ATM Physical Layer

Raj Jain

Professor of Computer and Information Science

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/
Physical Layer

- Physical Medium Dependent (PMD) Sublayer:
  - Fiber, Twisted-Pair, Coax, SONET, DS3
- Transmission convergence layer:
  - Convert bit stream to cell stream
  - Transmission frame adaptation: packing cells into frames
  - Cell delineation: scrambling and cell recovery after descrambling
  - HEC generation and verification
  - Cell rate decoupling: Insertion and suppression of idle cells
B-ISDN Physical Layer

- I.432 (1993) defines three PHY Interfaces at $T_B$ (NT1-NT2):
  - Full-duplex 155.52 Mbps
  - Subscriber to Network at 155.52 Mbps, Network to subscriber at 622.08 Mbps (For video distribution)
  - Full-duplex 622.08 Mbps
- Full-Duplex 155.52 Mbps
  - Coaxial cable pair (100-200 m max) using CMI coding
  - Single mode fiber pair (800-2000 m max) using NRZ
- 622.08 Mbps: Single mode fiber pair using NRZ
<table>
<thead>
<tr>
<th>Frame Format</th>
<th>Bit Rate/Line Rate</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Stream</td>
<td>25.6 Mbps/ 32 Mbaud</td>
<td>UTP-3</td>
</tr>
<tr>
<td>STS-1</td>
<td>51.84 Mbps</td>
<td>UTP-3</td>
</tr>
<tr>
<td>FDDI</td>
<td>100 Mbps/ 125 Mbaud</td>
<td>Multimode Fiber</td>
</tr>
<tr>
<td>STS-3c, STM-1</td>
<td>155.52 Mbps</td>
<td>UTP-5</td>
</tr>
<tr>
<td>STS-3c, STM-1</td>
<td>155.52 Mbps</td>
<td>Single-Mode Fiber, Multimode Fiber, Coax pair</td>
</tr>
<tr>
<td>Cell Stream</td>
<td>155.52 Mbps/ 194.4 Mbaud</td>
<td>Multimode Fiber, STP</td>
</tr>
<tr>
<td>STS-3c, STM-1</td>
<td>155.52 Mbps</td>
<td>UTP-3</td>
</tr>
<tr>
<td>STS-12, STM-4</td>
<td>622.08 Mbps</td>
<td>SMF, MMF</td>
</tr>
</tbody>
</table>
## PHYs for Public UNI

<table>
<thead>
<tr>
<th>Frame Format</th>
<th>Bit Rate</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS1</td>
<td>1.544 Mbps</td>
<td>Twisted pair</td>
</tr>
<tr>
<td>DS3</td>
<td>44.736 Mbps</td>
<td>Coax pair</td>
</tr>
<tr>
<td>STS-3c, STM-1</td>
<td>155.520 Mbps</td>
<td>Single-mode Fiber</td>
</tr>
<tr>
<td>E1</td>
<td>2.048 Mbps</td>
<td>Twisted pair, Coax pair</td>
</tr>
<tr>
<td>E3</td>
<td>34.368 Mbps</td>
<td>Coax pair</td>
</tr>
<tr>
<td>J2</td>
<td>6.312 Mbps</td>
<td>Coax pair</td>
</tr>
<tr>
<td>N × T1</td>
<td>N × 1.544 Mbps</td>
<td>Twisted pair</td>
</tr>
</tbody>
</table>
Transmission Structure

- I.432 specifies two options:
  - Sequence of cells. Synchronization using HEC.
  - SONET/SDH payload envelops
Cell-Stream Phy

- Continuous stream of cells. No framing.
- Hunt bit-by-bit for correct header.
- Look for $\delta$ correct headers before entering synch state
- $\alpha$ incorrect headers $\Rightarrow$ resynchronize
- $\alpha$ and $\delta$ are parameters.
- $VPI/VCI = 0/9 \Rightarrow$ Phy layer OAM cells (F1, F2, F3 level)
SONET/SDH Based Phy

- Allows SONET facilities to be used for ATM and non-ATM
- Lower speed ATM streams can be multiplexed into higher speed SONET streams
- H4 octet in the path header indicates offset to the boundary of the first cell following H4
- Some cell may need to be split between successive SONET frames.
- OAM information is carried in the SONET overhead octets. F1 and F2 in section overhead. F3 in path overhead.
SONET/SDH Phy

260 Columns

J1
B3
C2
G1
F2
H4
Z3
Z4
Z5

Cell

9 Rows

Path Overhead

9 Columns

The Ohio State University

Raj Jain
SONET STS-3c

- Payload rate = 9 × 260 × 8/125 = 149.76 Mbps
- Cell payload rate = 135.63 Mbps
- Cell delineation using HEC.
  - Look for 5-byte blocks with HEC separated by 48 bytes
- Cells are packed one after another ⇒ One can send 127 bits matching the scrambling sequence resulting in all 1’s or 0’s. Scramble by dividing by $1 + x^{43}$. Only one in $2^{43}$ patterns will cause all 1’s or 0’s.
- Self-synchronous scrambler
  ⇒ No need for synchronization.
  ⇒ Each bit error in fiber results in two bit errors after descrambling (multiplication).
ATM on SONET STS-3c

- The polynomial was chosen because it does not conflict with existing CRCs.
- Also 43 is larger than header length $\Rightarrow$ Header will not have two-bit errors.
Payload rate = 7 × 8 × 84/106.4 = 44.21 Mbps
Cell Payload rate = 12 cells per 125 µs = 36.864 Mbps
155 Mbps, 8b/10b

- 8b/10b code used in Fiber Channel
- 2 km multimode fiber or 100 m shielded twisted pair
- 155.52 Mbps ⇒ 194.4 Mbaud
- Cells delimited using a transmission frame
- Cell payload rate = $155.52 \times \frac{26}{27} \times \frac{48}{53}$
  \[= 135.63 \text{ Mbps} = \text{STS-3c rate}\]

<table>
<thead>
<tr>
<th>Frame Delimiter</th>
<th>OA&amp;M</th>
<th>Cell 1</th>
<th>Cell 2</th>
<th>...</th>
<th>Cell 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>5B</td>
<td>48B</td>
<td>53B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
100 Mbps 4b/5b

- 4b/5b used in FDDI
- 100 Mbps $\Rightarrow$ 125 Mbaud
- Cells delimited with TT pair
- Cell = TT + 53 bytes $= 2 + 106 = 108$ symbols
- Cell payload rate $= 100(53/54)(48/53) = 88.89$ Mbps
1.5 Mbps DS1

- Payload rate = 24 bytes/125 ms = 1.536 Mbps
- Cell delineation by HEC detection
- Cell payload rate = 1.536 * (48/53) = 1.391 Mbps

Framing bit

24th byte

193 bits

| F | Header |
| F |       |
| F | Header |
| F |       |
| F | Header |
| F |       |
Payload rate = 98 bytes/125 µs = 6.272 Mbps

97th and 98th byte are reserved.
96 Bytes per frame used for cell stream.

Cell delineation by HEC detection

Cell payload rate = \((48/53)(96\times8/125\mu s)\) = 5.928 Mbps
25.6 Mbps UTP

- Scrambling:
  - Pseudo-random numbers are generated using \( x^{10} + x^7 + 1 \)
  - Successive 4 bits are XOR’ed with 4-bits of data
  - All 53 bytes are scrambled
  - The random number generator is initialized to 3FF upon detection of two consecutive escape (X) nibbles. The two X nibles (00010) may not be octet-aligned.

- Coding: 4b/5b + NRZI
UTOPIA

- Universal Test & Operations PHY Interface for ATM
- A common PHY-ATM interface over a wide range of PHYs
- Chip-chip or board-board interface ⇒ Industry standard devices
- PHY-ATM interface not visible outside and so not required for interoperability

<table>
<thead>
<tr>
<th>ATM</th>
<th>Transmit Data</th>
<th>Transmit Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Receive Data</td>
<td>Receive Control</td>
</tr>
<tr>
<td>Management Entity</td>
<td>Management Interface</td>
<td>Test Interface</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Ohio State University

Raj Jain
UTOPIA

- UTOPIA Level 1 defines electrical interfaces for:
  - An 8-bit wide data path using an octet-level handshake at 25 MHz
  - An 8-bit data path using cell-level handshake at 25 MHz
  - 16-bit and 32-bit wide data paths may be defined for higher speeds
- UTOPIA Level 2
  - addresses 33 MHz operation for PCI bus and
  - 50 MHz operation for 622 Mbps
  - Multi-PHY operation
References

- “6,312 kbps UNI Specification”
- “Physical Interface Specifications for 25.6 Mb/s over Twisted Pair Cable,” June 11, 1995.