EE 304 TELECOMMUNICATIONS ESSENTIALS
HOMEWORK QUESTIONS AND ANSWERS

Homework Question 1

Allocated channel bandwidth for commercial TV is 6 MHz.

a. Find the maximum number of analog voice channels that can be transmitted in one commercial TV channel.

b. Using 8 bits to represent one sampled value, find the minimum bit rate required in digitally transmitting a TV signal.

c. Find the minimum bit rate required in digitally transmitting a TV signal, if 1024 levels are used to represent one sampled value.

d. Find the maximum number of digital voice channels that can be transmitted in one digital TV channel given in 1.b above.

e. Which level of E-Carrier European (CEPT) do you need to carry the bit rate you found in 1.c above?

Answer to Homework Question 1

a. One analog voice channel bandwidth is 4 KHz = 4×10^3 Hz.
In 6 MHz band, there are (6×10^6 Hz) / (4×10^3 Hz) = 1500 times 4 KHz.
So, maximum number of analog voice channels that can be transmitted in one commercial
TV channel = 1500

b. Sampling by twice the maximum frequency $\Rightarrow$ 6 MHz x 2 = 12 M samples per second
Minimum Bit Rate= 12 M samples per second x 8 bits / sample = 96 Mbps

c. Sampling by twice the maximum frequency $\Rightarrow$ 6 MHz x 2 = 12 M samples per second
To represent the sample with 1024 levels means 10 bits / sample
Minimum Bit Rate= 12 M samples per second x 10 bits / sample = 120 Mbps

d. One digital voice channel at the same number of bits representing one sample is 64 Kbps
In 96 Mbps, there are 96 M / 64 K = 1500 .
So, the maximum number of digital voice channels that can be transmitted in one digital channel is 1500, the same answer in 1.a above

e. Fourth level (E-4) 139.264 Mb/s (1920 Ch.)

Homework Question 2

In a library there exists 448000 books, each book has average 500 pages, each page has average 500 words, each word has average 5 letters, each letter is encoded by 8 bits.

a. Find the total number of bits that will present the total information content in the library.

b. Find the time (in years) needed to transmit the total information content in the library when a standard 56 Kbps modem is used (assume full rate can be utilized).

Answer to Homework Question 2

a. The total number of bits that will present the total information content in the library = 448000 x 500 x 500 x 5 x 8 = 4480 x 10^9 bits = 4480 Gbits=4.48 Tbps

b. The time needed to transmit the total information content in the library when a standard 56 Kbps modem is used (assuming full rate can be utilized) = 4480 Gbits/ 56 Kbps = 80.000.000 sec = 2.54 year

Homework Question 3

Write eight points to be seen in the new public network.

Answer to Homework Question 3

- End-to-end digitalization
- End-to-end optical or photonic networking
- Intelligent programmable network
- Very high bandwidth infrastructure
- Low-latency network, i.e. networks with minimum delays
- Networks to be able to follow multiprotocol
- QoS (Quality of Service) guarantees: Meeting bandwidth, latency, loss requirements
- Encryption and security

Homework Question 4

Comparing the carriers of microwave and optical communication systems:

a. Which one has higher frequency ?

b. Which one has shorter wavelength ?

c. Write the frequency range of HF.

d. Write the wavelength range of UHF.

Answer to Homework Question 4

a. Optical communication systems have higher frequency

b. Optical communication systems have shorter wavelength

c. 3 – 30 MHz.

d. 300 MHz – 3 GHz corresponds to wavelength range of
300000000 m/sec / 300000000 (1/sec) = 1 m
300000000 m/sec / 3000000000 (1/sec) = 0.1 m = 10 cm

Homework Question 5

a. How many total voice channels are transmitted in a 2.048 Mb/s system ?

b. How many total video channels can be transmitted in a 139.264 Mb/s system ?

Answer to Homework Question 5

a. 2.048 Mb/s / 64 Kb/s = 2048000b/s / 64000 b/s = 32 channels total channels
32 – 1 signalling channel – 1 synchronization channel = 30 voice channels.

b. One video channel in 1.b 96 Mbps or in 1.c 120 Mbps. In either case only one video channel can be transmitted in a 139.264 Mb/s system ?

Homework Question 6

a. For the analog signal v = 3.6 sin 6280 t, find the minimum sampling rate needed.

b. What happens if the sampling rate is 250 Hz ?

c. What happens if the sampling rate is 5 KHz ?

Answer to Homework Question 6

a. For the analog signal v = 3.6 sin 6280 t, find the minimum sampling rate needed = 2KHz.

b. If the sampling rate is 250 Hz, then the signal can not be recovered correctly at the receiver ?

c. If the sampling rate is 5 KHz, the signal can be recovered correctly, however there is no need to sample over the sampling rate since it will bring unnecessary complication and cost to electronics.

Homework Question 7

An analog signal has time variation $f(t) = 3 + 0.2 \cos(8000\pi t) - 0.3 \sin(4000\pi t)$.

a. Minimum how many samples should be taken to satisfy Nyquist requirement?

b. 256 levels is used to represent one sample. How many bits are required to transmit one sample value?

c. What is the mimimum transmission rate of this signal?

d. Would you allocate a 256 kbps channel to transmit this signal? Why?

e. Would you allocate a 32 kbps channel to transmit this signal? Why?

Answer to Homework Question 7

An analog signal has time variation $f(t) = 3 + 0.2 \cos(8000\pi t) - 0.3 \sin(4000\pi t)$.

a. Minimum how many samples should be taken to satisfy Nyquist requirement?

Maximum frequency = 4 KHz, i.e. sampling frequency = 8 KHz

The minimum number of samples per second needed to satisfy Nyquist requirement = **8000**

b. 256 levels is used to represent one sample. How many bits are required to transmit one sample value?

256 levels mean that each sample is represented by 8 bits since $256 = 2^8$

The number of bits needed to transmit one sample = **8 bits**

c. What is the mimimum transmission rate of this signal?

The mimimum rate in Kbps at which this signal is transmitted

= 8000 samples / sec x 8 bits / sample = **64 Kbps**

d. Would you allocate a 256 kbps channel to transmit this signal? Why?

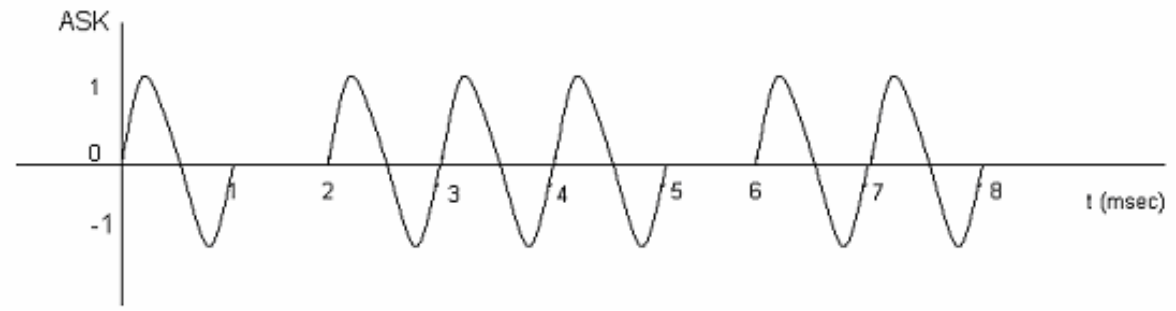
No because more than 64 kbps rate will be unnecessary in the recovery of the original signal.

e. Would you allocate a 32 kbps channel to transmit this signal? Why?

No because with a rate less than 64 kbps, the original signal will only be recovered with loss of information which is not desired.

Homework Question 8

a. For a carrier of sin (2000 π t), the Amplitude Shift Keying (ASK) Modulated signal is given below. Plot the digital information signal x(t).



b. If digital level "1" is represented by sin (2000 π t) and digital level "0" is represented by sin (4000 π t), plot the Frequency Shift Keying (FSK) Modulated signal for the digital information signal x(t) found in part a.

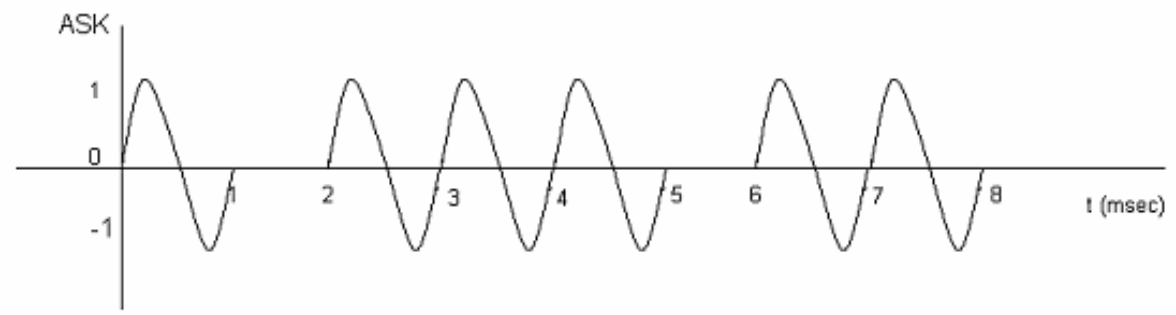
c. If digital level "1" is represented by sin (2000 π t) and digital level "0" is represented by cos (2000 π t), plot the Phase Shift Keying (PSK) Modulated signal for the digital information signal x(t) found in part a.

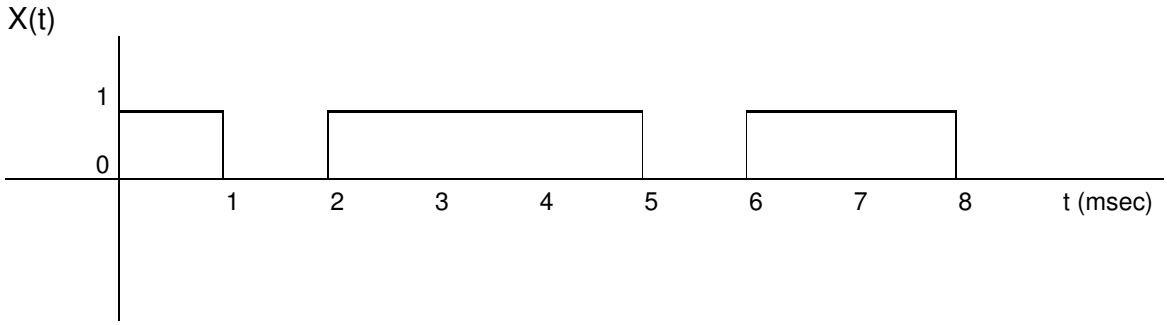
d. If the carrier in part a becomes sin (4000 π t), re-plot the Amplitude Shift Keying (ASK) Modulated signal given in part a.

e. Find the rate of the digital information signal x(t) found in part a.

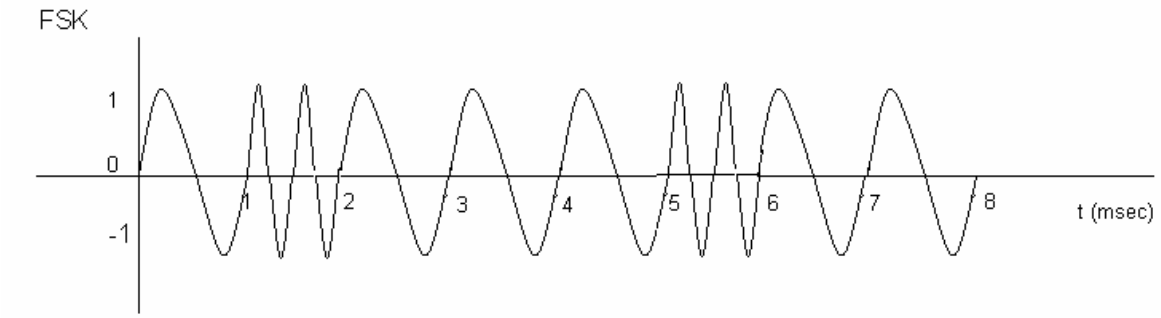
Answer to Homework Question 8

a. For a carrier of sin (2000 π t), the Amplitude Shift Keying (ASK) Modulated signal is given below. Plot the digital information signal x(t).

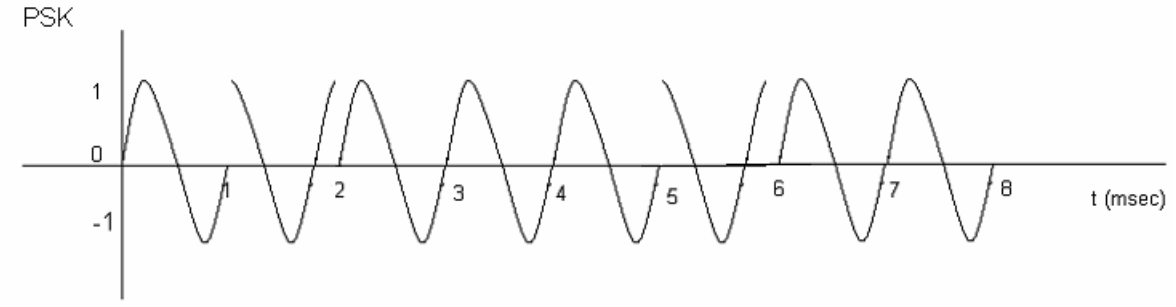




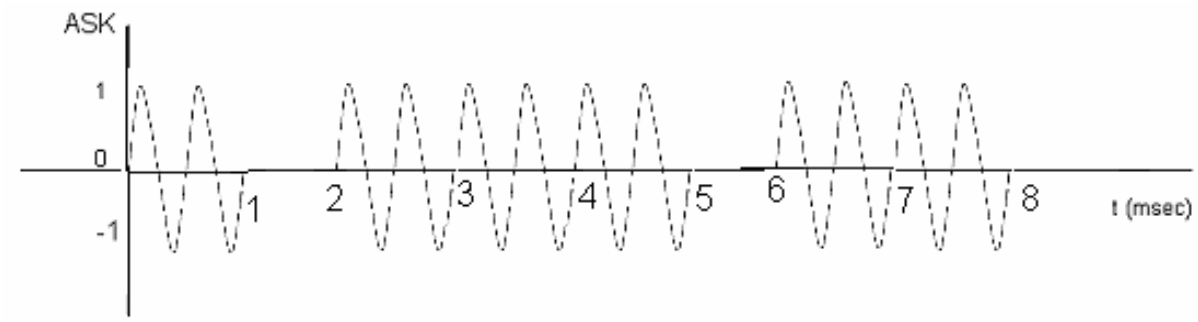
b. If digital level "1" is represented by sin (2000 π t) and digital level "0" is represented by sin (4000 π t), plot the Frequency Shift Keying (FSK) Modulated signal for the digital information signal x(t) found in part a.



c. If digital level "1" is represented by sin (2000 π t) and digital level "0" is represented by cos (2000 π t), plot the Phase Shift Keying (PSK) Modulated signal for the digital information signal x(t) found in part a.



d. If the carrier in part a becomes sin (4000 π t), re-plot the Amplitude Shift Keying (ASK) Modulated signal given in part a.

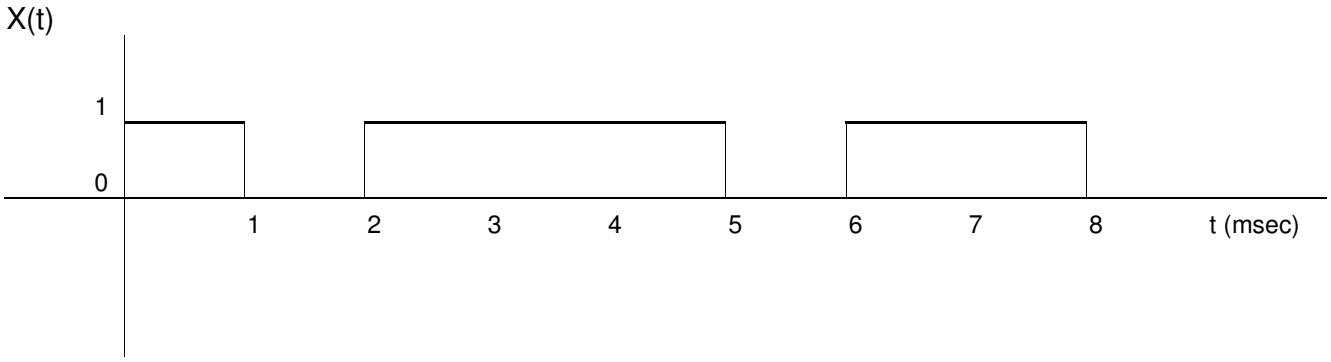


e. Find the rate of the digital information signal x(t) found in part a.

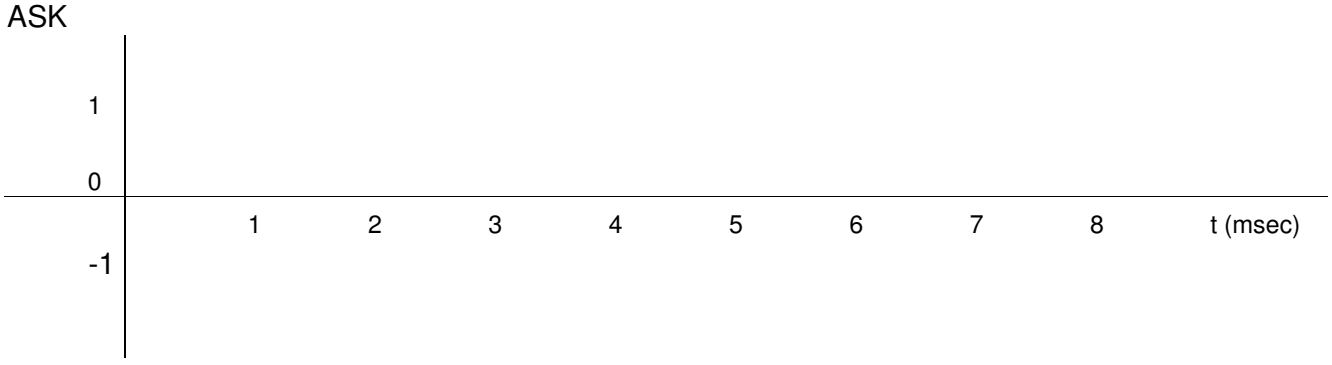
Rate of x(t) found in part a = 1 bit / msec = 1 bit / 10^{-3} sec = 10^{3} bits / sec = 1 kbps.

Homework Question 9

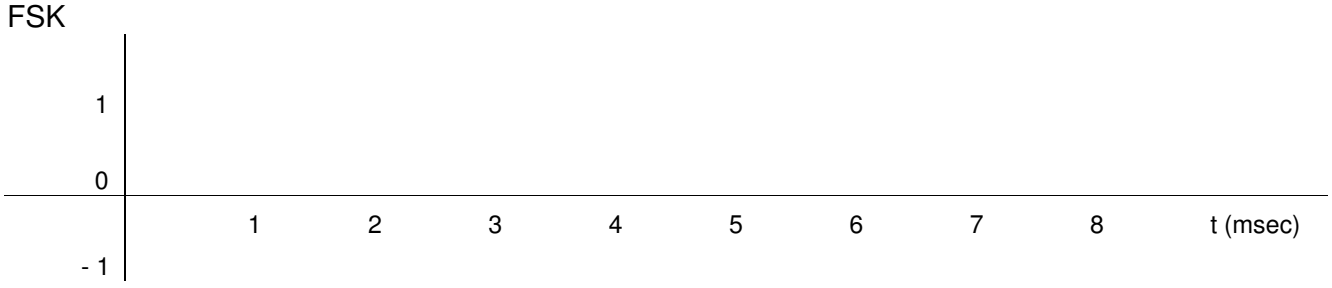
The digital signal X(t) given below.



a. If the carrier is sin (2000 π t), plot Amplitude Shift Keying (ASK) Modulated signal.

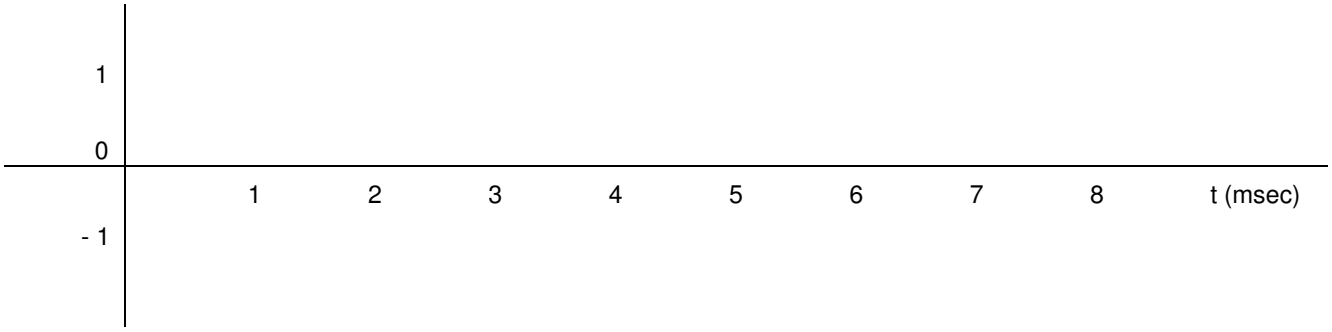


b. If digital level "1" is represented by sin (2000 π t) and digital level "0" is represented by sin (4000 π t), plot Frequency Shift Keying (FSK) Modulated signal.



c. If digital level “1” is represented by sin (2000 π t) and digital level “0” is represented by cos (2000 π t), plot Phase Shift Keying (PSK) Modulated signal.

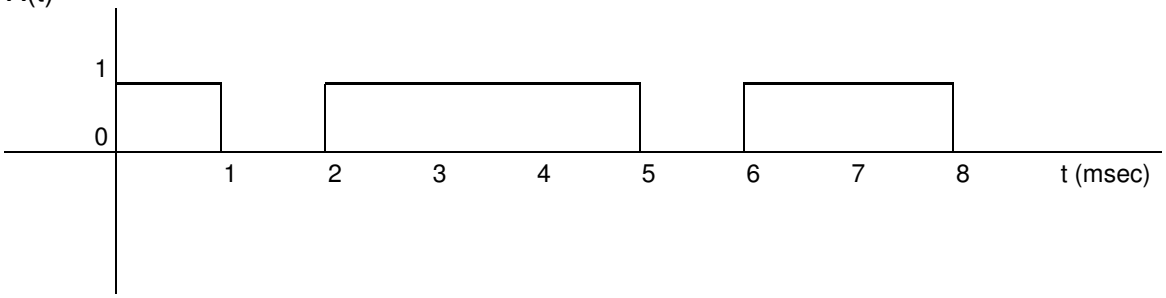
PSK



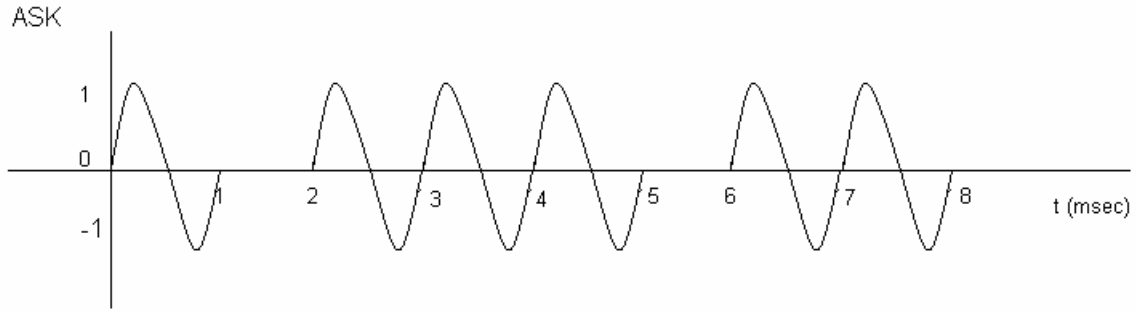
Answer to Homework Question 9

The digital signal X(t) given below.

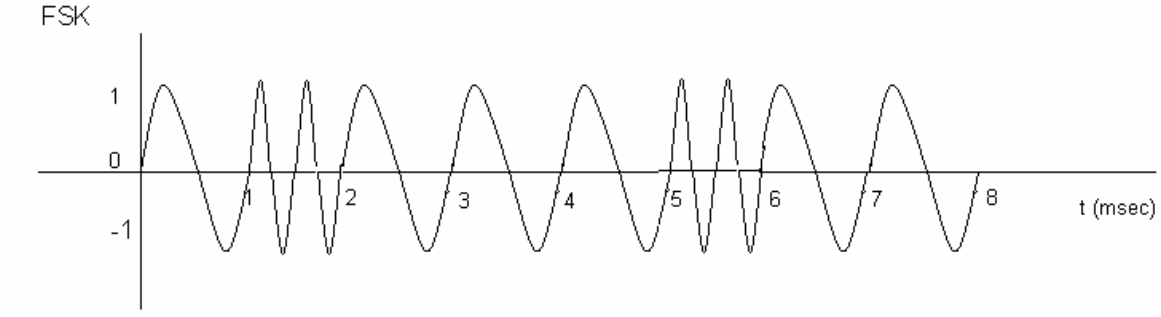
X(t)



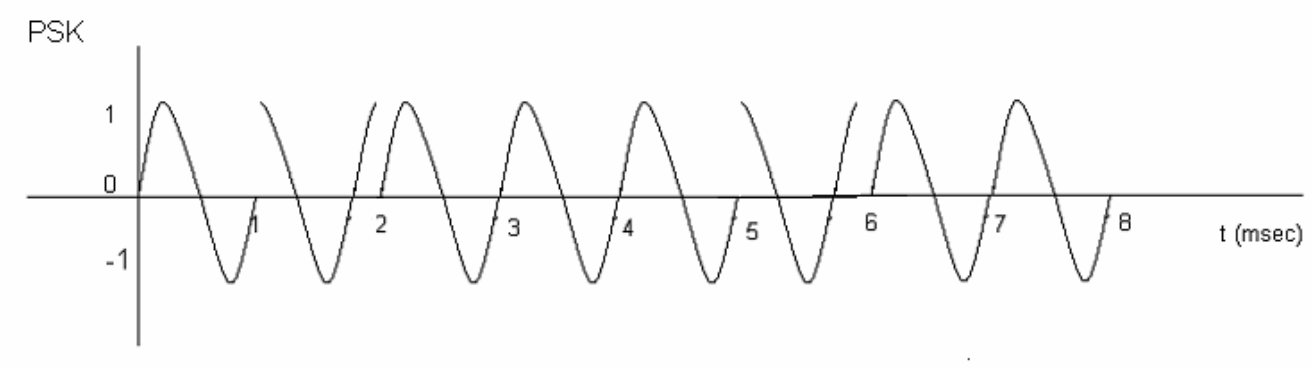
a. If the carrier is sin (2000 π t), plot Amplitude Shift Keying (ASK) Modulated signal.



b. If digital level “1” is represented by sin (2000 π t) and digital level “0” is represented by sin (4000 π t), plot Frequency Shift Keying (FSK) Modulated signal.

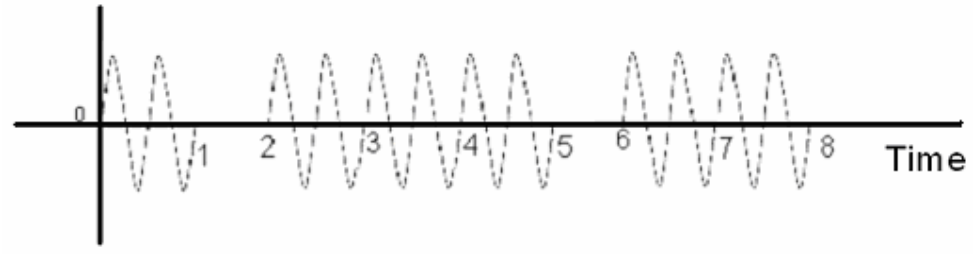


c. If digital level “1” is represented by sin (2000 π t) and digital level “0” is represented by cos (2000 π t), plot Phase Shift Keying (PSK) Modulated signal.



Homework Question 10

Eight bits of information is sent in the following modulated signal where time axis is in microseconds:



a. Write the type of modulation used. Why?

b. Find the carrier frequency.

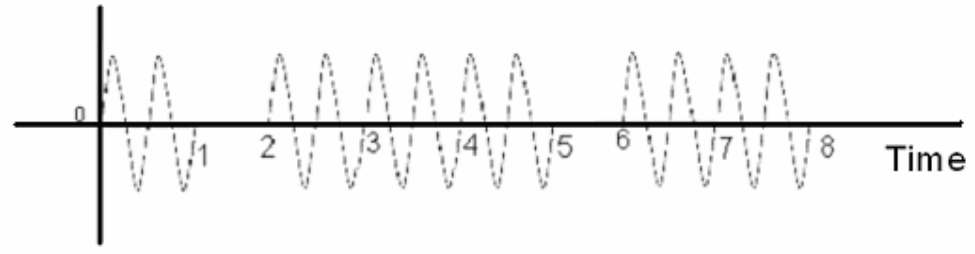
c. Find the rate of the information signal.

d. Plot the information signal if “1” is represented by no signal, and “0” is represented by 0.5 mV and no carrier.

e. Is this information signal convenient to carry 1 digital voice channel ? Why?
Is this information signal convenient to carry 1 digital video channel ? Why?

Answer to Homework Question 10

Eight bits of information is sent in the following modulated signal where time axis is in microseconds:



a. Write the type of modulation used. Why?

Solution: ASK (Amplitude Shift Keying) because digits "1" and "0" are differentiated with different amplitudes.

b. Find the carrier frequency.

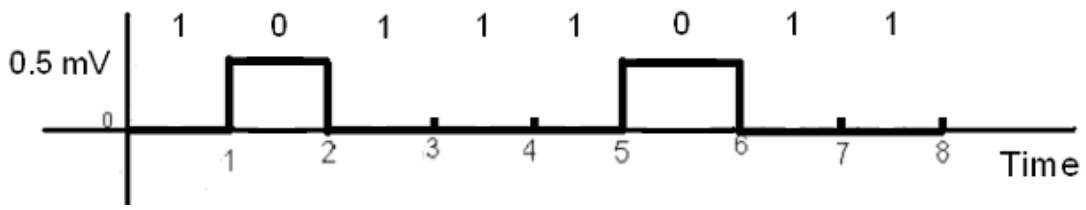
Solution: For one bit, duration is 1 μ sec. and the number of cycles=2
Thus,the carrier frequency = 2 cycle in 1 μ sec., i.e., 2 x 10^6 cycles/sec = 2 MHz.

c. Find the rate of the information signal.

Solution: One bit has duration of 1 μ sec.
Thus, the rate of the signal = 1 x 10^6 bits/sec = 1 Mbps.

d. Plot the information signal if "1" is represented by no signal, and "0" is represented by 0.5 mV and no carrier.

Solution:



e. Is this information signal convenient to carry 1 digital voice channel ? Why?
Is this information signal convenient to carry 1 digital video channel ? Why?

Solution: This information signal is convenient to carry 1 digital voice channel because the information signal has a rate of 2 Mbps and 1 digital voice channel needs only 64 kbps.

However, this information signal is not convenient to carry 1 digital video channel because the information signal has a rate of 2 Mbps and 1 digital video channel needs (6 x 10^6 x 2) samples / sec x 8 bits / sample = 96 Mbps.

Homework Question 11

Based on E-Carrier European (CEPT) hierarchies, you own 4 different types of multiplexers, E-1, E-2, E-3 and E-4.

a. Which of these multiplexers would you prefer to send one digital video channel?

b. Which of these multiplexers would you prefer to send 150 digital voice channels?

c. How efficient is your choice in part b ? What can happen if you use statistical multiplexer instead ? Explain.

Answer to Homework Question 11

Based on E-Carrier European (CEPT) hierarchies, you own 4 different types of multiplexers, E-1, E-2, E-3 and E-4.

a. Which of these multiplexers would you prefer to send one digital video channel ?
E-4
b. Which of these multiplexers would you prefer to send 150 digital voice channels ?
E-3
d. How efficient is your choice in part b ? What can happen if you use statistical multiplexer instead ? Explain.
It is not efficient because only 150 digital voice channels are used whereas there are 480 digital voice channels available in E-3.

If statistical mux of the right size is used instead, the traffic flow would be more efficient.

Homework Question 12

10000000 =10^7 books will be downloaded. Each book has average 100 pages, each page has average 100 words, each word has average 4 letters, each letter is encoded by 8 bits. Dense Wavelength Division Multiplexing (DWDM) system with 100 separate wavelengths (channels) is used to download the information. Each wavelength is modulated at 10 Gbps. Assuming no control bits or other bit redundancy is involved in the communication link:

a. What is the total number of bits that will present the total information content in 10^7 books?

b. What is the time required to download the total information content in the 10^7 books with the given DWDM system?

c. What is the number of DWDM channels required so that the same total information content in 10^7 books is downloaded in 32 milliseconds?

d. Find the number of years required to download the total information content in 10^7 books when a standard 56 Kbps modem is used (assuming full rate is utilized).

e. xDSL technology is used to download the same total information content in the 10^7 books. If the download takes 17.094 hours, find the rate of the download. Specify the type of xDSL used.

Answer to Homework Question 12

10000000 =10^7 books will be downloaded. Each book has average 100 pages, each page has average 100 words, each word has average 4 letters, each letter is encoded by 8 bits. Dense Wavelength Division Multiplexing (DWDM) system with 100 separate wavelengths (channels) is used to download the information. Each wavelength is modulated at 10 Gbps. Assuming no control bits or other bit redundancy is involved in the communication link:

a. What is the total number of bits that will present the total information content in 10^7 books?

The total number of bits that will present the total information content in 10^7 books = 10^7 x 100 x 100 x 4 x 8 = 3200 x 10^9 bits = **3.2 Tbits**

b. What is the time required to download the total information content in the 10^7 books with the given DWDM system?

The time required to download the total information content in the 10^7 books with the given DWDM system 3.2 Tbits / (10 Gbps x 100) = **3.2 sec**.

c. What is the number of DWDM channels required so that the same total information content in 10^7 books is downloaded in 32 milliseconds?

The number of DWDM channels required so that the same total information content in 10^7 books is downloaded in 32 milliseconds

$\Rightarrow$ 3.2 Tbits / (10 Gbps x (no.of channels)) = 32 x 10^{-3} sec

$\Rightarrow$ no.of channels = 3.2 Tbits / (10 Gbps x 32 x 10^{-3} sec) = **10000 channels**

d. Find the number of years required to download the total information content in 10^7 books when a standard 56 Kbps modem is used (assuming full rate is utilized).

The number of years required to download the total information content in 10^7 books when a standard 56 Kbps modem is used (assuming full rate is utilized) = 3.2 Tbits/ 56 Kbps = 57.143.000 sec = 57.143.000 sec/ (365 days / year x 24 hrs/day x 60 min./hr x 60 sec / min) = 57.143.000 sec/ (365 days / year x 86400 sec / day) = **1.812 years**

e. xDSL technology is used to download the same total information content in the 10^7 books. If the download takes 17.094 hours, find the rate of the download. Specify the type of xDSL used.

Rate of the download = 3.2 Tbits / (17.094 hours x 60 min./hr x 60 sec / min) **= 52 Mbps**

The type of xDSL used is **VDSL**.

Homework Question 13

In a library there exists 448000 books, each book has average 500 pages, each page has average 500 words, each word has average 5 letters, each letter is encoded by 8 bits. Dense Wavelength Division Multiplexing (DWDM) system with 16 separate wavelengths (channels) is used to transmit the information. Each wavelength is modulated at 2.5 Gbps. Assuming no control bits or other bit redundancy is involved in the communication link:

a. Find the total number of bits that will present the total information content in the library.

b. Find the time needed to transmit the total information content in the library with the given DWDM system.

c. Find the number of channels needed if another DWDM is to be used so that the same total information content in the library is transmitted in 112 milliseconds.

d. Find the time (in years) needed to transmit the total information content in the library when a standard 56 Kbps modem is used (assume full rate can be utilized).

e. xDSL technology is used to download the same total information content in the library. Which of the xDSL technologies would be appropriate to complete the download in less than 1 day? Also specify the maximum transmission distance.

Answer to Homework Question 13

a. The total number of bits that will present the total information content in the library = 448000 x 500 x 500 x 5 x 8 = 4480 x 10^9 bits = 4480 Gbits=4.48 Tbps

b. The time to transmit the total information content in the library with the given DWDM system = 4480 Gbits/ (2.5 Gbps x 16) = 112 sec.

c. The number of channels needed if another DWDM system is to be used so that the same total information content in the library is transmitted in 112 millisecond

⇒ 4480 Gbits/ (2.5 Gbps x (no.of channels)) = 112 x 10^{-3} sec

⇒ no.of channels = 4480 Gbits / (2.5 Gbps x 112 x 10^{-3} sec) = 16000

d. The time needed to transmit the total information content in the library when a standard 56 Kbps modem is used (assuming full rate can be utilized) = 4480 Gbits/ 56 Kbps = 80.000.000 sec = 2.54 year

e. 4480 Gbits/ (Download rate of xDSL) = 1 day x 24 hrs/day x 60 min./hr x 60 sec / min = 86400 sec

⇒ Download rate of xDSL = 4480 Gbits / 86400 sec = 51,851,852 bits/sec

This download rate can only be supported by VDSL for maximum transmission distance of 300 meters.

Homework Question 14

For a single TV channel, the bandwidth can be taken as 6 MHz.

a. What is the maximum number of analog voice channels that can be transmitted in two TV channels?

b. What is the required minimum bit rate to transmit one TV channel digitally, if one sample value is represented by 10 bits?

c. What is the required minimum bit rate to transmit one TV channel digitally, if one sample value is represented by 256 levels?

d. Maximum how many digital voice channels can be transmitted in one digital TV channel given in part c?

e. For the transmission of the bit rate you found in part b, which E-Carrier European (CEPT) level do you need?

Answer to Homework Question 14

For a single TV channel, the bandwidth can be taken as 6 MHz.

a. What is the maximum number of analog voice channels that can be transmitted in two TV channels?
One analog voice channel bandwidth is 4 KHz = 4 x 10^{3} Hz.
In 6 MHz band, there are (6 x 10^{6} Hz) / (4 x 10^{3} Hz) = 1500 times 4 KHz.
So, maximum number of analog voice channels that can be transmitted in two TV channels = 3000.

b. What is the required minimum bit rate to transmit one TV channel digitally, if one sample value is represented by 10 bits?

Sampling by twice the maximum frequency ⇒ 6 MHz x 2 = 12 M samples per second
To represent the sample with 10 bits means 10 bits / sample

Minimum Bit Rate= 12 M samples per second x 10 bits / sample = 120 Mbps

c. What is the required minimum bit rate to transmit one TV channel digitally, if one sample value is represented by 256 levels?

Sampling by twice the maximum frequency ⇒ 6 MHz x 2 = 12 M samples per second
To represent the sample with 256 levels means 8 bits / sample
Minimum Bit Rate= 12 M samples per second x 8 bits / sample = 96 Mbps

d. Maximum how many digital voice channels can be transmitted in one digital TV channel given in part c?
One digital voice channel at the same number of bits representing one sample is 64 Kbps
In 96 Mbps, there are 96 M / 64 K = 1500 .
So, the maximum number of digital voice channels that can be transmitted in one digital channel is 1500.

e. For the transmission of the bit rate you found in part b, which E-Carrier European (CEPT) level do you need?
Fourth level (E-4) 139.264 Mb/s (1920 Ch.)

Homework Question 15

a. Assuming that there are 2 billion telephone subscribers in the world and each subscriber is connected to the telephone exchange with twisted pair cable at an average distance of 4 km. If the cost of the twisted pair cable is 0.5 YTL /meter, find the total value (in YTL) of the twisted pair cable installed in such infrastructure.

b. Based on the result obtained in part a, what can you comment on the feasibility of fiber optics and DSL technology applications used in the local loop part of the telecommunication network? Explain.

Answer to Homework Question 15

a. Assuming that there are 2 billion telephone subscribers in the world and each subscriber is connected to the telephone exchange with twisted pair cable at an average distance of 4 km. If the cost of the twisted pair cable is 0.5 YTL /meter, find the total value (in YTL) of the twisted pair cable installed in such infrastructure.

Solution: The total value (in YTL) of the twisted pair cable installed in such infrastructure is

(2 billion telephone subscribers) x (3 km / subscriber) x (1000 m / km) x (0.1 YTL /meter)

$= 2 \times 10^{9} \times 4000 \times 0.5 \text{ YTL} = 4 \times 10^{12} \text{ YTL} = 4000 \times 10^{9} \text{ YTL} \approx 3000$ bilion $

b. Based on the result obtained in part a, what can you comment on the feasibility of fiber optics and DSL technology applications used in the local loop part of the telecommunication network? Explain.

Solution: Currently, fiber optics connection to all the local loop subscribers is not feasible since very big investment will be needed to replace the existing twisted pair installations. Under the present conditions, DSL technologies that utilize the existing twisted pair infrastructure seem much more feasible.

Homework Question 16

A 10 mile link operates at 10 GHz . Both transmitting and receiving antenna gains are 28.3 dBi each and cabling loss both at the transmitter and at the receiver are 5 dB each. Output power of the transmitter is 10 dBm.

a. Find the Unfaded Received Signal Level.

b. If a Fade Margin of 20 dB is used in the design, find the Receiver Sensitivity Threshold required.

c. Changing the operating frequency of the link to 1 GHz and keeping all the other link parameters the same, find the Unfaded Received Signal Level.

d. If for the 1 GHz link, the same receiver is used as in part b, find the Fade Margin.

e. Which is a better design, part b or part d ? Explain.

Answer to Homework Question 16

A 10 mile link operates at 10 GHz . Both transmitting and receiving antenna gains are 28.3 dBi each and cabling loss both at the transmitter and at the receiver are 5 dB each. Output power of the transmitter is 10 dBm.

a. Find the Unfaded Received Signal Level.

FSL = 96.6+20 log D+20 log$F$ = 96.6+20 log10+20 log10 = 96.6+20+20 = 136.6 dB

$P_o - L_c t_x + G_a t_x - L_c r_x + G_a t_x - FSL = RSL$

RSL = 10 dBm - 5 dB + 28.3 dBi - 5 dB + 28.3 dBi - 136.6 dB = - 80 dBm

b. If a Fade Margin of 20 dB is used in the design, find the Receiver Sensitivity Threshold required.

Fade Margin = Unfaded Receive Signal Level - Receiver Sensitivity Threshold

Receiver Sensitivity Threshold = - 80 dBm - 20 dB = -100 dBm

c. Changing the operating frequency of the link to 1 GHz and keeping all the other link parameters the same, find the Unfaded Received Signal Level.

FSL = 96.6+20 log D+20 log$F$ = 96.6+20 log10+20 log1 = 96.6+20+0 = 116.6 dB

$P_o - L_c t_x + G_a t_x - L_c r_x + G_a t_x - FSL = RSL$

RSL = 10 dBm - 5 dB + 28.3 dBi - 5 dB + 28.3 dBi - 116.6 dB = - 60 dBm

d. If for the 1 GHz link, the same receiver is used as in part b, find the Fade Margin.

Fade Margin = Unfaded Receive Signal Level - Receiver Sensitivity Threshold

= - 60 dBm - (-100 dBm) = 40 dB

e. Which is a better design, part b or part d ? Explain.

If the fade margin of 40 dB is needed due to atmospheric conditions of the microwave link in part d, then part d is a better design. If the atmospheric conditions of the microwave link in part d do not require 40 dB fade margin, but can still perform with 20 dB fade margin, then part b is a better design.

Homework Question 17

Given 3 microwave systems; M1 operating at L-Band, M2 operating at C-Band and M3 operating at milimeter wave. Assuming all the other system parameters (such as transmitter power, atmospheric conditions, receiver sensitivity, ...etc) are the same for all these 3 systems.

a. Which one of these 3 would you prefer if you want to design a longest possible link?

b. Which one of these 3 would you prefer if you want to design a link able to transmit the highest information bandwidth?

c. Considering no fade margin, what should be the receiver sensitivity threshold in dBm if 1 mile microwave link operating at 1 GHz is used whose output power is 1 dBm, both transmitting and receiving antenna gains are 25 dBi each and cabling loss both at the transmitter and at the receiver is of 2.2 dB each.

d. Find the fade margin if the receiver sensitivity threshold of the system given in part c is –70 dBm.

e. Which one of the links designed in part c and part d will be available with higher probability? Why?

Answer to Homework Question 17

a. Longest possible link is achieved by the lowest frequency link which is M1.

b. Highest carrier frequency has the possibility to carry the highest information bandwidth. Thus M3 will transmit the highest information bandwidth.

c. Free Space Loss FSL=96.6+20 log D+20 log F=96.6+20 log1+20 log1 = 96.6 dB
$P_o - L_c t_x + G_a t_x - L_c r_x + G_a t_x - FSL = RSL$
Received Signal Level, RSL=1 dBm–2.2 dB+25 dBi –2.2 dB+25 dBi –96.6 dB
= - 50 dBm
Since there is no fade margin, receiver sensitivity threshold = RSL = - 50 dBm

d. Fade Margin = Unfaded Receive Signal Level - Receiver Sensitivity Threshold
= - 50 dBm - (- 70 dBm) = 20 dBm

e. Link design in part d will be available with higher probability because it has 20 dBm fade margin whereas the link design in part c has no fade margin.

Homework Question 18

The first microwave link (LINK-1) operating at 10 GHz has a link distance of 1 mile. The second microwave link (LINK-2) operates at 1 GHz. In both of the links, both transmitting and receiving antenna gains are 20 dBi each and cabling loss both at the transmitter and at the receiver are 2 dB each.

a. What should be the link distance in the second link (LINK-2) so that both links (LINK-1 and LINK-2) have the same free space loss?

b. Find the Received Signal Level in LINK-1 if the output power of the transmitter in LINK-1 is 10.6 dBm.

c. Find the output power of the transmitter in LINK-2 if the Received Signal Level in LINK-2 is -72.6 dBm.

d. The Receiver Sensitivity Threshold (R_x) for LINK-1 is - 90 dBm and the Receiver Sensitivity Threshold for LINK-2 is - 60 dBm. Can LINK-1 and LINK-2 operate? Why?

e. For a given microwave transmitter and receiver system, you have made an unsuccessful link design. What can you do to make this link operate?

Answer to Homework Question 18

The first microwave link (LINK-1) operating at 10 GHz has a link distance of 1 mile. The second microwave link (LINK-2) operates at 1 GHz. In both of the links, both transmitting and receiving antenna gains are 20 dBi each and cabling loss both at the transmitter and at the receiver are 2 dB each.

a. What should be the link distance in the second link (LINK-2) so that both links (LINK-1 and LINK-2) have the same free space loss?

For LINK-1: FSL = 96.6+20log1+20log10 = 96.6+0+20 = 116.6 dB
For LINK-2: FSL = = 116.6 dB = 96.6+20logD+20log1 = 96.6+20logD +0
116.6 dB = 96.6+20logD ,i.e., logD=1 , D=**10 miles**

b. Find the Received Signal Level in LINK-1 if the output power of the transmitter in LINK-1 is 10.6 dBm.

$P_o - L_c t_x + G_a t_x - L_c r_x + G_a t_x - FSL = RSL$

RSL = 10.6 dBm - 2 dB + 20 dBi - 2 dB + 20 dBi - 116.6 dB = **- 70 dBm**

c. Find the output power of the transmitter in LINK-2 if the Received Signal Level in LINK-2 is -72.6 dBm.

$P_o = RSL + L_c t_x - G_a t_x + L_c r_x - G_a t_x + FSL$

P_o = -72.6 dBm + 2 dB - 20 dBi + 2 dB - 20 dBi + 116.6 dB = **8 dBm**

d. The Receiver Sensitivity Threshold (R_x) for LINK-1 is - 90 dBm and the Receiver Sensitivity Threshold for LINK-2 is - 60 dBm. Can LINK-1 and LINK-2 operate? Why?

For LINK-1, RSL = - 70 dBm > R_x = - 90 dBm. i.e., LINK-1 can operate.
For LINK-2, RSL = -72.6 dBm < R_x = - 60 dBm. i.e., LINK-2 can not operate.

e. For a given microwave transmitter and receiver system, you have made an unsuccessful link design. What can you do to make this link operate?

For the given microwave transmitter and receiver system, to make the link operate, link distance should be reduced.

Homework Question 19

Write 10 important parameters that should be taken into consideration in designing a General Telecommunication System.

Answer to Homework Question 19

Type of information to be sent (data, voice, video, multimedia etc.)
Transmitted power
Frequency of operation
Availability of design material
Economy of design
Information Content (Rate, Bandwidth) to be transmitted
Type of information to be transmitted (real-time voice, video, data, multimedia)
Length of the Link
Medium of Transmission
Noise in the Link
Performance criteria (Bit error rate or Signal to Noise Ratio)
Security required
Location to be used

Homework Question 20

Write 2 basic similarities and 3 basic differences between LMDS and FSO Systems.

Answer to Homework Question 20

LMDS	FSO
Atmospheric Link	Atmospheric Link
Access System	Access System
Microwave frequencies	Optical (Infrared) frequencies
Up to 622 Mbps	Can be up to 2.5 Gbps or even DWDM
Can cover up to 5 km	Coverage is 1.5-2 km

Homework Question 21

Explain the difference between Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) in LMDS.

Answer to Homework Question 21

In Time Division Duplexing (TDD), the subscriber and the base station take turns talking to each other. At any time, both parties will use the entire spectrum allocated for that link.

In Frequency Division Duplexing (FDD), the uplink and the downlink use different frequency bands separated by a large guard band.

Homework Question 22

In each of the below items (i, ii, iii, iv, v) 5 systems are named. For each item, write the name of the system which is unrelated to the other 4 systems.

i. Microwave, Radio Link, MMDS, Optical Fiber, LMDS

ii. STM-1, E-1, T-3, PDH, 2 Mbps/8 MBps Multiplexer

iii. FSO, SDH, LMDS, Fiber, STM-16

iv. PSTN, Circuit Switching, Packet Switching, PBX, E-1

v. ISDN, ADSL, Twisted Pair Cable, Coaxial Cable, Local Loop

Answer to Homework Question 22

In each of the below items (i, ii, iii, iv, v) 5 systems are named. For each item, write the name of the system which is unrelated to the other 4 systems.

i. Microwave, Radio Link, MMDS, Optical Fiber, LMDS
Answer: Optical Fiber

ii. STM-1, E-1, T-3, PDH, 2 Mbps/8 MBps Multiplexer
Answer: STM-1

iii. FSO, SDH, LMDS, Fiber, STM-16
Answer: LMDS

v. PSTN, Circuit Switching, Packet Switching, PBX, E-1
Answer: Packet Switching

v. ISDN, ADSL, Twisted Pair Cable, Coaxial Cable, Local Loop
Answer: Coaxial Cable

Homework Question 23

Write 1 common feature and 4 differences between Fiber Optic and Satellite Systems.

Answer to Homework Question 23

Fiber Optic Systems	**Satellite Systems**
Long Distance Communications	Long Distance Communications
Optical frequencies	Microwave frequencies
Cable	Free Space
10 Gbps - 40 Tbps	155 Mbps
Point-to-point or point-multipoint	Broadcast

Homework Question 24

If you have options of Twisted Pair, Coaxial, Microwave, Satellite and Optical Fiber Communication Systems. Using all of these systems, which one would you prefer to use for the following telecommunication applications:

i. Broadcast of a Turkish TV channel from Türkiye to Germany.
ii. Telephone traffic from Ankara to İstanbul.
iii. Low data rate LAN
iv. Multimedia transmission from Erzurum to Trabzon

v. Cable TV distribution in Adana

Answer to Homework Question 24

i. Broadcast of a Turkish TV channel from Türkiye to Germany: Satellite
ii. Telephone traffic from Ankara to İstanbul: Optical Fiber
iii. Low data rate LAN: Twisted Pair
iv. Multimedia transmission from Erzurum to Trabzon: Microwave
v. Cable TV distribution in Adana: Coaxial

Homework Question 25

What are the advantages and disadvantages of satellite telecommunication systems as compared to terrestrial telecommunication syatems.

Answer to Homework Question 25

Advantages of satellite telecommunication systems as compared to terrestrial telecommunication systems:

- Access to remote areas
- Coverage of large geographical areas
- Insensitivity to topology
- Cost is independent of distance

Disadvantages of satellite telecommunication systems as compared to terrestrial telecommunication syatems:

- High initial cost
- Propagation delay with GEO syatems
- Licencing requirements

Homework Question 26

a. What are the wavelengths commonly used in optical fiber communication (OFC) systems?

b. Which wavelength would you prefer for very long distance repeaterless OFC? Why?

c. Which wavelength would you prefer for very high rate OFC? Why?

Answer to Homework Question 26

a. 1310 nm, 1550 nm, 800 nm – 900 nm are the wavelengths commonly used in optical fiber communication (OFC) systems.

b. 1550 nm because this wavelength provides the minimum attenuation in the fiber.

c. 1310 nm because this wavelength provides the minimum dispersion in the fiber.

Homework Question 27

Compare Twisted Pair, Coaxial, Microwave, Satellite, Fiber and Free Space Optics Communication Systems in terms of:

a. Frequency of Operation,
b. Maximum Bit Rate which is possible to transmit,
c. Distance Between Repeaters.

Answer to Homework Question 27

Medium Type	Frequency of Operation	Maximum Bit Rate	Distance Between Repeaters
Twisted Pair	1MHz - 100MHz - 1GHz	2Mbps-100Mbps-1Gbps	2 km - 100 m
Coaxial	1 GHz	565 Mbps	2-3 km
Microwave	300 MHz - 40 GHz	622 Mbps	30-70 km
Satellite	390 MHz - 30 GHz	155 Mbps	800-1500-36000 km
Fiber	750 -194 THz	2.5 -10 Gbps -150 Tbps	50 -100 -6000 km
Free Space Optics	750 -194 THz	2.5 -10 Gbps -150 Tbps	1.5 -4 km

Homework Question 28

You have a multimode and a single mode fiber.

a. Write their core diameters, cladding diameters,
b. Which one is preferred for long distance communication and for LAN applications?
c. Which one is preferred to be used with an LED and with a laser diode?

Answer to Homework Question 28

a. For multimode fibers, core diameters are 50, 62.5 and 100 micrometers, corresponding cladding diameters are 125, 125 and 140 micrometers. For singlemode fibers, core diameter is 9 micrometers, cladding diameter is 125 micrometers.
b. Singlemode fibers are preferred for long distance communication and multimode fibers are preferred for LAN applications.
c. Multimode fibers are preferred to be used with an LED. Singlemode fibers are preferred to be used with a laser diode?

Homework Question 29

a. List the disturbances due to the atmosphere which effects Free Space Optical communication systems.
b. List the disturbances other than atmosphere which effects Free Space Optical communication systems

Answer to Homework Question 29

a. Disturbances due to the atmosphere effecting Free Space Optical communication systems are:

- Fog: Major effect to FSO.
- Rain and Snow: Have relatively little effect.
- Molecular Absorption
- Aerosol Absorption

- Molecular Scattering
- Aerosol Scattering
- Scintillation
- Beam Wander
- Beam Spreading

b. Disturbances other than atmosphere which effects Free Space Optical communication systems are:

- Physical obstructions**:** Flying birds can temporarily (for a short time) block a single beam
- Building sway/seismic activity: Movement of buildings can disturb receiver and transmitter alignment.
- Safety: Human exposure to laser beams

Homework Question 30

Describe the "packet" used in packet switching networks.

Answer to Homework Question 30

A packet (or frame, block, cell or datagram) is a container carrying control and data bits. Control and data bits can each be in various sizes, i.e. can contain different number of bits. Control bits (start, header, destination address, data sequence number, stop, ...etc) are used by the network nodes to route the packet under certain protocol (available bandwidth, existing noise, need for retransmission, latency considerations, ... etc).

Homework Question 31

a. Explain how the communication is established in circuit switching.
b. Explain how the communication is established in packet switching

Answer to Homework Question 31

a. Establishment of communication in circuit switching:

- When requested by the end user (for example when the user dials up the phone), a circuit is formed between the calling and the called party,
- A fixed share of the network resources for that connection are reserved for this specific communication during the full duration of conversation. İ.e no other call can use those resources until the communication ends. This means that the capacity provisioned on that specific path can only be used by this call, no one else can share or use the capacity available on that path,
- When the conversation is over, connection is released, i.e the circuit is disconnected.

b. Establishment of communication in packet switching:

- A packet (or frame, block, cell or datagram) is generated
- Packets are stored-and-forwarded by packet switches up to the destination
- Packets from many different sources are statistically multiplexed and sent to their destinations over virtual circuits
- Packet switches examine packet header and check destination against a routing table

- Packets are routed to the specified nodes.

Homework Question 32

Write 2 basic similarities and 3 basic differences between Fiber Optic and FSO Systems.

Answer to Homework Question 32

Write 2 basic similarities and 3 basic differences between Fiber Optic and FSO Systems.

Basic similarities:

- Both operate at optical carrier wavelengths,
- Both can handle very high information rates

Basic differences:

- Fiber Optics is used both in backbone and access networks, FSO is used mainly in the access networks,
- Repeaterless link distance in Fiber Optics can be hundred (or even thousand) kilometers where in FSO repeaterless link distance is maximum 4 – 5 km,
- Fiber Optics uses transmission medium of optical fiber cable whereas FSO uses atmospheric transmission.

Homework Question 33

Write 2 basic similarities and 3 basic differences between Microwave and Satellite Systems.

Answer to Homework Question 33

Write 2 basic similarities and 3 basic differences between Microwave and Satellite Systems.

Basic similarities:

- Both operate at microwave frequencies,
- Both are wireless systems

Basic differences:

- Repeaterless transmission distance in Microwave Systems is much shorter,
- Satellites can transmit to, and receive from, a large area (foot print or coverage), thus advantageous in point-to-multipoint and broadcast applications,
- Propagation delay is quite important in satellite communications, not so important in microwave.

Homework Question 34

Write 1 basic similarity and 4 basic differences between the Twisted Pair and the Coaxial Systems.

Answer to Homework Question 34

Write 1 basic similarity and 4 basic differences between the Twisted Pair and the

Coaxial Systems.

Basic similarity:

- Both use cable transmission,

Basic differences:

- Twisted Pair is not secure, coaxial is relatively more secure,
- Twisted Pair is usually for slow rate transmission and very high rate transmission can be realized for very short distances. Coaxial is higher bandwidth for longer distances.
- Coaxial Systems are usually used mainly in CATV networks whereas Twisted Pairs are employed in the classical analog local loop, xDSL and LAN applications,
- Twisted Pair is usually less expensive than coax and easier to install and reconfigure.

Homework Question 35

Among the Twisted Pair, FSO, Microwave, Satellite and Optical Fiber Communication Systems, which one will fit the best for the following telecommunication applications:

a. Heavy telephone traffic from İstanbul to İzmir.

b. ADSL.

c. Broadcast of Turkish TV channels to Germany.

d. Multimedia transmission from Mersin to Konya.

e. 1 Gbps access network in Ulus, Ankara.

Answer to Homework Question 35

Among the Twisted Pair, FSO, Microwave, Satellite and Optical Fiber Communication Systems, which one will fit the best for the following telecommunication applications:

a. Heavy telephone traffic from İstanbul to İzmir.
Answer: Optical Fiber Communication

b. ADSL.
Answer: Twisted Pair

c. Broadcast of Turkish TV channels to Germany.
Answer: Satellite

d. Multimedia transmission from Mersin to Konya.
Answer: Microwave

e. 1 Gbps access network in Ulus, Ankara.
Answer: FSO

Homework Question 36

Consider a telecommunication system using optical fiber.

a. Write the type of the light source, optical fiber, wavelength of operation you would prefer if it a long distance backbone application. Also explain the reasons of your preferences.

b. Write the type of the light source, optical fiber, wavelength of operation you would prefer if it a very high data rate backbone application. Also explain the reasons of your preferences.

Answer to Homework Question 36

Consider a telecommunication system using optical fiber.

a. Write the type of the light source, optical fiber, wavelength of operation you would prefer if it a long distance backbone application. Also explain the reasons of your preferences.

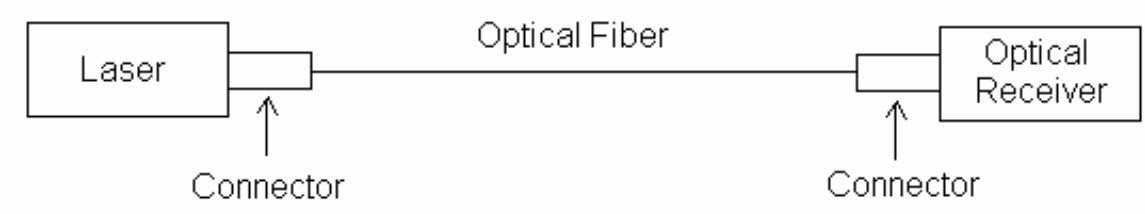
Semiconductor laser diode light source, single mode optical fiber, 1550 nm operating wavelength.
For choosing the laser, low spectral width and directionality.
For choosing the single mode optical fiber, support of high data data needed in backbone.
1550 nm gives the minimum attenuation in the fiber.

b. Write the type of the light source, optical fiber, wavelength of operation you would prefer if it a very high data rate backbone application. Also explain the reasons of your preferences.

Semiconductor laser diode light source, single mode optical fiber, 1310 nm operating wavelength.
For choosing the laser, low spectral width and directionality.
For choosing the single mode optical fiber, support of high data data needed in backbone.
1310 nm gives the minimum dispersion (minimum pulse spreading) in the fiber.

Homework Question 37

A basic block diagram of a fiber optics communication system is given below:



Link values are given in the below table:

LINK ELEMENT	VALUE
Laser output power	10 dBm
Laser to optical fiber connector loss	1 dB
Optical fiber attenuation	0.3 dB / km
Optical fiber to receiver connector loss	1 dB
Receiver Sensitivity	-60 dBm
Length of the optical fiber	100 km

a. Find the optical power delivered at the optical receiver.

b. Find the power margin in the link design of part a.

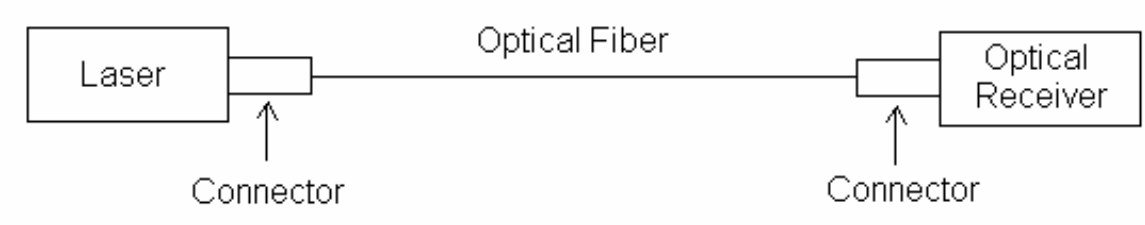
c. We have the same link values as given by the above table, except the length of the optical fiber is changed. Assuming that a power margin of 14 dBm is reasonable in the link design, find the maximum length of the optical fiber that can be used in the link design.

d. What happens if the optical fiber used in part c is 300 km?

e. What happens if the optical fiber used in part c is 50 km?

Answer to Homework Question 37

A basic block diagram of a fiber optics communication system is given below:



Link values are given in the below table:

LINK ELEMENT	VALUE
Laser output power	10 dBm
Laser to optical fiber connector loss	1 dB
Optical fiber attenuation	0.3 dB / km
Optical fiber to receiver connector loss	1 dB
Receiver Sensitivity	-60 dBm
Length of the optical fiber	100 km

a. Find the optical power delivered at the optical receiver.

Optical power delivered at the optical receiver

= 10 dBm - 1 dB - (0.3 dB / km) x 100 km - 1 dB = **- 22 dBm**

b. Find the power margin in the link design of part a.

Power margin = - 22 dBm - (-60 dBm) = **38 dB**

c. We have the same link values as given by the above table, except the length of the optical fiber is changed. Assuming that a power margin of 14 dBm is reasonable in the link design, find the maximum length of the optical fiber that can be used in the link design.

Power margin = 14 dBm = Optical power delivered at the optical receiver - (-60 dBm)

i.e., Optical power delivered at the optical receiver = 14 dBm - 60 dBm = -46 dBm

-46 dBm = 10 dBm - 1 dB - (0.3 dB / km) x (the maximum length of the optical fiber that can be used) - 1 dB

(0.3 dB / km) x (the maximum length of the optical fiber that can be used)= 8 - (- 46) = 54 dB

The maximum length of the optical fiber that can be used = 54 dB / 0.3 dB / km = **180 km**

d. What happens if the optical fiber used in part c is 300 km?

The link will not function

e. What happens if the optical fiber used in part c is 50 km?

The link will function, however the laser and / or the optical fiber and / or the receiver chosen will have unnecessarily better specifications than required. Thus the link design will be unnecessarily expensive.

Homework Question 38

In SDH system, mapping of data packets on an STM-1 frame is done by placing the data packets in the STM-1 payload area where three columns of bytes is secured as Path Overhead (POH) in the STM-1 payload area. RSOH, AU Pointer and MSOH occupy their known columns of bytes. Data packets to be transported are composed of 53 bytes each where 5 bytes are overhead and 48 bytes are data. Assuming that the packets can be split between the two consecutive rows in the STM-1 payload area:

a. Find the maximum integer number of packets that an STM-1 frame can carry.

b. If each of the packets in part a has 47 bytes data, find the number of data bits (carrying information) in one STM-1 frame.

c. What percent of the total STM-1 capacity is used by the information found in part b.

d. Find the rate of the information found in part b.

e. Find the rate (in bits / sec) of transport of the packets (overhead+data) found in part a.

Answer to Homework Question 38

In SDH system, mapping of data packets on an STM-1 frame is done by placing the data packets in the STM-1 payload area where three columns of bytes is secured as Path Overhead (POH) in the STM-1 payload area. RSOH, AU Pointer and MSOH occupy their known columns of bytes. Data packets to be transported are composed of 53 bytes each where 5 bytes are overhead and 48 bytes are data. Assuming that the packets can be split between the two consecutive rows in the STM-1 payload area:

a. Find the maximum integer number of packets that an STM-1 frame can carry.

In the STM-1 frame, first 9 columns of bytes are reserved for RSOH, AU Pointer and MSOH, leaving 270-9 = 261 columns of bytes for the payload area.

Three column of bytes are secured for the path overhead (POH) in the payload area leaving 261 – 3 = 258 colums of bytes for the payload area.

One column is 9 bytes. Thus there are total space for 258 x 9 = 2322 bytes in the payload area.

Packet size is fixed and 53 bytes

Since packets can be split between the two consecutive rows in the payload area, the maximum integer number of ATM cells that an STM-1 frame can carry = 2322 / 53 = 43 packets.

b. If each of the packets in part a has 47 bytes data, find the number of data bits (carrying information) in one STM-1 frame.

In one packet, there are 47 bytes of data, i.e., 47 payload bytes.

Thus, in one packet, there are 47 bytes x 8 bits / byte = 376 bits of data in one packet, i.e. 376 payload bits.

In part a, 43 packets are found in one STM-1 frame.

İ.e., there are 376 x 43 = 16,168 bits of data (carrying information) in one STM-1 frame

c. What percent of the total STM-1 capacity is used by the information found in part b.

STM-1 frame carries a total of (headers + information) 9 rows X 270 columns = 2,430 bytes = 2,430 bytes x 8 bits / byte) = 19,440 bits

Thus 16,168 bits / 19,440 bits x 100 = 83.17 % of the total STM-1 capacity is used by the actual information as found in part b.

d. Find the rate of the information found in part b.

One STM-1 frame is transmitted every 0.000125 seconds (1/8000th of a second)

In part b, it is found that the information in one STM-1 frame is 16,168 bits

Thus rate of the information found in part b is 16,168 bits in 0.000125 seconds. İ.e 16,168 bits x (1/0.000125 sec) = 129.344 Mbps

e. Find the rate (in bits / sec) of transport of the packets (overhead+data) found in part a.

In one STM-1 frame, 43 packets are found in part a.

43 packets are 43 packets x 53 bytes/packet x 8 bites / byte =18,232 bites in one STM-1 frame.

Thus rate of packets found in 1.a above is 18,232 bits in 0.000125 seconds, i.e., 18,232 bits x (1/0.000125 sec) = 145.856 Mbps

Homework Question 39

In the STM-1 frame of an SDH system, RSOH, AU Pointer and MSOH occupy their known columns of bytes and the Path Overhead (POH) occupies 3 columns from column 10 to

column 12. Data packets of 576 bytes each are loaded in the remaining part (i.e., the payload area) of the STM-1 frame. 24 bytes of the data packets are overhead and the remaining 552 bytes contain the actual data. Assuming that the packets can be split between the two consecutive rows in the STM-1 payload area,

a. Maximum how many data packets can be transported in one STM-1 frame ? Note: Your answer should be an integer number)

b. How many actual data bits exist within the total number of data packets found in part a ?

c. What is the actual data rate ?

d. Find the percentage of the total STM-1 capacity which is occupied by **none** actual data.

e. Assuming that the packets can be split between the 2 consecutive frames in the STM-1 payload area, how many frames do you need to load 80 data packets of 53 bytes each.

Answer to Homework Question 39

In the STM-1 frame of an SDH system, RSOH, AU Pointer and MSOH occupy their known columns of bytes and the Path Overhead (POH) occupies 3 columns from column 10 to column 12. Data packets of 576 bytes each are loaded in the remaining part (i.e., the payload area) of the STM-1 frame. 24 bytes of the data packets are overhead and the remaining 552 bytes contain the actual data. Assuming that the packets can be split between the two consecutive rows in the STM-1 payload area,

a. Maximum how many data packets can be transported in one STM-1 frame ? Note: Your answer should be an integer number)

In the STM-1 frame, first 9 columns of bytes are reserved for RSOH, AU Pointer and MSOH, leaving 270-9 = 261 columns of bytes

Three column of bytes are secured for the path overhead (POH) leaving 261 – 3 = 258 columns of bytes for the payload area.

One column is 9 bytes. Thus there are total space for 258 x 9 = 2322 bytes in the payload area.

Packet size is fixed and 576 bytes

Since packets can be split between the two consecutive rows in the payload area, the maximum number of data packets that can be transported in one STM-1 frame = 2322 / 576 = 4 data packets.

b. How many actual data bits exist within the total number of data packets found in part a ?

In one packet, there are 552 bytes of actual data, i.e., 552 payload bytes.

Thus, in one packet, there are 552 bytes x 8 bits / byte = 4416 bits of actual data in one packet, i.e. 4416 payload bits.

In part a, 4 packets are found in one STM-1 frame.

İ.e., there are total of 4416 x 4 = 17,664 bits of actual data (carrying information) in one STM-1 frame

c. What is the actual data rate ?

One STM-1 frame is transmitted every 0.000125 seconds (1/8000th of a second)

In part b, it is found that the actual data in one STM-1 frame is 17,664 bits

Thus the rate of the actual data found in part b, is 17,664 bits in 0.000125 seconds. İ.e 17,664 bits x (1/0.000125 sec) = 141.312 Mbps

d. Find the percentage of the total STM-1 capacity which is occupied by **none** actual data.

Total STM-1 capacity is 9 rows X 270 columns = 2,430 bytes = 2,430 bytes x 8 bits / byte) = 19,440 bits

In part c, it is found that the actual data in one STM-1 frame is 17,664 bits,

So, **none** actual data in one STM-1 frame is 19,440 bits -17,664 bits = 1,776 bits

Thus 1,776 bits / 19,440 bits x 100 = 9.13 % of the total STM-1 capacity is occupied by **none** actual data.

e. Assuming that the packets can be split between the 2 consecutive frames in the STM-1 payload area, how many frames do you need to load 80 data packets of 53 bytes each.

To load 80 data packets of 53 bytes each, we need 80 x 53 bytes = 4,240 bytes in the payload area

There are total space for 258 x 9 = 2,322 bytes in the payload area in one STM-1 frame.

In two STM-1 frames, we have total of 2,322 bytes x 2 = 4,644 bytes of payload area which is more than 4,240 bytes (which is needed to load 80 data packets of 53 bytes each).

Thus we need 2 frames.

Homework Question 40

a. What is the main purpose in forming a Local Area Network?
b. Write and explain the typical topologies used in LANs.
c. Briefly explain the ethernet operation mentioning also CSMA (Carrier Sense with Multiple Access), CD (Collision Detection), recovery from collision.
d. Draw the ethernet frame format and explain the fields and purposes of the fields in the frame format.

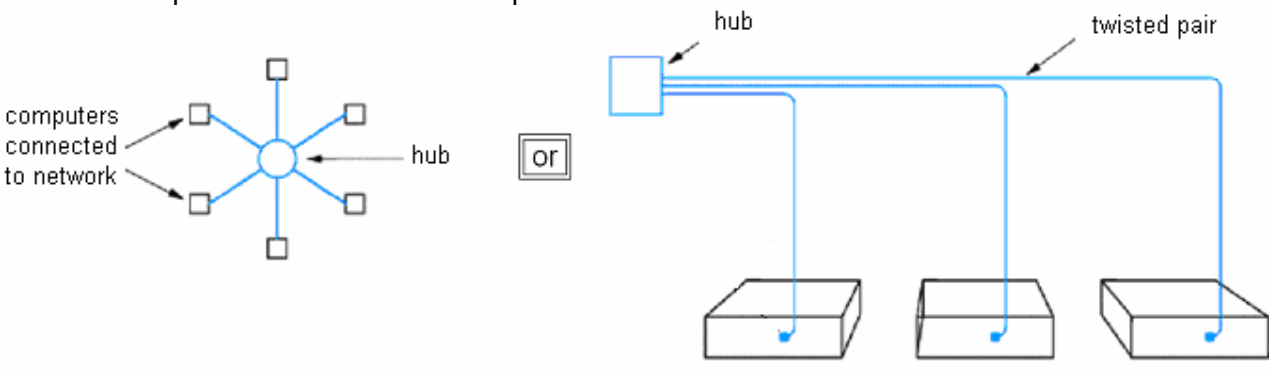
Answer to Homework Question 40

a. What is the main purpose in forming a Local Area Network?
Key idea in LAN development is to build a communication network within a local premise with reduced number of connections by *sharing* connections among many computers.

b. Write and explain the typical topologies used in LANs.
3 most popular topologies are star, ring and bus topologies.

Star topology

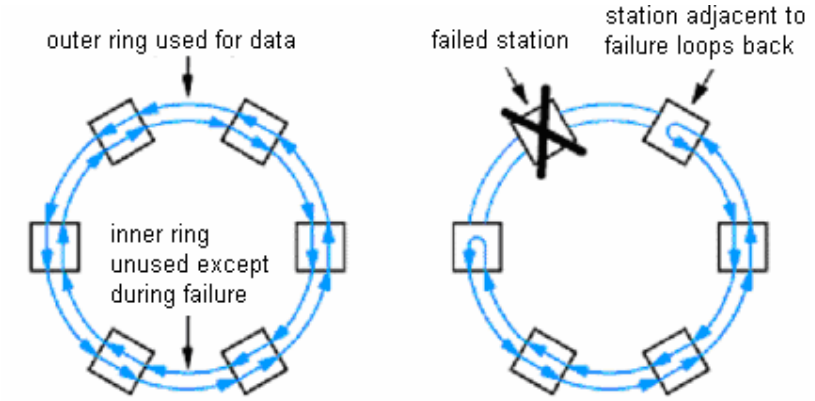
All computers attach to a central point:



Center of star is sometimes called a *hub*

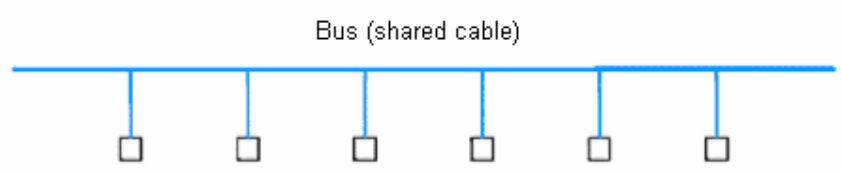
Ring topology

- Computers connected in a closed loop
- First passes data to second, second passes data to third, and so on
- In practice, there is a short connector cable from the computer to the ring
- Ring connections may run past offices with connector cable to socket in the office
-



Bus topology

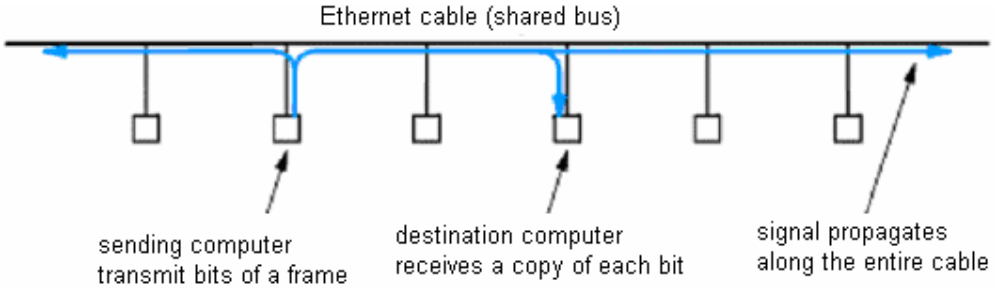
- Single cable connects all computers
- Each computer has connector to shared cable
- Computers must synchronize and allow only one computer to transmit at a time



c. Briefly explain the ethernet operation mentioning also CSMA (Carrier Sense with Multiple Access), CD (Collision Detection), recovery from collision.

Ethernet operation

- One computer transmits at a time
- Signal is a modulated carrier which propagates from transmitter in both directions along length of segment



CSMA (*Carrier Sense with Multiple Access*)

- No central control managing when computers transmit on ether
- Ethernet employs CSMA to coordinate transmission among multiple attached computers
- Carrier sense - computers want to transmit tests ether for carrier before transmitting
- Multiple access - multiple computers are attached and any computer can be transmitter

Collision detection - CD

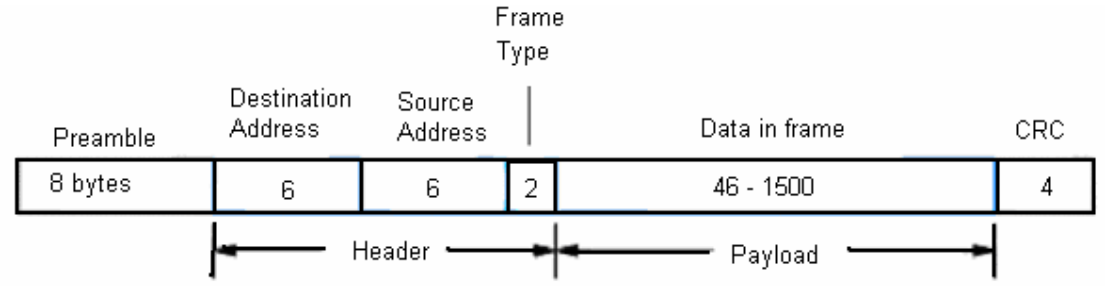
- Even with CSMA, two computers may transmit simultaneously
- Both check ether at same time, find it idle, and begin transmitting
- Window for transmission depends on speed of propagation in ether
- Signals from two computers will interfere with each other
- Overlapping frames is called a *collision*
- No harm to hardware
- Data from both frames is garbled
- Ethernet interfaces include hardware to detect transmission
- Garbled signal is interpreted as a collision
- After collision is detected, computer stops transmitting
- So, Ethernet uses CSMA/CD to coordinate transmissions

Recovery from collision

- Computer that detects a collision sends special signal to force all other interfaces to detect collision
- Computer then waits for ether to be idle before transmitting
- If both computers wait same length of time, frames will collide again
- Standard specifies maximum delay, and both computers choose random delay less than maximum
- After waiting, computers use carrier sense to avoid subsequent collision
- Computer with shorter delay will go first
- Even with random delays, collisions may occur, especially likely with busy segments
- Computers double delay with each subsequent collision
- Reduces likelihood of sequence of collisions

d. Draw the ethernet frame format and explain the fields and purposes of the fields in the frame format.

Ethernet frame format:



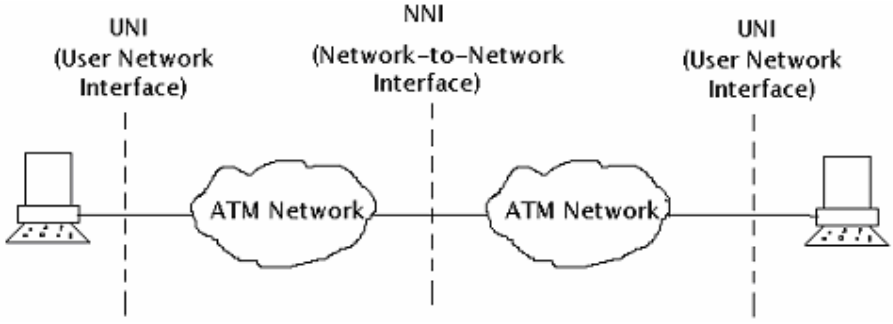
Field	Purpose
Preamble	Receiver synchronization
Destination address	Identifies intended receiver
Source address	Hardware address of sender
Frame type	Type of data carried in frame
Data	Frame payload
CRC	32-bit CRC code

Homework Question 41

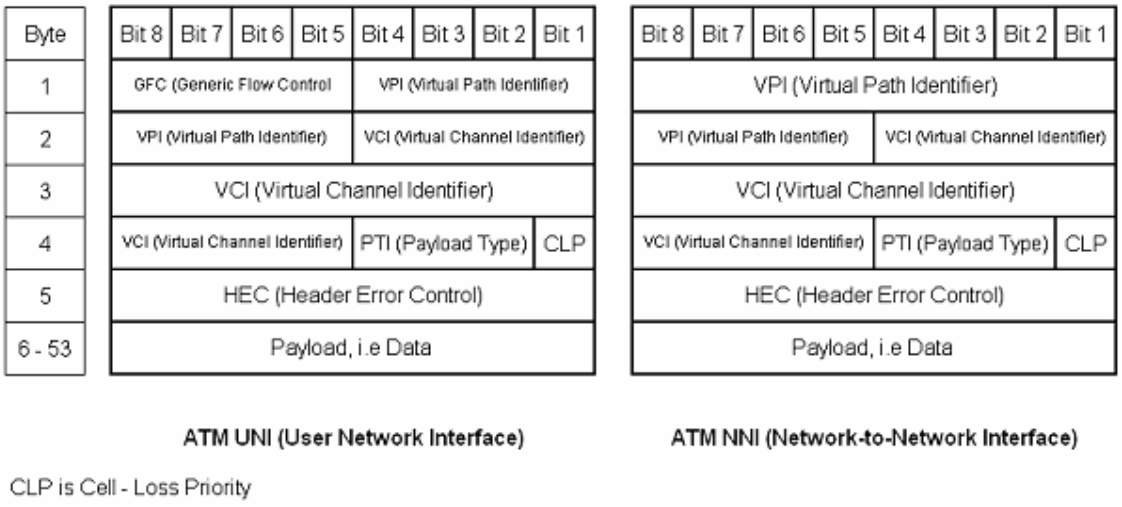
Explain the frame structures of X.25, Frame Relay and ATM.

Answer to Homework Question 41

X.25 has small packet size, generally 128 bytes or 256 bytes long.
Frame Relay packet sizes are large and variable (up to 4,096 bytes long).
ATM cell has fixed size of total 53 bytes length (byte being 8 bits).
First 5 bytes forms the header
The remaining 48 bytes comprise the payload of the cell whose format depends on the AAL type of the cell.
ATM Interfaces are shown below:



ATM Cell Structures for UNI and NNI Cells are given below:



GFC (Generic Flow Control) prevents overload conditions and control traffic flow.
VPI (Virtual Path Identifier) identifies virtual paths.
VPI and VCI together indicate the routing information within the ATM cell.
PTI (Payload Type Identifier) distinguishes between user cells and non-user cells, identifies the payload type carried in the cell and identifies control procedures.
CLP (Cell Loss Priority) indicates a cells loss of priority. This bit is set to one when a cell can be discarded due to congestion; if a switch experiences congestion, it will drop cells with this bit set. This results in giving priority to certain types of cells carrying certain types of traffic, such as video in congested networks.
HEC (Header Error Check) is used for detection and correction of 1-bit errors in the cell header, detection of multi-bit-errors in the header.

Homework Question 42

Write and explain the type of services provided by frame relay packet switching.

Answer to Homework Question 42

CIR (Committed Information Rate)
CIR is the rate (in bit/s) that the network agrees to transfer information over a virtual circuit under typical conditions. A virtual circuit can be either a permanent virtual circuit (PVC) or switched virtual circuit (SVC).
CIR applies to the rate of data entering the network.
The Commited Burst (B_c) is the maximum amount of data (in bits) that a network agrees to transfer under normal conditions over a measurement interval.
Data may be in the form of one frame or many frames.
Measurement Interval (T_c) is the time over which rates and burst sizes are measured.
In general, the duration of T_c is proportional to the burstiness of traffic.
$CIR = B_c / T_c$
CIR can be more than 20 different rates starting from 8 Kbps up to 2.048 Mbps.
EIR (Excess Information Rate).
EIR is the sustainable rate of information in excess of CIR, that the network will deliver if there is available bandwidth.
$EIR = B_e / T_c$
Total of information rate is CIR+EIR.
EIR can be more than 20 different rates starting from 8 Kbps and 1.536 Mbps

Homework Question 43

a. Write and explain the type of services provided by ATM cell switching.
b. Explain the structure in ATM Adaptation Layer 1 (AAL1).
c. Write the functions of AAL1, AAL2, AAL3/4, AAL5.

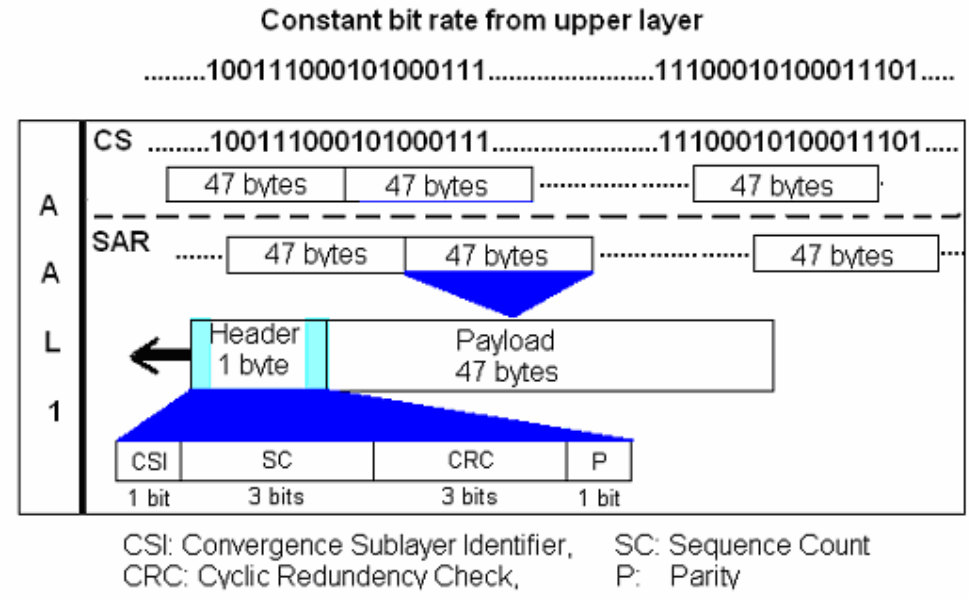
Answer to Homework Question 43

a. Write and explain the type of services provided by ATM cell switching.

a. **Constant Bit Rate (CBR)** supports applications that require continuous bandwidth and low delay, such as voice and uncompressed video.
Variable Bit Rate (VBR) supports applications that are less dependent on time, such as packetized voice, compressed video, and data. Like CBR, it provides a guaranteed amount of bandwidth, but at a lower cost.
Real-time Variable Bit Rate (rt-VBR) supports applications that requires end-to-end synchronization, such as compressed video and packetized voice.
Non-real-time Variable Bit Rate (nrt-VBR) supports interactive data applications that are less sensitive to timing, but still require a reliable supply of bandwidth.
Available Bit Rate (ABR) is designed for ATM-oriented applications that have the ability to adjust the transmission rate during times of network congestion, making use of available bandwidth without violating existing CBR and VBR contracts.
Unspecified Bit Rate (UBR) provides no guaranteed amount of bandwidth or limits on delay, and is therefore best suited for bursty traffic such as batch data. UBR cells may be dropped in order to satisfy existing CBR and VBR contracts.

- More than 20 different rates between 1 Mbps and 622 Mbps can be offered for various service types
- In ATM core networks rate can be 10 Gbps or more.

b. Explain the structure in ATM Adaptation Layer 1 (AAL1).



- In AAL1, Convergence Sublayer (CS) divides the bit stream into 47-byte segments passes them to the SAR sublayer below.
- Segmentation and Reassembly (SAR) layer accepts a 47-byte from CS and adds a one byte header.

- The result is a 48-byte data unit that is passed to the ATM layer where it is encapsulated in an ATM cell of 53 bytes.

c. Write the functions of AAL1, AAL2, AAL3/4, AAL5.

AAL1
- AAL1 supports CBR (constant bit rate) such as real time voice and real time video
- AAL1 allows ATM to connect existing digital telephone networks such as E-1.

AAL2
- Provides bandwidth-efficient transmission of low-rate, short and variable packets in delay sensitive applications
- Supports VBR and CBR.
- Also provides for variable payload within cells and across cells.

AAL3/4
- Supports connection-oriented and connectionless data services.

AAL5
- Simplified version of AAL3/4.
- Provides point-to-point and point-to-multipoint (ATM layer) connections.

Homework Question 44

Explain the encapsulation, when an Internet host requests a hypertext page over a dialup connection.

Answer to Homework Question 44

- Internet host that requests a hypertext page over a dialup connection.

  - First, the Hyper Text Transfer Protocol (HTTP) is used to construct a message requesting the page. The message, the exact format of which is unimportant at this time, is represented as follows:

  - Next, the Transmission Control Protocol (TCP) is used to provide the connection management and reliable delivery that HTTP requires, but does not provide itself. TCP defines a message header format, which can be followed by arbitrary data. So, a TCP message is constructed by attaching a TCP header to the HTTP message, as follows:

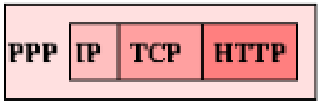
    

  - TCP does not provide any facilities for actually relaying a message from one machine to another in order to reach its destination. This feature is provided by the Internet Protocol (IP), which defines its own message header format. An IP message is constructed by attaching an IP header to the combined TCP/HTTP message:

  - Finally, although IP can direct messages between machines, it can not actually transmit the message from one machine to the next. This function is dependent

on the actual communications hardware. In this example, we are using a dialup modem connection, so it's likely that the first step in transmitting the message will involve the Point-to-Point Protocol (PPP):



- Note that PPP encapsulation is done by enclosing the entire message, not just attaching a header. This is because PPP may modify the message if it includes bytes that can not be transmitted across the link. The receiving PPP reverses these changes, and the message emerges. Encapsulating protocol can do anything it wants to the message - expand it, encrypt it, compress it - so long as the original message is extracted at the other end.

Homework Question 45

a. Write the basic structure of all IP packets.

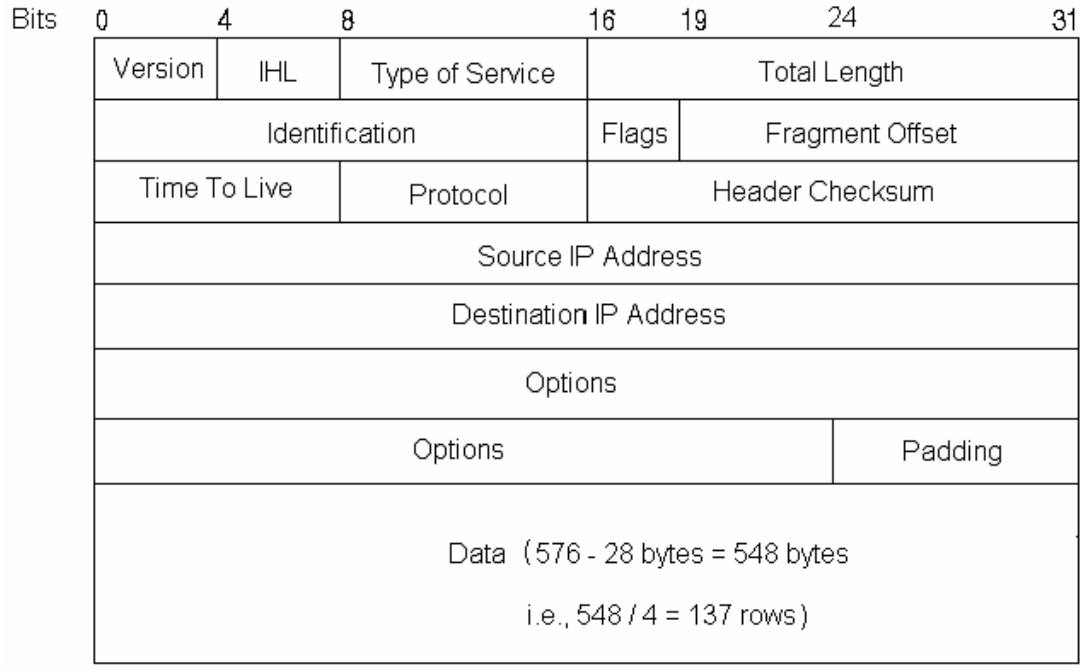
b. Draw the IPv4 packet structure and briefly explain all the fields if the header is 28 bytes with 7 bytes options field and the total packet size is 576 bytes.

Answer to Homework Question 45

a. Write the basic structure of all IP packets.

- All IP packets are structured the same way:
  - An IP header and
  - Followed by a variable-length data field

b. Draw the IPv4 packet structure and briefly explain all the fields if the header is 28 bytes with 7 bytes options field and the total packet size is 576 bytes.



Version (4 bits): Indicates the format of the internet header.
IHL (Internet Header Length) (4 bits): Is the length of the internet header in 32 bit words.
Type of Service (8 bits): Provides an indication of the abstract parameters of the quality of service desired.
Total Length (16 bits): Is the length of the datagram, measured in bytes, including internet header and data.
Identification (16 bits): An identifying value assigned by the sender to aid in assembling the fragments of a datagram.
Flags (3 bits): Various Control Flags.

Bit 0: reserved, must be zero

Bit 1: (DF) 0 = May Fragment, 1 = Don't Fragment.

Bit 2: (MF) 0 = Last Fragment, 1 = More Fragments.

Fragment Offset (13 bits): Indicates where in the datagram this fragment belongs. The fragment offset is measured in units of 8 bytes (64 bits). The first fragment has offset zero.
Time to Live (TTL) (8 bits): Indicates the maximum time the datagram is allowed to remain in the internet system. If this field contains the value zero, then the datagram must be destroyed. This field is modified in internet header processing.
Protocol (8 bits): Indicates the next level protocol used in the data portion of the internet datagram.
Header Checksum (16 bits): A checksum on the header only. Since some header fields change (e.g., time to live), this is recomputed and verified at each point that the internet header is processed.
Source Address (32 bits)
Destination Address (32 bits)
Options (56 bits):
Padding (8 bits): The internet header padding is used to ensure that the internet header ends on a 32 bit boundary. The padding is zero.
Data: (548 bytes = 137 rows)

Homework Question 46

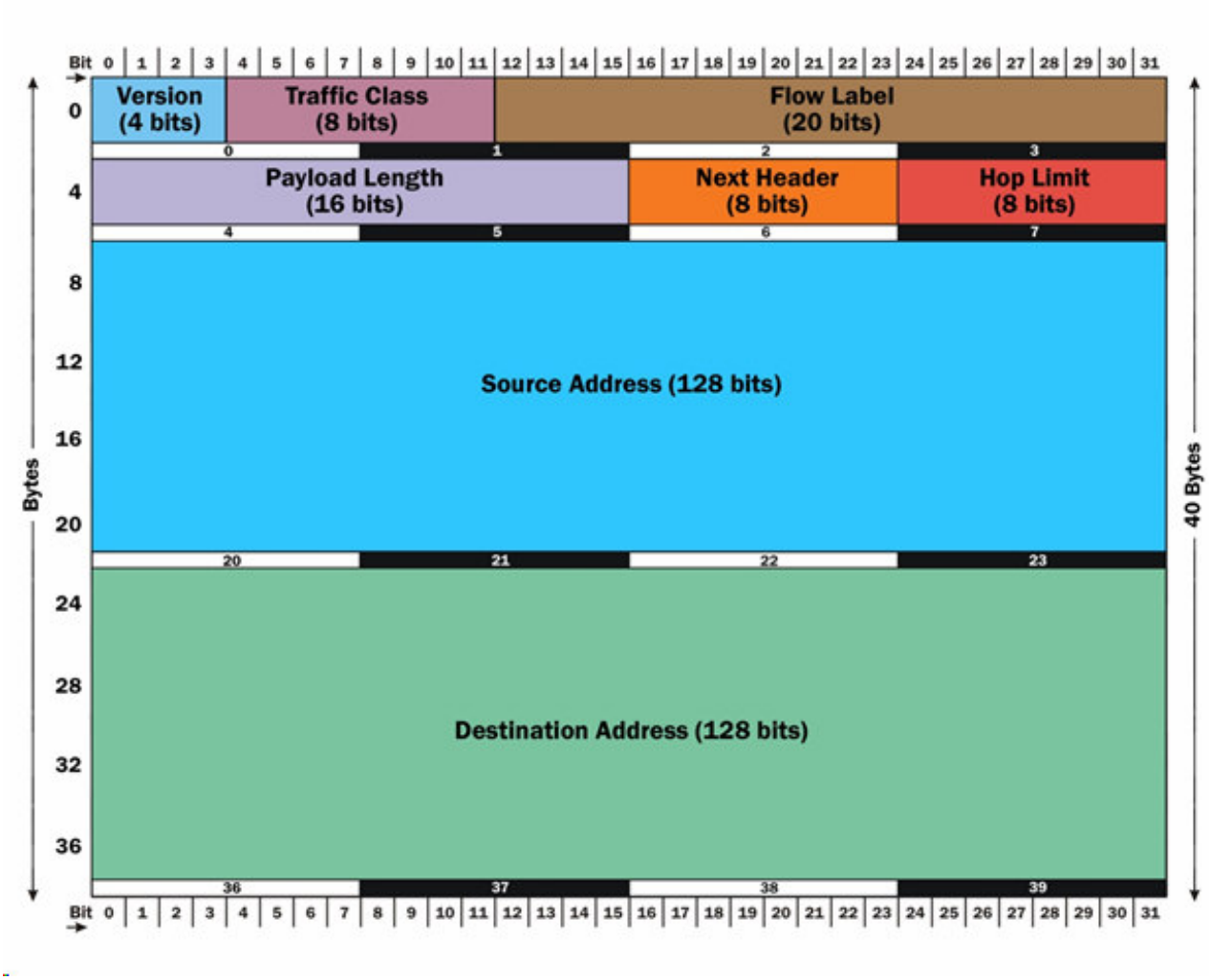
Show the IPv6 packet structure write the functions of all the boxes.

Homework Question 46

Show the IPv6 packet structure write the functions of all the boxes.

IPv6 PACKET HEADER

The IPv6 Packet Header is found at the start of every IPv6 Packet. It is always 40 bytes in length, Every bit of it is accounted for. It is twice the size of the (which results in 20 bytes of additional overhead in every IPv6 packet, compared to IPv4), yet has fewer fields. This is due to the far larger (4X) Source Address and Destination Address fields. It not only has fewer fields, it is actually much simpler. The complexity is moved off into Packet Header Extensions.



The **Version** field (4 bits) contains the value 6 in all IPv6 packets (imagine that!). In comparison, the Version field in all IPv4 packets contains the value 4. This field allows IPv4 and IPv6 traffic to be mixed in a single network.

The **Traffic Class** field (8 bits) is available for use by originating nodes and/or forwarding routers to identify and distinguish between different classes or priorities of IPv6 traffic, in a manner identical to that of IPv4 "Type of Service".

The **Flow Label** field (20 bits) is something new in IPv6. It can be used to tag up to 2^{20} (1,048,576) distinct traffic flows, for purposes such as fine grained bandwidth management (QoS). Its use is still experimental. Hosts or routers that do not support this function should set it to zero when originating a packet, or ignore it when receiving a packet. A specific traffic flow is identified by a 3-tuple which includes the Source Address, Destination Address and a Flow Control number. As with Differentiated Service, the Flow Label field is just a request for prioritization - the actual prioritization is done in routers in the path. Unfortunately most current routers do not process the Flow Label field, so at this time, QoS in IPv6 is identical to that in IPv4. Once routers process the Flow Label information, IPv6 QoS will be significantly better than that in IPv4.

The **Payload Length** field (16 bits) is the length of the IPv6 packet payload (data field) in bytes, not counting the standard packet header (as it is in IPv4 Total Length). However, the Payload Length DOES include the size of any extension headers, which don't even exist in IPv4. You can think of packet extension headers as being the first part of the data field (payload) of the IPv6 packet. Since the Payload Length field is 16 bits, the data field can be

up to 65,535 bytes long. A new Hop-by-Hop extension header is defined in RFC 2675, "IP Jumbograms", August 1999. If this extension header is present, it overrides the Payload Length field with a 32 bit value. This allows the payload length to be up to 4 gigabytes.

The **Next Header** field (8 bits) indicates the type of header immediately following the basic IPv6 packet header. It uses some of the same values as the IPv4 Protocol field but there are some new values possible in IPv6 Packet Headers.

If the Next Header field in the basic packet header contains the code for TCP (6), UDP (17) or SCTP (132), then the transport layer header (TCP, UDP or SCTP) begins immediately after the basic packet header, followed by the data. If the Next Header field contains the value for ICMPv6 (58), then the ICMPv6 header begins immediately after the basic packet header, and may be followed with data. Otherwise one or more IPv6 extension headers will be found between the basic packet header and the transport or ICMPv6 header, which may be followed by data. Since each extension header has another Next Header field (and a Header Length field), this constitutes a linked list of headers before the transport or ICMPv6 header, which is followed by the data.

The **Hop Limit** field (8 bits) serves the same purpose as the Time To Live field in the IPv4 Packet Header. It is used to prevent packets from being circling around indefinitely on a network. Every time a packet crosses a switch or router, the hop count is decremented by one. If the hop count reaches zero, the packet is dropped, and the node that drops the packet sends an ICMPv6 “time exceeded” message to the packet sender. This mechanism is used to implement the traceroute command.

The **Source Address** field (128 bits) contains the IPv6 address of the packet sender. This can be any unicast IPv6 address (link local, global or ULA). It cannot be a multicast address. In some cases (if the node does not yet have any unicast address), the unspecified address (::) may be used.

The **Destination Address** field (128 bits) contains the IPv6 address of the packet recipient. This can be a unicast IPv6 address (link local, global or ULA). It can also be a multicast IPv6 address of any scope. It cannot be the unspecified address.

Homework Question 47

a. What can be achieved by using Virtual Private Network (VPN)?
b. Write the three basic security features included in VPN.
c. Write the function of Point-to-Point Tunneling Protocol (PPTP).
d. Draw the packet structure of PPTP tunnelling.
e. Write two common VPN types.
f. Write the Advantages of VPN.

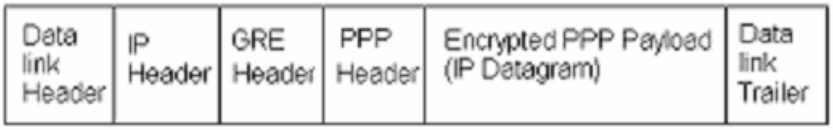
Answer to Homework Question 47

a. What can be achieved by using Virtual Private Network (VPN)?
   Connection of remote sites or users together in the same private network through the use of a public network (usually the Internet) can be achieved by using Virtual Private Network (VPN).
b. Write the three basic security features included in VPN.
   Encryption, authentication and tunneling.

c. Write the function of Point-to-Point Tunneling Protocol (PPTP).

PPTP encapsulates Point-to-Point Protocol (PPP) frames into IP datagrams for transmission over an IP-based internetwork, such as the Internet or a private intranet.

d. Draw the packet structure of PPTP tunnelling.



e. Write two common VPN types.

- Remote-Access VPN (or Virtual Private Dial-up Network (VPDN))
- Site-to-site VPN

f. Write the Advantages of VPN.

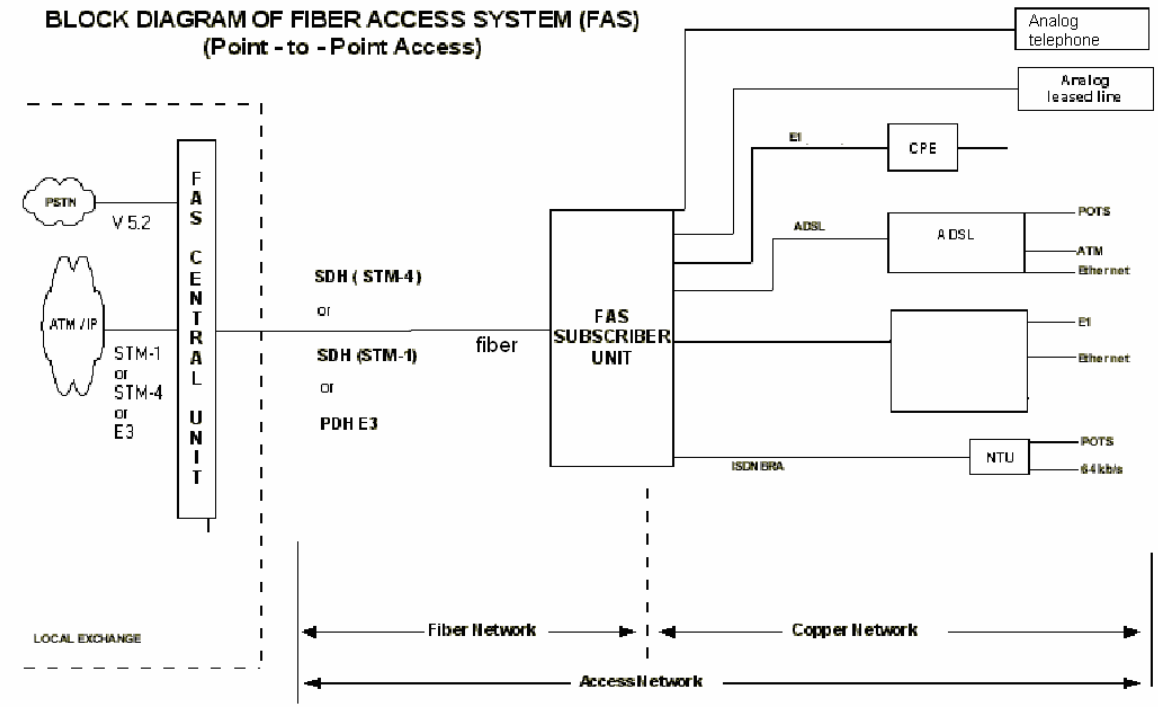
- Extends geographic connectivity
- Improves security
- Reduces operational costs versus traditional WAN
- Reduces transit time and transportation costs for remote users
- Provides global networking opportunities
- Provides broadband networking compatibility

Homework Question 48

Draw the basic block diagram of fiber optics point-to-point access system.

Answer to Homework Question 48

Draw the basic block diagram of fiber optics point-to-point access system.



Homework Question 49

a. Why is QoS (Quality of Service) needed?
b. What are the QoS parameters?
c. Give two examples of application QoS.
d. Give three examples of network QoS.

Answer to Homework Question 49

a. Why is QoS (Quality of Service) needed?

QoS is needed to provide service differentiation and performance assurance for Internet applications, i.e., QoS provides a specification of how good the offered network services are.

b. What are the QoS parameters?

- End-to-end delay,
- jitter,
- packet rate,
- burst,
- throughput,
- packet loss.

c. Give two examples of application QoS.

- Sample size 8-bit telephone voice quality. Sample rate 8 KHz, intermediate delay 125 μs
- 16-bit CD audio. 44.1 KHz, intermediate delay 22.7 μs.

d. Give three examples of network QoS.

- End-to-end delay:
  0 to 150 ms, acceptable for most applications
  150 to 400 ms, may impact some applications.
  > 400 ms, unacceptable
- Round-trip delay up to 800 ms, acceptable for conversation
- Packet loss ≤ 10^{-2} Telephone quality

Homework Question 50

a. Write the three basic characteristics of all optical networks.
b. Write four different ways of increasing the capacity in fiber optics networks.
c. Write five of the optical elements that can be used in all optical networking.
d. Write four types of optical switches being developed.

Answer to Homework Question 50

a. Write the three basic characteristics of all optical networks.

- High-capacity telecommunications networks,
- Based on all optical components.,
- All the network is to be designed with all optical elements, thus bandwidth will not be a limiting factor since opto electronic conversions will not be needed throughout the network.

b. Write four different ways of increasing the capacity in fiber optics networks.

- Installation of more fibers,
- Using time division multiplexed (TDM) signals in the same fiber to increase the bandwith handling capability of the fibers (both through fiber manufacturing and semiconductor laser modulation techniques supporting high rates of 40 Gbps),
- Introducing Wavelength Division Multiplexing (WDM) to provide many virtual fibers on a single physical fiber,
- Introducing Dense Wavelength Division Multiplexing (DWDM) to further increase drastically the information rate carrying capability of fibers (in the order of hundreds of Terabits per second).

c. Write five of the optical elements that can be used in all optical networking.

- Dense Wavelength Division Multiplexer (DWDM),
- Optical Amplifiers, Erbium-Doped Fiber Amplifier (EDFA),
- Narrowband Lasers having extremely narrow source spectral bandwidths (<< 1 nm),
- Fiber Bragg Gratings used in Optical Add/Drop Multiplexers (OADM) and in signal filtering,
- Optical Switches

d. Write four types of optical switches being developed.

- MEMS (Micro Electro Mechanical System) Switches
- Buble Switches,
- Liquid Crystal (LCD) Switches,
- Holographic Switces.

Homework Question 51

a. Write and explain four factors effecting the performance of GSM ans CDMA wireless systems.
b. What is done in wireless systems for the efficient use of the spectrum?
c. Write and explain the three types of Multiple Access Techniques.
d. Write the basic two kinds of CDMA.
e. Draw the DS-SS (Direct Sequence Spread Spectrum) System Transmitter Block Diagram and show the spreading of the information signal.
f. Draw the DS-SS (Direct Sequence Spread Spectrum) System Receiver Block Diagram.
g. Explain the 3G Technology Evolution by giving the system names and the relevant rates used in those systems.

Answer to Homework Question 51

a. Write and explain four factors effecting the performance of GSM ans CDMA wireless systems.

- Path Loss: The ratio of the transmitted power to the received power (measured in dB),

- Multipath: Artifact (noise) of reflections and echoes. Multipath can create secondary, tertiary, .. signals together with the primary signal,

- Fading: As the mobile stations move within a cell, multipath signals can rapidly add constructively or destructively based on their instanteneous amplitude and phases, yielding a total signal varying a lot in magnitude.

  This is known as Rayleigh fading (in the absence of direct path, i.e line of sight)

  Multipath delays can be predicted on statistical basis and systems are designed accordingly.

- Interference and Noise - Byproducts of molecules and aerosols in the air or currents in the electronics used.

b. What is done in wireless systems for the efficient use of the spectrum?

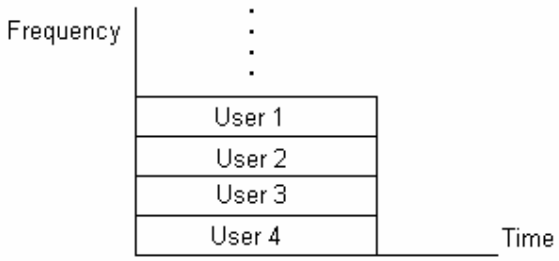
- Space division is applied: Split the service area into smaller coverage areas, cells in order to reuse frequencies across the cells.
- Multiple access techniques are applied to allow the sharing of the spectrum by multiple users.
- After differentiating the space and combining the multiple conversations into one channel, then spread spectrum, duplexing and compression are applied to use the bandwidth even more efficiently.

c. Write and explain the three types of Multiple Access Techniques.

1. **FDMA** (Frequency Division Multiple Access)

   - Divide assigned bandwidth into several channels or slots

   - Each user gets one frequency slot assigned that is used at will

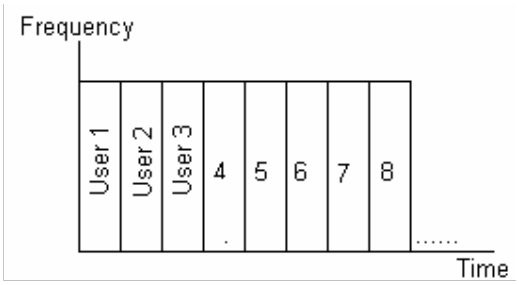


2. **TDMA** (Time Division Multiple Access)

   - Divide each channel into time slots; several calls per channel

   - Frequency band is not partitioned but users are allowed to use it only in predefined intervals of time, one at a time

   - GSM (Global System for Mobile Communications) uses TDMA



3. CDMA (Code Division Multiple Access)

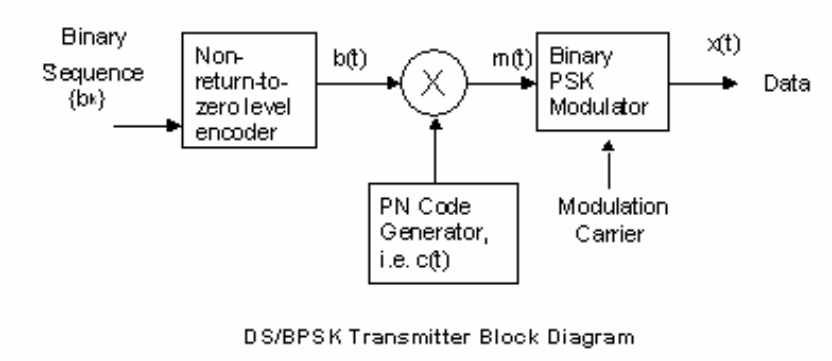
- Data is spread over a range of bandwidth wider than actually needed by the information content
- Mixes the signal with Pseudorandom Code (PN) and spreads the signal over a broad frequency range
- Spread receivers recognize the signal, acquire and despread it to obtain original signal

d. Write the basic two kinds of CDMA.

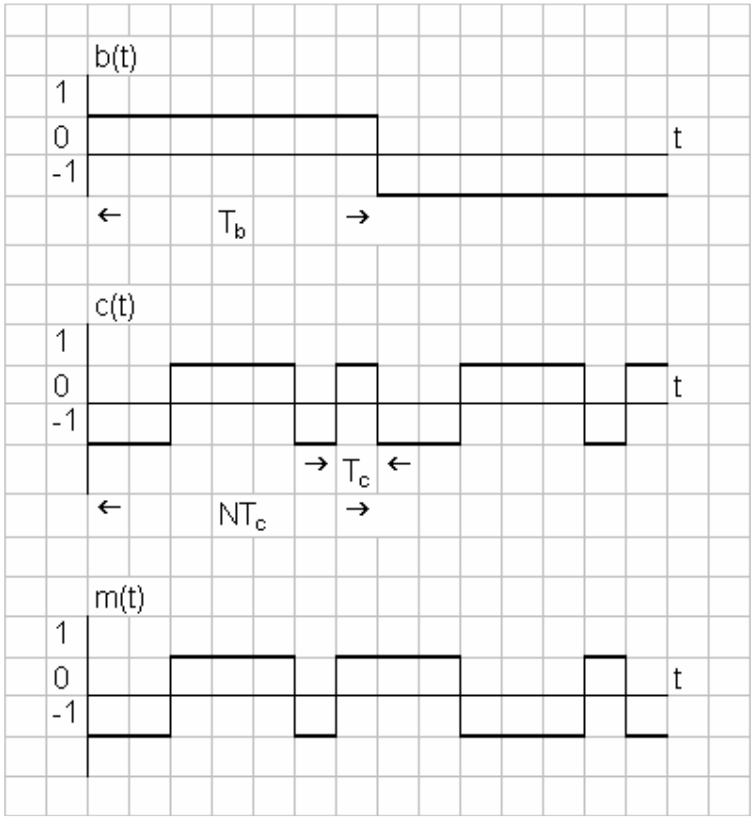
1) DS-CDMA (Direct Sequence CDMA)

2) FH-CDMA (Frequency Hopping Spread Spectrum)

e. Draw the DS-SS (Direct Sequence Spread Spectrum) System Transmitter Block Diagram and show the spreading of the information signal.



DS/BPSK Transmitter Block Diagram



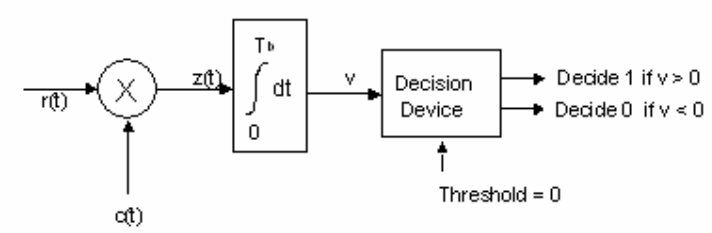
T_b is the period of one data bit

T_c is the period of one chip

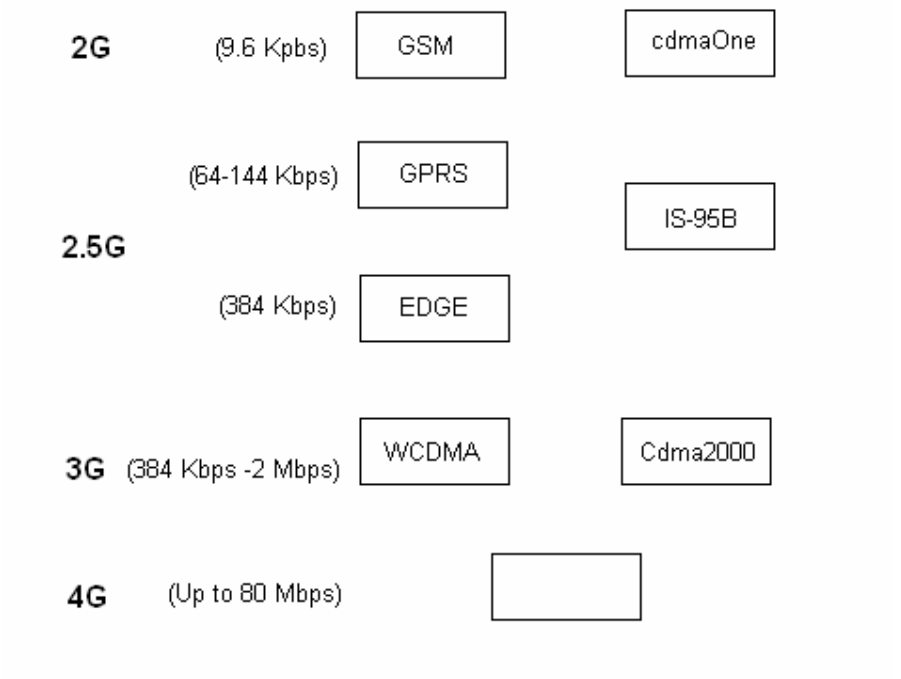
Chip rate, 1/Tc, is used to characterize a spread spectrum transmission system

Processing Gain or the **Spreading Factor** is defined as the ratio of the information bit duration over the chip duration. **$G_p = SF = T_b / T_c$**

f. Draw the DS-SS (Direct Sequence Spread Spectrum) System Receiver Block Diagram.



g. Explain the 3G Technology Evolution by giving the system names and the relevant rates used in those systems.


2G
(9.6 Kpbs)
GSM
cdmaOne
(64-144 Kbps)
GPRS
IS-95B
2.5G
(384 Kbps)
EDGE
3G
(384 Kbps -2 Mbps)
WCDMA
Cdma2000
4G
(Up to 80 Mbps)