Digital Carrier Systems

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Digital carrier standard

- **T-carrier**
  - North America, Japan
- **E-carrier**
  - Europe, South America
- **SONET/SDH**
  - world-wide new standard
Comparison of the layer

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<th>T-1</th>
<th>SONET/SDH</th>
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<td>Physical</td>
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<td>Data link</td>
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<tr>
<td>Physical</td>
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Organization of telephone services

The telephone message are routed through:
- a switch at the central office (CO) for a local calls
- a switching center for out-of-area calls
- toll exchanges for long distance calls

- The original IOT connections were made over an analog system called N-carrier.
- The T-carrier system was the first widely deployed digital transmission system.
T-1 carrier system

- 24 voice channels are sampled, quantized and encoded into a TDM PCM signal
- T-1 carrier has a transmission rate of 1.544 Mbps

- Bipolar encoding
  - B8ZS for T-1
  - B3ZS for T-3
- Full duplex
- Channel-based digital transmission

T-1 frame

- T-1 bit rate: \( \frac{(24 \times 8 + 1 \text{ bit})}{125 \mu s} = 1.544 \text{ Mbps} \)

- The early frame standard called D1, D2 and D3 were used.
- There are two framing standard for the T-1, called D4 (superframe) and extended superframe (ESF).
- The T-3 used the M13 framing.

1 frame bit: 125 \( \mu s \)
Frame and Superframe

- T-1 carrier frames are transmitted in groups of 12 called superframes.
- F-bit in even-numbered frame has a pattern of 101010 for synchronization.
- Signaling information is accomplished by robbing the LSB position of each channel. This is performed only in the 6th and 12th frame to keep distortion minimum.

Extended Superframe

- ESF framing groups 24 frames into an ESF superframe.
- Every 193rd bit are used for the above purposes.
Multiplexing

- **CSU (Channel Service Unit)**
  - performs several protective and diagnostic functions
- **DSU (Data Service Unit)**
  - convert the digital data from a (for example) router to T1 voltages and encoding.

**T-carrier Digital Multiplexing Hierarchy**

- Two 1.544 Mbps DS1 channels are multiplexed into a single 3.152 Mbps DS1C channel
- Two DS1C channels are multiplexed into a single 6.312 Mbps DS2 channel
- Seven DS2 channels are multiplexed into a single 44.736 Mbps DS3 channel
- Six DS3 channels are multiplexed into a single 274.176 Mbps DS4 channel
E1-frame

30 voice channels + 2 control channels

125 µs

Frame synchronization

Signaling channel

E1-bit rate: \((32 \times 8 \text{ bit})/125 \mu s = 2.048 \text{ Mbps}\)

E-carrier

Thirty 64 Kbps channels are multiplexed to create one 2.048 Mbps E1 channel

Four E1 channels are multiplexed into a single 8.448 Mbps E2 channel

Four E2 channels are multiplexed into a single 34.368 Mbps E3 channel

Four E3 channels are multiplexed into a single 139.264 Mbps E4 channel

Four E4 channels are multiplexed into a single 565.148 Mbps E5 channel
Digital carrier comparison

Europe

<table>
<thead>
<tr>
<th>x31</th>
<th>E1</th>
<th>x 4</th>
<th>E2</th>
<th>x 4</th>
<th>E3</th>
<th>x 4</th>
<th>E4</th>
<th>x 4</th>
<th>E5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.048</td>
<td>8.448</td>
<td>34.368</td>
<td>139.264</td>
<td>564.992</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

USA

<table>
<thead>
<tr>
<th>x24</th>
<th>T1</th>
<th>x 2</th>
<th>T1C</th>
<th>x 2</th>
<th>T2</th>
<th>x 7</th>
<th>T3</th>
<th>x 6</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.544</td>
<td>3.152</td>
<td>6.312</td>
<td>44.736</td>
<td>274.176</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Japan

<table>
<thead>
<tr>
<th>x24</th>
<th>J1</th>
<th>x 4</th>
<th>J2</th>
<th>x 5</th>
<th>J3</th>
<th>x 3</th>
<th>J4</th>
<th>x 4</th>
<th>J5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.544</td>
<td>6.312</td>
<td>32.064</td>
<td>97.728</td>
<td>397.200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PDH

- PDH = Plesiochronous Digital Hierarchy
- Digital transmission systems (T-carrier, E carrier) combine lower order multiplex stream to get higher bit rate
- Each device runs its own free-running clock
- Different streams have small differences in clock signals.
- Solve by adding justification bit

almost synchronous
PDH deficiencies (I)

- Lack of flexibility
  - impossible to identify a lower bit rate channel from the higher-order bit stream.

Extraction of 2 Mbps channel from 140 Mbps channel

PDH deficiencies (II)

- Lack of performance
  - No standard for monitoring the performance of traffic channel
  - No management channel

- Lack of ‘Mid-Fibre meet’
  - undefined interface specification on the line side of a line transmission

PDH

<table>
<thead>
<tr>
<th>G.703 interface</th>
<th>LTE</th>
<th>non standard line code and optical levels</th>
</tr>
</thead>
</table>

SDH

<table>
<thead>
<tr>
<th>standard Network Node Interface (NNI)</th>
<th>functional integration of MUX and LTE</th>
</tr>
</thead>
</table>
SDH & SONET

- What is SDH/SONET?
  - Standard interface developed for using in the public network
  - Multiplexing standard for optical fiber transmission
- SONET = Synchronous Optical Network
  - Refers to the system used within the U.S. and Canada
- SDH = Synchronous Digital Hierarchy
  - International community term (ITU-T recommendations)

SDH/SONET goals

- Goals
  - Make it possible for different carrier to interwork
  - Unify the U.S., European and Japanese digital system
  - Provide a way to multiplex multiple digital signal together
  - Provide support for operations, administration, and maintenance
- Characteristics
  - Use single master clock to synchronize
  - Bit stream can be added or extracted directly
  - Basic transmission rate = 155.52 Mbps
**SDH/SONET topology**

- Typical SDH/SONET topology is a dual ring (fiber optics)
- One ring is the working facility, and the other ring is the protection facility (standby)
- End-user devices operating on LANs or other transport systems are attached through terminal adapter

**SDH/SONET System**

- consists of switches, mux and repeaters
Multiplexing level

<table>
<thead>
<tr>
<th>SONET</th>
<th>SDH</th>
<th>Bit rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1/OC-1</td>
<td>(Not defined)</td>
<td>51.84</td>
</tr>
<tr>
<td>STS-3/OC-3</td>
<td>STM-1</td>
<td>155.52</td>
</tr>
<tr>
<td>STS-9/OC-9</td>
<td>STM-3</td>
<td>466.56</td>
</tr>
<tr>
<td>STS-12/OC-12</td>
<td>STM-4</td>
<td>622.08</td>
</tr>
<tr>
<td>STS-18/OC-18</td>
<td>STM-6</td>
<td>933.12</td>
</tr>
<tr>
<td>STS-24/OC-24</td>
<td>STM-8</td>
<td>1244.16</td>
</tr>
<tr>
<td>STS-36/OC-36</td>
<td>STM-12</td>
<td>1866.24</td>
</tr>
<tr>
<td>STS-48/OC-48</td>
<td>STM-16</td>
<td>2488.32</td>
</tr>
</tbody>
</table>

STS = Synchronous Transport Signal
OC = Optical Carrier
STM = Synchronous Transport Module

SDH Basic Frame structure

1 frame = 2430 bytes in 125 µs

Overhead:
- for system management information (OAM)
- SOH = Section Overhead
- LOH = Line Overhead
- TOH = Transport Overhead

Payload: user data
**SONET Basic Frame structure**

1 frame = 810 bytes in 125 µs

STS-1/OC1

Overhead:
- SOH = Section Overhead
- LOH = Line Overhead
- TOH = Transport Overhead

Payload: user data

---

**STM-1 Frame**

9 bytes in 261 bytes

frame #1

Payload #1

Payload #1

frame #2

Payload #2

Payload #2

row/column mapping

Applied Network Research Group  Department of Computer Engineering, Kasetsart University
SDH mux scheme

SDH Elements

Containers
Virtual Containers
Tributary Unit

Tributary Unit
Administrative Unit

Administrative Unit Group
STM-1
High order mux

STM-1 #1  STM-1 #2  STM-1 #N  MUX  byte interleave

Nx9  Nx261

stream