Final 2020

Q.1

a) Definitions

- `Channel capacity` is the maximum rate at which the data can be transmitted over a given communication path.
- `Digital signal`
    - its intensity maintains a constant level for some period then changes abruptly for another level,
    - is less prone to noise interference,
    - cheaper than analog signals.
    - suffer from more attenuation than analog signals,
- `Propagation delay` is the time it takes to signal to propagate from one node to another.
- `half-duplex` both stations can transmit but one station at a time
- `modulation rate` is the rate at which signal level changes and it depends on the encoding technique.

B)

solution manual p.11

3.13 a. (30 pictures/s) (480 × 500 pixels/picture) = 7.2×10^6 pixels/s

Each pixel can take on one of 32 values and can therefore be represented by 5 bits:

$$R = 7.2 \times 10^6 \text{ pixels/s} \times 5 \text{ bits/pixel} = 36 \text{ Mbps}$$

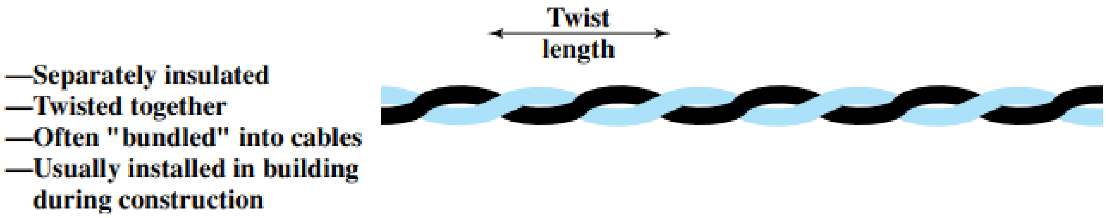
b. We use the formula: $C = B \log_2 (1 + SNR)$

$B = 4.5 \times 10^6$ MHz = bandwidth, and
$SNR_{dB} = 35 = 10 \log_{10} (SNR)$, hence
$SNR = 10^{35/10} = 10^{3.5}$, and therefore
$C = 4.5 \times 10^6 \log_2 (1 + 10^{3.5}) = 4.5 \times 10^6 \times \log_2 (3163)$
$C = (4.5 \times 10^6 \times 11.63) = 52.335 \times 10^6$ bps

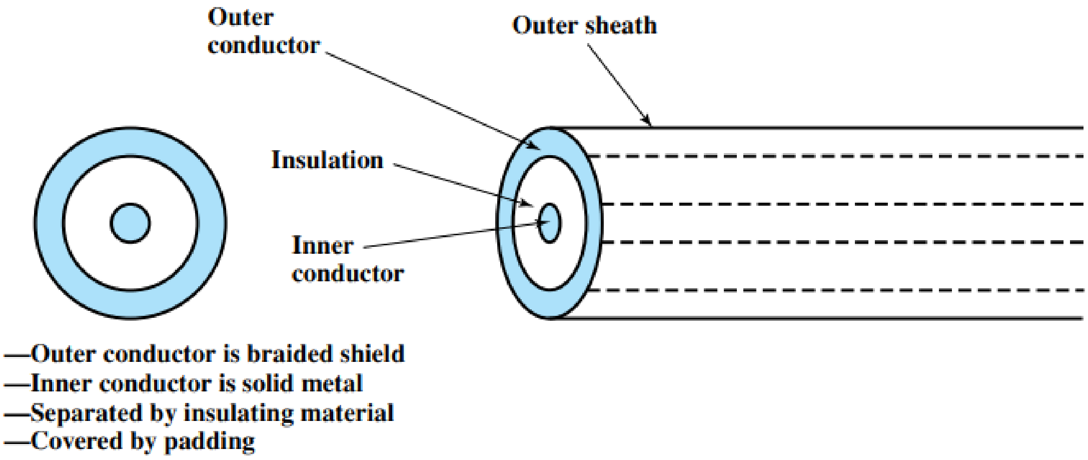
Q.2

A)

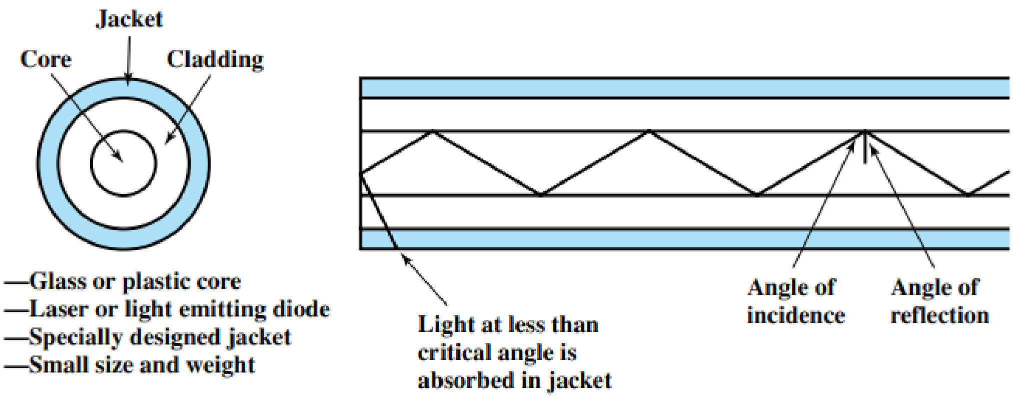
- Twisted pair copper wire
    - consists of two insulated copper wires arranged in regular spiral pattern.
    - Separately insulated
    - often bundled into cables
    - Most common and least expensive
    - limited in distance
    - Used for subscribers loops, and intrabuilding connections



- Coaxial cable
    - consists of two conductors, one is hallow cylinder and the other is wire, the wire is held in place by either insulating rings or by solid dielectric material.
    - Used to be the workhorse of the long distance communication
    - used by television distrbution, long distance telephone transmission, short run computer system links, and local area networks



- Optical Fiber cables
  - consists of
    - `core` is the innermost section: one or more thin strands of fibers made out of glass or plastic
    - `cladding` a glass or plastic coating that has different optical properties that are different from those of the core
    - `Jakect` the outermost layer provides protection against environmental dangers
  - has superior characteristics
    - greater capacity
    - smaller size and lighter weight
    - lower attenuation
    - electromagnetic isolation
    - greater repeater spacing
  - Used in long-haul trunks, subscriber loops, and LANs



(c) Optical fiber

B)

- Gain

$$G = \frac{7A}{\lambda^2} = \frac{7Af^2}{c^2}$$

- LOS
    - K is the adujsting factor

$$d = 3.57\sqrt{Kh}$$
$$d = 3.57(\sqrt{kh_1} + \sqrt{Kh_2})$$

- Free space loss

$$L_{dB} = 10 \log \frac{p_t}{p_r}$$
$$\frac{p_t}{p_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi df)^2}{c^2} = \frac{(cd)^2}{f^2 A_t A_r}$$

Q.3

A)

1. Why digital transmission is better than analog transmission.

- **Digital technology:** The advent of large-scale integration (LSI) and very-large-scale integration (VLSI) technology has caused a continuing drop in the cost and size of digital circuitry. Analog equipment has not shown a similar drop.
- **Data integrity:** With the use of repeaters rather than amplifiers, the effects of noise and other signal impairments are not cumulative. Thus it is possible to transmit data longer distances and over lower quality lines by digital means while maintaining the integrity of the data.
- **Capacity utilization:** It has become economical to build transmission links of very high bandwidth, including satellite channels and optical fiber. A high degree of multiplexing is needed to utilize such capacity effectively, and this is more easily and cheaply achieved with digital (time division) rather than analog (frequency division) techniques. This is explored in Chapter 8.
- **Security and privacy:** Encryption techniques can be readily applied to digital data and to analog data that have been digitized.
- **Integration:** By treating both analog and digital data digitally, all signals have the same form and can be treated similarly. Thus economies of scale and convenience can be achieved by integrating voice, video, and digital data.

2. List and briefly define important factors that can be used in evaluating or comparing the
   various digital-to-digital encoding techniques.

    - Factors on which digital-to-digital encoding techniques are evaluated

        - `signal spectrum`

            - A lack of high-frequency component means less bandwidth is required to transmit the signal
            - A lack of dc components means transformers can be used to couple signals together which reduces interference.
            - Signal distortion depends on the spectral properties of the transmitted signal; the transmission characteristics of the channel are worse near the edges.

        - `clocking`

            - provide a clock signal to synchronize the transmitted component,
            - provide a synchronization mechanism that is based on the transmitted signal

        - `Error detection`

            - Usually, it's a task for the data link layer but it's useful to have some error detection capability built into the physical layer

- `signal interference and noise immunity`
- `cost and complexity`

3. What is the signal form and signaling type in each of the following waveforms

KEY POINTS

- Both analog and digital information can be encoded as either analog or digital signals. The particular encoding that is chosen depends on the specific requirements to be met and the media and communications facilities available.
- **Digital data, digital signals:** The simplest form of digital encoding of digital data is to assign one voltage level to binary one and another to binary zero. More complex encoding schemes are used to improve performance, by altering the spectrum of the signal and providing synchronization capability.
- **Digital data, analog signal:** A modem converts digital data to an analog signal so that it can be transmitted over an analog line. The basic techniques are amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). All involve altering one or more characteristics of a carrier frequency to represent binary data.
- **Analog data, digital signals:** Analog data, such as voice and video, are often digitized to be able to use digital transmission facilities. The simplest technique is pulse code modulation (PCM), which involves sampling the analog data periodically and quantizing the samples.
- **Analog data, analog signals:** Analog data are modulated by a carrier frequency to produce an analog signal in a different frequency band, which can be utilized on an analog transmission system. The basic techniques are amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM).

B)

1. bandwidth

$$C = 2B\log_2 M$$
$$log_2 M = 4$$
$$B = 1200Hz$$

2. 2&3

for one signal element time can be defined as follows:

$$\textbf{MFSK} \qquad s_i(t) = A\cos 2\pi f_i t, \qquad 1 \le i \le M \tag{5.4}$$

where

$$\begin{aligned} f_i &= f_c + (2i - 1 - M)f_d \\ f_c &= \text{the carrier frequency} \\ f_d &= \text{the difference frequency} \\ M &= \text{number of different signal elements} = 2^L \\ L &= \text{number of bits per signal element} \end{aligned}$$

To match the data rate of the input bit stream, each output signal element is held for a period of $T_s = LT$ seconds, where T is the bit period (data rate $= 1/T$). Thus, one signal element, which is a constant-frequency tone, encodes L bits. The

154 CHAPTER 5 / SIGNAL ENCODING TECHNIQUES

total bandwidth required is $2Mf_d$. It can be shown that the minimum frequency separation required is $2f_d = 1/T_s$. Therefore, the modulator requires a bandwidth of $W_d = 2Mf_d = M/T_s$.

Q.4

A)

- `Flow control` is a technique for assuring that a transmitting entity doesn't overwhelm a receiving entity with data, as in absence of flow control the receiver's buffer may fill up and overflow while it's processing old data.
- Two flow control forms
    - Stop-and-wait
        - The simplest form of flow control, it works as following
            1. A source entity transmits a frame
            2. After the destination entity receives the frame, it indicates its willingness to accept another frame by sending back an acknowledgment to the frame just received
            3. The source must wait until it receives the acknowledgment before it sends the next frame.

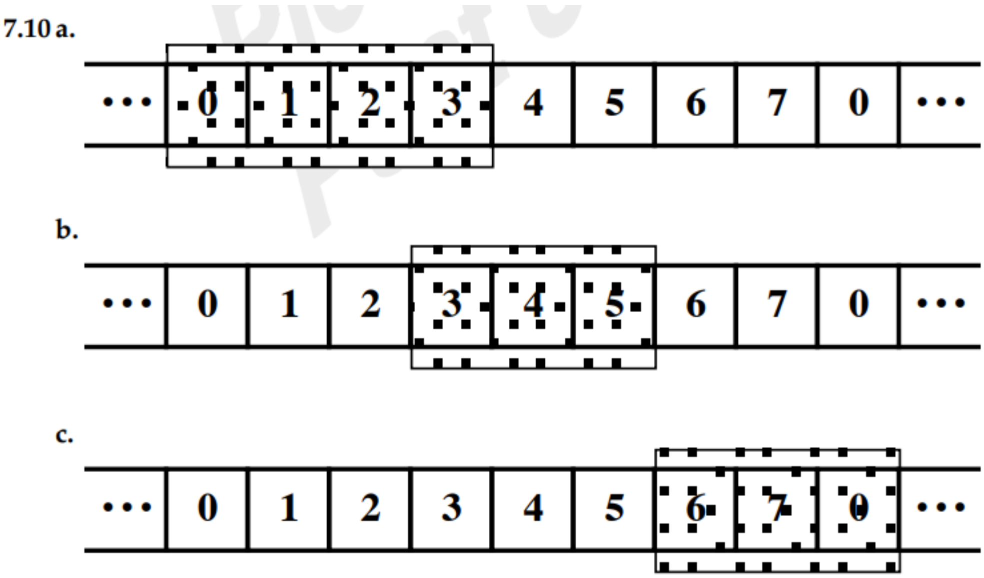
4. The destination can thus stop the flow of data by simply withholding the acknowledgment

- In situations where the bit length of the link is greater than the frame length serious inefficiencies result.

- Sliding window
    - much more efficient than stop-and-wait flow control.
    - The reason is that, with sliding-window flow control, the transmission link is treated as a pipeline that may be filled with frames in transit.

B)

solution manual p.37



Q.5

A)

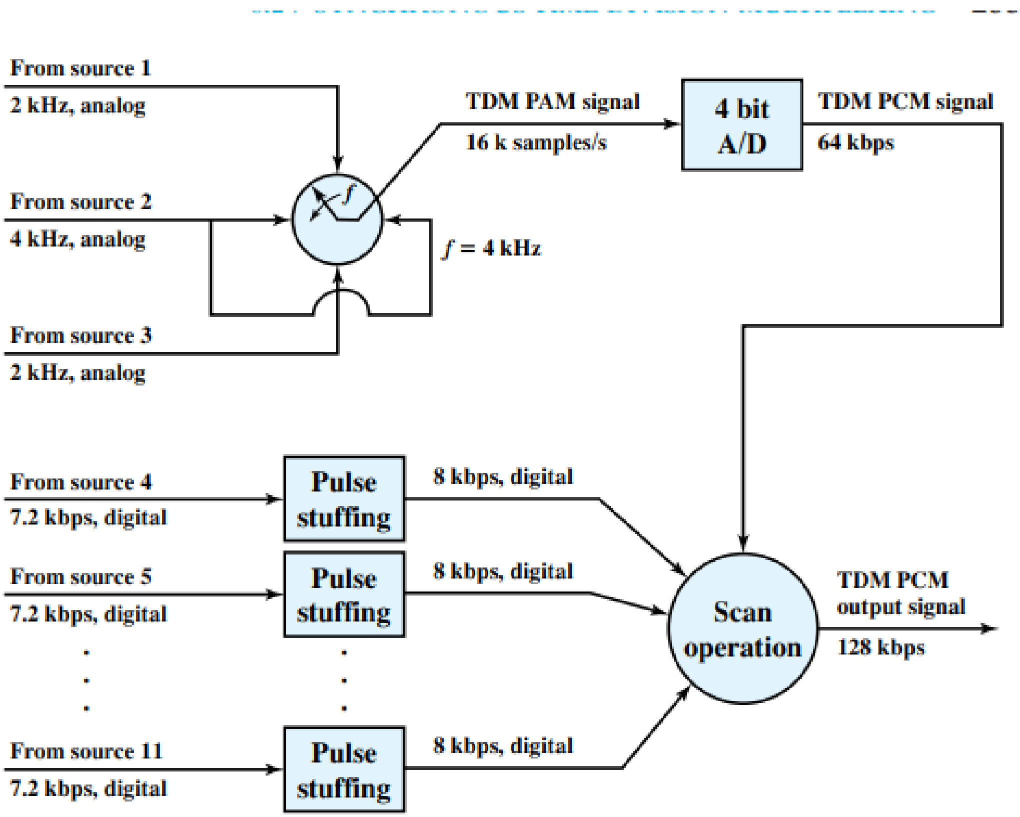
- uses frequency division multiplexing
- reserves the lowest $25KHz$ for voice, POTS(plain old telephone service). The voice is carried only in the $0 - 4KHz$ band; the

additional bandwidth is to prevent cross-talk between the voice and the data channels

- uses two echo cancellation or FDM to allocate two bads
    - smaller upstream band
    - larger downstream band
- uses FDM within the upstream and downstream bands. In this case, a single bitstream is split into multiple parallel bitstreams and each portion is carried in a separate frequency band.

B)

solution manual p.41



8.10 The structure is that of Figure 8.8, with one analog signal and four digital signals. The 500-Hz analog signal is converted into a PAM signal at 1 kHz; with 4-bit encoding, this becomes a 4-kbps PCM digital bit stream. A simple multiplexing

technique is to use a 260-bit frame, with 200 bits for the analog signal and 15 bits for each digital signal, transmitted at a rate of 5.2 kbps or 20 frames per second. Thus the PCM source transmits at (20 frames/sec) × (200 bits/frame) = 4000 bps. Each digital source transmits at (20 frames/sec) × (15 bits/frame) = 300 bps.