Transmission Efficiency

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Need For Transmission Efficiency

• Traditional communications
  – Each connection uses a dedicated transmission medium.
  – Example
    • Telephone Conversation (using dedicated circuit)
  – Problems?
    • Transmission services, transmission facilities and transmission media are expensive.
    • Data Delivering are burst in the short term time.
    • Others are idle.
• Two approaches are taken to achieve greater efficiency in the use of transmission services:
  – Multiplexing (傳輸多工)
  – Compression (資料壓縮)

• Multiplexing
  – Several information sources, each of which requires a given transmission capacity.
  – Sharing a larger transmission capacity.

• Compression
  – Techniques are used to reduce the number of bits required to represent a given information
  – Reducing the capacity needed for a given information source.

• Multiplexing
  – A function that permits two more data sources to share a common transmission medium such data source has its own channel.
  – Frequency-Division Multiplexing (FDM)

**FIGURE 6.1 Multiplexing.**

![Multiplexing Diagram]

\[ n \text{ inputs} \rightarrow \text{MUX} \rightarrow \text{1 link, n channels} \rightarrow \text{DEMUX} \rightarrow \text{n outputs} \]
• Usage of multiplexing and compression
  – Several sources can be compressed and multiplexed to share a transmission capacity
  – That is less than the sum of the capacity requirements of the individual sources.

• Multiplexing and compression are independent of one another and may be employed separately.

Motivation for Multiplexing

• Seeing Figure 6.1 (pp. 141)
  – N inputs/N outputs
  – Multiplexing (MUX)/ Demultiplexing (DEMUX)
Frequency-Division Multiplexing (FDM)

- FDM is a familiar and widely used form of multiplexing.
  - An simple example is its use in cable TV systems, which carry multiple video channels on a single cable.
- FDM is possible when the useful bandwidth of the transmission medium exceeds the required bandwidth of signals to be transmitted.
  - A number of signals can be carried simultaneously (different frequencies, not overlapped)

- Seeing Figure 6.3(a) (pp. 146)
  - Six signals are fed into a multiplexer, which modules each signal onto a different frequency (f1, .., f6).
  - Channel:
    Each modulated signal requires a certain bandwidth centered around its carrier frequency.
  - To prevent interference, the channels are separated by guardbands
- An example, seeing Figure 6.4 (pp. 146)
  - Seeing the bottom of p.p. 145
  - Voice signals (analog signals) are transmitted over a transmission medium. (300~3400Hz -> 4kHz)
(a) Frequency-division multiplexing

**FIGURE 6.3 FDM**

![Diagram of FDM](image)

(b) Bandwidths raised in frequency

(c) Bandwidths multiplexed into one channel

**FIGURE 6.4 FDM of Three Voice Channels.**
• FDM has been the mainstay of telephone transmission (voice signals) for many years
  – It is actually more efficient than digital system in terms of bandwidth.
    • The problem is that noise is amplified along with the voice signal.
  – The great decrease in the cost of digital electronics, has led to the widespread replacement of FDM system with TFM system in the telephone system.

• An Example: Broadcast TV and Cable TV System
  – Seeing Figure 6.5 and Table 6.2
Synchronous Time-Division Multiplexing (TDM)

- **Time-Division Multiplexing:**
  The sharing of a transmission facility by allotting (分配) a common channel to several different information channels, one at a time.

- **Seeing Figure 6.3(b) (pp. 146), a general case of TDM**

- **There are two variants of TDM in common use:**
  - Synchronous TDM (同步的 TDM)
  - Statistical TDM (統計計量的 TDM)
• **Synchronous Time-Division Multiplexing**
  – A method of TDM in which time slots (時間槽) on a shared transmission line are assigned to devices on a fixed predetermined basis.

• **Statistical Time-Division Multiplexing**
  – A method of TDM in which time slots on a shared transmission line are assigned to devices on demand (需求).
• In Figure 6.3(b):
  – Six Signal sources are fed into a multiplexer.
  – The multiplexer interleave (交互插入) the bits from each signal by taking turns transmitting bits from each of the signals in a round-robin (循環) fashion.
  – Each input uses 9.6 kbps. A single line with a capacity of at least 57.6 (9.6 * 6) kbps accommodates (適應) all six sources.

• A simple example of TDM is illustrated in Fig 6.6
  – At the receiver end, the demultiplexing process involves distributing the incoming data among three destination buffers.
• The data transmitted by a synchronous TDM system have a format something like that of Figure 6.7 (pp. 149)
  – The data are organized into frames, each of which contains a cycle of time slots.
  – In each frame one or more slots is dedicated to each data source.
  – The set of time slots dedicated one source, from frame to frame, is called a channel.
  – The slot length equals the transmitter buffer length
    • Character: Character-Interleaving Technique (asynchronous sources)
    • Bits: Bit-Interleaving Technique (synchronous sources)
Statistical Time-Division Multiplexing

• A typical application of a synchronous TDM involves linking a number of terminals to a share computer port.
  – Even if all terminals are actively in use, most of the time there is no data transfer at any particular terminal.

• Seeing Table 6.5 (pp. 155)
  – It is clear that the use of a synchronous time-division multiplexer for a group of such devices would be extremely inefficient.

### TABLE 6-5 Workload Generated by Various Terminal Types

<table>
<thead>
<tr>
<th>Terminal Type</th>
<th>Peak Data Rate (kbps)</th>
<th>Duty Factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line printer</td>
<td>19.2</td>
<td>50–90</td>
</tr>
<tr>
<td>Data-entry terminal</td>
<td>9.6</td>
<td>0.1–1.0</td>
</tr>
<tr>
<td>Data-enquiry terminal</td>
<td>9.6</td>
<td>10–30</td>
</tr>
<tr>
<td>Laser printer</td>
<td>64</td>
<td>20–50</td>
</tr>
<tr>
<td>Fax machine</td>
<td>256</td>
<td>5–20</td>
</tr>
<tr>
<td>Graphics terminal (noncompressed)</td>
<td>9.6</td>
<td>1–10</td>
</tr>
<tr>
<td>Graphics terminal (compressed)</td>
<td>64</td>
<td>10–30</td>
</tr>
<tr>
<td>Optical character reader</td>
<td>2.4</td>
<td>50–90</td>
</tr>
</tbody>
</table>

* Duty factor is the percentage of time that the device is transmitting or receiving.
• A much more efficient scheme than synchronous TDM is **statistical TDM**, also known as **asynchronous TDM** or **intelligent TDM**.

• Seeing Figure 6.10 (pp. 156)

• Statistical TDM takes advantage of the fact that the attached devices are not all transmitting all of the time, the data rate on the multiplexed line is less than the sum of the data rates of the attached devices.

• The statistical multiplexer does not send empty slots when there are no data to send.
  – There is more overhead per slot for statistical TDM because each slot carries an address as well as data.
• There is a trade-off (交換) between the size of buffer used and the data rate of the line
  – Using a mathematical discipline known as *queuing theory* (排隊理論).

• Despite the buffering requirements and overflow risk associated with statistical multiplexer.
  – They have by and large supplant (取代) synchronous multiplexers for many data communications applications.
  – The statistical multiplexer allows a significant saving in transmission costs.

• Synchronous multiplexers still have an important role to play in long-distance private and public networks.