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# SONET

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These slides are available at:

<http://www.cis.ohio-state.edu/~jain/cis777-99/>

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# What is SONET?

↳ synchronous optical network

↳ standard for digital optical transmission  
(bit pipe)

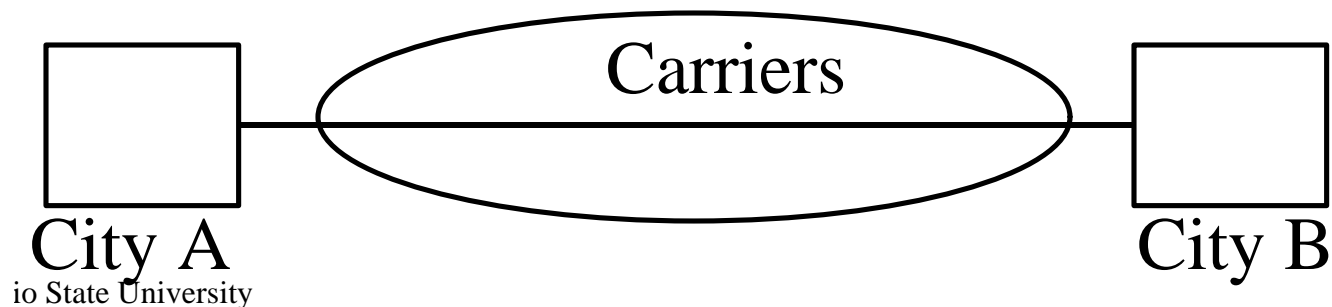
↳ Developed originally by Bellcore.

↳ standardized by ANSI T1X1

↳ standardized by CCITT

⇒ Synchronous Digital Hierarchy (SDH)

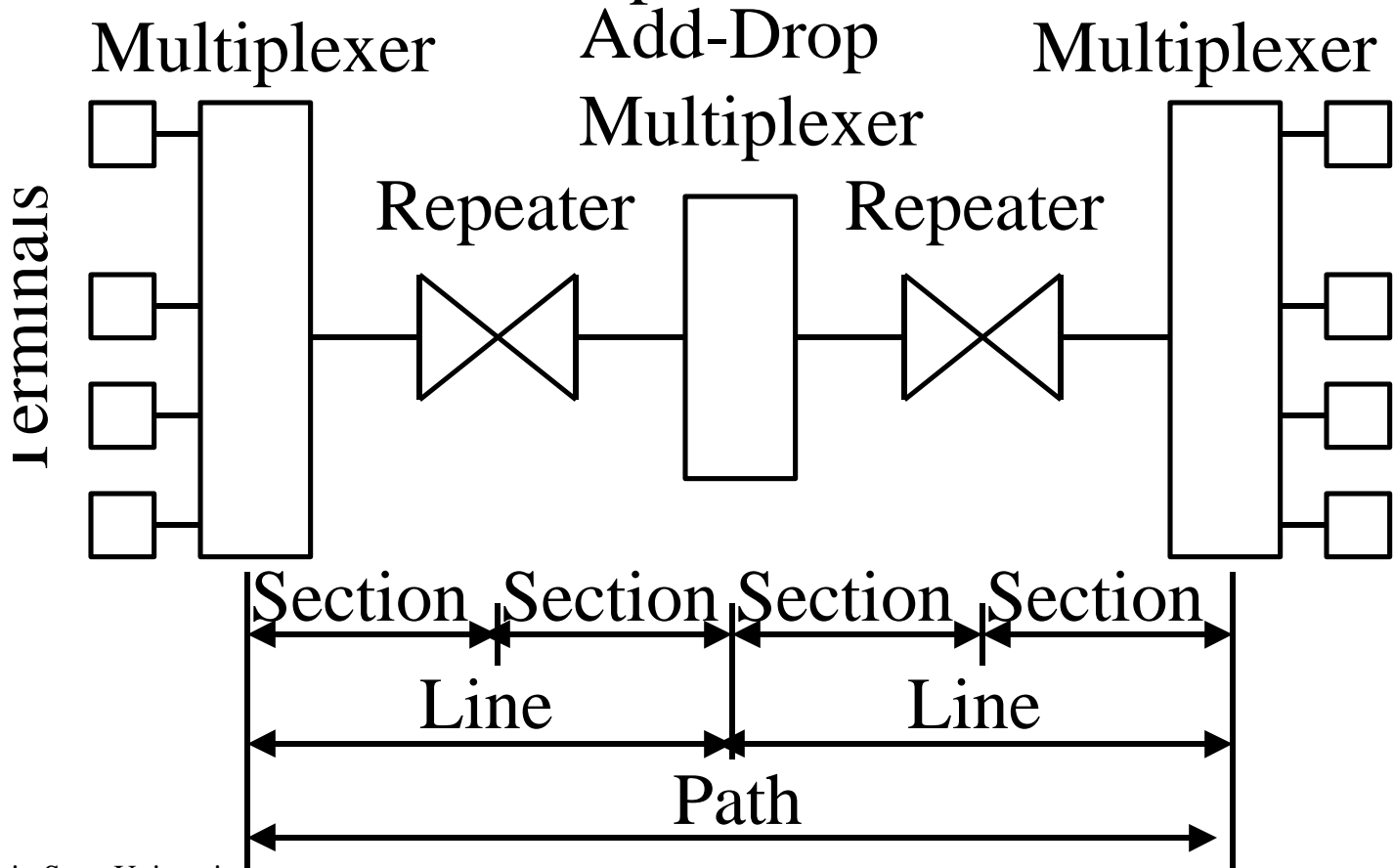
You can lease a SONET connection from carriers



# Physical Components

Section = Single run of fiber

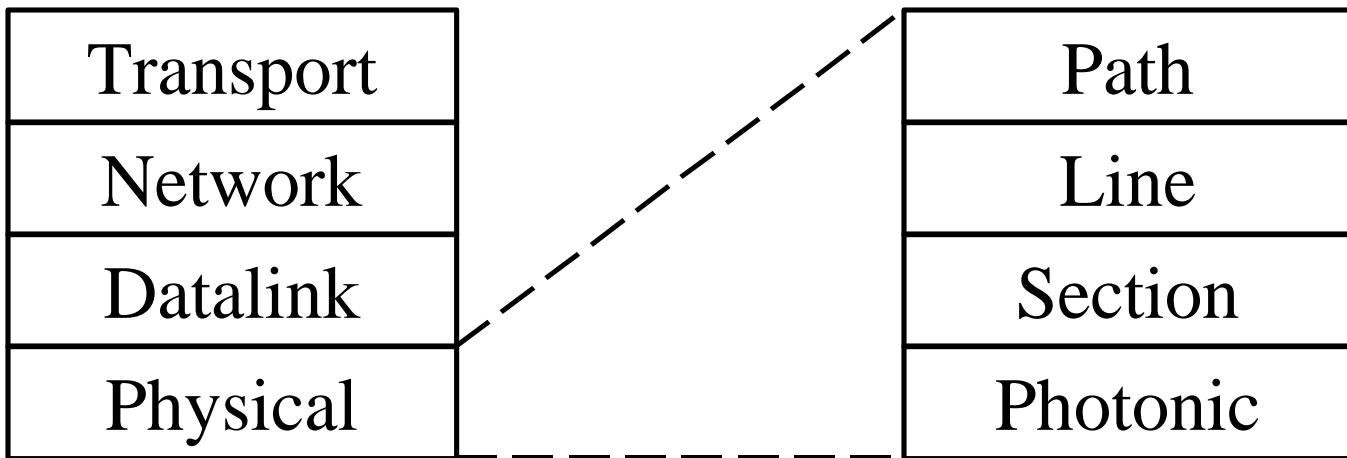
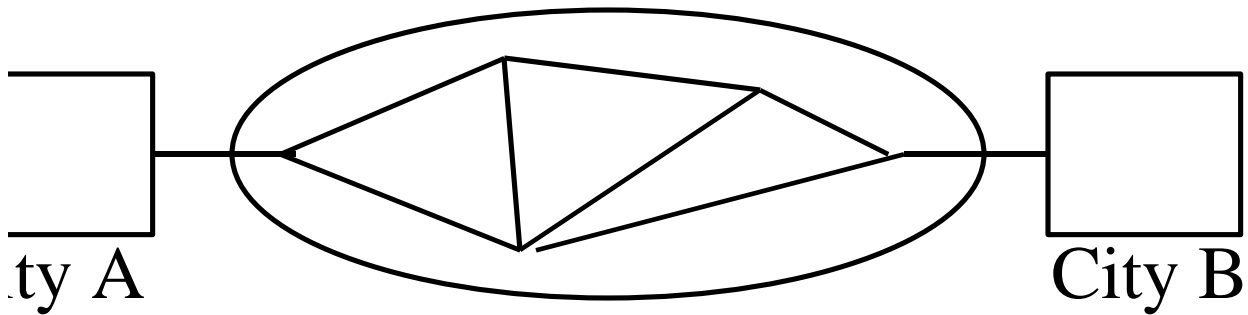
Line = Between multiplexers



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# SONET Protocols

Synchronous Optical **Network**



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# Protocols (Cont)

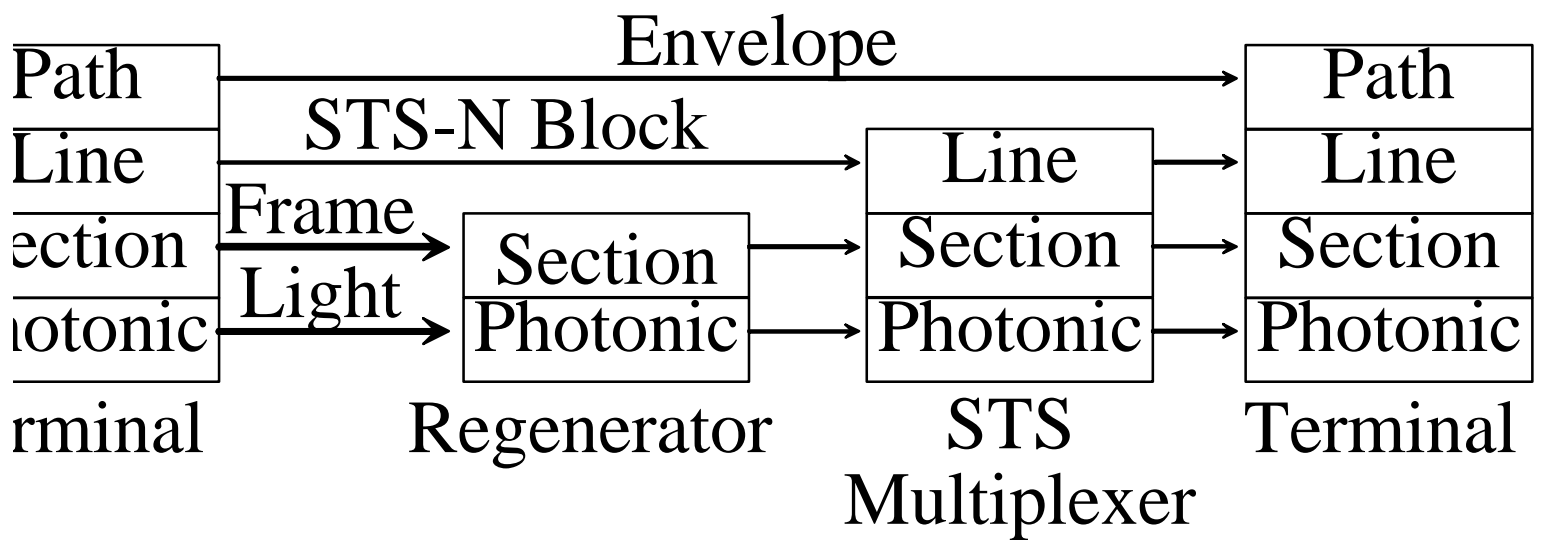
Photonic Layer: Characteristics of fibers, transmitter/receivers and encoding (ANSI T1.106-1988)

Section Layer: Transmission across a single link. Framing, scrambling, and error monitoring.

Line Layer: Signaling between multiplexer switches. Frame synchronization. Multiplexing of data into SONET frames.

Path Layer: End-to-end signaling issues. Mapping DS3, FDDI, BISDN into SONET payload.

# Protocol Hierarchy



# Signal Hierarchy

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

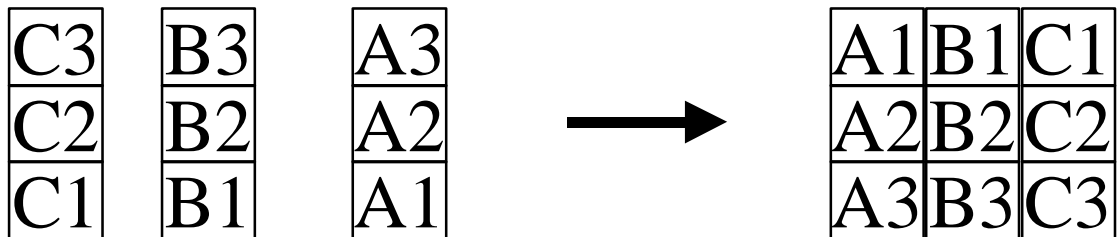
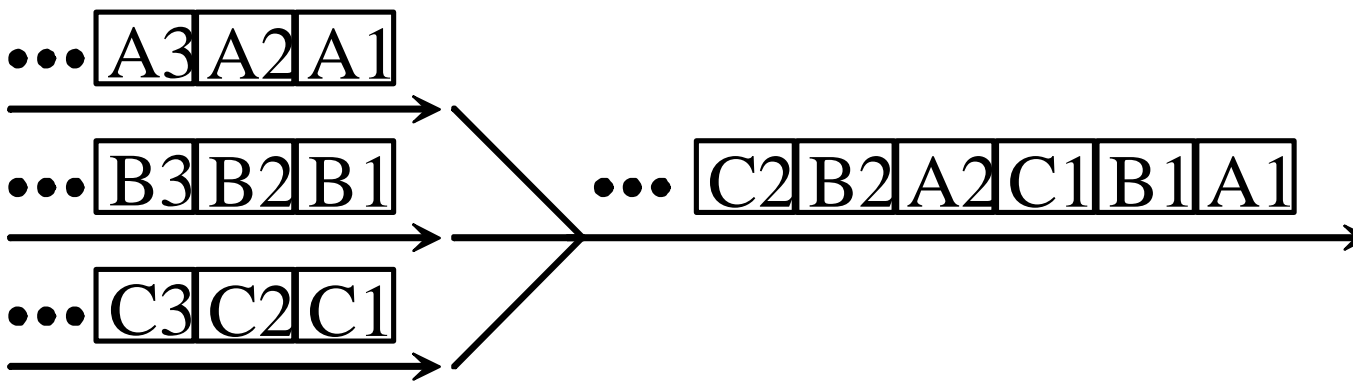
| ANSI Designation | Optical Signal | CCITT Designation | Data Rate (Mbps) | Payload Rate (Mbps) |
|------------------|----------------|-------------------|------------------|---------------------|
| STS-1            | OC-1           |                   | 51.84            | 50.112              |
| STS-3            | 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            |

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# Byte Multiplexing

Also known as byte interleaving

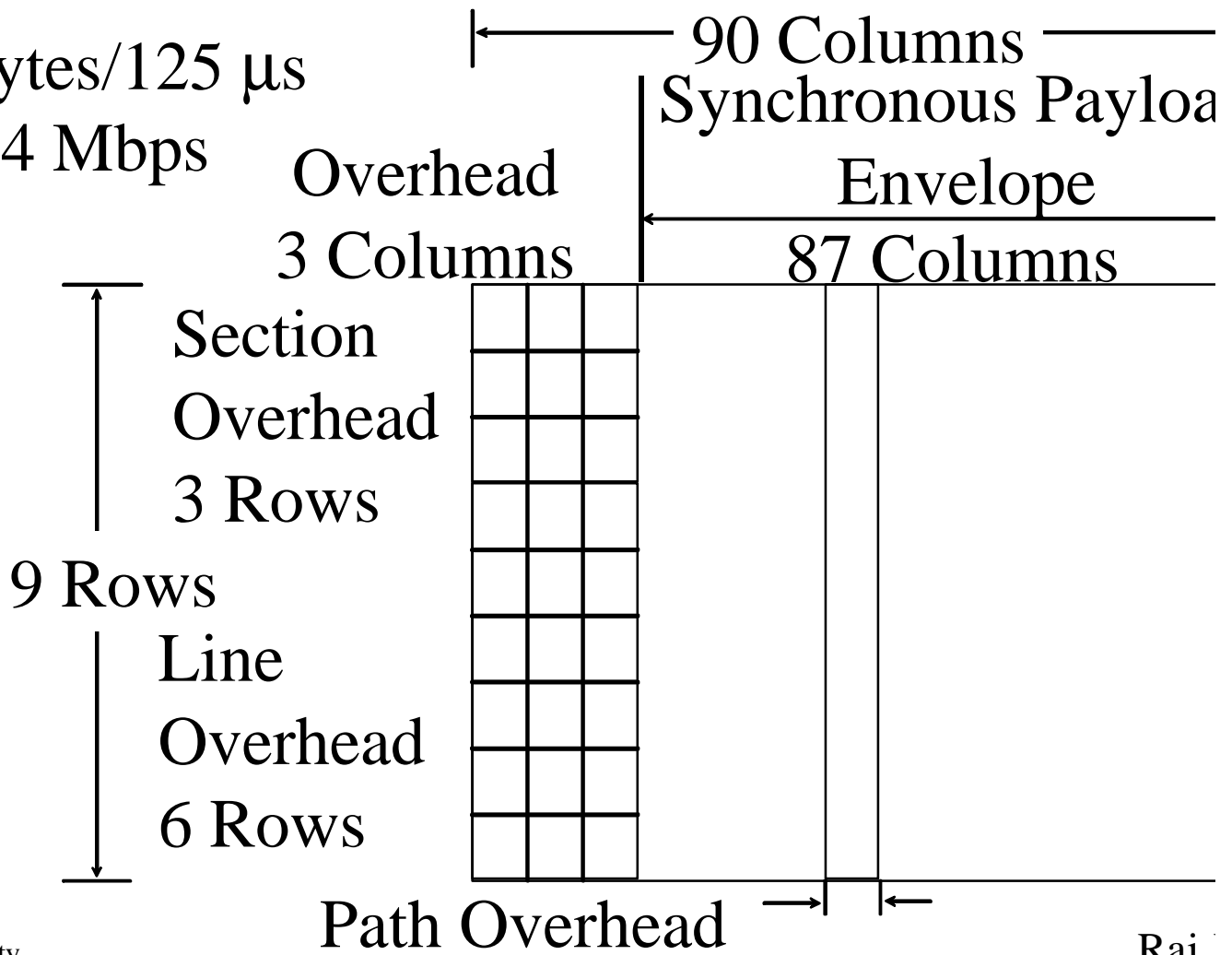
Easier to view in two dimension



# STS-1 Frame Format

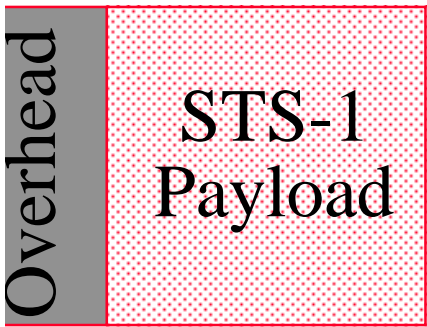
Overhead = Header.

810 Bytes/125  $\mu$ s  
= 51.84 Mbps



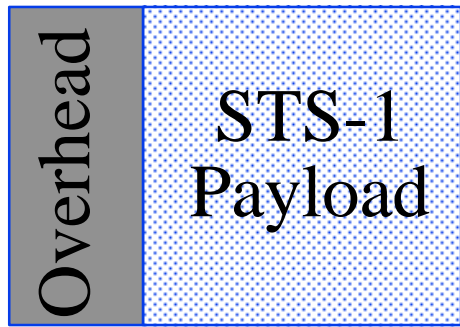
# Multiplexing

51.84 Mbps



+

51.84 Mbps



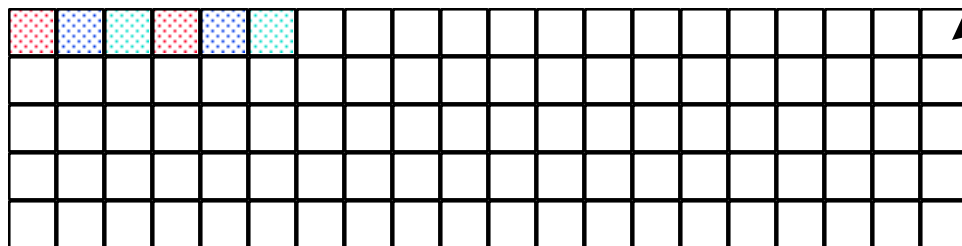
+

51.84 Mbps



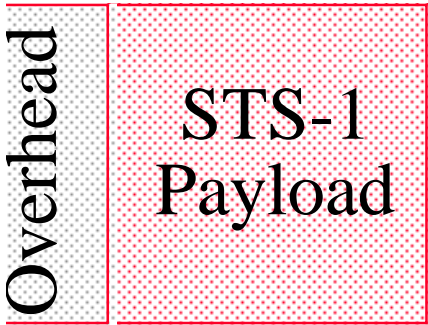
155.52 Mbps

1 Byte



# Concatenation

51.84 Mbps



+

51.84 Mbps



+

51.84 Mbps

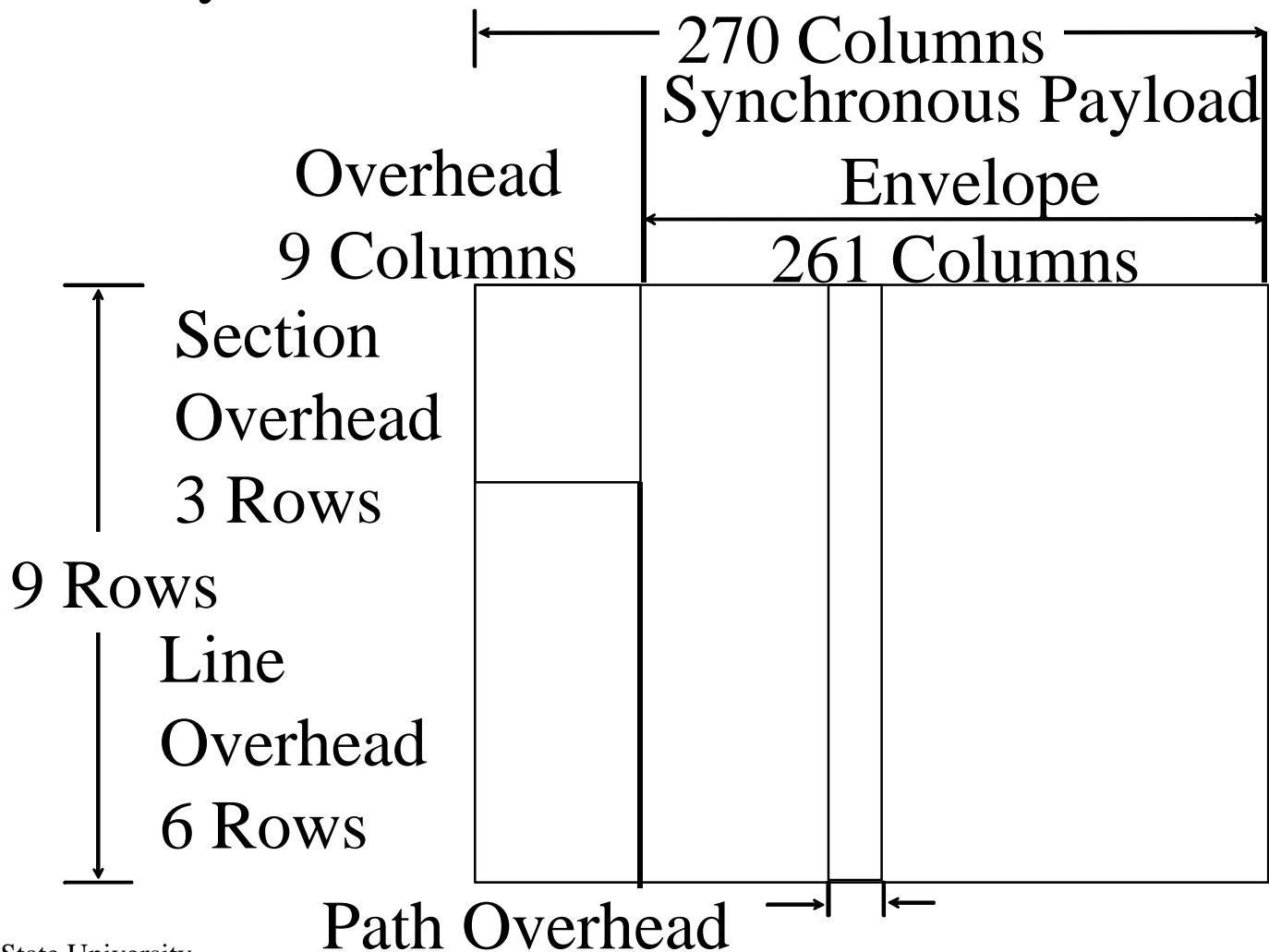


155.52 Mbps



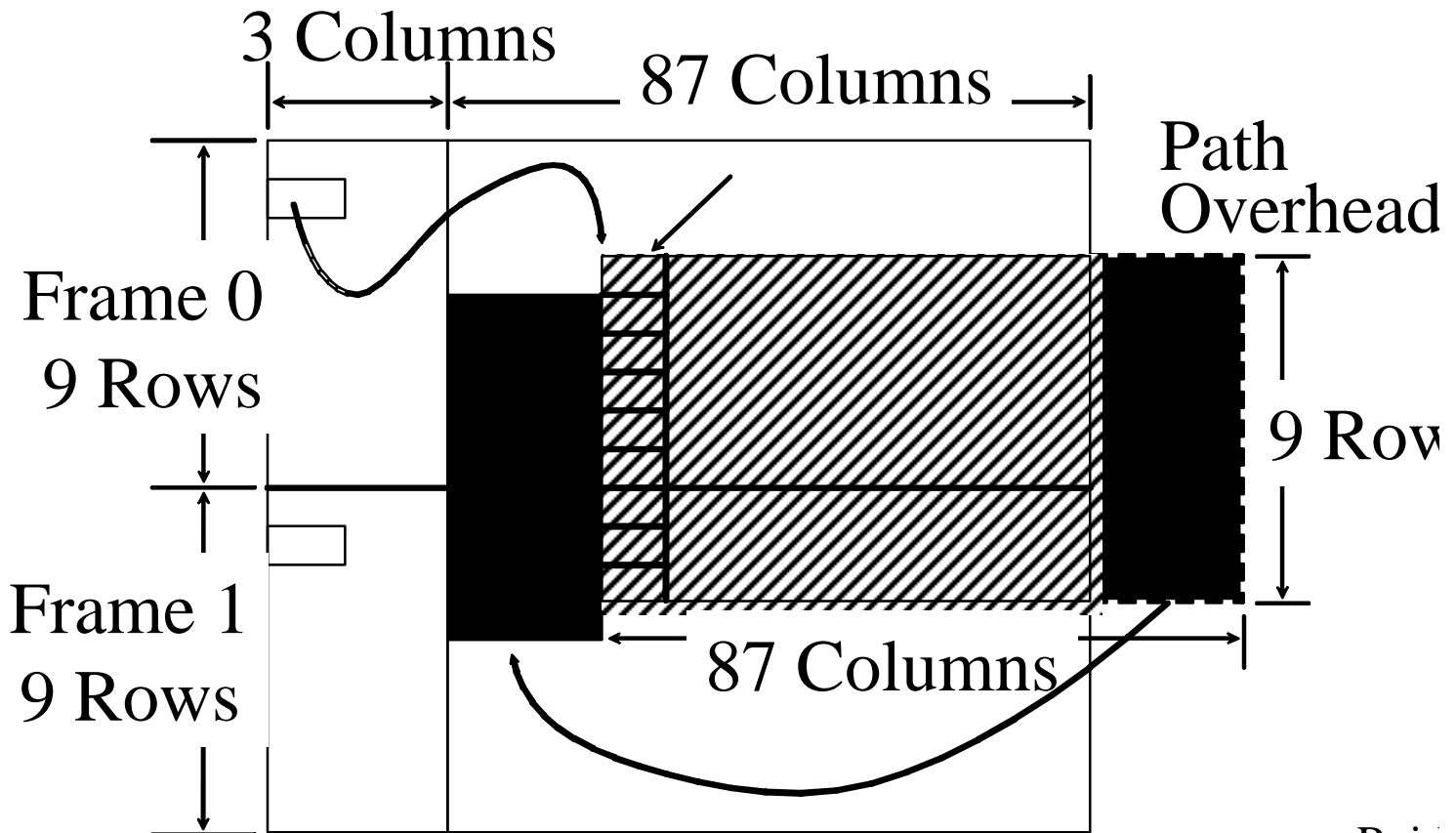
# STS-3c Frame Format

2430 Bytes/125 ms = 155.54 Mbps



# Location of SPE in STS-1

SPE supplied by the user  $\Rightarrow$  Can arrive at any time  
 $\Rightarrow$  SPE can straddle two successive STS frames



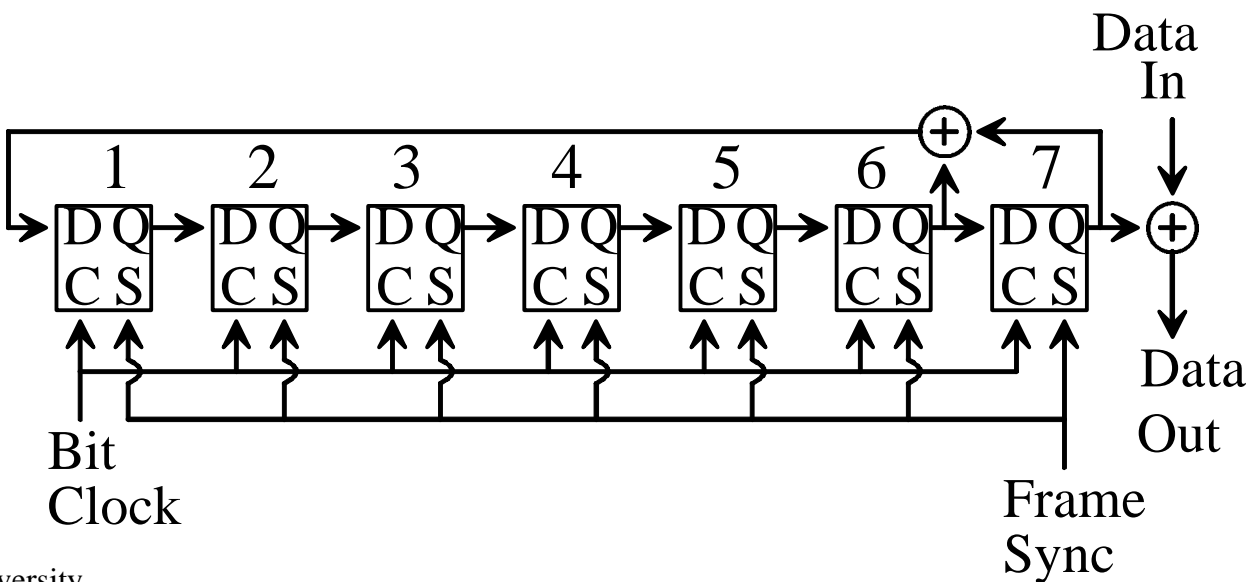
# crambling: Introduction

Two Methods:

Add random sequence

Divide by a number and send quotient. Similar to CRC  
th implemented by shift-registers.

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



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# Scrambling (Cont)

Set-Reset Synchronous scrambler:

Add a fixed random bit pattern.

Need to tell where to start adding

⇒ Need to synchronize.

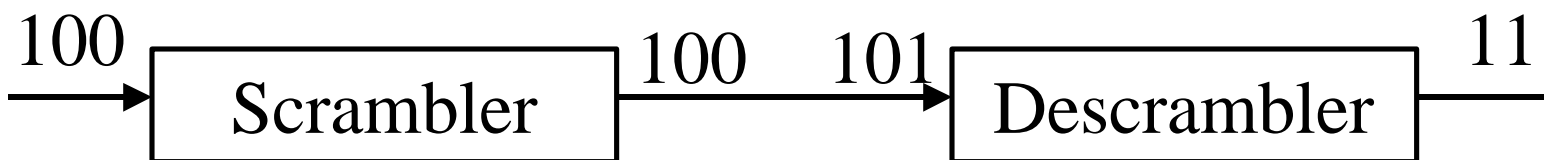
Self-synchronous scrambler: Divide by a fixed number

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



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# Scrambling

SONET uses NRZ coding.

1 = Light On, 0 = Light Off.

Too many 1's or 0's  $\Rightarrow$  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.

111 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.

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# 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

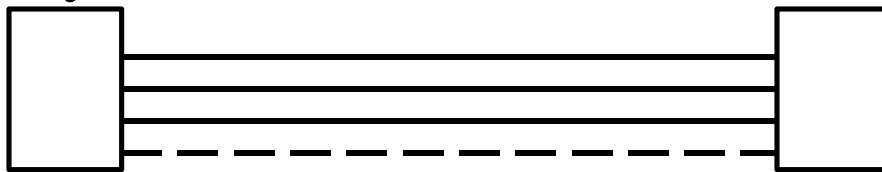
⇒ Higher speed lines ⇒ maintain sync for more bits

APS allows switching circuits on fault

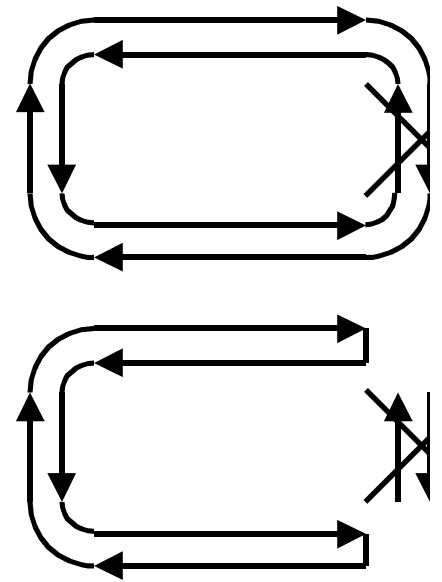
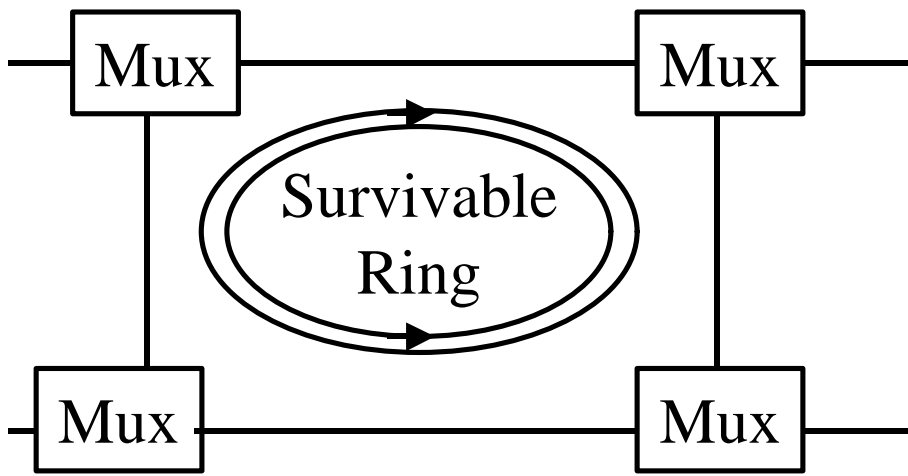
May take up to 50 ms to complete

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

⇒ Bi-directional operation

⇒ Traffic sent over shortest path

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# 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)

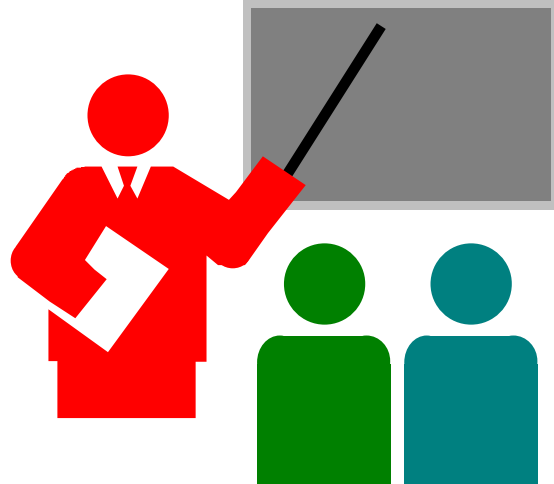
Network element vs Network node interface

Section vs regenerator section

Link vs multiplex section

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# Summary



§ONET

§DH

§TS-n, STM-n

§TS-3c

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# Homework

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

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# Additional References

Chapter 9 of FDDI Handbook by Raj Jain