

Digital Communications over Packet-Switched Networks

(ECE 446 – Lecture #09)

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Outline

- Last time: Internet protocols.
- Today: Circuit-switching – SONET, WDM.

Circuit Switching

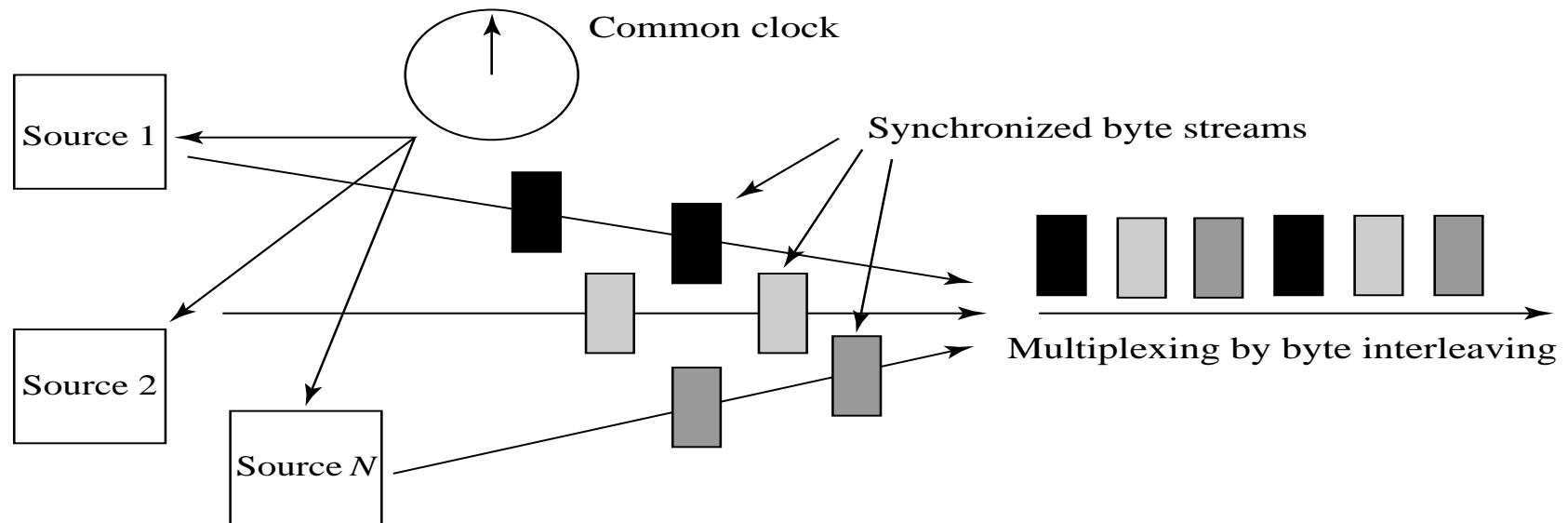
Wasn't this course on Digital Communications over *Packet Switched* Networks? Why are we going to spend two lectures on *Circuit Switching*???

- Because for some applications (e.g., generating CBR traffic), this is more efficient.
- Because many networks that carry data traffic are circuit-switched: telephone, cable TV, some cellular, satellite.
- Because some point-to-point links in packet-switched networks are implemented using technologies based on circuit-switching.
- And because of historical reasons.

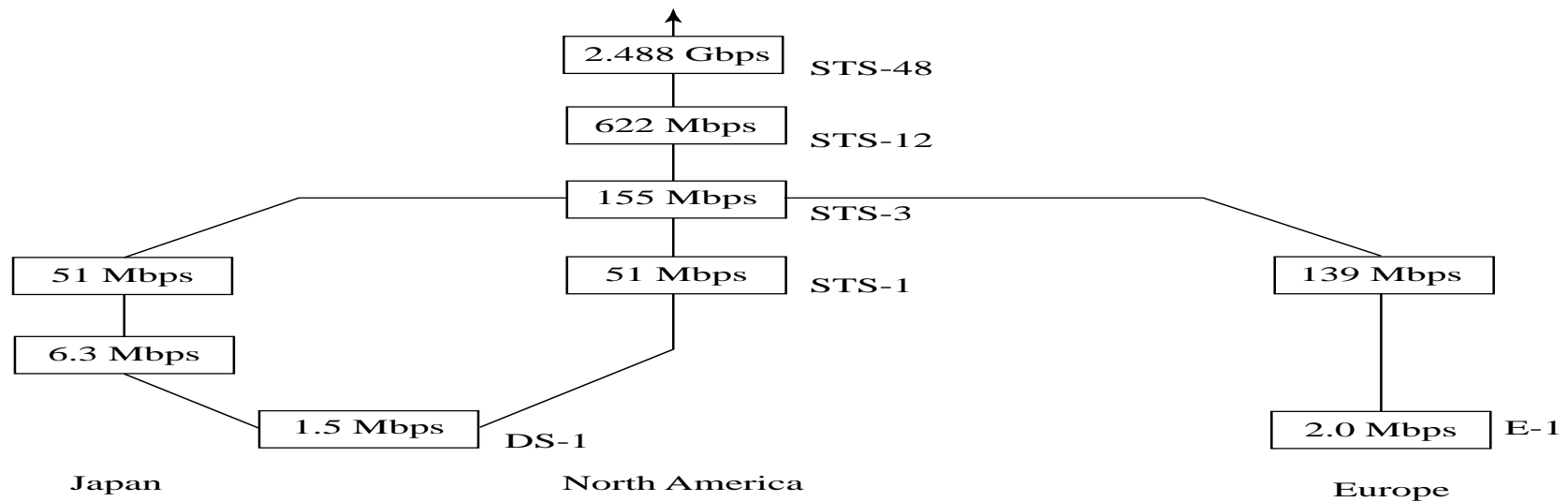
SONET: Synchronous Optical NETwork

End-to-end transport of bit streams:

- Encoding of bit streams into optical signals sent over optical fiber.
- All clocks in the network locked to a common master clock, TDM.

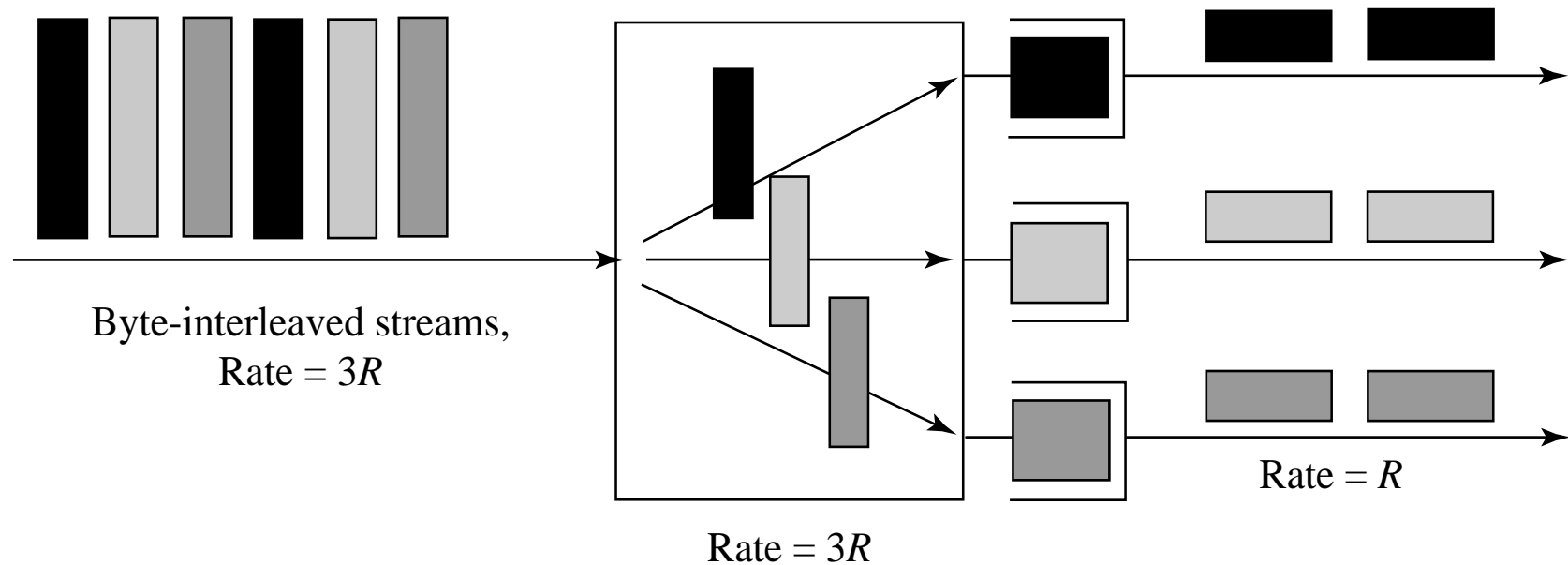


- Input streams of rate R bits/sec, multiplexed stream of rate NR bits/sec.
- Still need some (minimal amount of) buffering, to deal with *jitter*.
- Basic SONET signals:



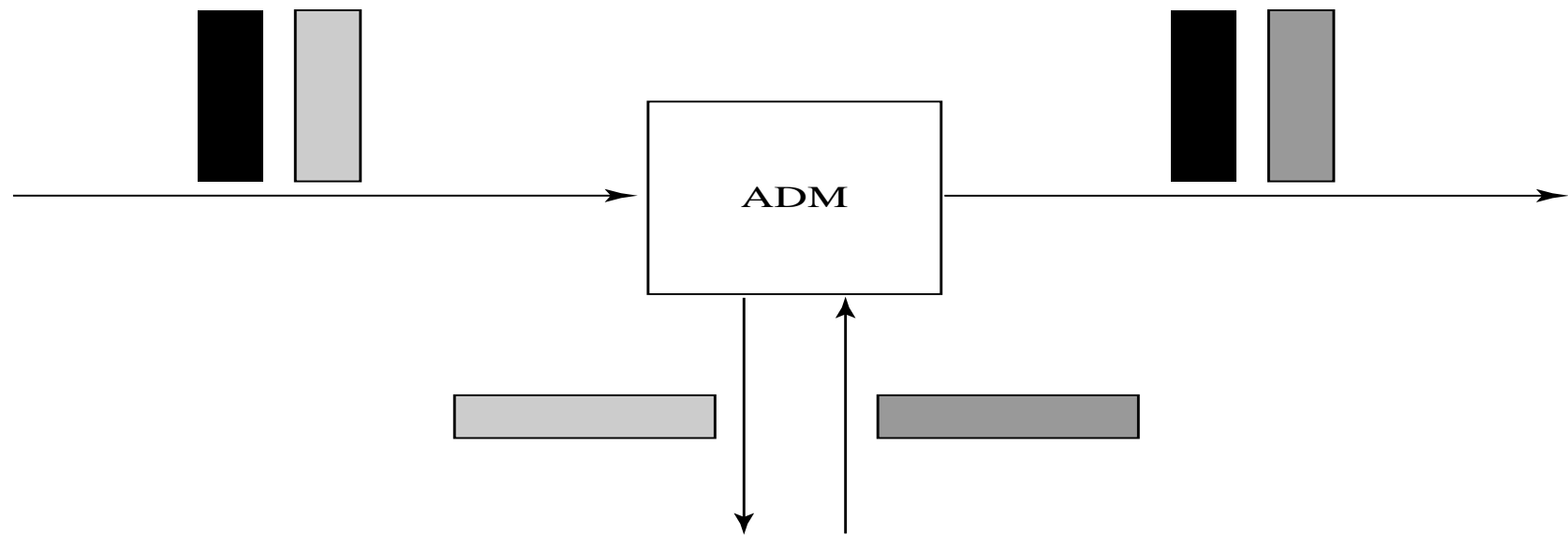
SONET Demultiplexers

Very simple mux/demux techniques – individual streams recovered from frame locations:



SONET Add/Drop Multiplexers

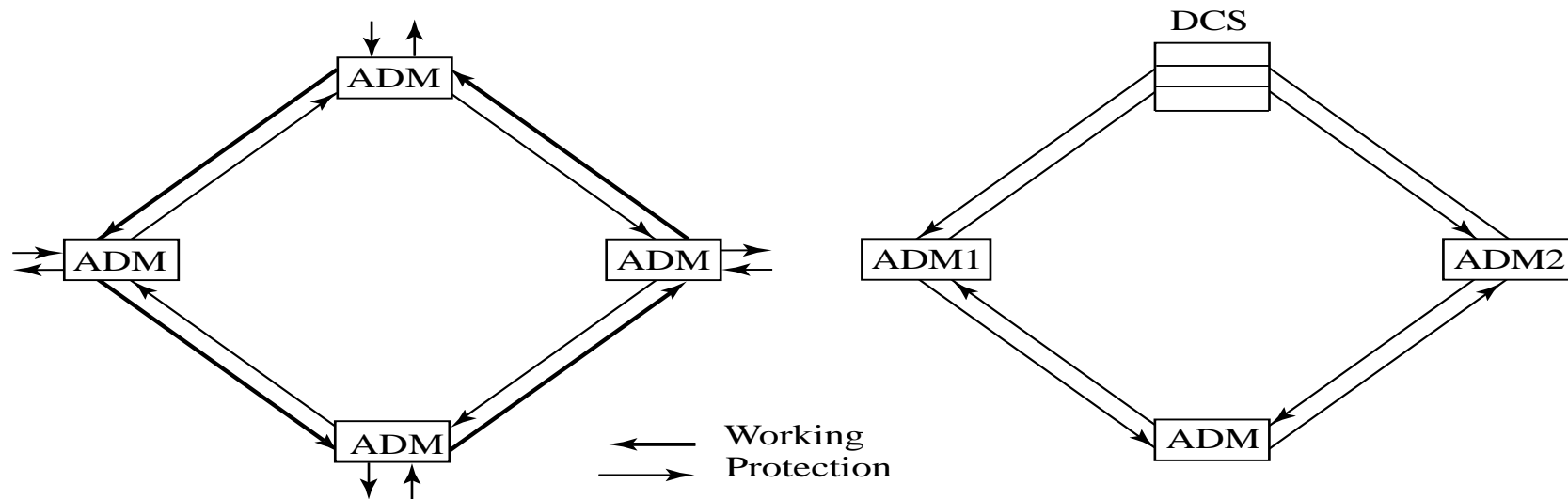
Take the data in an incoming multiplexed stream, replace it with some other data in an outgoing multiplexed stream:



(Useful to implement *rings*...)

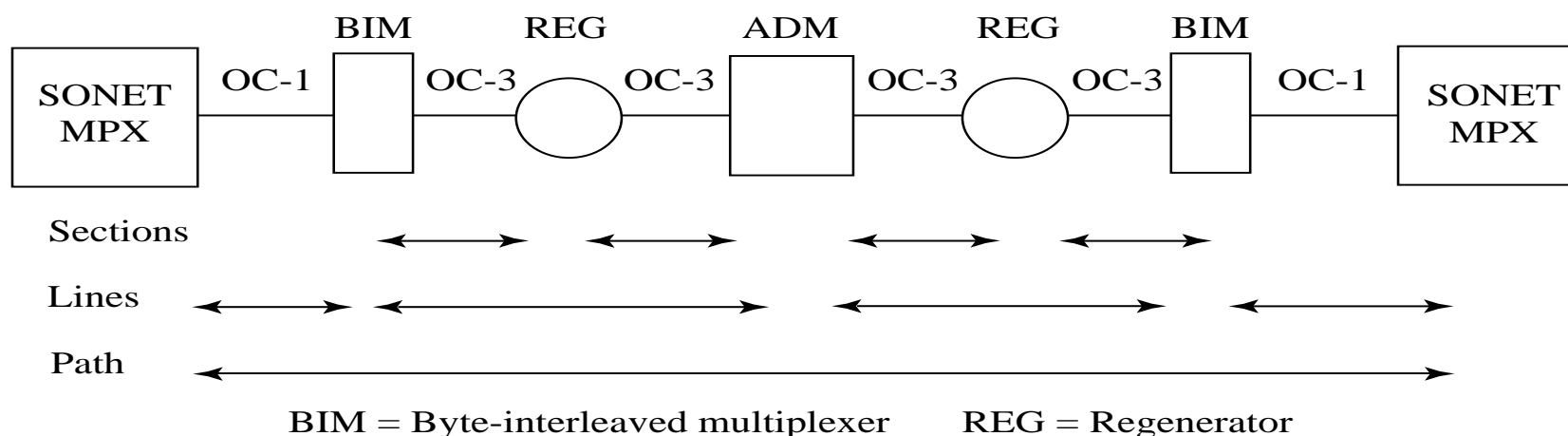
Robustness Issues

- One ring (counterclockwise) carries the working signal, one ring acts as backup (clockwise).
- Upon failures, switch to the backup ring.
- A digital cross-connect is used to modify/configure network topology.



SONET Frames (layers, again...)

Steps that a SONET frame has to go over end-to-end:

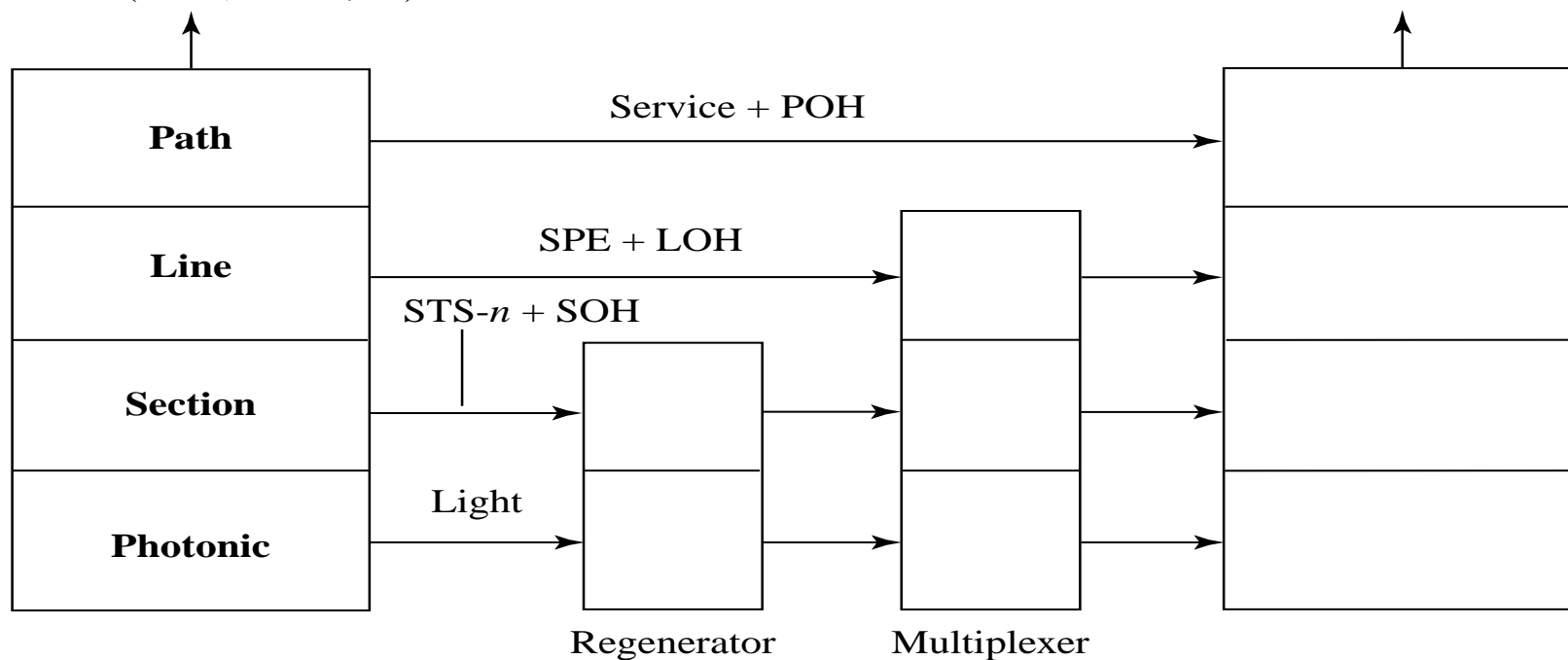


- Section: a physical link among devices in the network.
- Line: a connection among muxes (can include multiple regenerators).
- Path: and end-to-end connection (can include multiple muxes).

SONET Frames (layers, again...)

Layers in the description of SONET frames:

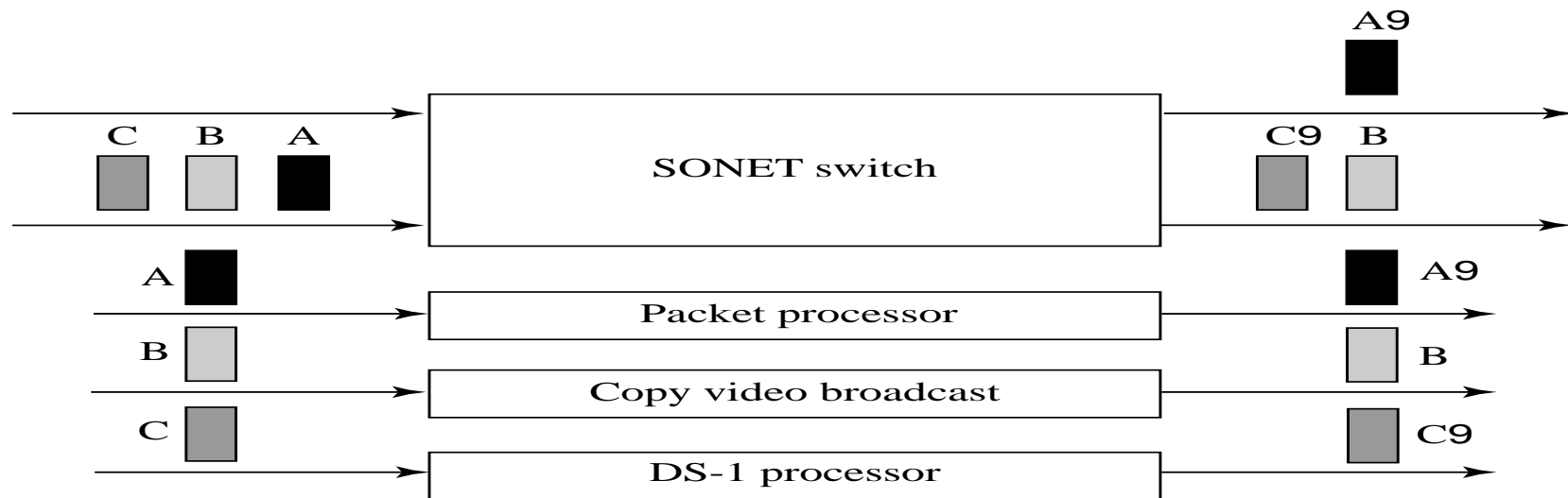
Services (DS- n , Video, ...)



Photonic \equiv physical, section \equiv link, line \equiv network, path \equiv transport.

Services over SONET

Data streams separated/recombined at switches, add/drop muxes:



- Very simple – time-division multiplexing using a global clock.
- Very fast – optical interconnects operating at gigabit speeds.

And This is Relevant to Packet-Switching Because?...

- Simple interleavers based on the time-synchronous signals make SONET popular.
- Signals in packet-switching routers are combined through statistical multiplexing, need not be synchronized.
- “Lightweight SONET”: fast optical links without central clock, only local.

Lightweight links provided very efficient interconnects for the backbone of a high speed, high capacity packet-switched network.

Wave-Division Multiplexing (WDM)

Essentially: FDMA on an optical fiber.

- Optical link: light source of a certain wavelength, modulated by data.
- Bandwidth of the fiber: approx. 25×10^{12} Hz, or 25000000 MHz.
- Electronic modulators generate signals that occupy a small fraction of all this available bandwidth.

In WDM, light sources of different wavelengths are modulated by separate data streams, sent over fiber, separated in the analog domain at the receiving end, and demodulated individually.

Networking with WDM

Individual links operating at +100 Gbps available. Networking challenges:

- Switching. Electronics are *much* slower. Without optical switches, this is useful only for backbone-type links.
- ADM. If not full switching, optics-based adding/dropping of wavelengths.
- Wavelength routing: map a light signal on an input port directly to a signal on an output port.
- Wavelength conversion: “change the carrier frequency”.
- Buffering. It is hard to store light...

Summary and What Next

- SONET: a network with a global clock and and time-division multiplexing.
- WDM: a way to exploit the huge bandwidth available on optical fibers.

Finish reading chapter 5:

- Next time: DSL and cable TV.

Credits: the figures used in these slides are from our textbook.