SONET

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SONET

- Synchronous Optical Network
- Standard developed by ANSI and Exchange Carrier Standards Association (ECSA)
- CCITT: Synchronous Digital Hierarchy (SDH)
- SONET links can be used in place of dark fiber
Two Views of SONET
Protocol Components of SONET

- **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.
Physical Components of SONET

- **Section**: Single run of fiber. Clock synchronization and timing issues
- **Line**: Sections connected via repeaters. Between multiplexers or switches
- **Path**: End-to-end
Protocol Hierarchy

Path
Line
Section
Photonic
Terminal

STSS-N Block
Frame
Light
Section
Photonic
Regenerator

Envelope

Line
Section
Photonic

Line
Section
Photonic
STS
Multiplexer

Path
Line
Section
Photonic
Terminal
## SONET/SDH Signal Hierarchy

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

STM=Syncronous 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>
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<tbody>
<tr>
<td>STS-1</td>
<td>OC-1</td>
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<td>51.84</td>
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<td>STM-1</td>
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<td>9620.928</td>
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</tbody>
</table>

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Byte Multiplexing

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

- \[ \begin{align*}
  \cdots & \quad A3 \quad A2 \quad A1 \\
  \cdots & \quad B3 \quad B2 \quad B1 \\
  \cdots & \quad C3 \quad C2 \quad C1 \\
  \cdots & \quad C2 \quad B2 \quad A2 \quad C1 \quad B1 \quad A1 \\
  \cdots & \quad C3 \quad B3 \quad A3 \\
  \cdots & \quad C2 \quad B2 \quad A2 \\
  \cdots & \quad C1 \quad B1 \quad A1 \\
\end{align*} \]
STS-1 Frame Format

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

- 90 Columns
- 87 Columns

- 9 Rows
  - Section Overhead 3 Rows
  - Line Overhead 6 Rows
  - Path Overhead 1 Column
Multiplexing

51.84 Mbps

Overhead

STS-1 Payload

+ 51.84 Mbps

Overhead

STS-1 Payload

+ 51.84 Mbps

Overhead

STS-1 Payload

155.52 Mbps
Concatenation

\[
\begin{align*}
\text{51.84 Mbps} & \quad \text{STS-1 Payload} & \quad \text{Overhead} \\
\text{51.84 Mbps} & \quad \text{STS-1 Payload} & \quad \text{Overhead} \\
\text{51.84 Mbps} & \quad \text{STS-1 Payload} & \quad \text{Overhead}
\end{align*}
\]

\[\downarrow\]

\[
\begin{array}{c}
\text{155.52 Mbps} \\
\text{Overhead} \\
\text{STS-3c Payload}
\end{array}
\]
STS-3c Frame Format

- STS-3c is similar to STM-1

270 Columns

Overhead
9 Columns

Payload
261 Columns

9 Rows
Location of SPE in STS-1

- SPE supplied by the user ⇒ Can arrive at any time ⇒ SPE can straddle two successive STS-1 frames
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 pseudorandom sequence, which is XOR’ed to incoming bits.

```
1111 1110-0000 0100-0001 1000-0101 0001-1110 0100-0101 1001-1101 0100-1111 1010-0001 1100-0100 1001-1011 0101-1011 1101-1000 1101-0010 1110-1110 0110-0101 010
```

- If user data is identical to (or complement of) the pseudorandom sequence, the result will be all 0’s or 1’s.
- T1, DS1, DS3, ...
- SONET
- SDH
- STS-n, STM-n
- STS-3c
<table>
<thead>
<tr>
<th>Framing</th>
<th>Framing</th>
<th>STS-1 ID</th>
<th>Trace</th>
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</thead>
<tbody>
<tr>
<td>A1</td>
<td>A2</td>
<td>C1</td>
<td>J1</td>
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<tr>
<td>B1</td>
<td>Orderwire</td>
<td>User</td>
<td>BIP-8</td>
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<tr>
<td>D1</td>
<td>Data Com</td>
<td>Data Com</td>
<td>C2</td>
</tr>
<tr>
<td>H1</td>
<td>Pointer</td>
<td>Pointer Action</td>
<td>APS</td>
</tr>
<tr>
<td>B1</td>
<td>APS</td>
<td>APS</td>
<td>K1</td>
</tr>
<tr>
<td>B2</td>
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<tr>
<td>D4</td>
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<td>D3</td>
<td>G1</td>
</tr>
<tr>
<td>D7</td>
<td>Data Com</td>
<td>Data Com</td>
<td>F2</td>
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<tr>
<td>D10</td>
<td>Data Com</td>
<td>D6</td>
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</tr>
<tr>
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<td>Growth</td>
<td>Orderwire</td>
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</tr>
<tr>
<td>Z2</td>
<td>Growth</td>
<td>E2</td>
<td>Z4</td>
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</table>

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## STS-3c Overhead bytes

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<td>B1</td>
<td>E1</td>
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<td>D2</td>
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<td>J1</td>
</tr>
</tbody>
</table>

(a) Section and line overhead  

(b) Path overhead