

# CS 4390: HW 3

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## 3.1 Data rate

*It is desired to send a sequence of computer screen images over optical fiber. The screen is  $3840 \times 2160$  pixels, each pixel being 24 bits. There are 60 screen images per second. What data rate is needed?*

$$\text{Data Rate} = \frac{\text{Number of bits}}{\text{Bits per second}}$$

There are  $24 \text{ bits} \cdot (3840 \times 2160) = 199,065,600$  bits per image. Transmitting 60 images per second gives a data rate of data rate is  $60 \cdot 199,065,600 = \underline{1.194 \cdot 10^{10}}$  bits per second.

## 3.2 Minimum bandwidth FDM

*Ten signals, each requiring 4000 Hz, are multiplexed onto a single channel using FDM. What is the minimum bandwidth required for the multiplexed channel? Assume that the guard bands are 400 Hz wide.*

$$B = [c_n \cdot c_b] + [(c_n - 1) \cdot G_{\text{width}}]$$

Where  $B$  represents the minimum bandwidth,  $c_n$  represents the number of channels,  $c_b$  represents the channel bandwidth, and  $G_{\text{width}}$  represents the guard band width. In this case, the minimum bandwidth required is  $[10 \cdot 4000\text{Hz}] + [(9) \cdot 400\text{Hz}] = \underline{43,600 \text{ Hz}}$ .

## 3.3 Analog sampling

*A 3-kHz (analog) signal is sampled every 1 msec. What is the (minimum) data rate of a digital channel required to carry this signal? Assume that the quantization uses 256 levels.*

$$R = 2 \times B \times \log_2(Q)$$

Where  $R$  is the data rate,  $B$  is the bandwidth, and  $Q$  is the quantization levels. The minimum data rate is  $2 \times (3 \cdot 10^3) \times \log_2(256) = \underline{48,000 \text{ bits per second}}$ .

## 3.4 Network topologies

*Three packet-switching networks each contain  $n$  nodes. The first network has a star topology with a central switch, the second is a (bidirectional) ring, and the third is fully interconnected, with a wire from every node to every other node. What are the best-, average-, and worst-case transmission paths in hops?*

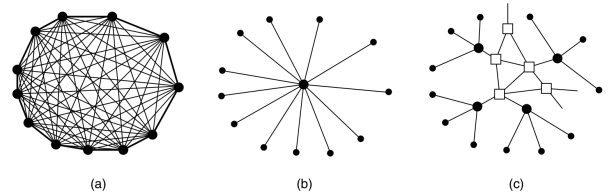


Figure 2-29. (a) Fully interconnected network. (b) Centralized switch. (c) Two-level hierarchy.

The best-, average-, and worst-case for star topology with central switch is 2 hops (e.g., the hop from source to central switch, then from central switch to the destination). The best-, average-, and worst-case for fully-interconnected network is 1 hop (e.g., the hop from source to destination). The best-, average-, and worst-case bi-directional ring is 1,  $n/2$ , and  $n - 1$  hops, respectively (e.g., the source and destination nodes are adjacent, the average of 1 hop and  $n - 1$  hops is  $n/2$ , and at worst the message must travel across all  $n - 1$  nodes, respectively).

## 3.5 Copper wire price

*A regional telephone company has 15 million subscribers. Each of their telephones is connected to a central office by a copper twisted pair. The average length of these twisted pairs is 10 km.*

*How much is the copper in the local loops worth? Assume that the cross section of each strand is a circle 1 mm in diameter, the density of copper is 9.0 grams/cm<sup>3</sup>, and that copper sells for \$6 per kilogram.*

$$V = \pi r^2 h$$

$$\text{Mass} = V \cdot \text{Density}$$

$$\text{Price} = \text{Mass} \cdot \text{Price per kg}$$

The volume of the twisted pair is  $\pi \cdot (0.05 \text{ cm})^2 \cdot (1,000,000 \text{ cm}) = 7,854 \text{ cm}^3$ . The mass is  $9 \cdot (7,854) = 70,686$  grams. The price is  $6 \cdot (70.686) = \underline{\$424,115}$ .

### 3.6 Downstream bandwidth

*A cable company decides to provide Internet access over cable in a neighborhood consisting of 5000 houses. The company uses a coaxial cable and spectrum allocation allowing 100 Mbps downstream bandwidth per cable. To attract customers, the company decides to guarantee at least 2 Mbps downstream bandwidth to each house at any time. Describe what the cable company needs to do to provide this guarantee.*

$$B = H \cdot GB$$

To guarantee 2 MBps downstream bandwidth to each of the 5,000 houses, the cable company will need to provide  $5,000 \cdot 2 \text{ Mbps} = 10,000 \text{ Mbps}$  total downstream bandwidth. Since the cable company has cables which can carry 100 Mbps, the cable company can use a multiplexing technique like FDM to divide the 10,000 Mbps into 100 cables each serving 50 houses.

### 3.7 Sattelite Problem

*Calculate the end-to-end transit time for a packet for both GEO (altitude: 35,800 km), MEO (altitude: 18,000 km), and LEO (altitude: 750 km) satellites.*

$$t = \frac{2 \cdot \Delta d}{c}$$

Where  $c$  represents the speed of light in a vacuum (e.g.,  $3 \cdot 10^5 \text{ km/s}$ ). The end-to-end transit time is 0.233, 0.12, and 0.015 seconds for GEO, MEO, and LEO (respectively).