SONET

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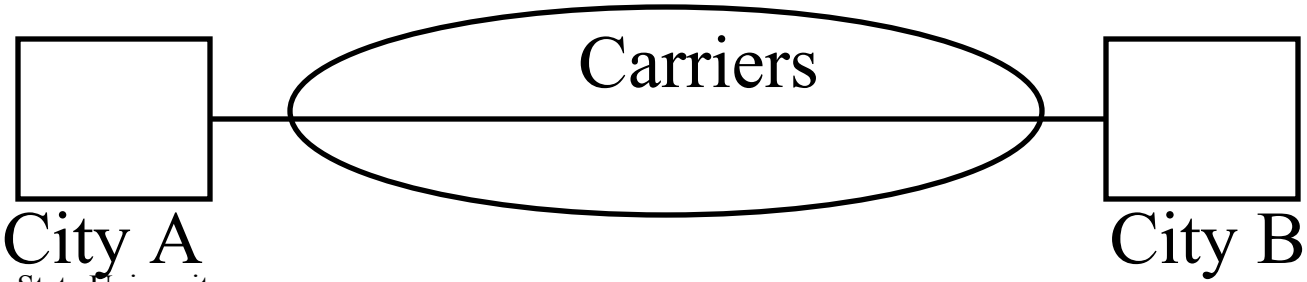
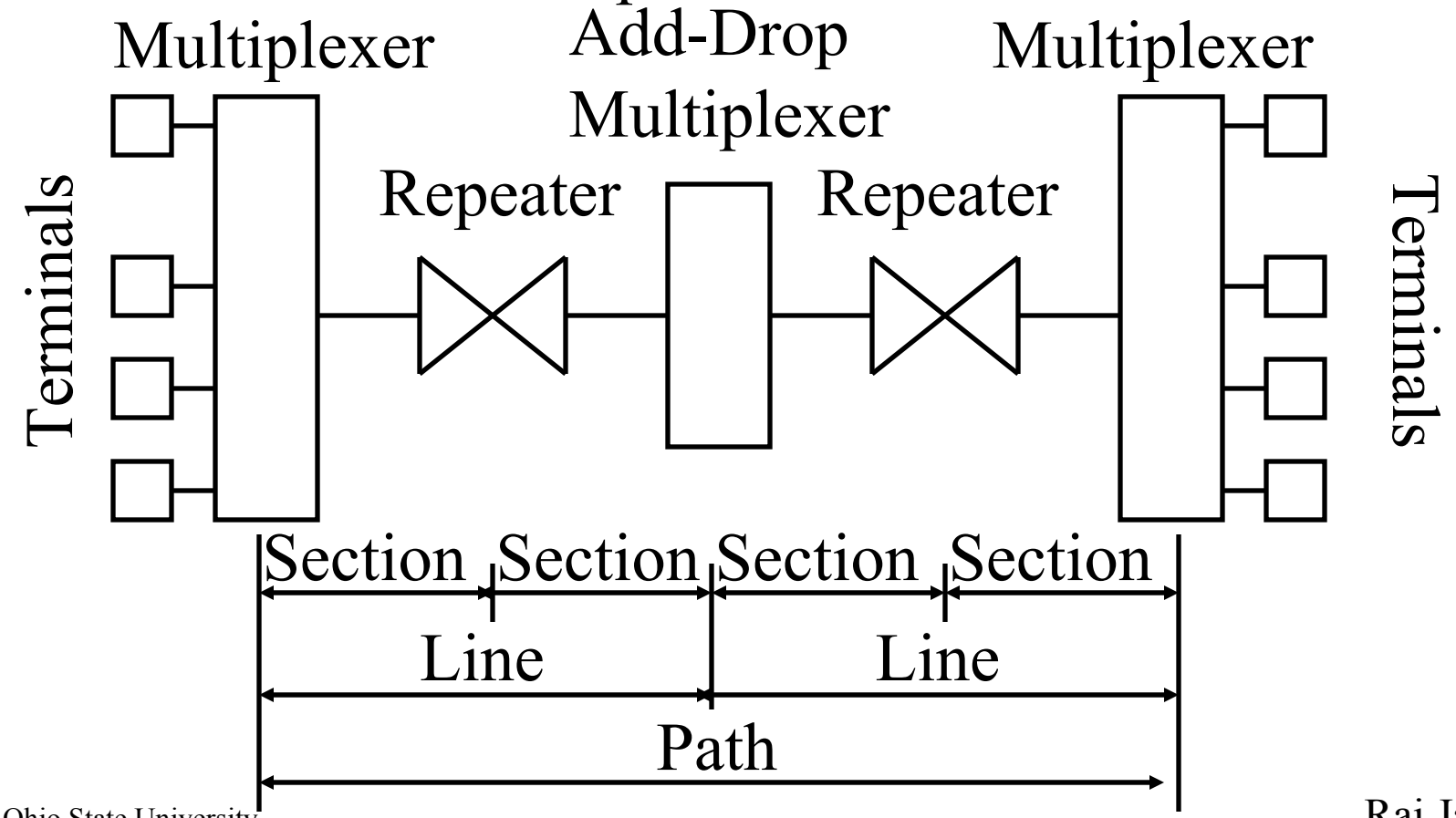
What is SONET?

- Synchronous optical network
- Standard for digital optical transmission (bit pipe)
- Developed originally by Bellcore.
  Standardized by ANSI T1X1
  Standardized by CCITT
  $\Rightarrow$ Synchronous Digital Hierarchy (SDH)
- You can lease a SONET connection from carriers



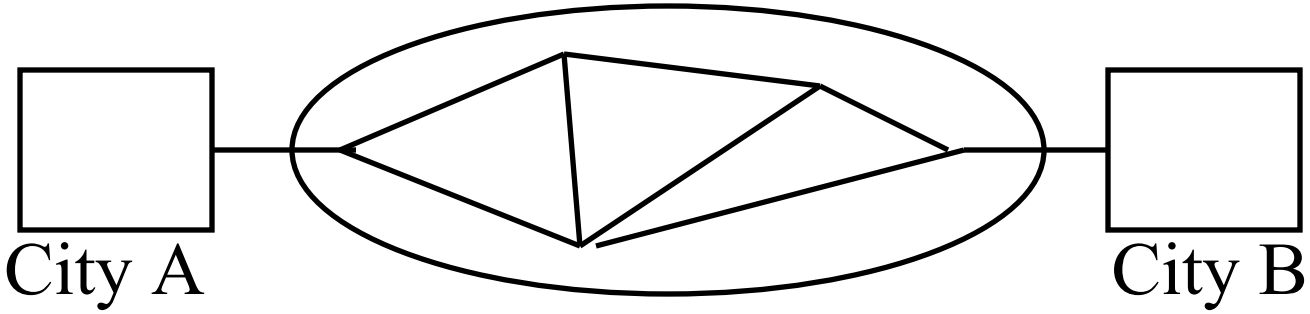
Physical Components

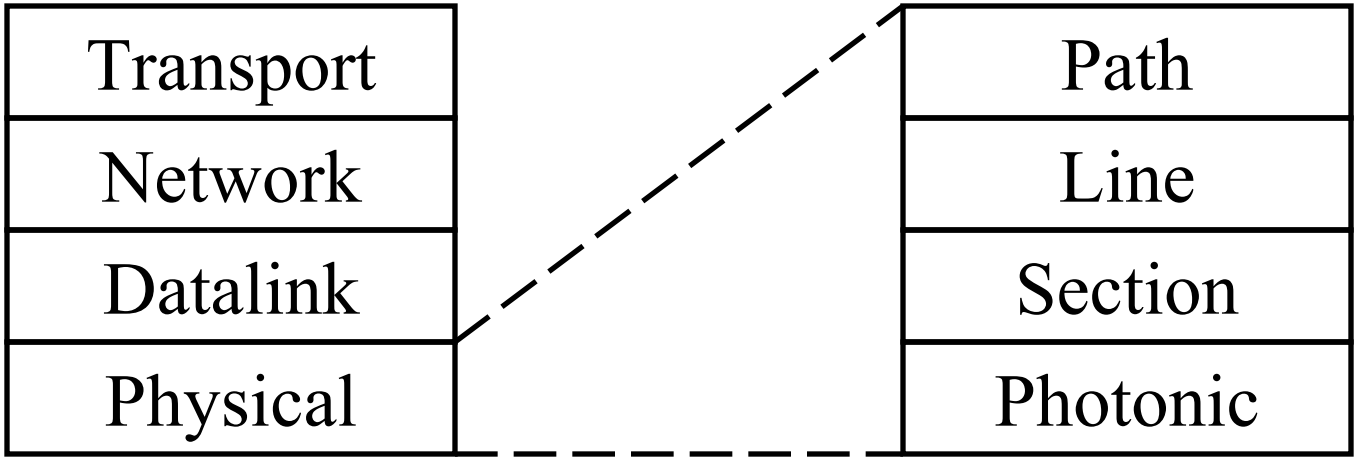
- Section = Single run of fiber
- Line = Between multiplexers



SONET Protocols

- Synchronous Optical **Network**

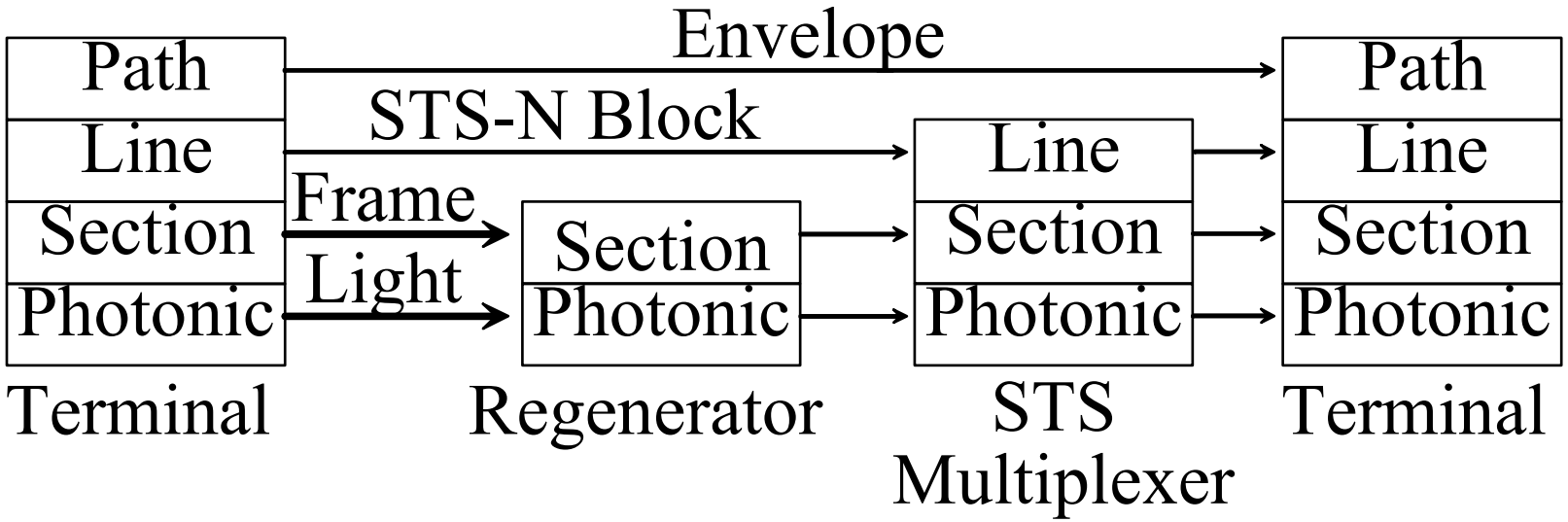




Protocols (Cont)

- Photonic Layer: Characteristics of fibers, transmitters, receivers and encoding (ANSI T1.106-1988)
- Section Layer: Transmission across a single link. Framing, scrambling, and error monitoring.
- Line Layer: Signaling between multiplexer switches. Frame synchronization. Multiplexing of data in to SONET frames.
- Path Layer: End-to-end signaling issues. Mapping DS3, FDDI, BISDN into SONET payload.

Protocol Hierarchy



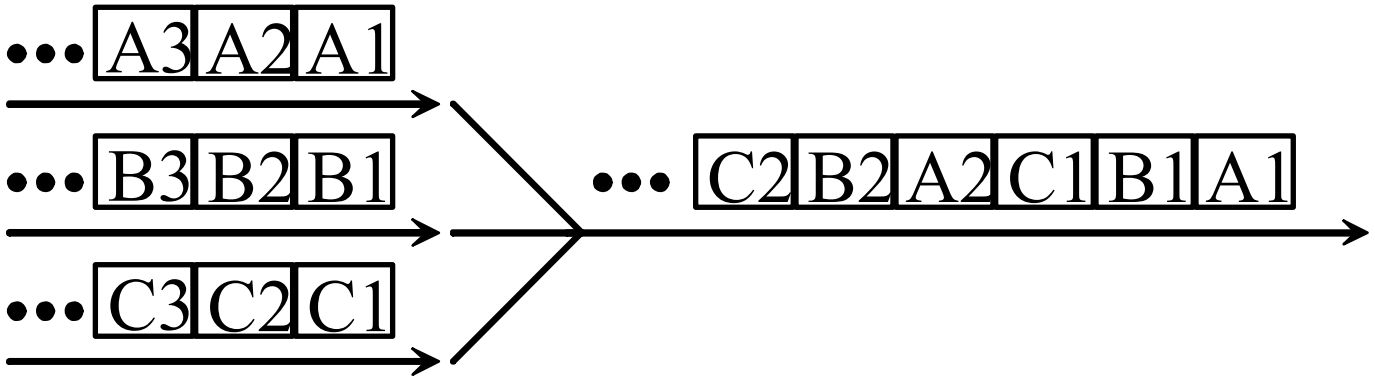
Signal Hierarchy

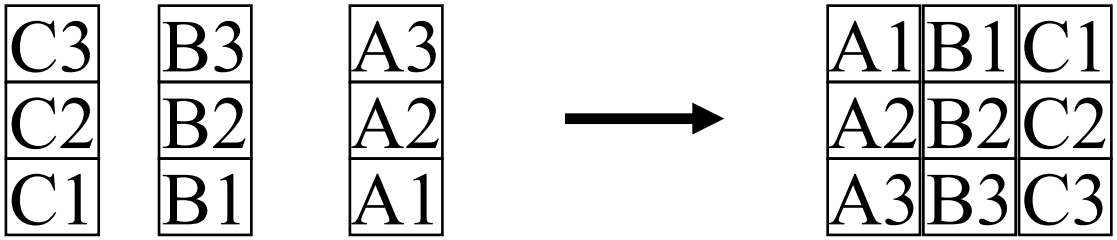
Synchronous Transport Signal Level n = STS-n = $n \times 51.84$ Mbps
STM=Synchronous Transport Module, OC=Optical Carrier level

ANSI Designation	Optical Signal	CCITT Designation	Data Rate (Mbps)	Payload Rate (Mbps)
STS-1	OC-1		51.84	50.112
STS-3	OC-3	STM-1	155.52	150.336
STS-9	OC-9	STM-3	466.56	451.008
STS-12	OC-12	STM-4	622.08	601.344
STS-18	OC-18	STM-6	933.12	902.016
STS-24	OC-24	STM-8	1244.16	1202.688
STS-36	OC-36	STM-12	1866.24	1804.032
STS-48	OC-48	STM-16	2488.32	2405.376
STS-96	OC-96	STM-32	4976.64	4810.176
STS-192	OC-192	STM-64	9953.28	9620.928

Byte Multiplexing

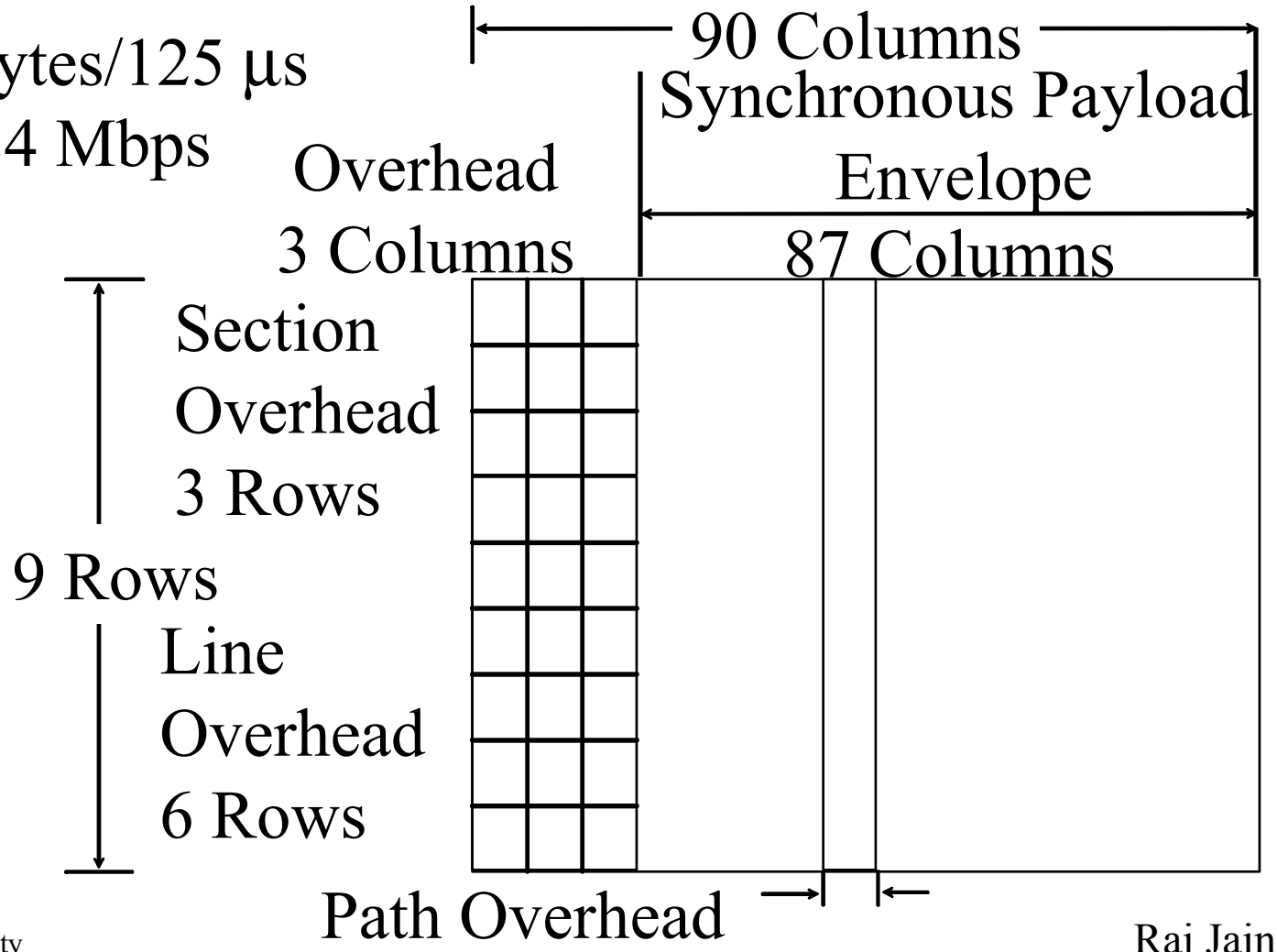
- Also known as byte interleaving
- Easier to view in two dimension



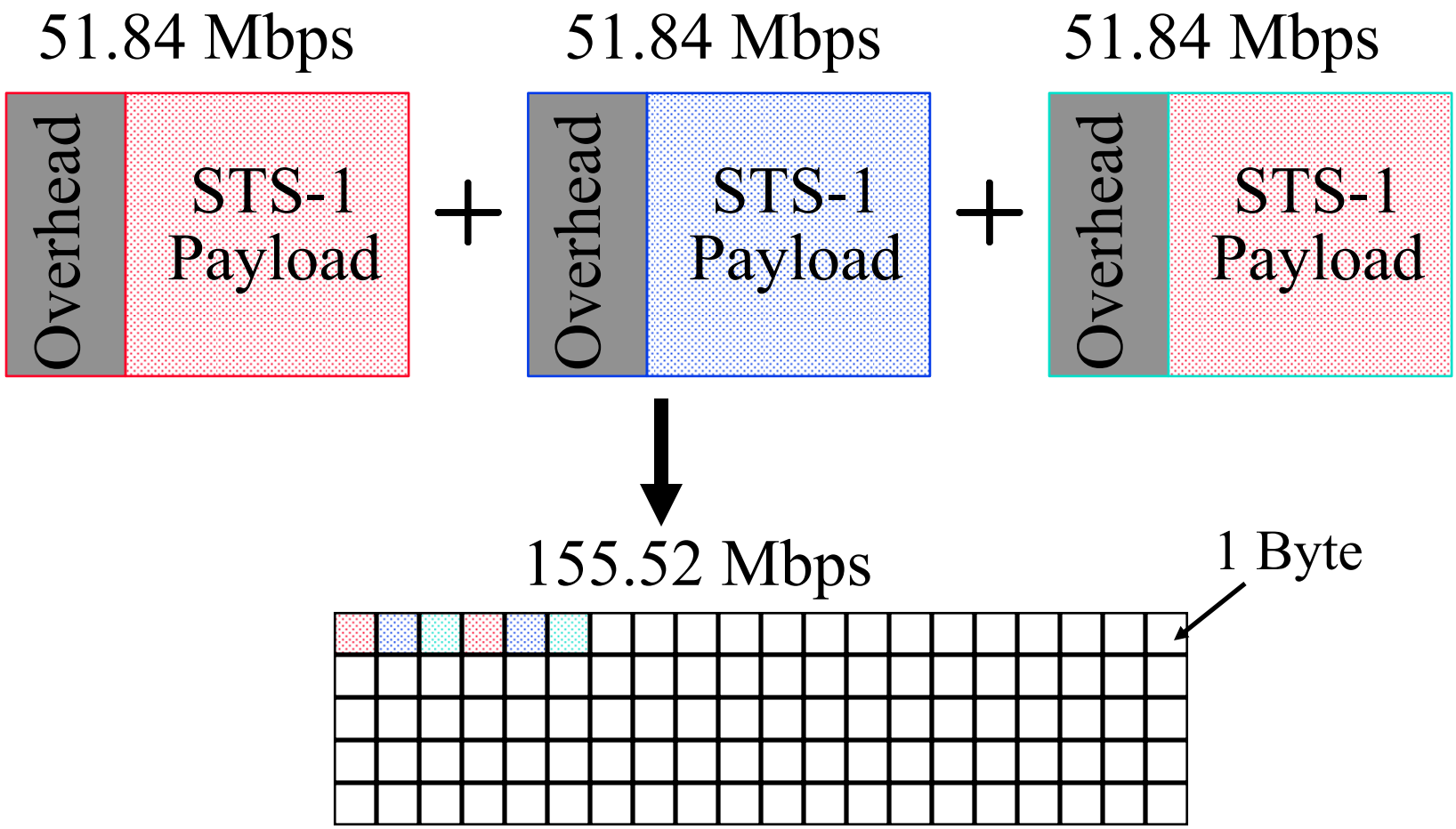


STS-1 Frame Format

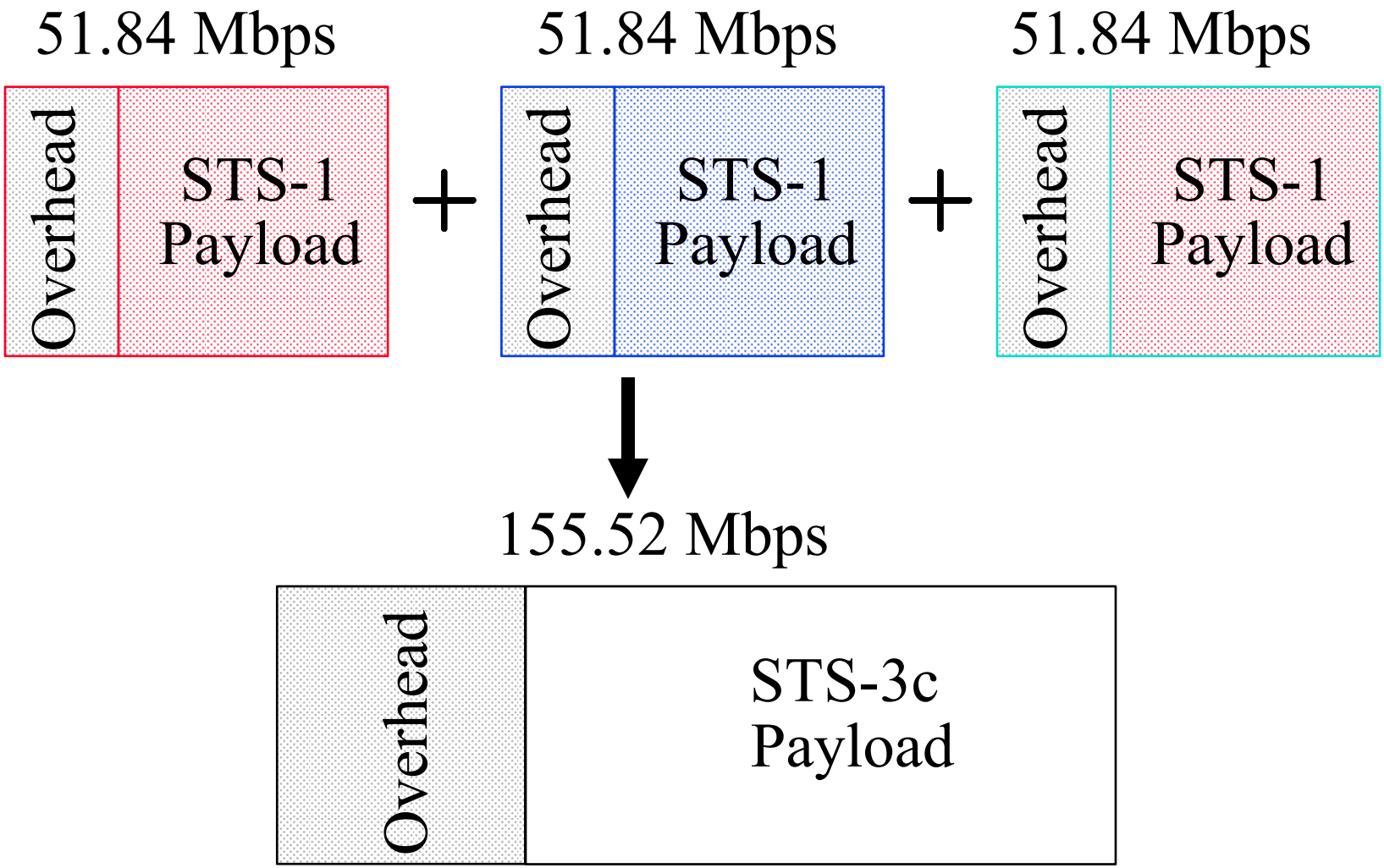
- Overhead = Header.
- 810 Bytes/125 μs
  = 51.84 Mbps



Multiplexing

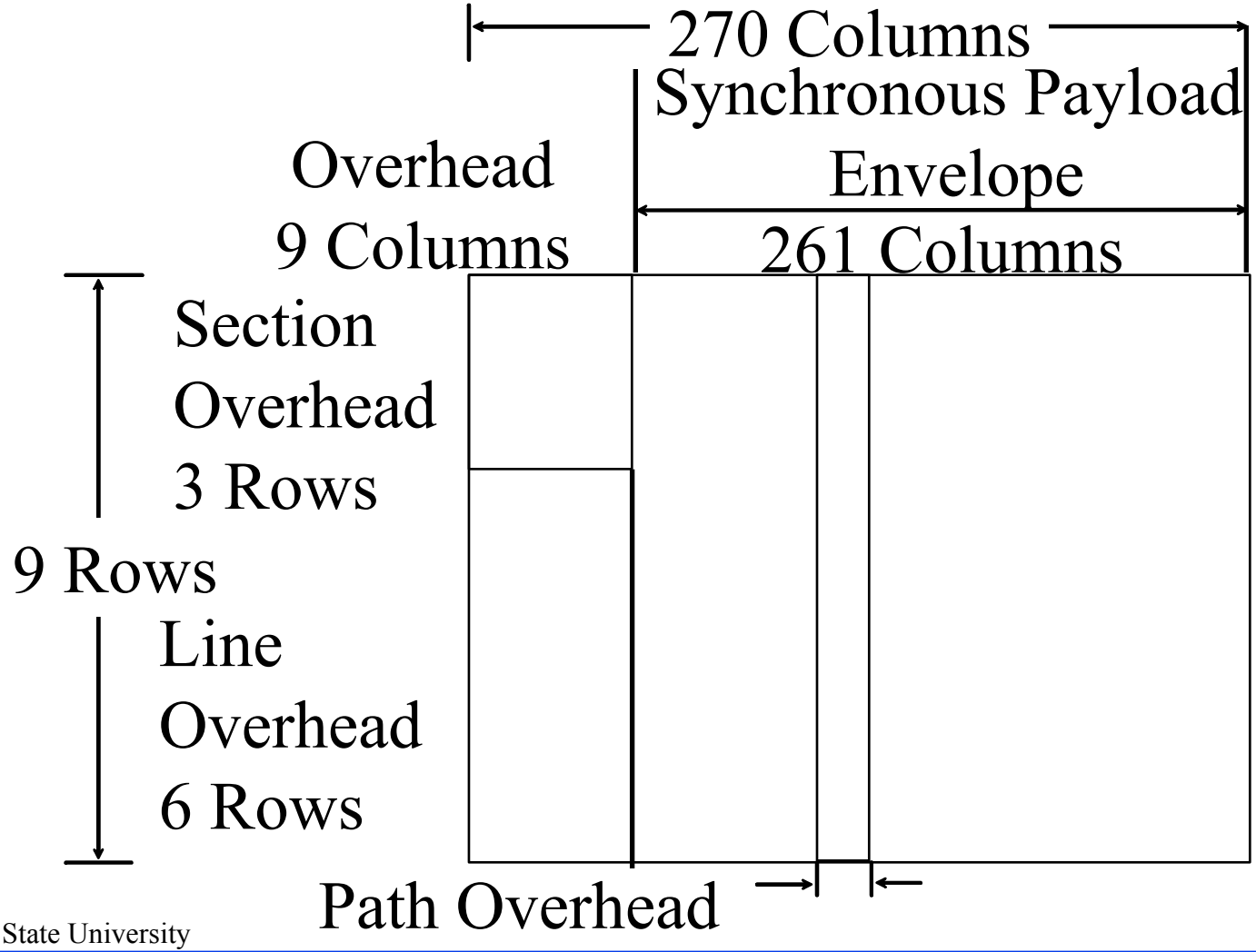


Concatenation



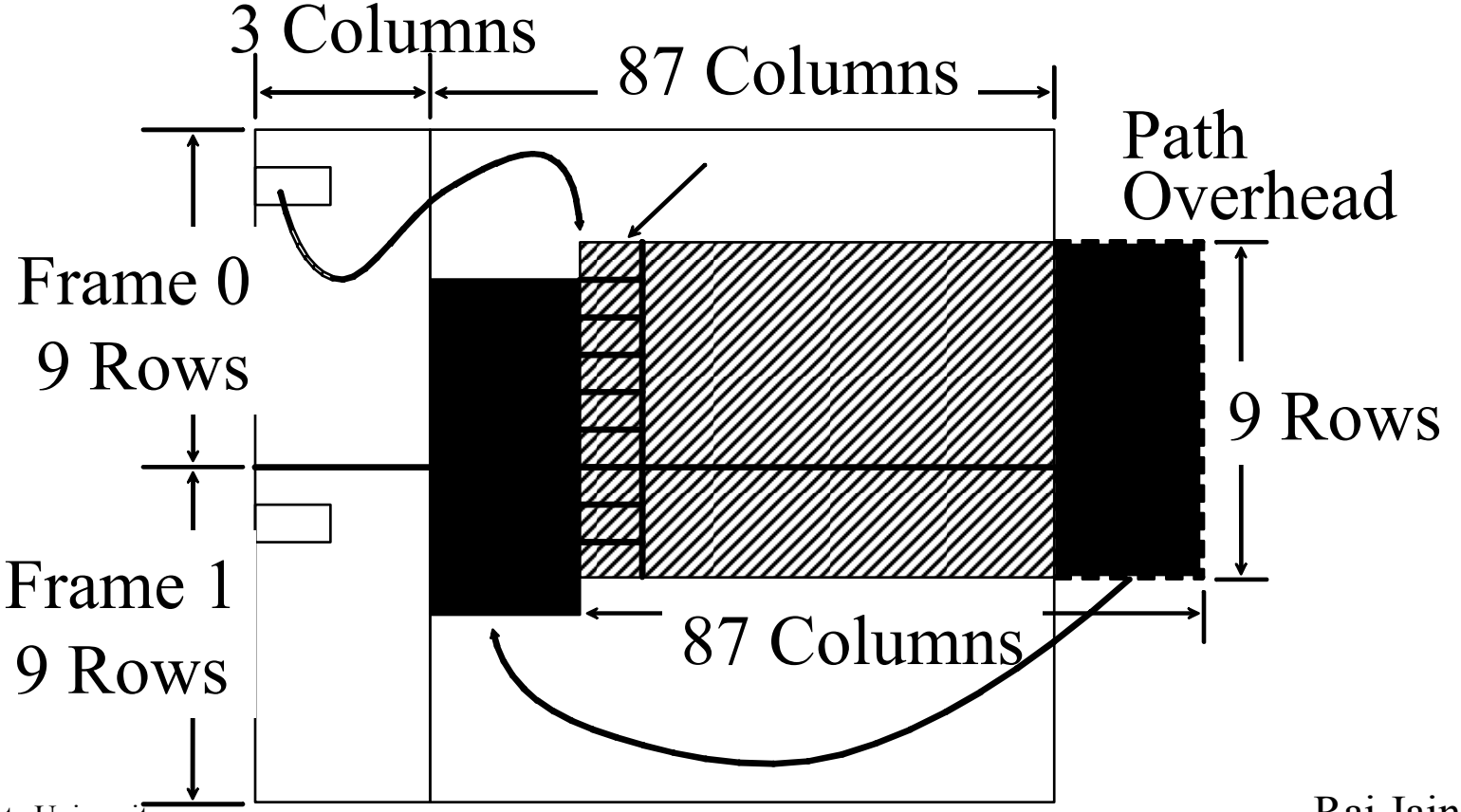
STS-3c Frame Format

- 2430 Bytes/125 μs = 155.54 Mbps



Location of SPE in STS-1

- SPE supplied by the user ⇒ Can arrive at any time
  ⇒ SPE can straddle two successive STS frames



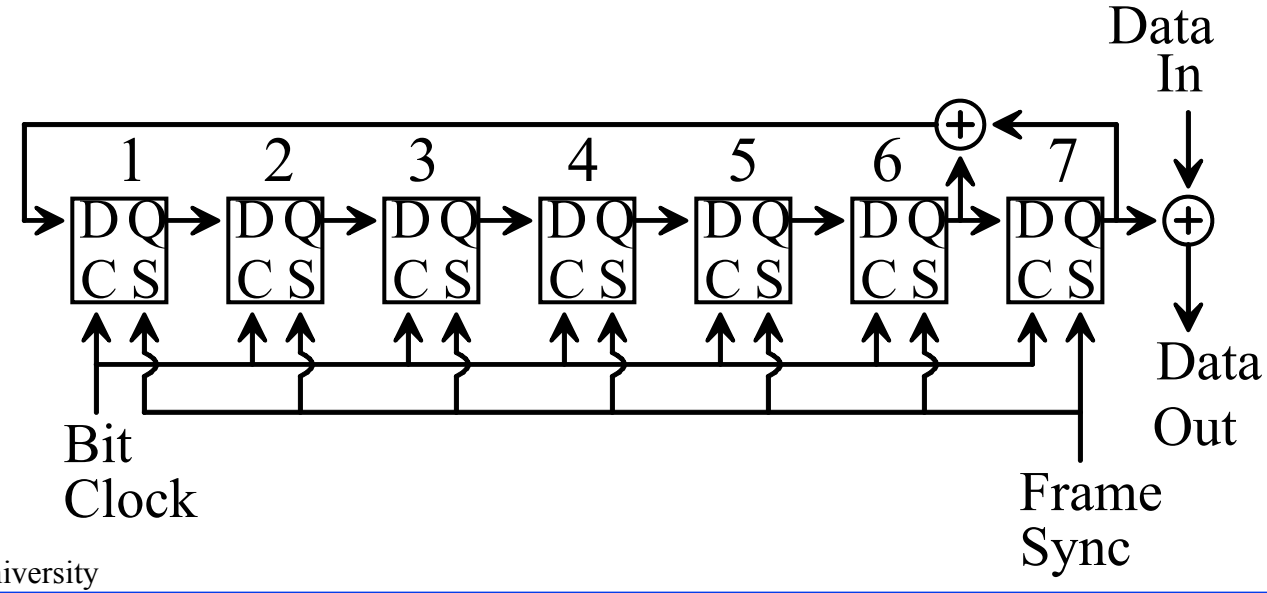
Scrambling: Introduction

Two Methods:

1. Add random sequence
2. Divide by a number and send quotient. Similar to CRC.

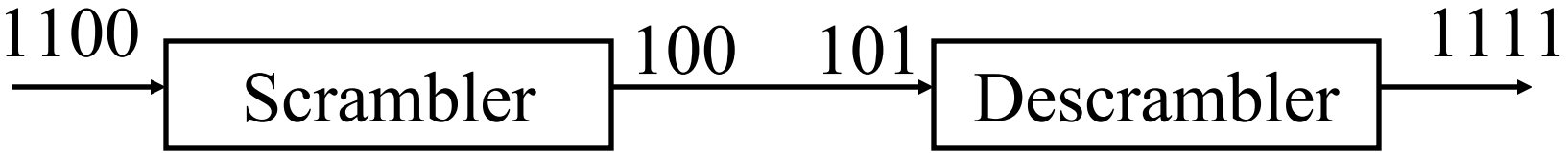
Both implemented by shift-registers.

Analyzed using polynomials. $1+x^6+x^7$



Scrambling (Cont)

- Set-Reset Synchronous scrambler:
  Add a fixed random bit pattern.
  Need to tell where to start adding
  ⇒ Need to synchronize.
- Self-synchronous scrambler: Divide by a fixed number.
  No need for synchronization.
  Errors multiply.
  Example: Send 12 using divider 3 ⇒ Send 4.
  1-bit error ⇒ Received 5 ⇒ 15 ⇒ 2-bit error in data.



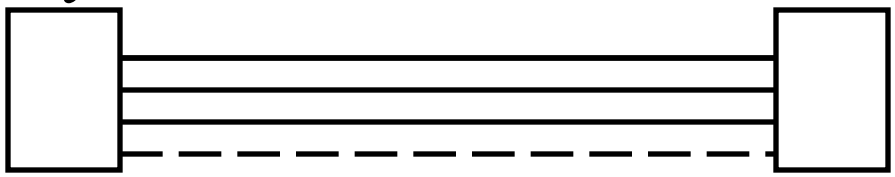
Scrambling

- SONET uses NRZ coding.
  1 = Light On, 0 = Light Off.
- Too many 1's or 0's ⇒ Loss of bit clocking information
- All bytes (except some overhead bytes) are scrambled
- Polynomial $1 + x^6 + x^7$ with a seed of 1111111 is used to generate a pseudo-random sequence, which is XOR'ed to incoming bits.

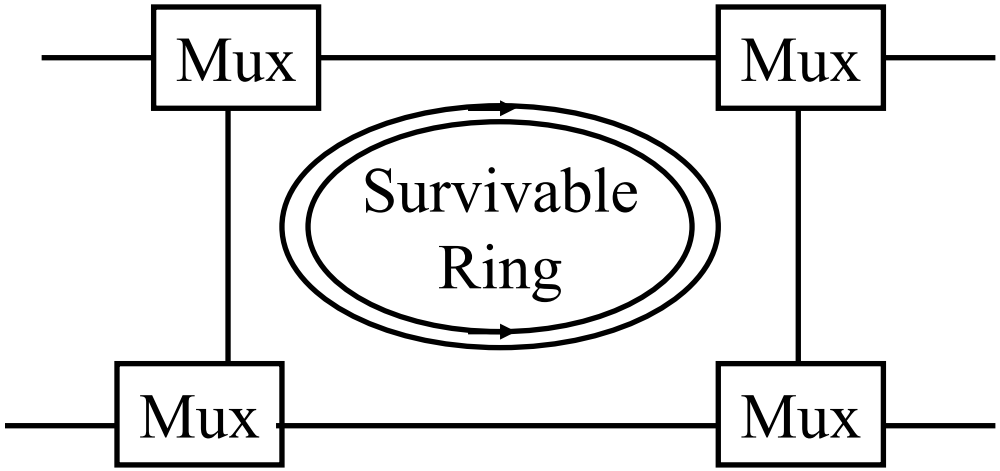
  1111 1110-0000 0100-0001 … 010
- If user data is identical to (or complement of) the pseudo-random sequence, the result will be all 0's or 1's.

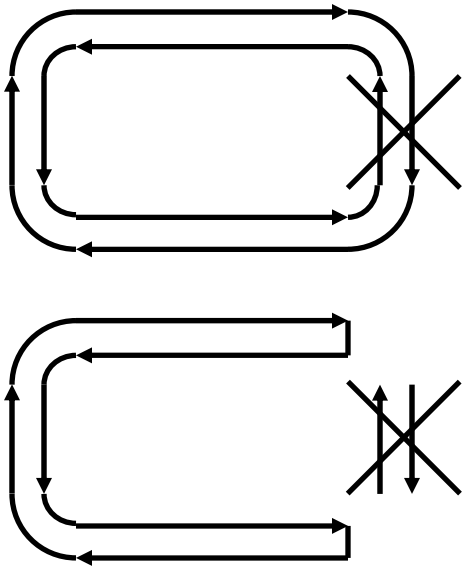
Automatic Protection Switching

- 100 ms or more is "loss of signal"
  2.3 ms or less is not "loss of signal"
  In-between is up to implementations
- Most implementations use 13-27 ms
  $\Rightarrow$ Higher speed lines $\Rightarrow$ maintain sync for more bits
- APS allows switching circuits on fault
- May take up to 50 ms to complete
- Wastes entire links as standby.
- Protection by routers works faster than by SONET



SONET Topology



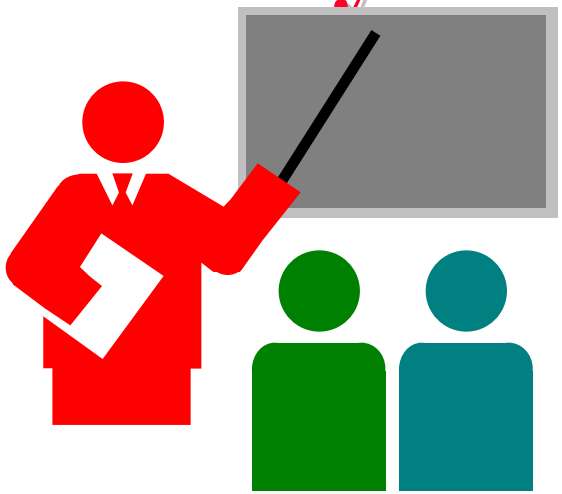


- Two fibers: Working + Protection
  On a fault, faulty cable is isolated and ring heals itself.
- Four Fibers: Two working + Two protection
  $\Rightarrow$ Bi-directional operation
  $\Rightarrow$ Traffic sent over shortest path

SONET vs SDH

- ANSI vs ITU-T
- Bits 5,6 of SPE/VC pointer are different [RFC2171]
- Synchronous payload envelope (SPE) vs Virtual Container (VC)
- Network element vs Network node interface
- Section vs regenerator section
- Link vs multiplex section

Summary



- SONET
- SDH
- STS-n, STM-n
- STS-3c

Homework

- Read Chapter 8 of Black's Emerging Technologies, 2nd Ed.

Additional References

- Chapter 9 of FDDI Handbook by Raj Jain