist of Interconnected Rings



Mesh Topology Networks using SONET Cross-Connects

- Cross-Connects are nxn switches
- Interconnects SONET streams
- More flexible and efficient than rings
- Need mesh protection & restoration



4.3.2 Optical Transport Networks

Provide optical wavelength connections between attached clients

- OADM: optical Add-drop multiplexer (WDM system)
  - Ideally, all processing in OADM is performed in the optical domain. expensive optical-to-electrical conversion is avoided
  - Fig 4.31 (WDM linear and ring networks)
  - (similar to SONET networks)
  - In WDM, each wavelength is modulated separately, can carry different transmission format. e.g. one wavelength for SONET, one wavelength for Gigabit-Ethernet

4.3.2 Optical Transport Networks

- Optical cross-connect and optical fiber switching
  - Optical fiber switching: transfer entire-multi-wavelength signals from input ports to output ports without WDM de-multiplexing
  - Optical cross-connect: switch individual wavelength signals.
    - Fig 4.32: all optical fiber switch and cross-connect
    - The cost of demodulating a single WDM signal and processing its components in the electronic domain is extremely high

      ⇒ keep WDM signals in the optical domain as they traverse the network

Optical Switching