I.C.E.™

Inspiring Creativity & Endeavour

IES | GATE | PSU

COMPUTER NETWORKS

For

COMPUTER SCIENCE

I.C.E.
Inspiring Creativity & Endeavour
IES | GATE | PSU

COMPUTER NETWORKS

Syllabus

Concept of layering. LAN technologies (Ethernet). Flow and error control techniques. IPv4/IPv6, routers and routing algorithms (distance vector, link state). TCP/ UDP and sockets, congestion control. Application layer protocols (DNS, SMTP, POP, FTP, HTTP). Network security: authentication, basics of public key and private key cryptography, digital signatures and certificates, firewalls. Basics of Wifi & switching, Digital signals.

ANALYSIS OF GATE PAPERS

Exam Year	1 Mark Ques.	2 Mark Ques.	Total
2003	2	3	8
2004	3	4	11
2005	5	2	15
2006	1	5	11
2007	2	6	14
2008	1	4	9
2009	-	5	10
2010	2	3	8
2011	2	2	6
2012	3	3	9
2013	3	2	7
2014 Set-1	2	3	8
2014 Set-2	3	2	7
2014 Set-3	3	3	9
2015 Set-1	4	2	8
2015 Set-2	2	3	8
2015 Set-3	2	3	8
2016 Set-1	2	4	10
2016 Set-2	3	4	11
2017 Set-1	2	3	8
2017 Set-2	1	2	5

CONTENTS

1 COMPUTER NETWORKS

1.1 INTRODUCTION

A Network is a set of devices (often referred to as nodes) connected by media links. A node can be a computer, printer, or any other devices capable of sending and / or receiving data generated by other nodes on the network. The links connecting the devices are called communications channels. E.g. fiber optic link, satellite link.

1.2 COMPUTER NETWORKS

Computer network means an interconnected collection of autonomous computers capable of having interconnections with each other. Computer network are generally organized as a series of layers or levels, each one built upon the one below it.

1.2.1 DESIGN ISSUE OF LAYER

- Every layer needs a mechanism for identifying senders and receivers. A mean should be there for a process on one machine to specify with whom it wants to talk.
- Design decisions should concern the rules for data transfer. It can either be simplex or half- duplex or full – duplex communication.
- Error control is an important issue and any error – detecting or correcting codes must be known on both ends of the connections. Protocol that make explicit for the receiver to allow the pieces to be put back together properly.

An issue that occurs at every level is how to keeps a fast sender from swapping a slow receiver with data. Issue that allows an arbitrarily long message to get accepted by the processes when there are multiple paths between source and destination, a route must be chosen. Sometimes this decision spilt over two or more layers.

1.2.2 NEED OF LAYERED STRUCTURE

The need for a layered structure arises from the following advantage that it provides:

1) **It reduces design complexity:**
   The whole architecture can be divided into modules (layers) and each module can be designed separately by a group of experts skilled in that area.

2) **It helps in getting the best expertise:**
   In layered structure it is not necessary that a designer must know everything about the computer network. An expert in physical communication can design physical layer whereas a software programmer can handle the applications layer part.

3) **Each layer has its distinct functions:**
   So it is very easy to analysis and understands the architecture.

4) **Each layer provides services to the upper layer:**

Upper layers have nothing to do with methods used by the lower layers for providing the services. This makes implementation of each layer independent of the other.

5) **Implementation Independency:**
Due to implementation independence, changes can be made in any layer without affecting the other layers. This implies that architecture moves along with the technology.

6) **Work Distribution:**
Work gets distributes among the layers. E.g. the user interfaces will be handled by upper layers, error and flow control by mid layer and actual transmission by lower levels. This helps in getting the work done systematically.

7) **Flexibility:**
Between each pair of adjacent there is an interface which defines primitive operations and services the lower layer offers to the upper layer. This makes possible to have different protocols in different layer; thereby providing flexibility in choosing the best protocol available for a particular implementation.

8) **Clear –cut Interface:**
Clear –cut interfaces also makes it simple to replace the implementation of one layer with a complete different implementation because all that is require for the new implementation is that it offers exactly the same set of services to its upstairs neighbor as the old implement. For e.g. if the communication medium is to be changed from copper wire to fiber optics, then only the physical layer implementations has to be changed. This does not affect the upper layers as physical layer implementation has to be changed. This does not affect the upper layers as physical layer continues to provide the same services in the same manner.

1.3 NETWORK HARDWARE

1. **Broadcast Networks**
Broadcast network have a single communications channel that is shared by all the machines on the network. Short messages, called packets sent by any machine are received by all the others. An address field within packet specifies for whom it is intended. Machine checks the address field on receiving. Its processes the packets if intended for it otherwise just ignore it. Broadcast systems allow the possibility of addressing a packet to all destinations by using a
special code in the address field. When a packet with this code is transmitted, it is received and processed by every machine on the network. Some broadcast system also support transmission to a subset of the machines, known as **multicasting**. We can also sent message to all machines. This type of transmission is called broadcast. E.g. bus Network.

2. **Point – to – Point Networks**
Point – to – point networks consists of many connections between individual pairs of machines. To go from the source to the destination, a packet on this network may have to first visit one or more intermediate machines.

1.4 LAN, MAN, WAN AND SAN

1.4.1 LOCAL AREA NETWORKS (LAN)

Local area networks (LAN) are privately – owned networks within a single building or campus of up to a few kilometers in size e.g. Networks within IIT campus.

1.4.2 METROPOLITAN AREA NETWORK (MAN)

Metropolitan area network (MAN) is basically a bigger version of a LAN and can support both data and voice. It covers a group of nearby corporate offices or a city and might be either private or public. E.g. Network connecting all IITs

1.4.3 WIDE AREA NETWORK (WAN)

Wide area network (WAN) spans large geographical area, often a country or continent. It contains a collection of machines intended for running user programs. In most wide area network, the subnet consists of two distinct components: transmission lines and switching elements. Transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links. Switching elements are specialized computers that connect three or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them. These switching computers have been called by various names in the past; the name router is now most commonly used.

1.4.4 SYSTEM AREA NETWORKS (SAN)

Another kind of network that we need to be aware of is SANs (system area networks). SANs are usually confined to a single room and connect the various components of a large computing system. For example, HiPPI (High Performance Parallel Interface) and Fiber Channel are two common SAN technologies used to connect massively parallel processors to scalable storage server and data vaults. (Because they often connect computers to storage servers, SANs are sometimes defined as storage area network s). e.g. Organization connected worldwide.

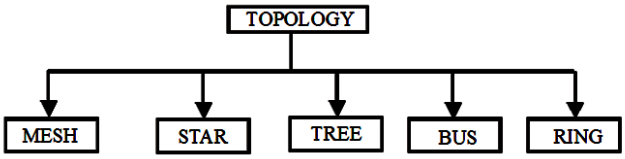
1.4.5 LINE CONFIGURATION

Line configuration refers to the way two or more communication devices attach to link. There are two possible line configurations:

i) **Point- to - Point**
   A point–to–point line configuration provides a dedicated link between two devices.
ii) **Multiport**
   A multiport line configuration is one in which more than two specific devices share a single link.

1.5 NETWORK TOPOLOGY

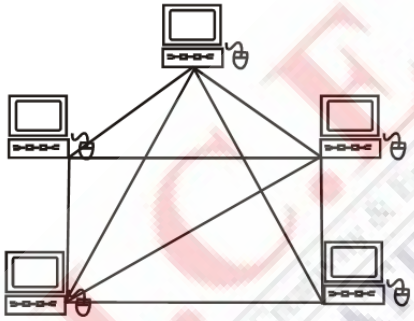
Topology refers to the way a network is laid out, either physically or logically. Two or more devices connect to a link, and then these two or more links form a topology.



The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called nodes) to each other. Topology is the relative status of the devices to be linked. It can either be peer- to –peer, where the devices share the link equally or primary – secondary, where one devices controls traffic and the others must transmit through it.

1.5.1 MESH

In a mesh topology, every device has a dedicated point – to – point link to every other devices. The term dedicated means that the link carries traffic only between the two devices it connects. Entire bandwidth is utilized by those two nodes. A fully connected mesh network having n devices has n (n-1)/2 physical channels. Thus, every device on the network must have (n-1) input/output (I/O) ports.



Advantages

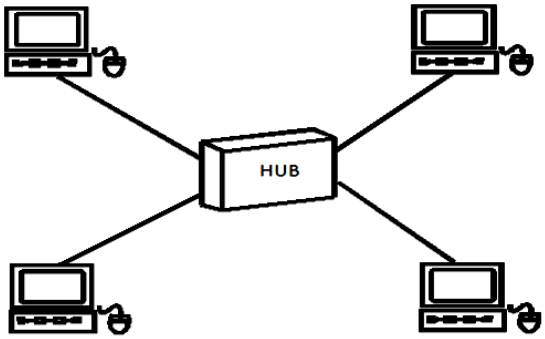
Guarantees that each connection carry its own data load, thus eliminating the traffic problems that can occur when links shared by multiple devices. If one link becomes unusable, it does not affect the entire system. Thus robust It guarantees privacy or security.

Disadvantages

As every device must be connected to every other device, installation and reconfiguration are difficult. The sheer bulk of the wiring can be greater than the available space. The hardware required to connect each link (I/O port and cable) can be prohibitively expensive.

1.5.2 STAR

In star topology, each device has a dedicated point – to – point link only to a central controller, usually called a hub. Thus the devices are not directly linked to each other. If one device wants to send data to another, it sends the data to the controller, and the relay the data to the other connected device.

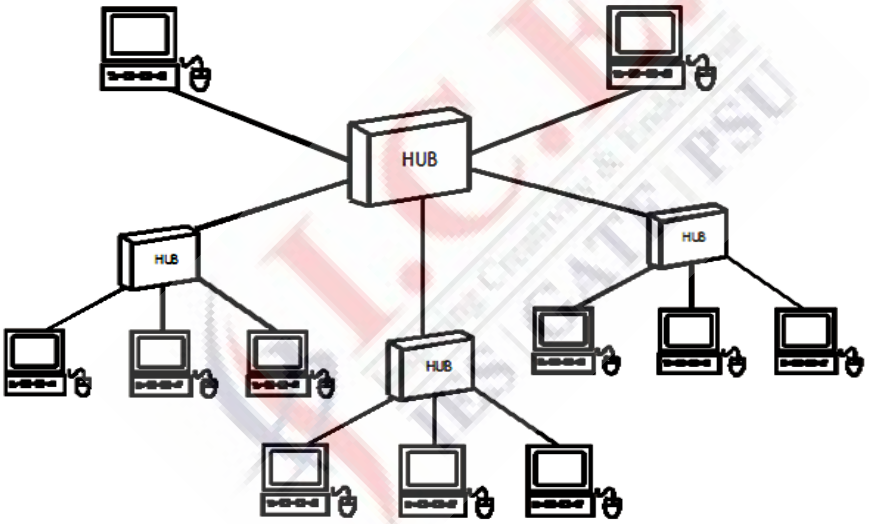


Advantages
Less expensive
Easy to install and reconfigure
Less cabling
Robustness
Easy fault identification and fault isolation.

Disadvantages
More cabling is required than some other topologies (such as tree, ring or bus)
If hub fails, entire network goes down.

1.5.3 TREE

Nodes in a tree are linked to a central hub that controls the traffic to the network.
Not every devices plug directly into the central hub. The majority of devices cannot to a secondary hub that in turn is connected to the central hub. The central hub in the tree is an active hub, which contains a repeater (a hardware devices that regenerators the received bit pattern before sending them out). The secondary hubs may be active or passive hubs. Passive hub provides a simple physical connection between the attached devices.

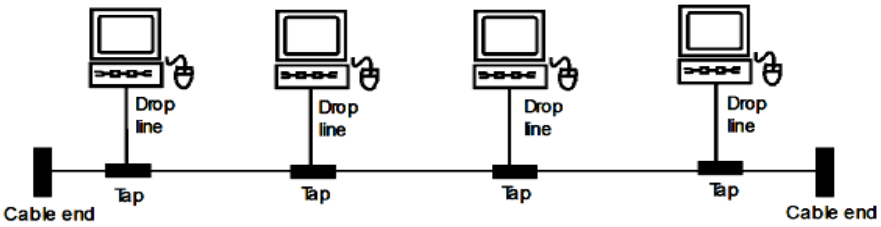


Advantages
Allow more devices to be attached to a single central hub and therefore increase the distance a signal can travel between devices. It allows the network to isolate and prioritize communication from different computers.

Disadvantage
Not Robust, if central hub goes down whole system will be affected. More cabling required as compared to bus or ring topology.

1.5.4 BUS

In bus topology one long cable acts as a background to link all the devices in the network. Nodes are connected to the bus cable by drop lines or tabs. A drop line is a connection running between the devices and the main cable. As a single travels along the backbone, some of its energy is transformed into heat. (So, it becomes weaker and weaker the faster it has to travel).Thus there is a limit on the number of taps a bus can support and on the distance between those tabs.



Advantages

Ease of installation.

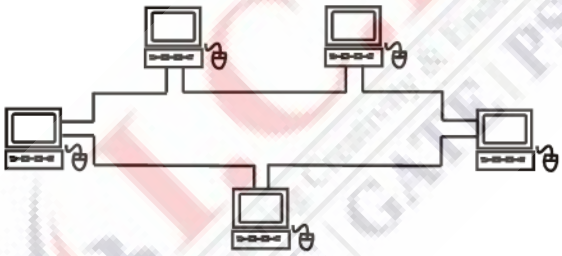
Uses less cabling than mesh, star or other topologies

Disadvantages

Difficult reconfiguration and fault isolation. Signal reflection at the taps cause degradation in quality. A fault or break in the bus cable stops all transmission.

1.5.5 RING

Each device has a decided point- to- point line configuration only with the two devices on either side of it. A signal is passed along the ring in one direction, from devices to device to device, until it reaches its destination. Each device in the ring incorporates a repeater. When a device receives a signal intended for another device, its repeater regenerates the bits and passes them along.



Advantages

Easy to install and reconfigure Fault isolation is simplified.

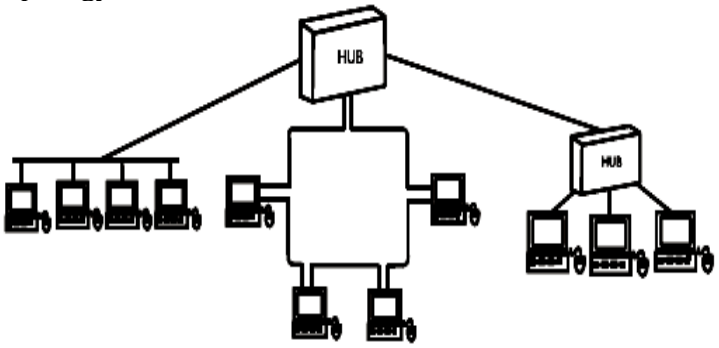
Disadvantages

A break in the ring can disable the entire network.

Fault identification is difficult.

1.5.6 HYBRID TOPOLOGY

Combination of several topologies of sub networks linked together in the larger topology, forms hybrid topology. Different topologies are connected to each other via a central controller in a star topology.



GATE QUESTIONS

1 ISO/OSI STACK AND SWO

Q.1 Host A is sending data to host B over a full duplex link. A and B are using the sliding window protocol for flow control. The send and receive window sizes are 5 packets each. Data packets (sent only from A to B) are all 1000 byte long and the transmission time for such a packet is 50μs Acknowledgement packets (sent only from B to A) are very small and require negligible transmission time. The propagation delay over the link is 200 μs. What is the maximum achievable throughput in this communication?

a) 7.69×10^6 bps b) 11.11×10^6 bps

c) 12.33×10^6 bps d) 15.00×10^6 bps

[GATE-2003]

Q.2 Match the List I with List II and select the correct answer by using the codes given below the lists.

List 1	List 2
P. Data Link Layer	1. Ensures reliable transport of data over a physical point to point link
Q. Network Layer	2. Encodes/decodes data for physical transmission
R. Transport Layer	Allows end to end communication between two processes
	4. Routes data from one network node to the next

a) P-1, Q.4, R-3 b) P-2, Q.4, R-1

c) P-2, Q.3, R-1 d) P-1, Q.3, R-2

[GATE-2004]

Q.3) How many 8-bit characters can be transmitted per second over a 9600 baud serial communication link using asynchronous mode of transmission with one start bit, eight data bits, and one parity bit and two stop bits?

a) 600 b) 800

c) 876 d) 1200

[GATE-2004]

Q.4 A serial transmission T1 uses 8 information bits, 2 start bits, 1 stop bit and 1 parity bit for each character.

A synchronous transmission T2 uses 3 eight-bit sync characters followed by 30 eight-bit information characters. If the bit rate is 1200 bits/ second in both cases, what are the transfer rates of T1 and T2?

a) 100characters/sec,153characters/sec

b)80 characters/sec, 136 characters/sec

c)100 characters/sec, 136 characters/sec

d)80 characters/sec,153 characters/sec

[GATE-2004]

Q.5 In a data link protocol, the frame delimeter flag is given by 0111. Assuming that bit stuffing is employed, the transmitter sends the data sequence 01110110 as

a) 01101011 b) 011010110

c) 011101100 d)0110101100

[GATE-2004]

Q.6 In a sliding window ARQ schemes, the transmitter's window size is N and the receiver's window size is M. The minimum number of distinct sequence numbers required to ensure correct operation of the ARQ scheme is

a) min(M, N) b) max(M, N)

c) M +N d) MN

[GATE-2004]

Q.7 A 20 Kbps satellite link has a propagation delay of 400 ms. The transmitter employs the "go back n ARQ" scheme with n set to 10. Assuming that each frame is 100

bytes long, what is the maximum data rate possible?

a) 5 Kbps b) 10 Kbps
c) 15 Kbps d) 20 Kbps

[GATE-2004]

Q.8 Consider a parity check code with three data bits and four parity check bits. Three of the code words are 0101011,1001101 & 1110001. Which of the following are also code words?

I. 0010111 II. 0110110
III. 1011010 IV. 0111010

a) I and III b) I,II and III
b) II and IV d) I, II, III and IV

[GATE-2004]

Q.9 The maximum window size for data transmission using the selective reject protocol with n-bit frame sequence number is

a) 2^n b) 2^{n-1}
c) $2^n - 1$ d) 2^{n-2}

[GATE-2005]

Q.10 Consider the following message M=1010001101.The cyclic redundancy check (CRC) for this message using the divisor polynomial $x^5 + x^4 + x^2 + 1$ is :

a) 01110 b) 01011
c) 10101 d) 10110

[GATE-2005]

Q.11 A channel has a bit rate of 4 kbps and one-way propagation delay of 20 ms. The channel oses stop and wait protocol. The transmission time of the acknowledgement frame is negligible. To get a channel efficiency of at least 50%, the minimum frame size should be

a) 80 bytes b) 80 bits
c) 160 bytes d) 160 bits

[GATE-2005]

Q.12 In the 4B/5B encoding scheme, every 4 bits of data are encoded in a 5 bit codeword. It is required that the codeword's have at most 1 leading and a most 1 trailing zero. How many such codeword's are possible?

a) 14 b) 16
c) 18 d) 20

[GATE-2006]

Q.13 On a wireless link, the probability of packet error is 0.2. A stop-and-wait protocol is used to transfer data across the link. The channel condition is assumed to be independent from transmission to transmission. What is the average number of transmission attempts required to transfer 100 packets?

a) 100 b) 125
c) 150 d) 200

[GATE-2006]

Q.14 Station A uses 32 byte packets to transmit messages to Station B using a sliding window protocol. The round trip delay between A and B is 80 ms and the bottleneck bandwidth on the path between A and B is 128 kbps. What is the optimal window size that A should :

a) 20 b) 40
c) 160 d) 320

[GATE-2006]

Q.15 Station A needs to send a message consisting of 9 packets to Station B using a sliding window (window size 3) and go-back-n error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no acts from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

a) 12 b) 14
c) 16 d) 18

[GATE-2006]

Q.16 The message 11001001 is to be transmitted using the CRC

EXPLANATIONS

Q. 1 (b)

Now, transmission time for 1 packet = 50 μs

Transmission time for 5 packet =5×50 μs=250μs

Propagation delay = 200μs

Total time = transmission time + propagation

Delay=250+200=450μs=450×10^{-6}μs

Finally, maximum achievable throughput

$$= \frac{\text{size of window}}{\text{total time}} \text{ bps}$$

Q.2 (a)

Q.3 (b)

Total number of bits=12

Modulation rate = 9600 baud

Number of characters (8 bit character) are transmitted

$$= \frac{9600}{12\text{bits}} = 800$$

Q.4 (c)

T_1: 1 character = (8+2+1+1)=12 bit

Transfer rate=1200/12

=100 char/sec.

T_2: Transfer character in bits

= 24+240 =264 bits

If 264 bits for 30 characters,

Then 1200 bits = ?

264/30 = 1200/X

Therefore X = 136.3 character/sec.

Q.5 (d)

Three consecutive ones are used for delimiter so whenever in data two consecutive one comes stuff a zero after them. Data is 01110110, After stuffing 0110101100.

Q.6 (c)

M+N: Because $W_s+W_r \leq$ Sequence numbers (because the maximum number of unacknowledged packets at sender will be W_s and at the receiver it will be W_r, similar to the sequence numbering in selective Repeat) where W_s is size of sender window and W_r is receiver window's size.

Q.7 (b)

Tx = 100*8 bits /20 Kbps = 40 ms

Tp = 400 ms,

a = Tp / Tx = 400/40 =10

Efficiency of GBN = W/(1+2a),

Where w=window size

= 10 = 10/(1+20)=10/21

BW utilization or throughput or max data rate

= efficiency * BW = (10/21)*20

It is nearly 10 Kbps

Q.8 (b)

Q. 9 (b)

Let us assume the following

1) Communication between two stations; station A and station B.
2) The size of window to be 8 (0,1,2, 3,4,5,6,7) Now, the communication between the two stations would be as follows

1) Station A sends frame 0 to station B
2) Station B receive frame 0 and sends an acknowledgement as RR1
3) Station A sends frame 1 to station B
4) Station B receive frame 1 and sends an acknowledge as RR2
5) Station A sends frame 2 to station B
6) Station B received frame 2 and sends an acknowledge as RR3
7) Station A sends frame 3 to station B
8) Station B received frame 3 and sends an acknowledge as RR4

9) Station A sends frame 5 to station B
10) Station B received frame 5 and sends an acknowledge as RR6. (Receive ready 6), i.e., it is ready to receive frame 6
11) Station A sends frame 6 to station B
12) Station B receive frame 6 and sends an acknowledgement(ack) as RR7(Receive ready 7), i.e, it is ready to receive frame 7
13) Now, RR7 is lost in the transmission. Since , station A will send frame 7 only after receiving RR7, so it will Time Out as RR7 is already lost.
14) Now, A times out retransmit frame 0
15) But B was expecting frame 7, so it considers frame 7 as lost and accept frame 0 as a new frame This problem is overcome by limiting the maximum windows size to 2^{n-1}

Q.10 (a) .

Generator polynomial is of degree 5 so append 50's to the end of data and then divide new data by generator polynomial

$x^5 + x^4 + x^3 + x^2 + 1 = 110101$

```
110101) 1010001101000000(
        110101
        0111011
         110101
         0111011
          110101
          00111110
           110101
           00101100
            110101
            0110010
             110101
             0001110
```

Remainder is 01110

Q.11 (d)

Efficiency of stop and wait
$= 1/(1+2a)$.
If $1/(1+2a) = 0.5$
$\Rightarrow 2*T_p = T_x$
$\Rightarrow L = 2*B*T_p = 160$ bits

Q.12 (c)

It says we have 5 bit codeword such that "it can't have two consecutive zeros in first and second bit" and also" can't have two consecutive zeros in last two bits.

Codeword with first two bits zero = 0|0|x|x|x|=8

Codeword with last two bits zero = |x|x|x|0|0|=8

Codeword with first & last two bits zero = 0|0|x|0|0|=2

Codeword with first OR last two bits zero = 8 + 8-2 =14

Therefore possible codewords = 32 - 14 =18

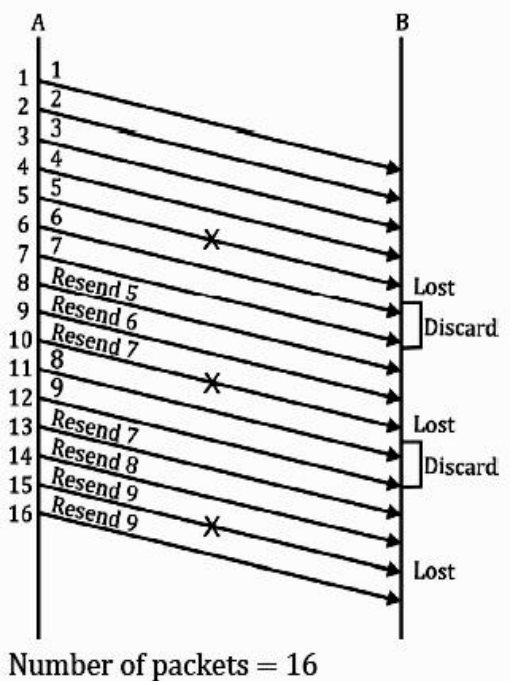
Q.13 (b)

Error rate is 0.2

In stop and wait protocol: sender will transmits $100*(1+(0.2)^1 + (0.2)^2 +(0.2)^3 + (0.2)^4 +...)$packets.

$= 100* (1/(1-0.02)) = 100/0.8$

= 125 (sum of infinite G.P. is a/(a-r))



Number of packets = 16

ASSIGNMENT QUESTIONS

Q.1 Protocols are
a) Agreements on how communication components and DTE's are to communicate
b) Logical communication channels used for transferring data
c) Physical communication used for transferring data
d) None of the above

Q.2 The method of communication in which transmission takes place in both directions, but only in one direction at a time is called
a) Simplex b) four wire circuit
c) Full duplex d) half duplex

Q.3 Error detection at the data link level is achieved by
a) bit stuffing
b) cyclic redundancy codes
c) Hamming codes
d) equalization

Q.4 Which of the following is a wrong example of a network layer?
a) Internet protocol (IP)-ARPANET
b) X.25 packet level protocol (PLP)-ISO
c) Source routing & domain USENET
d) X.25 level 2-ISO

Q.5 The topology with highest reliability is
a) bus topology b) star topology
c) ring topology d)mesh topology

Q.6 Baud means?
a) the number of bits transmitted per unit time
b) the number of bytes transmitted per unit time
c) the rate at which the signal changes
d) none of the above

Q.7 Star and stop bits are used in serial communication for
a) error detection
b) error correction
c) Synchronization
d) slowing down the communication

Q.8 Unmodulated signal coming from a transmitter is known as
a) Error signal
b) baseband signal
c) primary signal
d) none of the above

Q.9 Manchester code is a
a) BI-polar
b)non return to zero code
c) polar code
d) none of the above

Q.10 Pick the incorrect abatements.
a) Another name for primary/ secondary protocol is master /slave.
b) Peer to peer protocol provides equal status to all sites on the channel.
c) Priority, no –priority types come under master/slave protocol.
d) TDM is a primary/secondary non-priority system

Q.11 Pick the correct statement.
a) A switched circuit is a dial-up circuit that may encounter blockage (busy signal)
b) Non switched leased line supports higher data volume and quality than switched lines.
c) Non switched lines are expensive for high volume data.
d) Switched circuit provides time .

Q.12 Pick the incorrect statements that pertain to error retransmission used in continuous ARQ method.

EXPLANATIONS

Q.9 (b)
In bipolar code the signal varies among three levels. In non-return to zero code the signal remains the same throughout the bit cell. In unipolar code, there will be no signal either below zero or above zero. In Manchester code the signal level will not vary in the middle and is unipolar.

Q.16 (a)
Start and stop bits are not needed in synchronous transfer of data. So, it is 2400/8=300

Q.21 (a)
Bit stuffing is required when there is a flag of bit to represent one of the incidents, like start of frame, end of frame, etc., if the same flag of bits appear in the data stream, a zero can be inserted. The receiver deletes this zero from the data stream.

Q.27 (b)
As all lines are full-duplex and there are no self-connections, only the cross points above the diagonal needed. Hence formula for the number of cross points needed is n(n-1)/2

Q.28 (c)
Since there are six 1200 bps terminals 6×1200 + n×300=9600. Solving, n=8.

Q.32 (b)
Maximum data rate = $2H\log_2 V$ bps, where H is the bandwidth, V is the discrete levels. Here H is 3 kHz and V is 2

Q.33 (c)
Maximum number of the bps = $H\log_2$ (1+ SNR).

Q.34 (a)
In time division switches 2nT=1 frame period, where T is the memory access
time.

Q.45 (c)
The Huffman code for A will have 2 digits, B-3 digit, C-3 digits,D-2 digits and E-2 digits. This can be obtained by constructing the binary tree corresponding to the given probabilities.

Q.46 (c)
Refer to the explanation of the previous questions.

Q.47 (b)
Average code length is the sum of product of the length and probability of the occurrence of the symbols.
Here it is,
2×0.3+3×0.15+3×0.1+2×0.25+2×0.2=2.25.

Q.86 (a)
In synchronous transfer start and stop bits are never used.
Hence 240018 = 300 bits per sec.

Q.87 (d)
Consider the use of 1000 bit frames on a 1 Mbps satellite channel with a 270 ms delay. What is the maximum link utilization for ?
Given that the window size is 127
a = 270
So, $127 < 541 \quad (N < 2a + 1)$

$$\Rightarrow \text{Efficiency} = \frac{127}{541}$$

$$= 0.2348 = 23.48\%$$