SONET

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These slides are available at:
http://www.cse.ohio-state.edu/~jain/cis777-99/
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

Multiplexer - Add-Drop - Multiplexer

Terminals

Repeater - Repeater

Section - Section - Section - Section

Line - Line

Path
SONET Protocols

- Synchronous Optical Network

Diagram:

City A

Transport
Network
Datalink
Physical

Path
Line
Section
Photonic

City B
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 into SONET frames.
- Path Layer: End-to-end signaling issues. Mapping DS3, FDDI, BISDN into SONET payload.
Protocol Hierarchy

Path
Line
Section
Photonic
Terminal

STS-N Block
Frame
Light

Section
Photonic
Regenerator

Line
Section
Photonic
STS Multiplexer

Envelope

Path
Line
Section
Photonic
Terminal
## Signal Hierarchy

Synchronous Transport Signal Level $n = \text{STS}-n = n \times 51.84 \text{ Mbps}$

STM=Synchronous Transport Module, OC=Optical Carrier level

<table>
<thead>
<tr>
<th>ANSI Designation</th>
<th>Optical Signal</th>
<th>CCITT Designation</th>
<th>Data Rate (Mbps)</th>
<th>Payload Rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1</td>
<td>OC-1</td>
<td></td>
<td>51.84</td>
<td>50.112</td>
</tr>
<tr>
<td>STS-3</td>
<td>OC-3</td>
<td>STM-1</td>
<td>155.52</td>
<td>150.336</td>
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<td>OC-9</td>
<td>STM-3</td>
<td>466.56</td>
<td>451.008</td>
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<td>OC-12</td>
<td>STM-4</td>
<td>622.08</td>
<td>601.344</td>
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<td>STM-6</td>
<td>933.12</td>
<td>902.016</td>
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<td>STM-8</td>
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<td>1202.688</td>
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<td>OC-36</td>
<td>STM-12</td>
<td>1866.24</td>
<td>1804.032</td>
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<td>STM-16</td>
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<td>4810.176</td>
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<td>OC-192</td>
<td>STM-64</td>
<td>9953.28</td>
<td>9620.928</td>
</tr>
</tbody>
</table>
Byte Multiplexing

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

Diagram:

```
  A3 A2 A1
  B3 B2 B1
  C3 C2 C1

  --->
  C2 B2 A2 C1 B1 A1
  A1 B1 C1
  A2 B2 C2
  A3 B3 C3
```

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### STS-1 Frame Format

- **Overhead** = Header.
- **810 Bytes/125 \( \mu \text{s} \)**
  
  \[ \times 8 = 6480 \text{ Bytes} \]

\[ \frac{6480}{125} \mu \text{s} = 51.84 \text{ Mbps} \]

#### Frame Layout:

<table>
<thead>
<tr>
<th>Overhead</th>
<th>Synchronous Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 Columns</td>
<td>87 Columns</td>
</tr>
<tr>
<td>Envelope</td>
<td></td>
</tr>
</tbody>
</table>

#### Overhead Components:

- **Section Overhead**
  - 3 Columns
  - 3 Rows

- **Line Overhead**
  - 6 Rows

- **Path Overhead**
  - 9 Rows
Multiplexing

51.84 Mbps + 51.84 Mbps + 51.84 Mbps = 155.52 Mbps

Overhead

STS-1 Payload

1 Byte
Concatenation

51.84 Mbps + 51.84 Mbps + 51.84 Mbps = 155.52 Mbps
STS-3c Frame Format

- 2430 Bytes/125 μs = 155.54 Mbps
- 270 Columns
- Synchronous Payload Envelope
- 261 Columns
- Overhead
  - 9 Columns
  - Section Overhead
    - 3 Rows
  - Line Overhead
    - 6 Rows
  - Path Overhead
Location of SPE in STS-1

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

Frame 0
9 Rows

Frame 1
9 Rows

Path Overhead
9 Rows
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.

```
1100 100 1111101
```

Diagram:
```
Scrambler 100 101 Descrambler 1111
```

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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.
  
  $1111 \ 1110 \ 0000 \ 0100 \ 0001 \ \ldots \ 010$
- 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
  ⇒ 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
  \( \Rightarrow \) 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