Example on Unit II: Logical Link Control
CS3025: Computer Networks TY(Comp)
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Network Performance Measured by: Bandwidth (Throughput) and Latency (Delay). Book: Computer Networks by L L Peterson and B S Davie

BW :

- No. of bits transmitted over the network in a certain period of time.
- How long it takes to transmit a data?
- 10 Mbps means 10 million bits delivered per second.
- Mbps means 10^6 Or 1 000 000
- 1/10 Mbps = 0.1 microsecond (μs) to transmit each one bit.
- Microsecond means 10^{-6}
- It means one bit is 1 μs wide over the medium in terms of time.
- For 2 Mbps, 1/2Mbps = 0.5 μs wide

Latency:

- How long it takes to travel from one end to another end of network?
- Measured in terms of time
- 24 milliseconds means it takes 24 ms to deliver the message from one end to another
- RTT Round Trip Time is the two way time taken.

Latency = Propagation Time + Transmit Time + Queuing Delay

Propagation Time is the propagation delay wrt the speed of light latency
For vacuums = 3×10^8 m/s ie for unguided media
For cable = 2.3×10^8 m/s ie for guided media
For Fiber = 2.0×10^8 m/s

Propagation Time = Distance / Speed of Light

Propagation Time = Distance of wire / Effective Speed of Light over wire

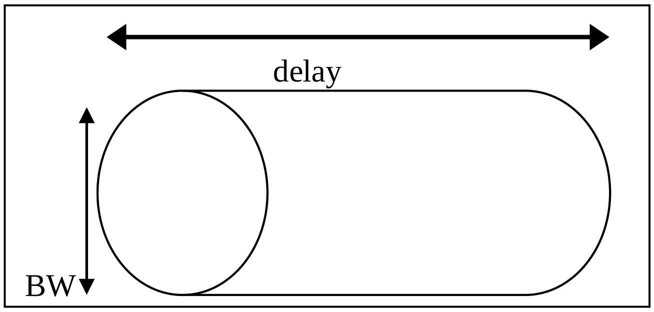
PT = d/v where d is the distance and v is velocity of propagation

Transmit Time: It is the amount of time required to transmit the given amount of data.

Transmit Time = Transfer Size / Bandwidth *Note: Transfer Size is the amount of Data*
Transmit Time = Length of frame /data transfer rate

TT = L /R

Delay x Bandwidth Product



Consider latency corresponds to the length of pipe and diameter of pipe is the bandwidth then product of length and BW gives the volume of pipe ie no. of bytes that could be transit at any given instant.

Throughput:

Throughput = *Transfer Size* / Transfer Time

where Transfer Time = PT + Transmit Time
= RTT + (Size of Data / BW)
= RTT + (1 / BW) x *Transfer Size*

Performance of Stop and Wait

Time to send data $T_D = T_I + n\,T_F$ where T_D is Propagation Delay

where T_I = Time for initialization, T_F = Time to send one frame, n = no. of frames

$T_D = n(2\,t_{prop\ time} + t_{frame})$

Utilization $u = t_{frame} / 2\,t_{prop\ time} + t_{frame}$

u = TT/TT = Transmit Time/Transfer Time

Let $a = t_{prop\ time} / t_{frame}$

If a<1, then $t_{prop\ time} < t_{frame}$

If a>1, then $t_{prop\ time} > t_{frame}$

Then

Utilization u = 1/ 1 + 2a

We know
$t_{prop\ time}$ = distance / velocity = d/v

t_{frame} = length of frame (Size) / data rate (BW) = L /R

Therefore a **=** $t_{prop\ time}$ / t_{frame} = (d/v) / (L/R) = Rd/vL

Throughput = L / (t_{frame} + RTT)

Channel Efficiency = (L/R) /(RTT + L/R) or **Throughput in bps / DTR**

Example of Calculating Propagation Time

<u>Ex.1:</u> Find the RTT (Round Trip Time) for the dial up connection over telephone cable for distance 10 km

<u>Solution:</u>

Distance = d = 10 km = 10×10^3m

Velocity of propagation over cable = v = 2.3×10^8m/s

Propagation time(PT) = d/v = $10 \times 10^3 / 2.3 \times 10^8$

= $(10/2.3) \times 10^{-5}$

= 4.3478×10^{-5}

= 43.478×10^{-6}

PT (One Way) = 43.478 μs

RTT = 2 x Propagation Time **=** 2 x 43.478 μs = 86.956 μs =87 μs

Example of Calculating Latency

Ex.2: Find the RTT (Round Trip Time) for the dial up connection over telephone cable for distance 10 km. Calculate the latency to transfer 1 MB data with 1 Mbps bandwidth.

Solution:

PT (One Way) is calculated in Ex.1 = 43.478 μs

1 MB = 1 x 10^6 Bytes = 1 000 000 x 8 = 8 000 000 bits

TT = 1 MB /1 Mbps = 1 M x 8 / 1 Mbps = 8 000 000 bits / 1 000 000 bps = 8 seconds

Latency = PT + TT + Queuing Time

Consider queuing time is negligible then

Latency = PT + TT = 43.478 μs + 8 s

Latency Vs Bandwidth

Case I: For small amount of data latency dominates bandwidth.

Ex.3 Find the transfer time for 1 byte of data over 1 Mbps and 100 Mbps bandwidth with 1 ms RTT and 100ms RTT.

Solution:

1 byte / 1 Mbps = 8 / 1 000 000 = 8 μs
and
1 byte / 100 Mbps = 8 / 100 000 000 = 0.08 μs

Therefore to transfer 1 byte of data, whether the channel is 1 Mbps or 100 Mbps is relatively insignificant. While time to transmit is quite significant.

Case II: For large amount of data bandwidth dominates latency

<u>Ex.4</u> Find the transfer time to transfer 25 MB of data over 1 Mbps and 100 Mbps bandwidth with 1 ms RTT and 100ms RTT

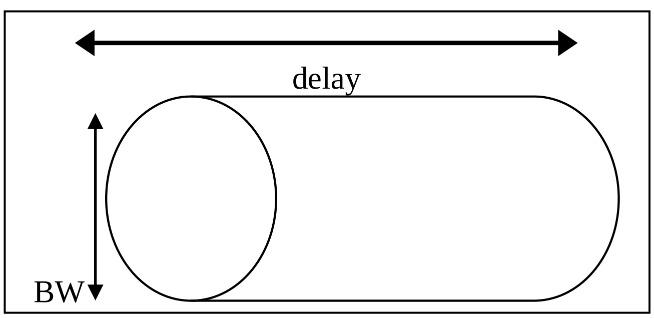
<u>Solution:</u>

25 M bytes / 1 Mbps = 25 M x 8 / 1 000 000 = 200 M / 1000 000 = 200 s

25 M bytes / 10 Mbps = 25 M x 8 / 10000000 = 200 M / 10000000 = 20 s

25 M bytes / 1Gbps = 25 M x 8 / 10^9 = 200 M / 10^9 = 0.2 s

Delay x Bandwidth Product



Consider latency corresponds to the length of pipe and diameter of pipe is the bandwidth then product of length and BW gives the volume of pipe ie no. of bytes that could be transit at any given instant.

<u>Ex.5</u> Calculate the delay x bandwidth product for one way latency equal to 50 ms and bandwidth is 45 Mbps.

<u>Solution:</u>

$= 50 \times 10^{-3}$ s x 45×10^6 bits/s

$= 2250 \times 10^3$

$= 2.25 \times 10^6$ bits = 281.25 KB

Link Type	Velocity	BW	Distance	RTT	Delay x BW
Dial-up	2.3×10^8 m/s	56 Kbps	10 Km	87 μs	5 bits
Wireless LAN	3×10^8 m/s	54 Mbps	50 m	0.33 μs	18 bits
Satellite	3×10^8 m/s	45 Mbps	35,000 km	230 ms	10 Mb
Cross country Fiber	2×10^8 m/s	10 Gbps	4000 km	40 ms	400 Mb

<u>Ex.6</u> Calculate the delay x bandwidth product considering the RTT for v= 2.3×10^8 m/s, R= 56Kbps and distance= 10Km. Find the 1-bit length in time and meters or Kilometers?

<u>Solution:</u>

Distance = d = 10 km = 10×10^3m

Velocity of propagation over cable = v = 2.3×10^8m/s

Propagation time = d/v = $10 \times 10^3 / 2.3 \times 10^8$

$= (10/2.3) \times 10^{-5}$

$= 4.3478 \times 10^{-5}$

$= 43.478 \times 10^{-6}$

= 43.478 μs

RTT = 2 x Propagation Time **=** 2 x 43.478 μs = 86.956 μs =87 μs

Product = Latency x BW = 87 μs x 56 kbps
= $87 \times 10^{-6} \times 56 \times 10^3$ bits
= 4872×10^{-3}
= 4.872 = 5 bits

Bit Length: Length of 1 bit in time & distance for Bandwidth 56 Kbps

TT = 1 bit /56 kbps = 0.01785 x 10^{-3} = 17.85 μs

Therefore = 17.85 μs x 5 = 86.9652 = 87 μs

Therefore Round Trip Distance is = 20 Km
1-bit distance is = 20Km/5 = 4 Km.

Ex.7 Calculate the delay x bandwidth product considering the RTT for v= 3 x 10^8m/s, R= 54 Mbps and distance= 50m. Find the 1-bit length in time and meters or Kilometers?

Solution:

Distance = d = 50 m

Velocity of propagation in Vacuum = v = 3 x 10^8m/s

Propagation time = d/v = 50 / 3 x 10^8

= (50/3) x 10^{-8}

= 0.16666 x 10^{-6}

= 0.1666 μs

RTT = 2 x Propagation Time **=** 2 x 0.1666 μs = 0.3333 μs = 0.33 μs

Product = Latency x BW =0.33 μs x 54 Mbps
= 0.33 x 10^{-6} x 54 x 10^6 bits
= 17.82 bits
= 18 bits

Bit Length: Length of 1 bit in time & distance for Bandwidth 54Mbps

TT = 1 bit /54 Mbps = 0.01851 x 10^{-6} = 0.01851 μs

Therefore = 0.01851 μs x 18 = 0.33 μs

Therefore Round Trip Distance is = 100 m
1-bit distance is = 100m/18 = 5.55 m.

Throughput

Throughput = Transfer Size / Transfer Time

Transfer Time = RTT + (1 / BW) x Transfer Size
= RTT + (Transfer size/ BW)

Ex. 8 Find the throughput to transfer 1 MB file over 1 Mbps bandwidth and 1Gbps network. RTT is 100 ms for both networks.

Solution:

Case I: 1 MB file over 1 Mbps line

Transfer Time = RTT + (Transfer Size /BW)
Transfer Time/ BW= 1 MB / 1 Mbps
= 1 000 000 x 8 / 1 000 000 s
= 8 000 000 / 1 000 000 s
= 8 sec
= 8000 ms

Therefore to transfer a file of 1 Mb over 1 Mbps line with RTT 100 ms, it takes 80 RTT ie 80 x 100 ms = 8000 ms.

Transfer Time = 100 ms + 8000ms = 8100 ms

Throughput = Transfer Size / Transfer Time

Throughput = 1 MB / 8100 ms
= $1 \times 10^6 \times 8 / 8100 \times 10^{-3}$ s
= $8 \times 10^6 / 8.100$ s
= 0.987 Mbps
= 987 kbps

Case II: 1 MB file over 1 Gbps line

Transfer Time = RTT + (Transfer Size /BW)
Transfer Time/ BW= 1 MB / 1 Gbps

Transfer Time = 1 MB / 1 Gbps
= 1 000 000 x 8 / 1 000 000 000 s
= 8 000 000 / 1 000 000 000 s
= 8 ms

Therefore to transfer a file of 1 Mb over 1 Gbps line with RTT 100 ms, it does not take even a 1 RTT

Transfer Time = 100 ms + 8ms = 108 ms

Throughput = 1 MB / 108 ms
$= 1 \times 10^{6} \times 8 / 108 \times 10^{-3}$ s
$= 8 \times 10^{6} / 0.108$ s
= 74.07 Mbps

Examples 9,10,11 from: Computer Networks by L L Peterson and B S Davie

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<u>Ex 9:</u> Calculate the total time required to transfer a 1.5 MB file in the following cases, assuming a RTT of 80 ms, a packet size of 1 KB data and initial 2xRTT of handshaking before data is sent.

i) The bandwidth is 10 Mbps, and data packets can be sent continuously.

Data Size = 1.5 MB = $1.5 \times 8 \times 10^{6}$ bits
= 1.5 x 8 x 1024 x1024 bits
= 12,582,912

Transfer Time = RTT + (Transfer Size /BW)

= 2 RTT + (Data Size / BW)

= 2 x 80 ms + (12,582,912 / 10 000 000 bps)

= 160 ms + 1.258 s

= 0.160 s + 1.258 s
= 1.418 s

ii) The bandwidth is 10 Mbps, but after we finish sending each data packet, we must wait one RTT before sending the next.

Transfer Time = RTT + (Transfer Size /BW)

Packet Size is 1 KB
No of Packets = 1.5 MB /1 KB = 12,582,912 / (1024x8) bits = 1536

No. of RTT Required during Transfer are = 1535

Therefore 1535 x 80 = 1228000 ms
= 122.8 s
= 1.418 s (From part (i)) + 122.8 s
= 124.218 s

iii) The link allows infinitely fast transmit, but limits BW such that only 20 packets can be sent per RTT.

20 Packets per RTT
Hence 1536 packets / 20 packets = 76.8 RTT
Therefore 6.144 s + 2 RTT

Ex 10: Consider point-to-point link 50 km in length. At what BW would propagation delay (at a speed of 2×10^8 m/s) equal transmit delay for 100-byte packets? What about 512-byte packets?

Propagation time = d/v = $50 \times 10^3 / 2 \times 10^8$

$= (50/2) \times 10^{-5}$

$= 250 \times 10^{-6}$

= 250 μs

BW for 100 byte packet is

BW = 100 byte / 250 microseconds
= 800 bits /250 μs
= 3.2 Mbps

BW for 512 byte packet is

BW = 512 byte / 250 microseconds

= 4096 bits /250 μs
= 16.384 Mbps

<u>Ex. 11</u> Suppose a 128-Kbps PTP link is setup between Earth and a rover on Mars. The distance from earth to mars is 55 Gm and data travels with the speed of light.

(a) Calculate the minimum RTT for link
(b) Calculate the delay x BW product for the link
(c) A camera on rovers takes picture of its surroundings and sends these to earth. How quickly after a picture is taken can it reach mission control on earth? Assume image size is 5 MB

Propagation delay = $55 \times 10^9 / 3 \times 10^8$ = 183.33 seconds
Therefore RTT = 2 x 183.33 = 366.66

Product of delay and BW = $183.33 \times 128 \times 10^3$ = 2.9 MB

Transfer time for 5 MB data with 128 Kbps BW

TT = 41,943,040 bits / 128 000 = 327.68 seconds

Thus total transmit time = 327.68 + 183.33 (One way propagation) = 511.01 s

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Problems on utilization (0-1), throughput (bps) and channel efficiency (%)

Ex. 12: For satellite Propagation Time = 270 ms and DTR = 56 Kbps and frame size is 4000 bits. Calculate the utilization, throughput and channel efficiency

<u>Solution:</u> t_{frame} = L / R = 4000/56000 = 71 ms

a= 270/71
= 3.8 Therefore a>1

Utilization =u= (1/1+2a) = 1/(1+(2 x 3.8))
= 0.1162
= 0.12

RTT = 2 x 270 = 540 ms
Throughput = 4000/ (71 + 540) = 4 Kb / 611 ms = 6.54 Kbps

Channel Efficiency = 6.54 / 56 = 11.67%

Ex. 13a: For telephone lines DTR = 9.6 Kbps, Velocity = 2 x 10^8 m/s, L = 500 bits, d=100 m and 5000 m. Calculate the utilization, throughput and channel efficiency

Solution:

$t_{prop\ time}$ = distance / velocity = d/v = 100/2 x 10^8 m/s = 0.5 μS

t_{frame} = length of frame (Size) / data rate (BW)
= L /R = 500/9600
= 52 ms

a **=** $t_{prop\ time}$ / t_{frame}
= 0.5 μS / 52 ms
= 0.0005 ms / 52 ms
= 0.0000096 Therefore a<1

or

a **=** (d/v) / (L/R) = Rd/vL

a= (9600x100)/(2 x 10^8 x 500)

= 0.0000096 Therefore a<1

u= 1/(1+(2 x 0.0000096))
= 1/1.0000192
= 0.9998
= 1

Throughput = L / (t_{frame} + RTT)

RTT = 2 x 0.5 μS = 1 μS

Throughput = 500/ (52 ms +1 μS) = 0.5 Kb / .052001 s = 9.6 Kbps

Channel Efficiency = 9.6 / 9.6 = 1 = 100%

For d = 5000 m

$t_{prop\ time}$ = distance / velocity = d/v = 5000/2 x 10^8 m/s =25 µS

t_{frame} = length of frame (Size) / data rate (BW)
= L /R = 500/9600
= 52 ms

a **=** $t_{prop\ time}$ / t_{frame}
= 25 µS / 52 ms
= 25 ms / 52
= 0.0004807 Therefore a<1

or

a **=** (d/v) / (L/R) = Rd/vL

a= (9600x5000)/(2 x 10^8 x 500)

= 0.00048 Therefore a<1

u= 1/(1+(2 x 0.00048))
= 1/1.00096
= 0.999
= 1

Throughput = L / (t_{frame} + RTT)

RTT = 2 x 25 µS = 50 µS

Throughput = 500/ (52 ms +50 µS) = 500 / 0.054+0.000050 = 9606 bps

Channel Efficiency = 9.6 / 9.6 = 1 = 100%

Ex. 13b: For telephone lines DTR = 19.6 Kbps, Velocity = 2.3×10^8 m/s, L = 600 bits, d=1000 m and 4000 m. Calculate the utilization, throughput and channel efficiency

Solution:

$t_{prop\ time}$ = distance / velocity = d/v = 1000/2.3×10^8 m/s = 4.34 μs

t_{frame} = length of frame (Size) / data rate (BW)
= L /R = 600 bits/19200 bits per second
= 0.03125 s
= 31.25 ms

a **=** $t_{prop\ time}$ / t_{frame}
= 4.34 μS / 31.25 ms
= 4.34×10^{-6} s / 31.25×10^{-3} s
= 4.34×10^{-3} / 31.25
= 0.00434 / 31.25
= 0.00013888 Therefore a<1

or

a **=** (d/v) / (L/R) = Rd/vL

a= (19200x1000)/(2.3×10^8 x 600)

= 0.00013888 Therefore a<1

u= 1/(1+(2 x 0.00013888))
= 1/1.00027776
= 0.99

Throughput = L / (t_{frame} + RTT)

RTT = 2 x 4.34 μS = 8.68 μS

Throughput = 600/ (31.25 ms +8.68 μS)
= 600/ (31.25 +0.00868) $\times 10^{-3}$

$= 600 \mathbf{x}\ 10^3 /31.25868 = 19.190 \mathbf{x}\ 10^{-3} = 19190$ bps = 19.190 kbps

Channel Efficiency = 19.190 kbps /19.2 kbps =99%

For d = 4000 m

a=

u=

e=

Ex. 14: DTR = 1 Gbps, RTT = 30 ms, Frame = 1 KB

Calculate the throughput and channel efficiency

Solution:

t_{frame} = length of frame (Size) / data rate (BW) = L /R=8000/1Gbps = 8 μS

throughput= 8000/(8 μS + 30 ms) = 8 Kbps /0.030008 = 266 Kbps

efficiency= 266 Kbps /1 Gbps = 0.027%

Ex 15: Data Rate: 4 Kbps, Propagation delay = 20 ms, Efficiency/Utilization = 50% =0.5. Find frame size?

Solution:

u = 1/(1+2a)

u(1+2a) = 1

u + 2au =1

2au = 1-u

a = (1-u)/2u

= (1-0.5)/2 x 0.5

= 0.5/1

a =0.5

a = PropagationTime / Transmission time

a = Prop Time /(frame Size L / data rate R)

$a = tprop/(L/R)$

$L = tprop \times R / a$

$= 20 \text{ ms} \times 4 \text{ Kbps} / 0.5$

$= 20 \times 4 / 0.5 = 160$ bits

<u>Ex. 16</u>: Frame size=1000 bits DTR=1 Mbps RTT = 25 ms. Calculate the sliding window size and number of bits required to represent sequence number. (Sequence number width in terms of bits.)

<u>Solution:</u>

1000/1000000 = 1 ms

25 ms /1ms = 25 frames

For 25 frames = 5 bits are required

<u>Ex.17:</u> Calculate link utilization if R=19.2 kbps, L= 960 bits, Window size =3 and Propagation time=0.06s. What is the maximum window size for 100 percent link utilization? What will happen if window size is reduced to 7?

<u>Solution:</u>

$t_{frame} = L/R = 960/19200 = 0.05s$

$a = 0.06/0.05 = 1.2$

$2a+1 = 2*1.2+1 = 3.4$

$w=3 < 2a+1$ therefore $u = 3/3.4 = 88\%$

$w=7 > 2a+a$ therefore $u = 100$

Min size for 100% utilization = w = 2a+1 = 3.4 = 4

Ex.18: A point-to-point satellite transmission line connecting two computers uses a stop and wait protocol and has the following properties

Data Transmission Rate (DTR) = 64 kbps
Frame Size = 2048 bytes
One Way Propagation Delay = 180 ms
Acknowledgement Size = 10 bytes
Processing Delay of one computer = 25 ms
Determine the throughput and Utilization.

Solution:
Frame Transmission Time = (2048x8)/64000 =0.256s = 256ms
Ack Transmission Time = (10x8)/64000 = 1.25 ms
Total time to transmit frame and receive ack is =
Frame Trans Time + Ack Trans Time + Proc Delay + 2xProp Delay
= 256 ms + 1.25 ms + 2x25 ms + 2x180 ms
=256 ms + 1.25 ms + 50 ms + 360 ms
= 667.25 ms
=0.667s
Throughput = (2048 x 8) / 0.667 = 24.563 kbps
a = Prop Time / Transfer Time =180 ms / 256 ms = 0.7
Utilization=u= = 1/(1+2a) = 1/(1+1.4) = 41.67%

Ex.19: Here, we ask you to use accurate RTT and transmission delay to calculate the throughput. You should assume that no messages or ACKs are lost due to errors. You use a 10 Mbps link to send a series of 1250 byte messages across Pune using the Simplex noisy channel protocol. The one way propagation delay of this link is 25 ms. What is the maximum PERCENTAGE (%) of the link bandwidth that can be used? Please derive your final answer in (%) only.

Solution: Given PT(One way) = 25 ms, L = 1250 bytes and R = 10 Mbps.

RTT (Two way PT) =25 ms x 2 = 50 ms

Transmit Time (TT) = L/R = 1250x8/ 10 Mbps = 10,000 bits/10,000,000 bits
= 0.001 s = 1 ms

Throughput = L/(RTT+TT) = 1250x8 bits/(50ms+1ms)
= 10,000 bits/ 51 x 10-3 s
= 10,000,000 /51 s
= 1,96,078 bps

Efficiency = Throughput in bps/ bandwidth
= 1,96,078/10,000,00
= 00196 = 1.96%
Therefore % of link bandwidth used is 1.96%

Ex.20: Here, we ask you to use accurate RTT and transmission delay to calculate the throughput. You should assume that no messages or ACKs are lost due to errors. You use a 1 Mbps link to send a series of 1250 byte messages across Pune using the Simplex noisy channel protocol. The one way propagation delay of this link is 5 ms. What is the maximum PERCENTAGE (%) of the link bandwidth that can be used? Please derive your final answer in (%) only.

Solution: Given PT(One way) = 5 ms, L = 1250 bytes and R = 1 Mbps.

RTT (Two way PT) = 5 ms x 2 = 10 ms

Transmit Time (TT) = L/R = 1250x8/ 1 Mbps = 10,000 bits/1,000,000 bits
= 0.01 s = 10 ms

Throughput = L/(RTT+TT) = 1250x8 bits/(10ms+10ms)
= 10,000 bits/ 20 x 10-3 s
= 10,000,000 /20 s
= 5,00,000 bps

Efficiency = Throughput in bps/ bandwidth
= 5,00,000/1,000,00
= 0.5 = 50%
Therefore % of link bandwidth used is 50%

Ex.21: For the network
Data Rate : 8 Kbps
Propagation delay = 40 ms
Efficiency = 80%
Find frame size?

Solution: $a=(1-u)/2u$

$= (1-0.8)/(2x0.8) = 0.125$

$L = (tprop \times R)/a$

$= (40x8)/0.125 = 2560$ bits

Ex.22: For the network

Data Rate : 6 Kbps

Propagation delay = 20 ms

Efficiency = 60%

Find frame size?

Solution: $a=(1-u)/2u = (1-0.6)/(2x0.6) = 0.3333$

$L = (tprop \times R)/a = (20x6)/0.3333 = 360.0360 = 360$ bits

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Ex.23: A frame oriented data communication system operates at a transmission rate of 1024 kbps with a frame length of 1024 bytes over a long distance link which produces a one way propagation delay of 40ms. A flow control system is required using a window mechanism. Determine the minimum window size which allows for optimum throughput.

Solution:

$$Nt_f > 2\ tp + t_f$$

$$N > 2\ tp / t_f + 1$$

Transfer Time = L/R = 1024x8 / 1024x100 = 8ms

N = (2x 40) /8 + 1 = 11

Ex.24: A frame oriented data communication system operates at a transmission rate of 512 kbps with a frame length of 512 bytes over a long distance link which produces a one way propagation delay of 20ms. A flow control system is required using a window mechanism. Determine the minimum window size which allows for optimum throughput.

Solution: Transfer Time = L/R = 512x8 / 512x100 = 8ms

N = (2x 20) /8 + 1 = 6

Ex.25: Consider the network with following parameters
Frame size = 1000 bits
Propagation Delay = 10 ms
Data Transfer Rate = 10 Mbps
Find the number of packets on communication pipe?
Find the number of bits required for sequence number?

If Propagation delay is changed to 1 ms and bandwidth to 2 Mbps
Find the number of packets on communication pipe?
Find the number of bits required for sequence number?

Out of these two scenarios, which scenario will give better utilization of channel? why?

Solution:
Part-I
Calculate BW x Delay product

=10 000 000 x 10 x 10-3
=100 000 000 x 10-3
= 100 000
= 100 kilobits
Frame size 1000 bits

Therefore = 100 000 /1000 = 100 packets
Considering RTT = 200 packets
Sequence No will need 8 0r 9 bits

Part-II
Calculate BW x Delay product

= 2 000 000 x 1 x 10-3
= 2 000 000 x 10-3
= 2000 bits

Frame size 1000 bits

Therefore = 2000 /1000 = 2 packets
Considering RTT = 4 packets
Sequence No will need 2 or 3 bit

Second will give better utilization.

Ex.26: Consider the network with following parameters
Diameter = 2000 Km
Frame Size = 64 bytes
Propagation Velocity = 30 microseconds per 10 kilometer
Find the number of bits required for sequence number?

Solution:

Ex.27: For telephone lines
DTR = 19.2 Kbps
Velocity = 2.3 x 108 m/s
L = 600 bits
d=1000 m and 4000 m
Calculate the utilization, throughput and channel efficiency

Solution:

Problems on CRC Polynomial

Ex.18: Find the CRC if

$M(x) = x^7 + x^6 + x^5 + x^2 + x$

$G(x) = x^4 + x^3 + 1$

Sol: Method –I : Polynomial Method
Message = M(x) = (k+n) -bits
Divisor = G(x) = P = n+1 bits

$F = g(x) = x^c = n\text{-bits}$

$G(x)\ \overline{)M(x) * x^c}\ (\ Q(x)$

$T(x) = (k+n)$ bits

Ex. $M(x) =$

$G(x) = \mathbf{x^4 + x^3 + 1}$

$g(x) = x^4$

Therefore $M(x) * x^c$

$= (\mathbf{x^7 + x^6 + x^5 + x^2 + x})\mathbf{*}\ x^4$

$\mathbf{= x^{11} + x^{10} + x^9 + x^6 + x^5}$

$$
\begin{array}{l}
\qquad\qquad\quad \text{------------------------} \\
\mathbf{x^4 + x^3 + 1)\ \ x^{11} + x^{10} + x^9 + x^6 + x^5}\ (x^7 + x^5 + x^4 + x^2 + x \\
\qquad\qquad\qquad\quad \mathbf{x^{11} + x^{10} + x^7} \\
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\qquad\qquad\qquad\quad \mathbf{x^9 + x^7 + x^6 + x^5} \\
\qquad\qquad\qquad\quad \mathbf{x^9 + x^8 + x^5} \\
\text{------------------------------} \\
\qquad\qquad\qquad\qquad \mathbf{x^8 + x^7 + x^6} \\
\qquad\qquad\qquad\qquad \mathbf{x^8 + x^7 + x^4} \\
\text{------------------------------} \\
\qquad\qquad\qquad\qquad\quad \mathbf{x^6 + x^4} \\
\qquad\qquad\qquad\qquad\quad \mathbf{x^6 + x^5 + x^2} \\
\hline
\qquad\qquad\qquad\qquad\qquad\quad \mathbf{x^5 + x^4 + x^2} \\
\qquad\qquad\qquad\qquad\qquad\quad \mathbf{x^5 + x^4 + x} \\
\hline
\qquad\qquad\qquad\qquad\qquad\qquad\quad \mathbf{x^2 + x}
\end{array}
$$

Remainder R=F $\mathbf{x^2 + x\ \ =\ \ 0110}$

M = K bit messages
F = n bits frame check sequence (FCS)

T = (k + n) bits frame where n<k

P = n+1 is the predermined divisor

We want mod (T,P) = 0

Rewrite $T = M\ 2^n + F$

$F = M\ 2^n / P$

M(x) = $x^7 + x^6 + x^5 + x^2 + x$ = 11100110

G(x) = $x^4 + x^3 + 1$ = 11001

Ex: M = 11100110 (8 bits)

P = 11001 (5 bits)

P= 5 hence n=4 bits F = 4 bits to be calculated

M 2^n = M 2^4 =111001100000

2^4 M / P = 111001100000 / 11001

```
          --- -----------------
11001)  111001100000  ( 10110110
          11001
-------------------------------
               10111
              11001
------------------------------
                 11100
                11001
-------------------------------
                  10100
                   11001
----------------------------
                     11010
                     11001
------------------------------
                          0110
```

Remainder R=F= 0110

<u>Ex.18</u>: Find the CRC/FCS/Checksum using polynomial method for

Message = M(x) = $x^8+x^7+x^5+x^3+x$

Divisor= G(x) = x^4+x^2+1

Send the frame to the destination and check the correctness of frame**.**

Sol: Method –I : Polynomial Method
Message = M(x) = (k+n) –bits, Divisor = G(x) = P = n+1 bits
F= g(x) = x^c = n-bits

G(x))$\overline{M(x) * x^c}$ (Q(x) ,T(x) = (k+n) bits

Ex. M(x) = $x^8+x^7+x^5+x^3+x$
G(x) = $x^4 + x^2 + 1$
g(x) = x^4

Therefore M(x) * x^c = = $(x^8 + x^7 + x^5 + x^3 + x) * x^4$
$= x^{12} + x^{11} + x^9 + x^7 + x^5$

$x^4 + x^2 + 1$) $x^{12} + x^{11} + x^9 + x^7 + x^5$ ($x^8 + x^7 + x^6 + x^2 + x+1$
$x^{12} + x^{10} + x^8$

$x^{11} + x^{10} + x^9 + x^8 + x^7 + x^5$
$x^{11} + x^9 + x^7$

$x^{10} + x^8 + x^5$
$x^{10} + x^8 + x^6$

$x^6 + x^5$
$x^6 + x^4 + x^2$

$x^5 + x^4 + x^2$
$x^5 + x^3 + x$

$x^4 + x^3 + x^2 + x$
$x^4 + x^2 + 1$

$x^3 + x + 1$

Remainder R=F $x^3 + x + 1$= 1011

Examples on Hamming Code:

Ex1 : If Data Word is = 1111 calculate the code word?

Solution:

1 2 **3** 4 **5 6 7**

Step-I: Initially: Insert the check bits as 0 at positions 1,2 and 4→ 00**1**0**111**

Step-II: Calculate check bit at position 1.

Check bit at position 1 is a even parity of bits at positions 3, 5, 7;

Bits at positions 3,5,7 are 111, therefore check bit will be 1 to make it even parity.

Step-II: Calculate check bit at position 2.

Check bit at position 2 is a even parity of bits at positions 3, 6, 7;

Bits at positions 3,6,7 are 111, therefore check bit will be 1 to make it even parity.

Step-III: Calculate check bit at position 4.

check bit at position 4 is a even parity of bits at positions 5, 6, 7.

Bits at positions 5,6,7 are 111, therefore check bit will be 1 to make it even parity.

Therefore code word n = 1111111

Ex 2: If Data Word is = 1011 calculate the code word?

Solution:

1 2 **3** 4 **5 6 7**

Step-I: Initially: Insert the check bits as 0 at positions 1,2 and 4→ 00**1**0**011**

Step-II: Calculate check bit at position 1.

Check bit at position 1 is a even parity of bits at positions 3, 5, 7;

Bits at positions 3,5,7 are 101, therefore check bit will be 0 to make it even parity.

Step-II: Calculate check bit at position 2.

Check bit at position 2 is a even parity of bits at positions 3, 6, 7;

Bits at positions 3,6,7 are 111, therefore check bit will be 1 to make it even parity.

Step-III: Calculate check bit at position 4.

check bit at position 4 is a even parity of bits at positions 5, 6, 7.

Bits at positions 5,6,7 are 011, therefore check bit will be 0 to make it even parity.

Therefore code word n = 0110011

Ex 3: Test if 0110111 code word is correct, assuming they were created using an even parity Hamming Code .If one is incorrect, indicate what the correct code word should have been. Also, indicate what the original data was.

Solution:

1 2 **3** 4 **5 6 7**

Re-Check each parity bit using

Check bit at position 1 is an even parity of bits at positions 1, 3, 5, 7 that is b1+b3+b5+b7

check bit at position 2 is an even parity of bits at positions 2, 3, 6, 7 that is b2+b3+b6+b7

check bit at position 4 is an even parity of bits at positions 4, 5, 6, 7 that is b4+b5+b6+b7

Step-I: Re-check check bit at position 1

0110111 : b1+b3+b5+b7 = 0111, odd parity : incorrect

Step-II: Re-check check bit at position 2
0110111 : b2+b3+b6+b7 =1111, even parity: correct
Step-II: Re-check check bit at position 4
0110111 : b4+b5+b6+b7 = 0111, odd parity : incorrect

Parity bits 1 and 4 are incorrect
1 + 4 = 5, so the error occurred in bit 5
Therefore code word n = 0110011

Hamming Code(8,4) [Source: http://users.cis.fiu.edu/~downeyt/cop3402/hamming.html]

1. Mark all bit positions that are powers of two as parity bits. (positions 1, 2, 4, 8, 16, 32, 64, etc.)
2. All other bit positions are for the data to be encoded. (positions 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, etc.)
3. Each parity bit calculates the parity for some of the bits in the code word. The position of the parity bit determines the sequence of bits that it alternately checks and skips.
   Position 1: check 1 bit, skip 1 bit, check 1 bit, skip 1 bit, etc. (1,3,5,7,9,11,13,15,...)
   Position 2: check 2 bits, skip 2 bits, check 2 bits, skip 2 bits, etc. (2,3,6,7,10,11,14,15,...)
   Position 4: check 4 bits, skip 4 bits, check 4 bits, skip 4 bits, etc. (4,5,6,7,12,13,14,15,20,21,22,23,...)
   Position 8: check 8 bits, skip 8 bits, check 8 bits, skip 8 bits, etc. (8-15,24-31,40-47,...)
   Position 16: check 16 bits, skip 16 bits, check 16 bits, skip 16 bits, etc. (16-31,48-63,80-95,...)
   Position 32: check 32 bits, skip 32 bits, check 32 bits, skip 32 bits, etc. (32-63,96-127,160-191,...)
   etc.
4. Set a parity bit to 1 if the total number of ones in the positions it checks is odd. Set a parity bit to 0 if the total number of ones in the positions it checks is even.

Here is an example:

A byte of data: 10011010
Create the data word, leaving spaces for the parity bits: _ _ 1 _ 0 0 1 _ 1 0 1 0
Calculate the parity for each parity bit (a ? represents the bit position being set):

- Position 1 checks bits 1,3,5,7,9,11:
  ? _ 1 _ 0 0 **1 _ 1** 0 **1** 0. Even parity so set position 1 to a 0: **0 _ 1 _ 0** 0 **1 _ 1** 0 **1** 0
- Position 2 checks bits 2,3,6,7,10,11:
  0 **? 1** _ 0 **0 1** _ 1 **0 1** 0. Odd parity so set position 2 to a 1: 0 **1 1** _ 0 **0 1** _ 1 **0 1** 0
- Position 4 checks bits 4,5,6,7,12:
  0 1 1 **? 0 0 1** _ 1 0 1 **0**. Odd parity so set position 4 to a 1: 0 1 1 **1 0 0 1** _ 1 0 1 **0**

- Position 8 checks bits 8,9,10,11,12:
  0 1 1 1 0 0 1 **? 1 0 1 0**. Even parity so set position 8 to a 0: 0 1 1 1 0 0 1 **0 1 0 1 0**
- Code word: 011100101010.

Finding and fixing a bad bit

The above example created a code word of 011100101010. Suppose the word that was received was 011100101110 instead. Then the receiver could calculate which bit was wrong and correct it. The method is to verify each check bit. Write down all the incorrect parity bits. Doing so, you will discover that parity bits 2 and 8 are incorrect. It is not an accident that 2 + 8 = 10, and that bit position 10 is the location of the bad bit. In general, check each parity bit, and add the positions that are wrong, this will give you the location of the bad bit.

Test if **011100101110** code word is correct, assuming they were created using an even parity Hamming Code .If one is incorrect, indicate what the correct code word should have been. Also, indicate what the original data was.
Step 1 011100101110
For position 1 check bits(1,3,5,7,9,11) even parity 1 is set 0. Position 1 is correct
Step 2 011100101110
For position 2 check bits (2,3,6,7,10,11) odd incorrect for even set it to 1
Step 3 011100101110
For position 4 check bits are (4,5,6,7,12,13,14,15,20,21,22,23)
Even correct.
Step 4 011100101110
For position 8 check bits are (8-15,24-31,40-47)
Odd ..incorrect
you will discover that parity bits 2 & 8 are incorrect .
2+8 =10, and that bit position is the location of the bad bit.
Original code word - **011100101010**

IP Addressing Problems for TE Computer Jan 2016 Semester

Characteristics of 8-bit block of IP Address

254 :1111 1110 = block of 2 addresses
252 : 1111 1100 = block of 4 addresses
248 : 1111 1000 = block of 8 addresses
240 : 1111 0000 = block of 16 addresses
224 : 1110 0000 = block of 32 addresses
192 : 1100 0000 = block of 64 addresses
128:1000 0000 = block of 128 addresses

CIDR Block Prefix	# Equivalent Class C	# of Host Addresses	CIDR Block Prefix	# Equivalent Class C	# of Host Addresses
/27	1/8th of a Class C	32 hosts	/19	32 Class C	8,192 hosts
/26	1/4th of a Class C	64 hosts	/18	64 Class C	16,384 hosts
/25	1/2 of a Class C	128 hosts	/17	128 Class C	32,768 hosts
/24	1 Class C	256 hosts	/16	256 Class C	65,536 hosts
/23	2 Class C	512 hosts	/15	512 Class C	131,072 hosts
/22	4 Class C	1,024 hosts	/14	1,024 Class C	262,144 hosts
/21	8 Class C	2,048 hosts	/13	2,048 Class C	524,288 hosts
/20	16 Class C	4,096 hosts			

Problems:

Ex 1	A computer network has 141.14.0.0 IP address. The network has to be divided into four equal sub-networks and each network needs about 16000 IP addresses. Find the subnet mask for subnetted network. How many number of IP addresses will be in each subnetwork? Give the first and last IP address assigned to each block.
Ans	Subnet mask : 255.255.192.0 No. of IP addresses in each subnetwork = 16384-2 Subnet 1 : 141.14.0.1 To 141.14.63.254 (64 x 256) = 16384-2 Subnet 1 : 141.14.64.1 To 141.14.127.254 (64 x 256) = 16384-2 Subnet 1 : 141.14.128.1 To 141.14.191.254 (64 x 256) = 16384-2 Subnet 1 : 141.14.192.1 To 141.14.255.254 (64 x 256) = 16384-2
Ex 2	Suppose that instead of using 16 bits for the network part of a class B address originally, 20 bits had been used. How many class B networks would have been? A network on the Internet has a subnet mask of 255.255.240.0. What is the maximum number of hosts it can handle?
Ans	With a 2-bit prefix, there would have been 18 bits left over to indicate the network. Consequently, the number of networks would have been 218 or 262,144. However, all 0s and all 1s are special, so only 262,142 are available. The mask is 20 bits long, so the network part is 20 bits. The remaining 12 bits are for the host, so 4096 host addresses exist.
Ex 3	A block of addresses is granted to a small organization. We know that one of the address is 205.16.37.39/28. Calculate the size of block? 16 What will be first IP address? 205.16.37.32 What will be last IP address? 205.16.37.47

Ex 4	An organization has an IP address 192.1.20.0 and need to create four sub networks. Find the subnet mask and give ranges of all sub networks in a decimal dotted form.
Ans	IP 192.1.20.0 Subnet mask 255.255.255.192 Sub networks are 192.1.20.0 to 63 64 to 127 128 to 191 192 to 255
Ex 5	How CIDR can assigns block of 2,4,8 and16 IP addresses using IP4? Give the prefix and netmask for above four blocks.
Ans	Find the block of addresses from CIDR address 167.199.170.82/27. How many addresses it can support? Show manually the first and last IP address in the block. Number of addresses in the block are 232 – 227 = 25 = **32** = 5-bits for host id IP Address in Binary 10100111 11000111 10101010 01010010 167.199.170.82/27. First address 10100111 11000111 10101010 010**00000** ie 167.199.170.64/27 Last Address 10100111 11000111 10101010 010**11111** ie 167.199.170.95/27 Therefore Number of IP Addresses in Block are=32 Therefore first address will be 167.199.170.64/27 Therefore last address will be 167.199.170.95/27
Ex 6	A block of addresses is granted to a small organization. We know that one of the address is 205.16.37.39/28.
Ans	Calculate the size of block? 16 What will be first IP address? 205.16.37.32 What will be last IP address? 205.16.37.47
Ex 7	You have a class A network address 10.0.0.0 with 40 subnets, but are required to add 60 new subnets very soon. You would like to still allow for the largest possible number of host IDs per subnet. Which subnet mask should you assign?
Ans	40 subnets : needs 6 bits for host id Additional 60 subnets : needs 6 bits for host id Total 40+60 = 100 needs 7 bits for host id Therefore 7 bits will be used from second octant from left 10.0.0.0

	255.**1111111**0.0.0 = 255.254.0.0
Ex 8	What is the network address and host address in IP address 227.77.33.88.
Ans	**No network-id or host-id** It is class D address
Ex 9	Suppose that instead of using 16 bits for the network part of a class B address originally, 20 bits had been used. How many class B networks would have been?
Ans	2^{18} = 262144-2 =262142
Ex 10	A class B network address 130.50.0.0. is subneted as follows. The last 10 bits of the hosts id are allotted for host number and the remaining 6 bits are reserved for subnet number. How many subnets and hosts are possible with the above addressing scheme?
Ans	6 bits for subnet id = 2^6 = 64-2 = 62 subnets 10 bits for hosts = 2^{10} = 1024 -2 = 1022 hosts per subnet