CS3200: Computer Networks

Lecture 4

IIT Palakkad

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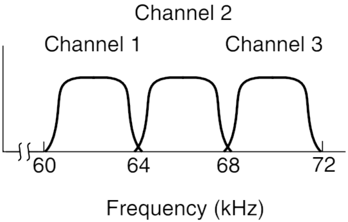
Multiplexing

- We have several scenarios where users share a common medium.
- If we go with a packet switching setup on the entire resource; what would happen?
- The major cost of installing a link is infrastructure and civil works and not the price per bandwidth of the link.
- To reduce cost to users, we can set a large bandwidth link and allocate chunks of resource to users. This idea is known as **multiplexing**.

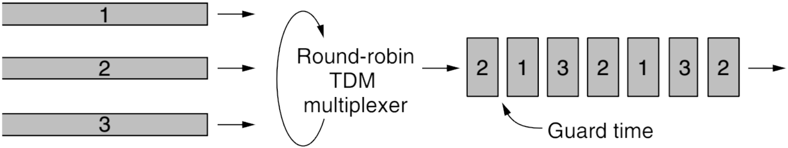
Frequency Division Multiplexing

- Used in passband transmission to share a channel.
- Divides the spectrum into frequency bands, with each user having exclusive possession of some band in which to send their signal.
- **Guard bands** are added between channels to keep them well separated.



Time Division Multiplexing

- Users take turns (in a round-robin fashion), each one periodically getting the entire bandwidth for a little burst of time.
- Small intervals of **guard time** analogous to a frequency guard band may be added to accommodate small timing variations.



Code Division Multiplexing

- A form of **spread spectrum** communication in which a narrowband signal is spread out over a wider frequency band.
- More tolerant to interference, as well as allows multiple signals from different users to share the same frequency band.
- Each bit time is subdivided into m short intervals called **chips**. Each station is assigned a unique m-bit code called a chip sequence.
- To transmit a 1 bit, a station sends its chip sequence. To transmit a 0 bit, it sends the negation of its chip sequence.

Code Division Multiplexing

For example, if we have a 1-MHz band available for 100 stations. How would FDM and CDMA compare?

Let us use the symbol $S_i \in \{+1, -1\}^m$ to indicate the m length chip vector for station i, and $\overline{S}_i$ for its negation. All chip sequences are pairwise orthogonal, by which we mean

$$S_i \bullet S_j = \frac{1}{m} \sum_{k=1}^{m} S_i(k) \cdot S_j(k) = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{otherwise} \end{cases}$$

It is known how to generate such orthogonal chip sequences using a method known as **Walsh codes**.

Code Division Multiplexing

The combined signal is

$$Y = \sum_i b_i \cdot S_i + (1 - b_i) \cdot \overline{S}_i,$$

where $b_i \in \{0, 1\}$. To recover station j's signal, the receiver will just take the inner product of Y with S_j. i.e.,

$$\begin{aligned} Y \bullet S_j &= \sum_i b_i \cdot S_i \bullet S_j + (1 - b_i) \cdot \overline{S}_i \bullet S_j \\ &= b_j + (1 - b_j) \cdot -1 = 2b_j - 1 \end{aligned}$$

Equivalently, we have

$$b_j = (Y \bullet S_j + 1)/2$$