Module-03 and 04

Problems

Problem 01

- If the bandwidth of the line is 1.5 Mbps, RTT is 45 msec and packet size is 1 KB, then find the link utilization in stop and wait.

- **Solution-**

- Given-

  Bandwidth = 1.5 Mbps

  RTT = 45 msec

  Packet size = 1 KB

- **Calculating Transmission Delay-**

- Transmission delay (T_t)

  = Packet size / Bandwidth

  = 1 KB / 1.5 Mbps

  = (2^{10} x 8 bits) / (1.5 x 10^6 bits per sec)

  = 5.461 msec

- **<u>Calculating Propagation Delay-</u>**

- Propagation delay (T_p)

  = Round Trip Time / 2

  = 45 msec / 2

  = 22.5 msec

- **<u>Calculating Value Of ‘a’-</u>**

  $a = T_p / T_t$

  $a = 22.5$ msec / 5.461 msec

  $a = 4.12$

- **<u>Calculating Link Utilization-</u>**

- Link Utilization or Efficiency (η)

  = 1 / 1+2a

  = 1 / (1 + 2 x 4.12)

  = 1 / 9.24

  = 0.108

  = 10.8 %

Problem 02

- Using stop and wait protocol, sender wants to transmit 10 data packets to the receiver. Out of these 10 data packets, every 4th data packet is lost. How many packets sender will have to send in total?

- Solution

1, 2, 3, **4**, 4, 5, 6, **7**, 7, 8, 9, **10**, 10

- The lost packets are- 4, 7 and 10.
- Thus, sender will have to send 13 data packets in total.

Problem 03

- A sender uses the stop and wait ARQ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 Kbps. Size of an acknowledgement is 100 bytes and the transmission rate at the receiver is 8 Kbps. The one way propagation delay is 100 msec.
- Assuming no frame is lost, the sender throughput is ___________ bytes/sec.

- **Solution-**

- Given-
- Frame size = 1000 bytes
- Sender bandwidth = 80 Kbps
- Acknowledgement size = 100 bytes
- Receiver bandwidth = 8 Kbps
- Propagation delay (T_p) = 100 msec

- **<u>Calculating Transmission Delay Of Data Frame-</u>**

- Transmission delay (T_t)

  = Frame size / Sender bandwidth

  = 1000 bytes / 80 Kbps

  = (1000 x 8 bits) / (80 x 10^3 bits per sec)

  = 0.1 sec

  = 100 msec

- **Calculating Transmission Delay Of Acknowledgement-**

- Transmission delay (T_t)
  = Acknowledgement size / Receiver bandwidth
  = 100 bytes / 8 Kbps
  = (100 x 8 bits) / (8 x 10^3 bits per sec)
  = 100 msec

- **Calculating Useful Time-**

- Useful Time

  = Transmission delay of data frame

  = 100 msec

- **Calculating Total Time-**
- Total Time

  = Transmission delay of data frame + Propagation delay of data frame + Transmission delay of acknowledgement + Propagation delay of acknowledgement

  = 100 msec + 100 msec + 100 msec + 100 msec

  = 400 msec

- **Calculating Efficiency-**

- Efficiency (η)

  = Useful time / Total time

  = 100 msec / 400 msec

  = 1 / 4

  = 25%

- **Calculating Sender Throughput-**

- Sender throughput
  = Efficiency (η) x Sender bandwidth
  = 0.25 x 80 Kbps
  = 20 Kbps
  = (20 x 1000 / 8) bytes per sec
  = 2500 bytes/sec

Problem 04

The values of parameters for the stop and wait ARQ protocol are as given below-

- Bit rate of the transmission channel = 1 Mbps
- Propagation delay from sender to receiver = 0.75 ms
- Time to process a frame = 0.25 ms
- Number of bytes in the information frame = 1980
- Number of bytes in the acknowledge frame = 20
- Number of overhead bytes in the information frame = 20
- Assume that there are no transmission errors. Then the transmission efficiency (in %) of the stop and wait ARQ protocol for the above parameters is _____________ . (correct to 2 decimal places)

- **<u>Solution-</u>**

- Given-
  Bandwidth = 1 Mbps
  Propagation delay (T_p) = 0.75 ms
  Processing time ($T_{process}$) = 0.25 ms
  Data frame size = 1980 bytes
  Acknowledgement frame size = 20 bytes
  Overhead in data frame = 20 bytes

- **Calculating Useful Time-**

- Useful data sent
  = Transmission delay of useful data bytes sent
  = Useful data bytes sent / Bandwidth
  = (1980 bytes – 20 bytes) / 1 Mbps
  = 1960 bytes / 1 Mbps
  = (1960 x 8 bits) / (10^6 bits per sec)
  = 15680 µsec
  = 15.680 msec

- **Calculating Total Time-**

- Total time

  = Transmission delay of data frame + Propagation delay of data frame + Processing delay of data frame + Transmission delay of acknowledgement + Propagation delay of acknowledgement

  = (1980 bytes / 1 Mbps) + 0.75 msec + 0.25 msec + (20 bytes / 1 Mbps) + 0.75 msec

  = 15.840 msec + 0.75 msec + 0.25 msec + 0.160 msec + 0.75 msec

  = 17.75 msec

- **Calculating Efficiency-**

- Efficiency (η)

  = Useful time / Total time

  = 15.680 msec / 17.75 msec

  = 0.8833

  = 88.33%

Problem 05

- Consider two hosts X and Y connected by a single direct link of rate 10^6 bits/sec. The distance between the two hosts is 10,000 km and the propagation speed along the link is 2×10^8 m/sec. Host X sends a file of 50,000 bytes as one large message to host Y continuously. Let the transmission and propagation delays be p milliseconds and q milliseconds respectively.
- Then the value of p and q are-

  p = 50 and q = 100

  p = 50 and q = 400

  p = 100 and q = 50

  p = 400 and q = 50

- **Solution-**
-
- Given-

  Bandwidth = 10^6 bits/sec

  Distance = 10,000 km

  Propagation speed = 2×10^8 m/sec

  Packet size = 50,000 bytes

- **Calculating Transmission Delay-**

- Transmission delay (T_t)
  = Packet size / Bandwidth
  = 50000 bytes / 10^6 bits per sec
  = ($5 \times 10^4 \times 8$ bits) / 10^6 bits per sec
  = (4×10^5 bits) / 10^6 bits per sec
  = 0.4 sec
  = 400 msec

- **<u>Calculating Propagation Delay-</u>**

- Propagation delay (T_p)

  = Distance / Propagation speed

  = 10000 km / (2 x 10^8 m/sec)

  = 10^7 m / (2 x 10^8 m/sec)

  = 50 msec

Problem 06

- 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?

- Given-

  Probability of packet error = 0.2

  We have to transfer 100 packets

- When we transfer 100 packets, number of packets in which error will occur = 0.2 x 100 = 20.

  Then, these 20 packets will have to be retransmitted.
- When we retransmit 20 packets, number of packets in which error will occur = 0.2 x 20 = 4.

  Then, these 4 packets will have to be retransmitted.
- When we retransmit 4 packets, number of packets in which error will occur = 0.2 x 4 = 0.8 ≅ 1.

Then, this 1 packet will have to be retransmitted.

From here, average number of transmission attempts required = 100 + 20 + 4 + 1 = 125.

Problem 07

- 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 bytes long and the transmission time for such a packet is 50 μs. 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?

- **Solution-**

- Given-

  Sender window size = Receiver window size = 5

  Packet size = 1000 bytes

  Transmission delay (T_t) = 50 µs

  Propagation delay (T_p) = 200 µs

- **Calculating Bandwidth-**

- We know,
  Transmission delay = Packet size / Bandwidth

- So, Bandwidth
  = Packet Size / Transmission delay (T_t)
  = 1000 bytes / 50 μs
  = (1000 x 8 bits) / (50 x 10^{-6} sec)
  = 160 Mbps

- **<u>Calculating Value of ‘a’-</u>**

$a = T_p / T_t$

$a = 200\ \mu sec / 50\ \mu sec$

$a = 4$

- **Calculating Optimal Window Size-**

- Optimal window size

  = 1 + 2a

  = 1 + 2 x 4

  = 9

- **Calculating Efficiency-**

- Efficiency (η)

  = Sender window size / Optimal window size

  = 5 / 9

  = 0.5555

  = 55.55%

- **Calculating Maximum Achievable Throughput-**

- Maximum achievable throughput

  = Efficiency (η) x Bandwidth

  = 0.5555 x 160 Mbps

  = 88.88 Mbps

  = 88.88 x 10^6 bps or 11.11 x 10^6 Bps

Problem 08

- Consider 100 frames are being sent. Compute the fraction of the bandwidth that is wasted on overhead (headers and retransmissions) for a protocol on a heavily loaded 50 Kbps satellite channel with data frames consisting of 40 bits header and 3960 data bits. Assume that the signal propagation time from the earth to the satellite is 270 msec. ACK frames never occur. NAK frames are 40 bits. The error rate for data frames is 1% and the error rate for NAK frames is negligible.

Useful Data Sent-

Since each frame contains 3960 data bits, so while sending 100 frames,
Useful data sent
= 100 x 3960 bits
= 396000 bits

- **<u>Useless Data Sent / Overhead-</u>**

In general, overhead is due to headers, retransmissions and negative acknowledgements.

Now,

The error rate for data frames is 1%, therefore out of 100 sent frames, error occurs in one frame.

This causes the negative acknowledgement to follow which causes the retransmission.

- So, we have-

  Overhead due to headers = 100 x 40 bits = 4000 bits.

  Overhead due to negative acknowledgement = 40 bits.

  Overhead due to retransmission = 40 bits header + 3960 data bits = 4000 bits.

- From here,

  Total overhead

  = 4000 bits + 40 bits + 4000 bits

  = 8040 bits

- **<u>Calculating Efficiency-</u>**

- Efficiency (η) = Useful data sent / Total data sent

- Here,
  Useful data sent = 396000 bits
  Total data sent = Useful data sent + Overhead = 396000 bits + 8040 bits = 404040 bits

- Substituting the values, we get-
  Efficiency (η)
  = 396000 bits / 404040 bits
  = 0.9801

- **<u>Calculating Bandwidth Utilization-</u>**

- Bandwidth Utilization

  = Efficiency x Bandwidth

  = 0.9801 x 50 Kbps

  = 49.005 Kbps

- **<u>Calculating Bandwidth Wasted-</u>**

- Bandwidth wasted

  = Bandwidth – Bandwidth Utilization

  = 50 Kbps – 49.005 Kbps

  = 0.995 Kbps

- **<u>Calculating Fraction of Bandwidth Wasted-</u>**
- Fraction of bandwidth wasted

= Wasted Bandwidth / Total Available Bandwidth

= 0.995 Kbps / 50 Kbps

= 0.0199

= 1.99 %

Problem 09

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?

Solution

Average frame transmission time T_{fr} is 200 bits/200 kbps or 1 ms. The vulnerable time is 2×1 ms = 2 ms. This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the one 1-ms period that this station is sending.

Problem 10

A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second b. 500 frames per second

c. 250 frames per second.

Performance of ALOHA Protocol (2)

- Probability{0 arrivals in 2X sec} = $\dfrac{e^{-2G}\,(2G)^0}{0!}$
- Throughput (S) : G Prob{0 arrivals in 2X sec}
- Throughput (S) = Ge^{-2G}

Solution

The frame transmission time is 200/200 kbps or 1 ms.

a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-2G}$ or $S = 0.135$ (13.5 percent). This means that the throughput is $1000 \times 0.135 = 135$ frames. Only 135 frames out of 1000 will probably survive.

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-2G}$ or $S = 0.184$ (18.4 percent). This means that the throughput is $500 \times 0.184 = 92$ and that only 92 frames out of 500 will probably survive. Note that this is the maximum throughput case, percentagewise.

c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case $S = G \times e{-}^{2G}$ or $S = 0.152$ (15.2 percent). This means that the throughput is $250 \times 0.152 = 38$. Only 38 frames out of 250 will probably survive.

Problem 11

A slotted ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the throughput if the system (all stations together) produces

a. 1000 frames per second b. 500 frames per second

c. 250 frames per second.

Performance of Slotted ALOHA Protocol (2)

- Probability{0 arrivals in X sec} = $\dfrac{e^{-G}\,G^{0}}{0!}$
- Throughput(S) : G Prob{0 arrivals in X sec}
- Throughput(S) = Ge^{-G}

Solution

The frame transmission time is 200/200 kbps or 1 ms.

a. If the system creates 1000 frames per second, this is 1 frame per millisecond. The load is 1. In this case $S = G \times e^{-G}$ or $S = 0.368$ (36.8 percent). This means that the throughput is $1000 \times 0.0368 = 368$ frames. Only 386 frames out of 1000 will probably survive.

b. If the system creates 500 frames per second, this is (1/2) frame per millisecond. The load is (1/2). In this case $S = G \times e^{-G}$ or $S = 0.303$ (30.3 percent). This means that the throughput is $500 \times 0.0303 = 151$. Only 151 frames out of 500 will probably survive.

c. If the system creates 250 frames per second, this is (1/4) frame per millisecond. The load is (1/4). In this case $S = G \times e^{-G}$ or $S = 0.195$ (19.5 percent). This means that the throughput is $250 \times 0.195 = 49$. Only 49 frames out of 250 will probably survive.

Problem 12

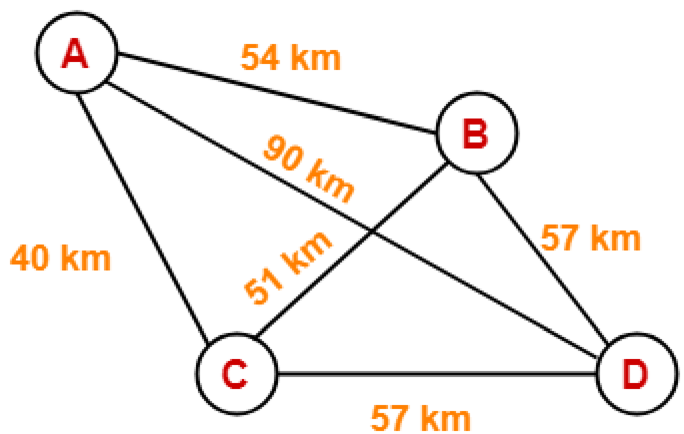
A network using CSMA/CD has a bandwidth of 10 Mbps. If the maximum propagation time (including the delays in the devices and ignoring the time needed to send a jamming signal) is 25.6 μs, what is the minimum size of the frame?

Solution

The frame transmission time is $T_{fr} = 2 \times T_p = 51.2$ μs. This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision. The minimum size of the frame is 10 Mbps × 51.2 μs = 512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet.

Problem 13

- The network consists of 4 hosts distributed as shown in figure.
- Assume that this network uses CSMA/CD and System A as a source and System C as destination. The signal travels with a speed of $3 * 10^5$ Km/sec. if sender sends at 1 Mbps, what could be the minimum size of the packet?



Note:

In CSMA / CD,

The condition to detect collision is-

Packet size >= 2 x (distance / speed) x Bandwidth $=2 * 40 * 10^6 / 10^5 = 800$

Problem 14

Consider a CSMA/CD network that transmits data at a rate of 100 Mbps over 1 Km cable with no repeaters. If the minimum frame size required for this network is 1000 bytes. What is the signal propagation speed (Km/sec) in the cable?

$$v = 2 * D * BW / L$$

where v= signal propagation speed, D is the distance, BW is the Bandwidth, L is length of message.

v=2*1*100*10^6/(1000*8)=25000 Km/sec