CS4/MSc

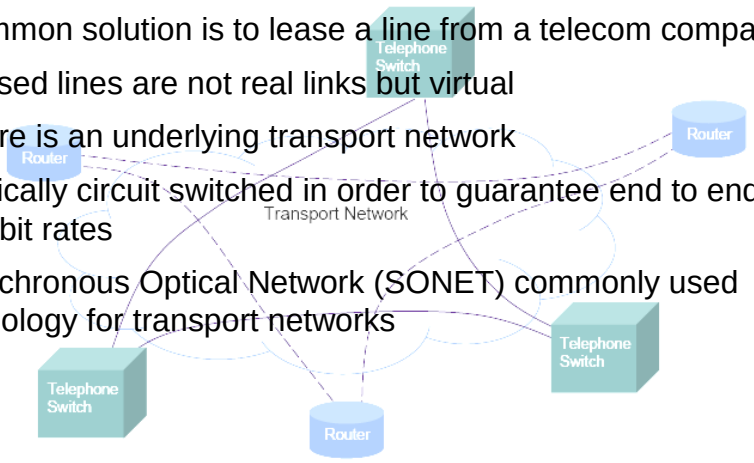
Computer Networking

Lecture 12

Transport Networks (SONET)
and circuit-switched networks

Transport Networks and SONET/SDH

- In most cases installing a new link is not practical
- Common solution is to lease a line from a telecom company
- Leased lines are not real links but virtual
- There is an underlying transport network
- Typically circuit switched in order to guarantee end to end fixed bit rates
- Synchronous Optical Network (SONET) commonly used technology for transport networks



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Transport network components

- Terminal
  - The point of connection for the user
- Multiplexor
  - Different flows are merged to share a high-speed link and flows diverge to their end terminal (Add Drop Multiplexors)
  - Essentially a simple switch
- Regenerator
  - Needed when signal level in the fibre becomes too low on long distance lines
- Link
  - Covered in previous lecture

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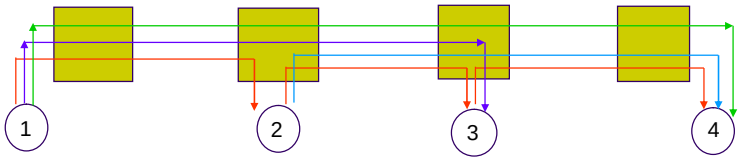
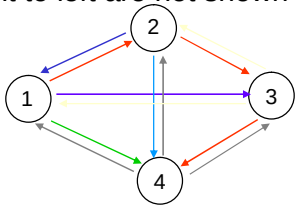
Linear ADM Topology

- ADMs connected in linear fashion
- Tributaries inserted and dropped to connect clients



- Tributaries traverse ADMs transparently
- Connections create a *logical* topology seen by clients
- Tributaries from right to left are not shown



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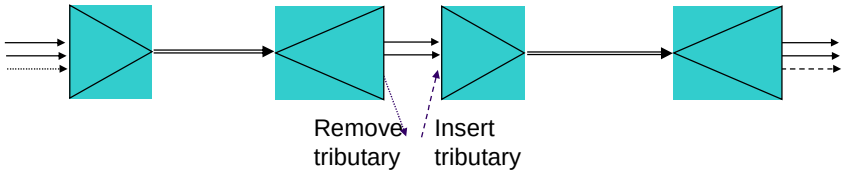
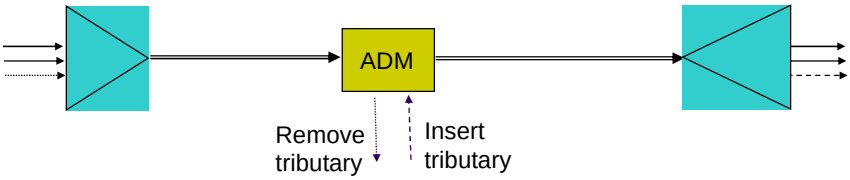
Add-Drop Multiplexors

- Individual tributaries in the multiplexed stream can be dropped and added independently of other tributaries
- Earlier systems required multiplexed streams to be demultiplexed before a tributary could be removed or added:



- SONET ADMs allow this without demultiplexing and remultiplexing:



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SONET – Synchronous Optical NETwork

- North American TDM physical layer standard for optical fiber communications
- CCITT SDH (Synchronous Digital Hierarchy) the same standard worldwide
- Used for long distance backbone networks
- 8000 frames/sec. (T_{frame} = 125 µsec)
  - Legacy from digital voice transmission: 4kHz voice bandwidth, Nyquist sampling, 8 bits per sample
- Overhead bytes to facilitate network management
  - Extensive capabilities for operations, administration and maintenance

IEC tutorial at: www.iec.org/online/tutorials/sonet/

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SONET digital hierarchy

STS-n : (Electrical) *Synchronous Transport Signal level n*

OC-n : *Optical Channel level n*

Frame time is constant, size increases in proportion to n

Electrical signal	Optical signal	Bit rate (Mbps)
STS-1	OC-1	51.84
STS-3	OC-3	155.52
STS-9	OC-9	466.56
STS-12	OC-12	622.08
STS-18	OC-18	933.12
STS-24	OC-24	1244.16
STS-36	OC-36	1866.24
STS-48	OC-48	2488.32
STS-192	OC-192	9953.28

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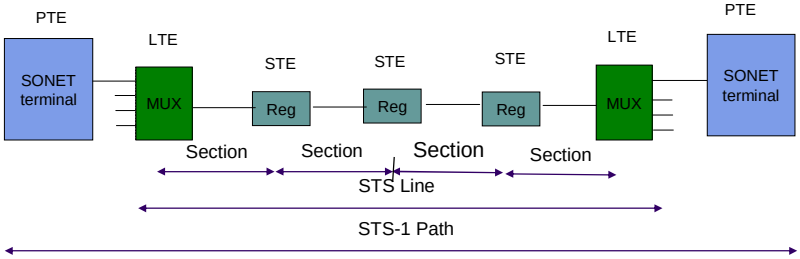
SONET network structure



STE = Section Terminating Equipment, e.g., a repeater/regenerator
LTE = Line Terminating Equipment, e.g., a STS-1 to STS-3 multiplexer
PTE = Path Terminating Equipment, e.g., an STS-1 multiplexer

- A *section* deals with transmission of STS-n signals across the physical medium
- A *line* refers to the span between two adjacent multiplexers
- A *path* is the span between two terminals, encompassing one or more lines

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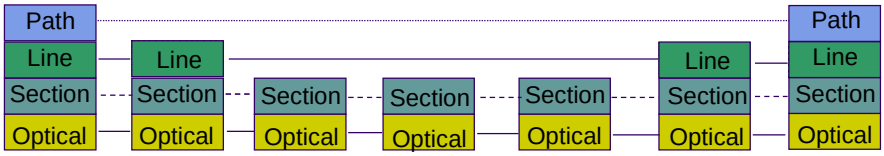
SONET network architecture

- Multiplexers associated with the path level work at a lower level of the STS-n hierarchy than the multiplexers at the line level
  - a typical information flow along a path starts at the edge of the network at a flow rate e.g. STS-1
  - this is then aggregated into higher flow rates within the network
  - and is delivered at the end-point back at the lower flow rate
- Each type of equipment works in both the electrical and optical domains
  - converts from optical to electrical on reception
  - converts from electrical to optical for onward transmission:



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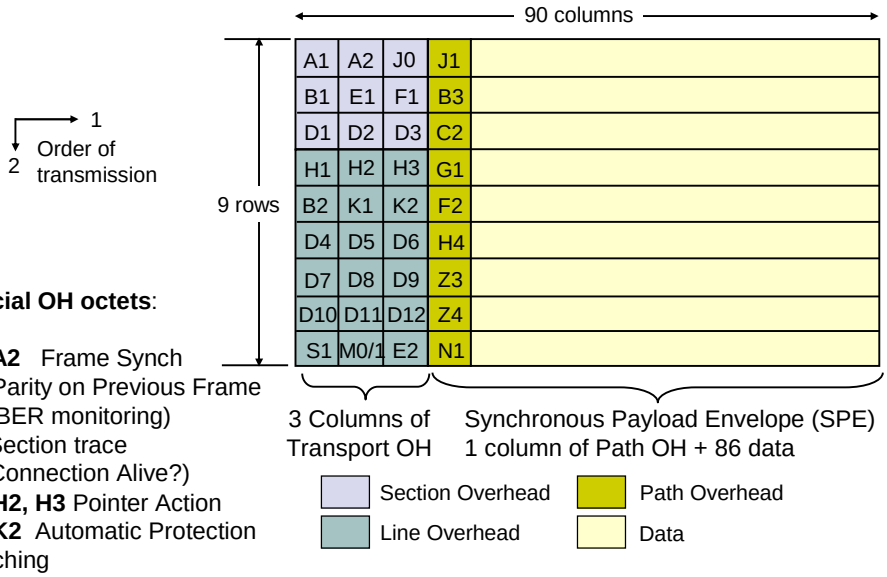
STS-1 Frame

810x64kbps=51.84 Mbps
810 Octets per frame @ 8000 frames/sec



Special OH octets:

A1, A2 Frame Synch
B1 Parity on Previous Frame (BER monitoring)
J0 Section trace (Connection Alive?)
H1, H2, H3 Pointer Action
K1, K2 Automatic Protection Switching

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STS-1 Frame – Payload Alignment

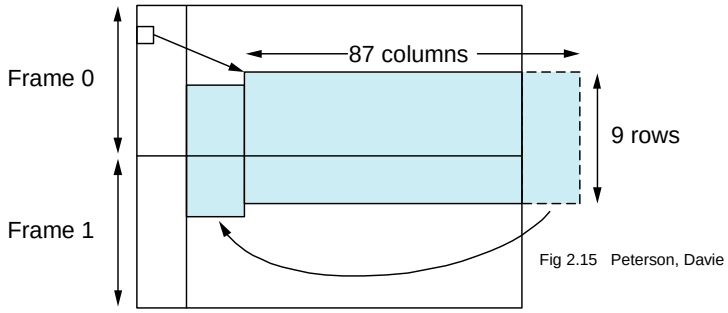

Fig 2.15 Peterson, Davie

– the SPE is *not* aligned with the STS-1 frame
  » H1 & H2 bytes point to first byte of the SPE
  » SPE overlaps two successive STS-1 frames in general

– pointer structure maintains synchronisation of frames and SPEs where their clock frequencies differ slightly

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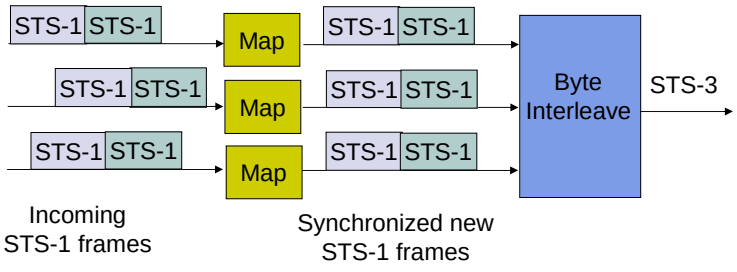
Multiplexing STS-1 signals into an STS-n signal

– byte-interleaved time-division multiplexing

– each STS-1 signal is synchronised to the local mux clock
  » section and line overhead of incoming STS-1 signal are terminated
  » SPE payload remapped into a new STS-1 frame synchronised with local clock:
    - pointer in new STS-1 frame adjusted as necessary



– to multiplex k STS-n signals into an STS-kn signal, STS-n signal first de-interleaved into STS-1 signals and then re-interleaved

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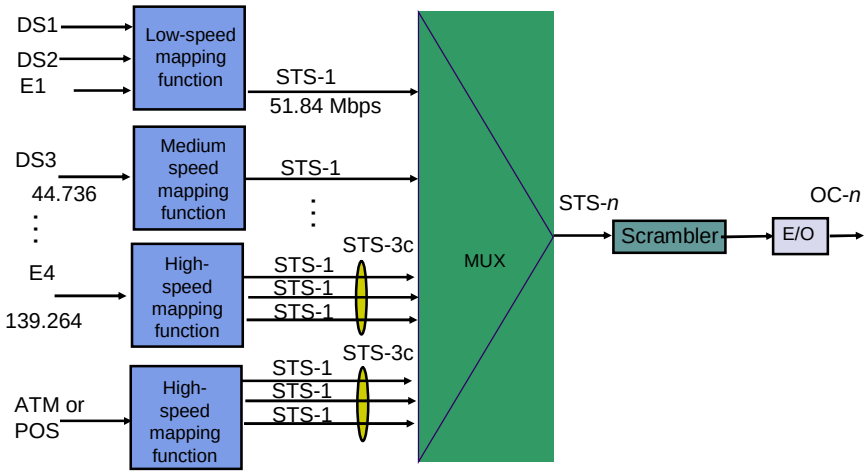
SONET Multiplexing



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Virtual tributaries

- Synchronous formats also defined at sub-STS-1 level
- STS-1 payload can be subdivided into *virtual* tributaries (VTs)

VT type	Bit rate (Mbps)	Size of VT
VT1.5	1.728	9 rows, 3 cols
VT2	2.304	9 rows, 4 cols
VT3	3.456	9 rows, 6 cols
VT6	6.912	9 rows, 12 cols

- VT1.5 corresponds to the DS-1 rate, etc.
- VTs are still visible at higher rates
  - » an individual VT containing a DS-1 can be extracted without demultiplexing the entire STS-1 frame
  - » improves switching and *grooming* performance (consolidating or segregating traffic for efficiency)

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Circuit-Switched Networks

Connections in transport networks are almost permanent

- Switching is static
- Usually done manually by an engineer who (re)sets the connections

- Circuit-switched networks
  - Handle streams of data (like transport nets)
  - But connections are dynamic; think of the telephone network

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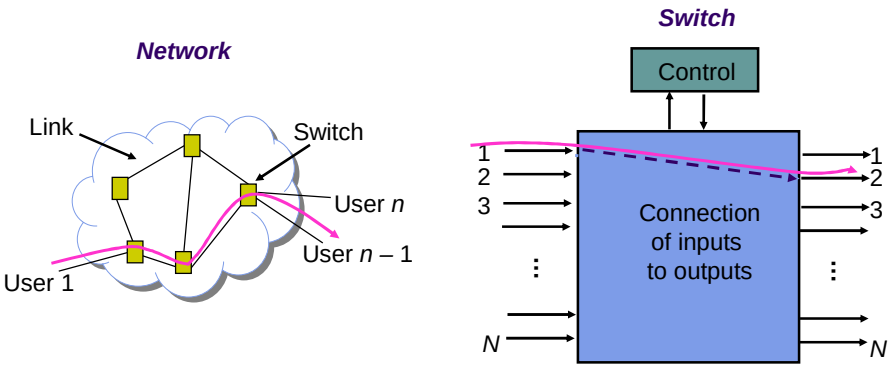
Circuit-switching

- Provide connectivity between users across a network
- A sequence of switches must be set across the network to set up a circuit
- Resources are dedicated to an end-to-end connection



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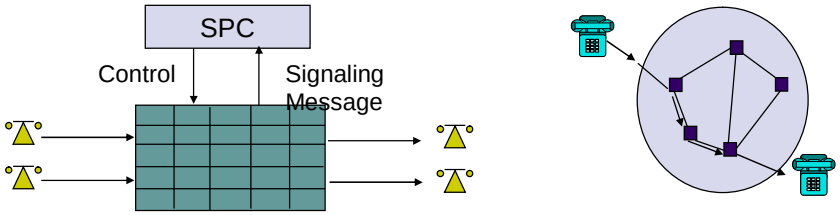
Switching in the Telephone Network

Switches between users must be configured to make the desired connections

– under Stored Program Control (SPC) i.e. computer control, in digital exchanges



- Straightforward if switching in the same local exchange
- Switch reconfiguration needed in several exchanges *en route* for remote calls

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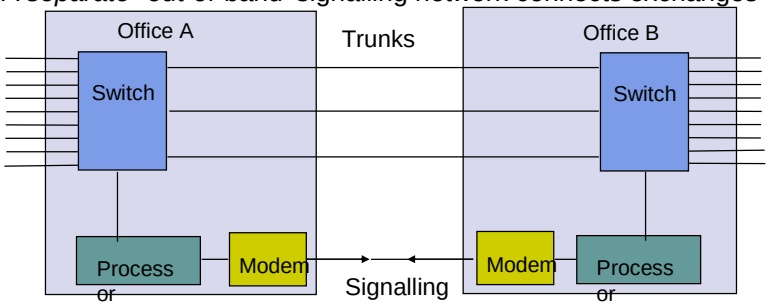
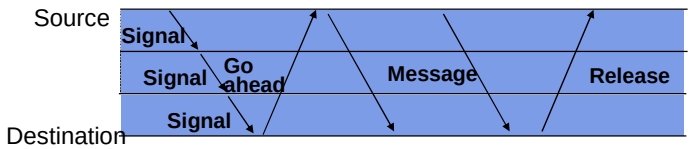
Signalling

– Signalling system between exchanges is used to set switch configurations

– A *separate* `out-of-band' signalling network connects exchanges



e.g. call setup:



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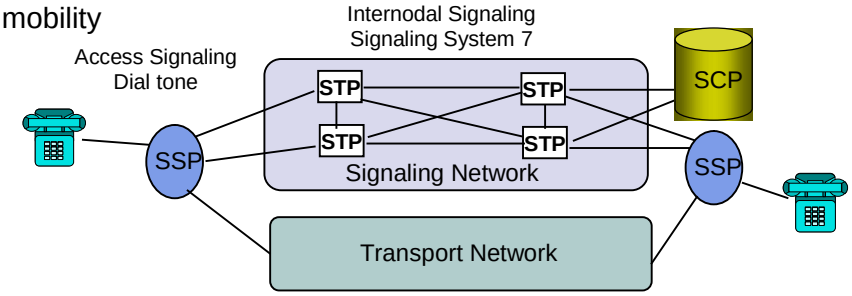
Signalling Network

- Common Channel Signaling (CCS) #7 deployed in 1970s
- Signaling network based on highly reliable packet switching network
- Processors & databases attached to signaling network enabled many new services: caller id, call forwarding, call waiting, user mobility



SSP = service switching point (signal to message)
STP = signal transfer point (packet switch)
SCP = service control point (processing)

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