Digital Carrier

- 64kbps
- 64kbps
- 64kbps
- 64kbps
- 320kbps

Digital Carrier Hierarchy

1. The Basic channel is a DS0 = 64kbps
2. DS1 = 24 x DS0 plus framing = 1.544Mbps
3. DS1C = 2 x DS1
4. DS2 = 4 x DS1
5. DS3 = 28 x DS1

The US Digital Carrier System

- Synchronous Optical Network
- STS-n is the electrical standard, OC-n the optical one
- Basic channel STS-1 = about 52Mbps
- OC-3 = about 155Mbps
- OC-12 = about 600Mbps
- OC-48 = about 2500Mbps, etc.
European Digital Carrier

- Basic channel: DS0 = 64kbps
- E1 = 30 x DS0 + 2 x 64kbps for signaling = 2.048Mbps
- No signaling embedded in the user channels.

T1 Service: A Carrier System Applied to End-User Demand

Definitions

- T1 and DS1 are synonymous
- To the end-user, a T1 represents either
  - a digital transmission path of 1.536Mbps/sec,
  - or 24 "channels", with each channel capable of carrying a voice call or digital data up to 56kbps/sec.
- Channels are 64kbps "wide", more about that later…

Market Environment

- Typical uses for the T1
  - Voice trunks (ACDs)
  - Small Business Internet Access
  - Next higher speed after ISDN
- T1 is a "mature" market with established manufacturers; growth is modest.
Voice Applications

- 24 Voice Trunks
- PBX
- Channel Bank
- TI Facility

Data/Hybrid Applications

- Video Conference
- LAN Router
- CSU/DSL
- Voice

Trends

- T1 facilities will continue to be in widespread use.
- T1 is being used to carry “Frame Relay” data traffic.
- The next step after T1 (possibly multiple ones) is DS3=45Mbit/sec private lines and ATM (Asynchronous Transfer Mode) networks over SONET.

Synchronous Transmission

<table>
<thead>
<tr>
<th>Data: 1 1 1 0 1 1 1 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit:</td>
</tr>
<tr>
<td>Receive:</td>
</tr>
<tr>
<td>Timing:</td>
</tr>
</tbody>
</table>

What if:
What does a “raw” T1 Signal

A “channelized” T1

- A “Frame” consists of 8 bits for each channel, strung one after the other
  - 8 bits/channel times 24 channels = 192 bits
- One “Framing Bit” is added to each frame
  - Total frame length is 193 bits
- 8000 frames are sent per second
  - 8000 times 193 = 1,544,000

The T1 Frame (D4 Format)

Restrictions on the T1 signal

- In the bit stream, there must never be more than 15 consecutive “0”s.
- Over short periods of time, there must be at least 12.5% “1”s in the signal.
Signaling in a T1

- At the T1 level
  - “Superframe” signaling uses groups of 12 T1 frames to create timing and signaling patterns
  - “Extended Superframe” signaling uses 24 T1 frames to create timing, error detection, and signaling capabilities

SF and ESF Signaling

Superframe Signaling (Sequence of 12 framing bits):
100011011100

Extended Superframe (Sequence of 24 framing bits):
DCD0DCD0DCD1DCD0DCD1DCD1

Signaling in a T1 cont...

- Inside each channel
  - Voice channels use signaling bits to indicate on-hook and off-hook conditions
  - Data channels may include signaling bits and bits that enforce the “1”’s density

Voice Channel Signaling

<table>
<thead>
<tr>
<th>Frame</th>
<th>Bits 1 2 3 4 5 6 7 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>2</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>3</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>4</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>5</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>6</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>7</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>8</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>9</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>10</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>11</td>
<td>v v v v v v v v</td>
</tr>
<tr>
<td>12</td>
<td>v v v v v v v v</td>
</tr>
</tbody>
</table>
CSU - Channel Service Unit

• Interface between the customer and the carrier circuit.
• Regenerates the signal
• Provides or recovers timing
• Passes a T1 signal (DSI-X) to the customer equipment

DSU - Data Service Unit

• Receives a T1 signal from the CSU
• Converts the signal to a “short-haul” interface format
  – RS-232
  – V.35
  – RS-422
• Can access and “break out” individual channels.

MUX - the Multiplexer

• Combines numerous voice and data input streams into a T1
• May use the 24-channel format
• Often uses proprietary channel assignments

DCS - Digital Cross-Connect

• Used by carriers and large end-users
• Electronically connects T1s to each other, or
• Connects channels from one T1 to channels in another T1.