Transmission Efficiency

- Front End Processors
- Port Sharing Devices
- Multiplexers: FDM, TDM, STDM
- Data Compression Devices
- Inverse Multiplexers
A front end processor is a communications assistant for the host computer that allows terminals to share a high-speed host computer channel.

- It handles communications with the outside world for the host.
- It is usually a special-purpose microcomputer.
Front End Processor (FEP) continued

- It can perform a variety of functions, including: Input/Output management between the terminals and host computer, polling and selecting, buffering, code conversion, protocol conversion, parallel/serial conversion, historical logging, and statistical logging.
- Protocol converters allow a device or computer that uses one protocol to talk to another computer that uses a different protocol.
Port Sharing Devices

- Ports connect communications to a host computer and/or FEP.
- The number of ports a computer or FEP has places a limit on its capacity for communications.
- Port sharing devices (concentrator) are used to extend capacity by allowing many terminals to share one port.
- Port sharing devices are located near the host computer or FEP.
CONNECTION WITHOUT PORT-SHARING DEVICE

Device #1

Device #2

Device #3

Port #1

Port #2

Port #3

Computer or front-end processor

Device #1

Device #2

Device #3
Multipoint and Intelligent Controller.
Line Splitters & Remote Intelligent Controllers

- Line Splitter's perform the same function as port sharing devices
- Except they are located remotely from the FEP & host computer
- Remote Intelligent Controller is like a line splitter & it performs some FEP functions
MULTIPLEXERS

Communication controllers are often referred to as multiplexers. The function of multiplexing is also found in devices called cluster or intelligent controllers. Multiplexing combines several independent channels of data onto a high-speed data line. Adding multiplexers to a communications network reduces the number of communications lines needed to support a given number of devices.
Multiplexers

- Often called a MUX
- Allows several devices to share the same communication circuit
- Main Purpose = minimize communication circuit costs
- Normally used in pairs
- Main advantage = fewer lines & modems are needed
Efficient utilization of a transmission medium is obtained through multiplexing in either frequency or time.
EXAMPLE #1

Input Total
1200 bps X 8 = 9600 bps

Output Total
9600 bps

Eight lower speed channels MULTIPLEXED onto one higher speed channel

Multiplexer

I < O
EXAMPLE #2

Input Total
4800 bps X 7 = 33600 bps

Output Total
33600 bps

7 lower speed channels MULTIPLEXED onto one higher speed channel
EXAMPLE #3

Input Total
9600 bps X 6 = 57600 bps

Output Total
57600 bps

Six lower speed channels MULTIPLEXED onto one higher speed channel
EXAMPLE #4

Nine lower speed channels MULTIPLEXED onto one higher speed channel

Output Total
63900 bps
MULTIPLEXERS

A MULTIPLEXER has equal (or less than) input and output data rates. For example, six channels operating at 9600 bps \((6 \times 9600 \text{ bps} = 57600 \text{ bps})\) can be multiplexed onto a single 64000 bps line to reduce long-haul transmission costs.
FDM - TDM - STDM

Multiplexers can be separated into three major categories:

- Frequency Division Multiplexers (FDM)
- Time Division Multiplexers (TDM)
- Statistical Time Division Multiplexers (STDM)
FREQUENCY DIVISION MULTIPLEXERS (FDM)

- Frequency Division Multiplexers (FDM)
  - FDM can be looked upon as having a stack of four or more modems which operate different frequencies so their signals can travel down a single communication circuit.
  - In FDM the Frequency Division Multiplexer and the modem are usually a single piece of hardware.
  - The Multiplexer utilizes the available bandwidth of a voice grade circuit and divides it into multiple subchannels.
FREQUENCY DIVISION MULTIPLEXED CIRCUIT (FDM)

Host

Front End

Guard Bands

3100 hertz available bandwidth

FDM

FDM

Voice Grade Circuit

300

3400

800 - 1
400 - 0
1,000 - 0
1,400 - 1
1,600 - 0
2,000 - 1
2,200 - 0
2,600 - 1
FDM (Continued)

Host

1200 bps

FDM

9600 bps

FDM

D#1

D#2

D#3

D#4

1200 bps
TIME DIVISION MULTIPLEXERS (TDM)

2. Time Division Multiplexers (TDM)

- Time Division Multiplexing (TDM) is really a type of time slicing or sharing the use of a communication circuit among two or more devices. Each device takes its turn.
- In TDM, the multiplexer takes a character or bit from each transmitting device and puts them together into a frame.
- The frames are put onto a high speed data stream for transmission to the other end of the circuit.
- TDM has two separate pieces of hardware: Multiplexer and Modem.
- TDM is generally more efficient and usually costs less to maintain than FDM.
TIME DIVISION MULTIPLEXERS CIRCUIT (TDM)
TDM
Character & Bit Interleaving

- TDM multiplexing is performed one character or one bit at a time.
- It is called character interleaving or bit interleaving because every fourth character or bit transmitted over the multiplexer's trunk port is destined for the same branch port.
- e.g. Four lanes merge into one lane then splits back into four lanes
TDM

Host

Front End

TDM

Modem

32 bit frame

D CB A

32 bit frame

D CB A

Voice Grade Circuit

TDM

Modem

A

B

C

D
TIME DIVISION MULTIPLEXING

TDM: Divides the bandwidth into time slots. Each time slot belongs to a user. Within each time slot a single bit or group of bits can be sent. Usually uses digital transmission (baseband) within channel

```
| SUB CHANNEL 1 | SUB CHANNEL 2 | SUB CHANNEL 3 | SUB CHANNEL 1 |
```
TIME DIVISION MULTIPLEXING

- No guardbands required
- Needs framing and timing on channel
- Used in telephone "T1" carrier system:
  (24 phone calls, 64Kb subchannels within 1.544 Mb/sec channel)
- Unused bandwidth is lost
- Can be built in Hardware and/or software
- Buffering required - Bandwidth allocated in bursts
- Subchannels can be switched via reassignment of slot numbers
T-1 Facilities

• T-1 facility used by companies for expanding networking and controlling costs.
• Most commonly used as leased dedicated transmission between customer premises.
• Help in setting private networks like:
  ➤ Private voice networks
  ➤ Private data networks
  ➤ Video teleconferencing
  ➤ High-speed digital facsimile
  ➤ Internet access
# North American and International TDM Carriers Standards

<table>
<thead>
<tr>
<th>Designation</th>
<th>No. of voice channels</th>
<th>Data Rate</th>
<th>Level</th>
<th>No. of voice channels</th>
<th>Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS-1</td>
<td>24</td>
<td>1.544</td>
<td>1</td>
<td>30</td>
<td>2.048</td>
</tr>
<tr>
<td>DS-1C</td>
<td>48</td>
<td>3.152</td>
<td>2</td>
<td>120</td>
<td>8.448</td>
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<tr>
<td>DS-2</td>
<td>96</td>
<td>6.312</td>
<td>3</td>
<td>480</td>
<td>34.368</td>
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<tr>
<td>DS-3</td>
<td>672</td>
<td>44.736</td>
<td>4</td>
<td>1920</td>
<td>139.264</td>
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<tr>
<td>DS-4</td>
<td>4032</td>
<td>274.176</td>
<td>5</td>
<td>7680</td>
<td>565.148</td>
</tr>
</tbody>
</table>
Data Transmission through the Network

DS-1 Facility (1.544 MB/S)

Time Division Multiplexing (TDM) of twenty-four 64 kb/s channels into a 1.544 Mb/s signal, along with 8 kb/s of framing, forms the DS-1 signal. This signal is the workhorse of digital transmission systems.

- 1 "F" bit/frame
- 24 channels/frame
- 8 bits/channel
- 193 bits/frame
- 8,000 frames/sec.
- 1.544 Megabits/sec.
DS-1 TRANSMISSION FORMAT

- Bit #193 is a framing bit, used for synchronization
- For voice channels:
  - 8 bit PCM used on five of six frames.
  - 7-bit PCM used on every sixth frame, bit 8 of each channel is a signaling bit
- For Data Channels:
  - Channel 24 used for signaling only in some schemes.
  - Bit 8 is a control bit
  - Bits 1-7 used for 56 kbps service
  - Bits 2-7 used for 9.6 kbps, 4.8kbps, and 2.4 kbps service.
SONET/SDH

- **SONET** *(synchronous optical network)* is an optical transmission interface.
- Originally proposed by BellCore and standardized by ANSI.
- Compatible version, **SDH** *(synchronous digital hierarchy)*, published by ITU-T.
- Provides specifications for taking advantage of the high-speed digital transmission capability of optical fiber.
## SONET/SDH Signal Hierarchy

<table>
<thead>
<tr>
<th>SONET Designation</th>
<th>ITU-T Designation</th>
<th>Data Rate (Mbps)</th>
<th>Payload Rate (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1/OC-1</td>
<td></td>
<td>51.84</td>
<td>50.112</td>
</tr>
<tr>
<td>STS-3/OC-3</td>
<td>STM-1</td>
<td>155.52</td>
<td>150.336</td>
</tr>
<tr>
<td>STS-9/OC-9</td>
<td>STM-3</td>
<td>466.56</td>
<td>451.008</td>
</tr>
<tr>
<td>STS-12/OC-12</td>
<td>STM-4</td>
<td>622.08</td>
<td>601.344</td>
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<tr>
<td>STS-18/OC-18</td>
<td>STM-6</td>
<td>933.12</td>
<td>902.016</td>
</tr>
<tr>
<td>STS-24/OC-24</td>
<td>STM-8</td>
<td>1244.16</td>
<td>1202.688</td>
</tr>
<tr>
<td>STS-36/OC-36</td>
<td>STM-12</td>
<td>1866.24</td>
<td>1804.032</td>
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<tr>
<td>STS-48/OC-48</td>
<td>STM-16</td>
<td>2488.32</td>
<td>2405.376</td>
</tr>
</tbody>
</table>
(b) STM-N frame format

SONET/SDH Frame Formats
SONET/SDH Frame Formats
3. **Statistical Time Division Multiplexers (STDM)**

- Statistical Time Division Multiplexers (STDM) allow the connection of more devices to the circuit than the capacity of the circuit.
- For example, if you have 12 devices connected to a STDM Multiplexer and each device can transmit at 1200 bps, then your total is \((12 \times 1200) = 14,400\) bps transmitted in a given instant of time.
- However, if the STDM/Modem/Circuit combination has a maximum speed of only 9600 bps, then you might find a period of delay. Some data will be held back by buffers when too many devices transmit at maximum capacity for too long a period of time.

\[
I = 14,400 \text{ bps} \quad O = 9600 \text{ bps} \quad 14,400 \text{ bps} > 9600 \text{ bps}
\]
STDM (Continued)

One 9,600 bps line supporting six 2,400 bps devices
The technique of Statistical Time Division Multiplexing takes into account the fact that there is some downtime and that all terminals do not transmit at their maximum rate capacity for every possible microsecond that is available.

STDM operates in either asynchronous mode (character-by-character transmission) or synchronous mode (block transmission).
STDM (Continued)

Voice Grade Circuit

<table>
<thead>
<tr>
<th>Address</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

Frame

Host

Front End

TDM

Modem

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Modem

TDM

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STDM

- Takes advantage of the sporadic nature of terminal users and allocates bandwidth on demand
- This adds overhead (address)
- Downside: if all devices are constantly transmitting, STDM will not provide an acceptable transmission time.
STDM

- Statistical refers to the method of time slot allocation
- Statistical formulas are used to determine how many time slots are allocated to a given device
- STDM is more efficient than TDM when there is intermittent transmission from terminals
TDM vs. STDM

- **TDM**: Time Division Multiplexing
  - **First Cycle**:
    - A1, B1, C1, D1
  - **Second Cycle**:
    - A2, B2, C2, D2

- **STDM**: Statistical Time Division Multiplexing
  - **First Cycle**:
    - A1, B1, B2, C2
  - **Second Cycle**:
    - Extra Bandwidth Available

- **Empty Slots**: Wasted Bandwidth
  - **TDM** contrasted with statistical TDM
  - STDM dynamically allocates time slots

- **To Remote Computer**

- **Data**
  - = Address
  - = Data
Inverse Multiplexers

- Used when speed is more important
- An inverse multiplexer can combine the bandwidth of two telephone lines for use by a single terminal
- The high-speed trunk port is attached to the terminal or front ends and the low-speed branch ports are attached to the modems and phone lines.
Data Compression Devices

- This is another method to improve transmission efficiency
- Send the same information with fewer bits resulting in higher bandwidth utilization
- Several methods are used. e.g. special shorthand notations such as Mbps = megabits per second
Data Compression

Types of Data Compression

• Run-Length Encoding
• V.42bis Compression and ZIP
• Video Compression
• Fractal Compression
• Facsimile Compression
Data Compression: Example

Run-Length Encoding

- Used to compress any type of repeating character sequence.
- Efficiency depends on the number of repeated character occurrences in the data to be compressed and the average repeated character length.
- Standard measure of compression efficiency is the compression ratio, which is the ratio of the length of the uncompressed data to the compressed data.
Run-Length Encoding

Sc = Special character indicating compression follows
X = Any repeated data character
Cc = Character count; the number of times the compressed character is to be repeated

(a) Compression format

<table>
<thead>
<tr>
<th>Original Data String</th>
<th>Encoded Data String</th>
</tr>
</thead>
<tbody>
<tr>
<td>$********55.72</td>
<td>$Sc*655.72</td>
</tr>
<tr>
<td>-------- Sc-9</td>
<td>GunsbbbbbbbbbbbbbButter GunsScb9Butter</td>
</tr>
</tbody>
</table>

(b) Compression format