# Chapter 4:

**3.** Suppose that a frequency band $W$ Hz wide is divided into $M$ channels of equal bandwidth.

a. What bit rate is achievable in each channel? Assume all channels have the same SNR.

Each user uses *W*/*M* bandwidth. Using Shannon's Channel Capacity formula:

$$\text{Bit rate} = (\frac{W}{M})\log_2(1+SNR) \text{ bps}$$

b. What bit rate is available to each of $M$ users if the entire frequency band is used as a single channel and TDM is applied?

In this case, the total bit rate afforded by the *W* Hz is divided equally among all users:

$$\text{Bit rate} = \frac{W\log_2(1+SNR)}{M} \text{ bps}$$

c. How does the comparison of (a) and (b) change if we suppose that FDM requires a guard band between adjacent channels? Assume the guard band is 10% of the channel bandwidth.

Because of the guard band we expect that the scheme in (b) will be better since the bit rate in (a) will be reduced. In (a), the bandwidth usable by each channel is 0.9*W*/*M*. Thus, we have:

$$\text{Bit rate} = (0.9\frac{W}{M})\log_2(1+SNR) \text{ bps}$$

**4.** In a cable television system (see Section 3.8.2), the frequency band from 5 MHz to 42 MHz is allocated to upstream signals from the user to the network, and the band from 550 MHz to 750 MHz is allocated for downstream signals from the network to the users.

**Solutions follow questions:**

a. How many 2 MHz upstream channels can the system provide? What bit rate can each channel support if a 16-point QAM constellation modem is used?

The system can provide:

$$\frac{(42-5)MHz}{2\frac{Mhz}{Channel}} = \text{18 upstream channels.}$$

For bandpass channels, we have:

$$R = (2\times10^6)\frac{pulses}{\sec ond} * 4\frac{bits}{pulse} = 8 \text{ Mbps}$$

b. How many 6 MHz downstream channels can the system provide? What bit rates can each channel support if there is an option of 64-point or 256-point QAM modems?

Similarly, the system can provide:

$$\frac{(750-550)MHz}{6\frac{Mhz}{Channel}} = 33 \text{ upstream channels.}$$

$$R_{\text{64-point}} = (6\times10^6)\frac{pulses}{second} * 6\frac{bits}{pulse} = 36 \text{ Mbps}$$

$$R_{\text{256-point}} = (6\times10^6)\frac{pulses}{second} * 8\frac{bits}{pulse} = 48 \text{ Mbps}$$

**49.** Explain where the following fit in the OSI reference model:

**Solutions follow questions:**

a. A 4 kHz analog connection across the telephone network.

Physical Layer: the actual 4 kHz analog signal exists only in the physical layer of the OSI reference model.

b. A 33.6 kbps modem connection across the telephone network.

Data-Link Layer: a 33.6 kbps modem uses framing, flow-control, and error correction to connect a user to the switch.

c. A 64 kbps digital connection across the telephone network.

Physical Layer: the digital link across the network is controlled by many higher layer functions, but the 64 kbps signal that carries user information is analogous to the 4 kHz signal used over the twisted pair that runs to the user's premises.

**61.** Suppose that setting up a call requires reserving $N$ switch and link segments.

a. Suppose that each segment is available with probability $p$. What is the probability that a call request can be completed?

For a call to be completed, every segment in the circuit must be free. Thus, assuming that each switch and link has a probability $p$ of being available, and assuming that this probability is independent of all others,

$$P[\text{every circuit free}] = P[1^{st} \text{ free}]P[2^{nd} \text{ free}]\ldots P[N^{th} \text{ free}] = p^N$$

b. In allocating switch and transmission resources, explain why it makes sense to give priority to call requests that are almost completed rather than to locally originating call requests.

For calls that are almost completed, resources are already locked up, so if the call is denied, there is a large overhead penalty. Thus they should be given priority. To illustrate, suppose locally originating calls are given a higher priority. One can then envision a situation where very few completed connections exist, but all resources are used by partially completed calls.

**Additional problems:**

**A1**: *Give a daily life example for Time Division Multiplexing.*
*Give a daily life example for Frequency Division Multiplexing.*
*Give a daily life example for Code Division Multiplexing.*

**Solution**: TDM—appointments for meeting, questioning in lecture based on the instructor's ordering, Doctor's appointments etc.

FDM—AM/FM radio, TV, etc.

CDM—conversations using different languages, party with background music (not exactly orthogonal coding scheme), some cell phones.

A2: *Give a scenario in which circuit switching is more efficient than the packet switching. Give an example to show that packet switching is better than circuit switching.*

**Solution**: CS is better than PS—huge data transfer, highly reliable data transfer etc

PS is better than PS—less reliable data transfer, control messages exchanges, best effort data services...etc.