$$\text{Throughput} = \text{Efficiency} \times \text{Bandwidth}$$

$$\text{Throughput} = \frac{T_t}{T_t + 2 \times T_p} \times \text{Bandwidth}$$

$$\text{Throughput} = \frac{L / B}{T_t + 2 \times d / v} \times B$$

Example 11.5

What is the utilization percentage of the link in Example 11.4 if we have a protocol that can send up to 15 frames before stopping and worrying about the acknowledgments?

Solution

The bandwidth-delay product is still 20,000 bits. The system can send up to 15 frames or 15,000 bits during a round trip. This means the utilization is 15,000/20,000, or 75 percent. Of course, if there are damaged frames, the utilization percentage is much less because frames have to be resent.

Example 11.4

Assume that, in a Stop-and-Wait ARQ system, the bandwidth of the line is 1 Mbps, and 1 bit takes 20 ms to make a round trip. What is the bandwidth-delay product? If the system data frames are 1000 bits in length, what is the utilization percentage of the link?

Solution

The bandwidth-delay product is

$$(1 \times 10^6) \times (20 \times 10^{-3}) = 20{,}000 \text{ bits}$$

Q.1 A channel has a bit rate of 4 Kbps and one way propagation delay of 20 msec. The channel uses stop and wait protocol. The transmission time of the acknowledgement frame is negligible. To get a channel efficiency of at least 50%, calculate the minimum frame size.

Solution-

Given-

Bandwidth = 4 Kbps

Propagation delay (Tp) = 20 msec

Efficiency >= 50%

Let the required frame size = L bits.

Calculating Transmission Delay-

Transmission delay (Tt)= Packet size / Bandwidth

= L bits / 4 Kbps

Calculating Value Of 'a'-

a = Tp / Tt

a = 20 msec / (L bits / 4 Kbps)

a = (20 msec x 4 Kbps) / L bits

Condition For Efficiency To Be At least 50%-

For efficiency to be at least 50%, we must have-

1 / 1+2a >= 1/2

a <= 1/2

Substituting the value of ‘a’, we get-

(20 msec x 4 Kbps) / L bits <= 1/2

L bits >= (20 msec x 4 Kbps) x 2

L bits >= $(20\ x\ 10^{\ -3} sec\ x\ 4\ x\ 10^{3}\ bits\ per\ sec)\ x\ 2$

L bits >= 20 x 4 bits x 2

L >= 160

From here, frame size must be at least 160 bits.

Q.2 Consider two hosts X and Y connected by a single direct link of rate$\mathbf{10^6}$bits/sec. The distance between the two hosts is 10,000 km and the propagation speed along the link is $\mathbf{2\ x\ 10^8}$ m/sec. Host X sends a file of 50,000 bytes as one large message to host Y continuously. Calculate the transmission and propagation delays be p milliseconds and q milliseconds respectively.

Then the value of p and q are-

Solution-

Given-

Bandwidth = $\mathbf{10^6}$bits/sec

Distance = 10,000 km

Propagation speed = $\mathbf{2\ x\ 10^8}$ m/sec

Packet size = 50,000 bytes

Calculating Transmission Delay-

Transmission delay (Tt)= Packet size / Bandwidth

= 50000 bytes / 10^6 bits per sec

= (5 x 10^4 x 8 bits) / 10^6 bits per sec

= (4 x 10^5 bits) / 10^6 bits per sec

= 0.4 sec

= 400 msec

Calculating Propagation Delay-

Propagation delay (Tp)= Distance / Propagation speed

= 10000 km / ($\mathbf{2 \; x \; 10^8}$ m/sec)

= $10^{\,7}$m / ($\mathbf{2 \; x \; 10^8}$m/sec)

= 50 msec

Q.3 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?

Solution:

Given-

Bandwidth = 20 Kbps

Propagation delay (Tp) = 400 ms

Frame size = 100 bytes

Go back N is used where N = 10

Calculating Transmission Delay-

Transmission delay (Tt)= Frame size / Bandwidth

= 100 bytes / 20 Kbps

= (100 x 8 bits) / (20 x 10^3 bits per sec)

= 0.04 sec

= 40 msec

Calculating Value Of 'a'-

a = Tp / Tt

a = 400 msec / 40 msec

a = 10

Calculating Efficiency-

Efficiency (η)= N / (1+2a)

= 10 / (1 + 2 x 10)

= 10 / 21

= 0.476

= 47.6 %

Calculating Maximum Data Rate Possible-

Maximum data rate possible or Throughput= Efficiency x Bandwidth

= 0.476 x 20 Kbps

= 9.52 Kbps

≅ 10 Kbps

Q.4

$$\text{Efficiency } (\eta) = \frac{\text{Number of frames sent in one window}}{\text{Total number of frames that can be sent in one window}}$$

OR

$$\text{Efficiency } (\eta) = \frac{\text{Sender Window Size in the Protocol}}{\text{Optimal Sender Window Size}}$$

OR

$$\text{Efficiency } (\eta) = \frac{\text{Sender Window Size in the Protocol}}{1 + 2a}$$

Consider a $128\ x\ 10^3$ bits/sec satellited communication link with one way propagation delay of 150 msec. Selective Retransmission (repeat) protocol is used on this link to send data with a frame size of 1 KB. Neglect the transmission time of acknowledgement. The minimum number of bits required for the sequence number field to achieve 100% utilization ?

Solution-

Given-

Bandwidth = $128\ x\ 10^3$ bits/sec

Propagation delay (Tp) = 150 msec

Frame size = 1 KB

Now,

To achieve 100% utilization, efficiency must be 100%.

Efficiency is 100% when sender window size is optimal i.e. 1+2a

Calculating Transmission Delay-

Transmission delay (Tt)= Frame size / Bandwidth

= 1 KB / ($128\ x\ 10^3$ bits per sec)

= (1 x 10^3 x 8 bits) / ($128\ x\ 10^3$ bits per sec)

= 62.5 msec

Calculating Value of 'a'-

a = Tp / Tt

a = 150 msec / 62.5 msec

a = 2.4

Calculating Optimal Sender Window Size-

Optimal sender window size= 1 + 2a

= 1 + 2 x 2.4

= ⌈5.8⌉

= 6

Calculating Number Of Sequence Numbers Required-

In SR Protocol, sender window size and receiver window size are same.

So, sender window size = receiver window size = 6

Now,

For any sliding window protocol, minimum number of sequence numbers required

= Sender window size + Receiver window size= 6 + 6

= 12

Calculating Bits Required in Sequence Number Field-

To have 12 sequence numbers

Minimum number of bits required in sequence number field

= $\lceil log_2 12)\rceil$

= 4

Thus,

Minimum number of bits required in sequence number field = 4

With 4 bits, number of sequence numbers possible = 16

We use only 12 sequence numbers and rest 4 remains unused.