**Mallika Kejriwal CS 542 HW2**

**1)Find Nyquist Formula and describe :**

**a) what this theory can be used in communication network system**

Henry Nyquist (AT&T Engineer) in 1924 stated that even a perfect channel has a finite transmission capacity. He derived an equation for a finite bandwidth noiseless channel stating its maximum data rate for transmission.

His formula is used to calculate the channel capacity with an assumption of noiseless environment.

$$C = 2B \log_2 M$$

Nyquist Formula is theoretical formula for idle condition without taking into account the practical conditions.

**b) How to estimate communication capacity**

$$C = 2B \log_2 M \quad \text{(assumption - no noise )}$$

C - capacity or maximum data rate we can achieve measure in bits/second

B - Bandwidth of channel

M - Number of levels we have in our transmitted signal

In case of dial up internet access - Modems convert data into analog representation and send via transmission line.

Bandwidth - 3100 Hz of Voice channel .

M =2 ( high and low )

$C = 2 \times 3100 \log_2 (2)$

= 6200 Bits/ Second or 6.2kbps

but when we use Dial up internet - the speed is 56kbps . To achieve this we increase the number of levels to 512 levels (bandwidth can't be increased for voice channel ). This would give us 55,800 bits/sec. If we want to increase up further - the next level will be 1024. The more levels the more chance of error as in noiseless environment higher levels makes it harder for the receiver to understand what it receives, so there is a practical limit to number of levels and hence the capacity. This capacity formula was improved by Shannon Hartley which is discussed in next answer.

**2)Find a theorem to measure a link capacity with signal to noise level environment. Describe how it works.**

Shannon Capacity is used to measure a link capacity with signal to noise level environment. It is an advance version of Nyquist formula given by Shannon Hartley taking into account noisy environment. It is more practical approach in finding the Capacity.

Signal to Noise Ratio = $\frac{\text{signal power}}{\text{noise power}}$

Shannon Capacity :

$$C = B \log_2 ( 1 + SNR ) \quad \text{(noisy environment )}$$

where,

C = Capacity or maximum data rate we can achieve measure in bits/second

B = Bandwidth

SNR = Signal to noise ratio
To see how it works let's do an example
How to calculate SNR
Signal power = 20 watts
Attenuated Power = 10 watts ( we take the received power as signal power in SNR )
Noise power = 2 watts ( thermal noise , noise from some impulse etc )
Signal to noise ratio SNR = 10w / 2w = 5 ( dimensionless)
as noise level increases - less information gets communicated and that's what Shannon capacity equation captures .
as signal power increases - more information gets communicated
How to calculate Capacity
Given,
SNR = 255
Bandwidth = 1MHz = $1x10^6$ Hz
$C = 1X10^6 \log_2 ( 1+255 )$
$= 10^6 \log_2 (256) \rightarrow 10^6 x 8 \rightarrow$ 8 Mbps
Shannon's capacity doesn't captures few things. In practice , increasing bandwidth allows for more noise and also increasing signal power causes increased inter modulation noise.

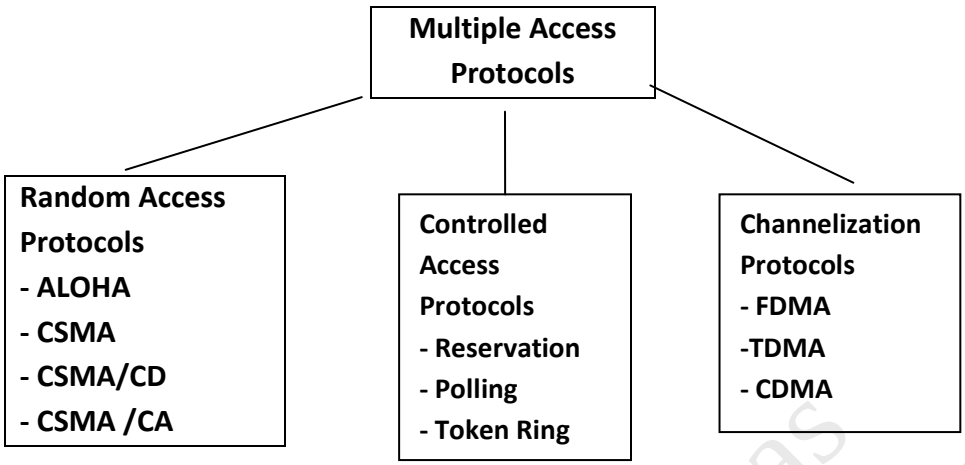
### 3) What is MAC protocol in data link layer and why do we need?

**Data link layer** is divided into to sub layers one being Link Layer Control and other being MAC.
**Media Access Control** is sub layer of data link layer. MAC has protocols like ALOHA, CSMA , Token ring which provides addressing and channel access control mechanism. It allocates the single broadcasting channel amongst competing users. It is also called shared medium network. It is responsible for moving data packets from one NIC ( Network Interface Cards ) to another across the share channel. Each computer has its unique MAC Address. These addresses are required to make local Ethernet or wifi function. One of the biggest application of MAC is in Ethernet LAN network. In Ethernet there is a shared wire and many stations connecting to it, if two stations transmit at same time the two transmission could collide and we will not receive any data. What we like to do is figure out a way by which we can get different stations or nodes can somehow manage to communicate by collaboratively figuring out how to transmit on the medium. The idea is to make only one node transmit at the same time. This problem is solved by MAC - Media Access Control Protocol. MAC acts as interface between link layer control and network's physical layer. It ensures that transmission channel is shared fairly amongst all attached station and prevents data collision in the link , along with synchronization of frames.
Below is quick diagram describing MAC frames which is used in MAC Protocols.

| Preamble 7 Bytes | SFD 1Byte | Destination Address 6 Bytes | Source Address 6Bytes | Length or Type 2 bytes | Data and Padding 46 - 1500 Bytes | CRC 4Bytes |
|---|---|---|---|---|---|---|

**MAC FRAME**

**4) Find various MAC protocols and their main characteristics, and how they work.**




**A) Random Access Protocols -** In Random Access Protocol no station is superior to other and hence no priority is given to one over another. One station has no control over another station. The protocol defines weather a user should send data or not. Some of the Random Access protocols methods are described below -

**1)ALOHA**

ALOHA is a Multiple access protocol at data link layer and is a system for coordinating and providing access to share communication without interference or collision. There are two type of ALOHA - Pure ALOHA and Slotted ALOHA

In pure ALOHA the stations first transmit frames while sending the data . If two stations are transmitting at the same time a state of collision occurs and frames are destroyed. If frame is transferred to receiver an acknowledgment is anticipated. The sender waits for a random amount of time for acknowledgement and if it doesn't comes through , it assumes that the frame has been destroyed and retransmits the frame. To improve the efficiency of Pure ALOHA- slotted ALOHA was invented. In this the time of shared channel is divided into discrete units called slots. Frames can be sent only at the beginning of slot with limitation of one frame at each slot. Even though this protocol is followed strictly the possibility of collision still exists when two stations send at the same time slot.

**2)CSMA/CD ( used in Ethernet and IEEE 802.3)**

Carrier Sense multiple access with collision detection is used when multiple devices which share the same transmission line try to use it at the same time. In this the data sent is to all the users sharing the same hub. The working is below in simple steps.

Step1 - Wait for the time until some other host is not transmitting

Step 2 - Start to transmit your data

Step 3 - If another host also starts transmitting at the same time, send a jamming signal and wait till random amount of time to retransmit.

The application of CSMA/CD is now obsolete and is supported for backward compatibility and half duplex connections.

**B)Controlled Access Protocols -** In this unlike Random Access Protocols a stations has to consult other stations to find which station has right to send data. An authorization is required by a station from others to send data. Some Controlled Access Protocols methods are described below -

**1) Token ring (IEEE 802.5)** In Token ring , the topology of network is used to determine in which order they will send data. The access network used in a Token Ring Method is called Token Passing.

A token is basically a specific bit sequence which is passed around the network. Only the computer that hold s the token can transmit data.

Step 1 - The token is passed around the communication link until one station takes control over it.

Step2 - The station which has the token starts sending the Data Frames to the network.

Step3 - The frames is passed around the network from one station to another until the destination address on the frame matches the address of one of the station.

Step 4 - The frame is then copied and marked to indicate that the data has reached the station.

Step 5 - The original frame is again transmitted in the link until is reaches the source station where transmission is considered successful before frame is deleted.

Step6 - A new token is generated by the source computer and send across the ring to follow the same steps above.

Speed - 4 -16 Mbits/second

**2) Token Bus (IEEE 802.4)**

The token bus is very similar to Token Ring. Here stations are connected in a single bus structure. As each station knows the address of successor - logical ring is formed and once one station is done sending the data , it puts the address of its successor in the token.

**3)Polling**

In polling one device is the primary station and rest devices are secondary station. It the duty of primary station to coordinate the process. When the data is supposed to be send to any station it has to go through primary station even though the destination is a secondary device. It uses poll function and select function.

**4)Reservation**

A station makes a reservation prior to sending data in this. In this time is divided into intervals. If there are 5 Computers there are 5 mini slots in the reservation frame. In each interval, reservations frame is first send before sending the data frame.

**C)Channelization Protocols-** In this the available bandwidth is divided between different stations in time, frequency or through code.

**1)FDMA ( Frequency division multiplexing access)**

Available Bandwidth is divided into frequency bands and each station owns one of these bands. It can used with digital as well as analog signals. Small Guard Bands are used in this in order to prevent any station interference.

**2)TDMA ( Time division multiplexing access )**

In Time division multiplexing access each station is allocated a time slot in which it can send its data. One of the limitations of TDMA is achieving synchronization. It is used in 2G cellular systems.

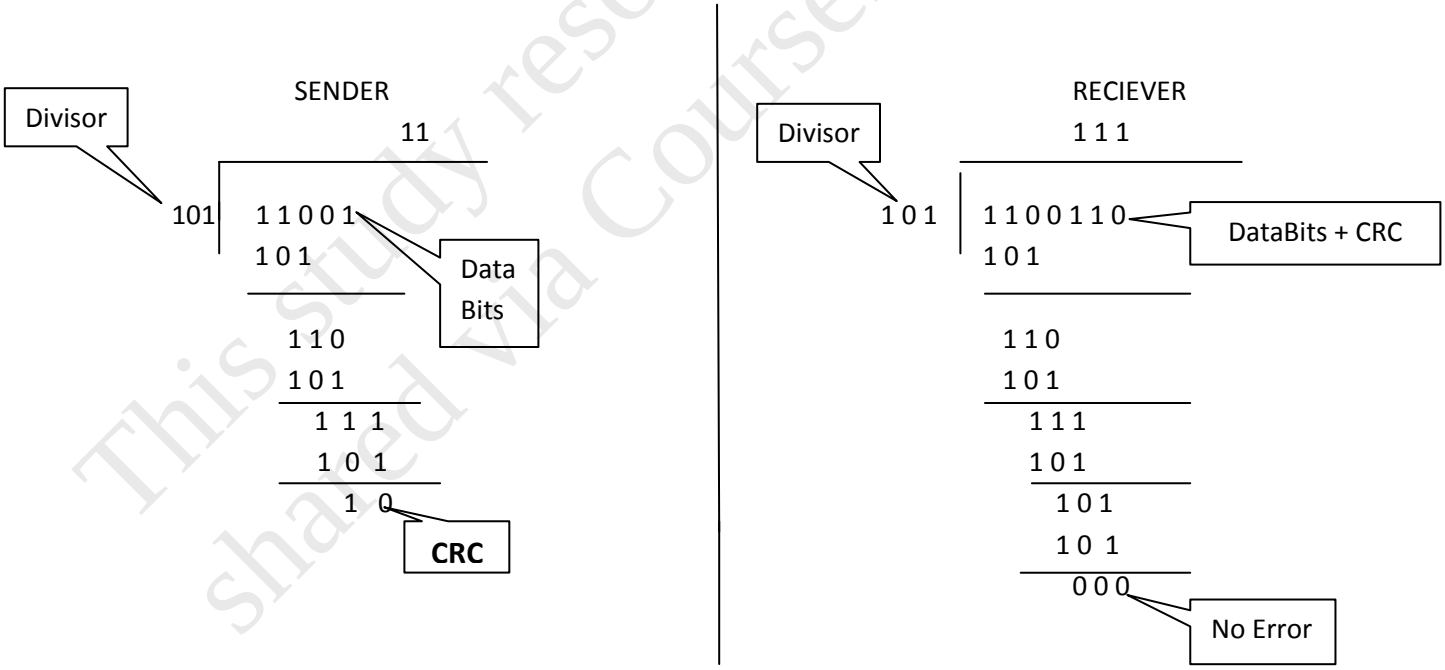
**3)CDMA ( Code Division Multiple Access )**

In CDMA a spread spectrum Technology is used. This is achieved with the use of different codes to separate between different station rather than frequency.

## 5) Describe CRC error control of the data link layer

Cyclic Redundancy Check is an error detecting code which detects accidental changes to Raw Data. It is also called Polynomial Code. Over fiber or high quality copper error rate is lower so retransmission is more efficient and hence instead to correcting the data we attempt to detect it using CRC. Block of data entering the Data Link Layer get a short Check Value attached , based on the remainder of polynomial division of its content.

- A division is performed on the bits being send by the sender and the remainder is calculated.
- The divisor value is agreed upon by both the sender and the receiver.
- Now this remainder is called check value and it is added to the end of actual bits which will be sent.
- The resulting bits are called codeword.
- The codeword is transmitted by the data link layer of sender to Data link layer of receiving end.
- The receiver performs division on codeword using the same divisor.
- If the remainder contains all the data bits as zero the data is kept else it is discarded and request for retransmission follows.




**How CRC Works**

**6) What are relations and differences between Data transfer speed (R) and signaling rate (Rs). Describe them with examples.**

| Data Transfer Speed (R) | Signaling Rate (Rs) |
|---|---|
| **Data Transfer Speed or Data Rate (R)**can be explained as number of bits which can be transferred in 1second. | **Signaling Rate or Signal Rate or Baud Rate (Rs)** can be explained as the number of signals or pulses an element sends in 1 second. |
| The unit of Date rate is bps (bits per second). | The unit of Signaling rate is Baud |
| Speed of 56kbps in Dialup modem means that 56000 bits ie combinations of 0 and 1's can be transferred in a second. | 3600 baud means that the channel can change its states from 0 to 1 upto 3600 times in 1 second. |
| It is also called Data Rate or bit rate. | It is also called Baud rate or Pulse Rate |
| The efficiency of data communications increases with increase of Data Transfer Speed. | The efficiency of data communications increases with decrease of signaling rate. |

**Relation between Data Transfer Speed ( R) and Signaling Rate ( Rs )**

The relationship between the Data Transfer rate and Signaling rate depends on many things one of theme being value of r. It is given as -

$$S = c \times N \times \frac{1}{r} \text{ baud}$$

where,
r is the ratio of number of data elements carried by each signal.
N is the data rate (bps)
c is the case factor - varies for each case
S is the number of signal elements.
This relationship also depends on data pattern. It can be all '0's or all '1's. It can be alternating 0 or 1.
The value of c would vary for worst case , average case and best case.
Maximum signal Rate would give us worst case and minimum signal rate would give us best rate.
Lets work this out with an example.
Suppose a signal is carrying data on which one data element is encoded as one signal element (r = 1)
If bit rate is 200kbps , what is the average value of baud rate if c is between 0 and 1 ?
Solution -
On average c would be 1/2 .
baud rate S = c x N x1/r baud
200 kbps = 200,000 bps = DATA RATE
1/2 x 200,000 x 1 = 100,000 = 100kbaud = Signal rate

# References

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