Computer Networks CS301 Notes

09 September 2021 14:54

– Subhojit Ghimire 1912160

* OSI Model : (Entire Syllabus)

- → Physical layer : Cables, Topology, Transmission models, Encoding, LAN, Device, Modulation
- → Data link : Stop & Wait, GoBack-N and Selective Repeat, MAC Protocols, Switching, Error Control, Ethernet frame format
- → Network : IP addressing, Routing Protocols, IPV_4 Header, IPV_6 Header
- → Transportation : TCP, UDP, Headers
- → Session :
- → Presentation :
- → Application : DNS, HTTP, SMPT, FTP, Port Number

* Network Security : Public key, Private key, Symmetric and Asymmetric key,

× ———— × ———— × ———— ×

* Computer Network :

Sender (Program) —connection→ Receiver (Protocol)

Functionalities (>70)

Mandatory	Optional
1. Error Control	1. Encryption / Decryption
2. Flow Control	2. Checkpoint
3. MUX, DEMUX	

These >70 functionalities in computer Network are discussed by categorising them as a model - OSI

Open Systems Interconnection Model (7 Layers)

* TCP/IP Protocol Suit OR Internet Protocol
Vs
OSI Layer

5 Layer TCP/IP (ARPANET)	OSI Model (ISO)	4 Layer TCP/IP (ARPANET)	
Application layer	Application layer Presentation layer Session layer	Application layer	Process to Process
Transport layer	Transport layer	Transport layer	Host to Host
Network layer	Network layer	Internet layer	Source to Destination
Data Link layer	Data link layer	Network Access layer	Node to Node
Physical layer	Physical layer		

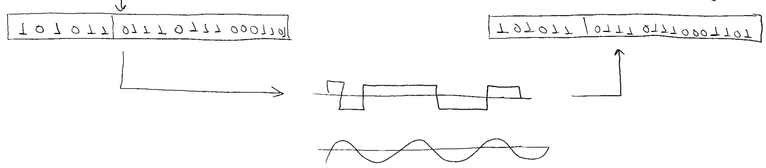
→ 4 layer TCP/IP is more practical or imp. than 5-layer

→ LIFO (Stack) format.

* Physical layer and its functionalities

- → Cables and Connectors
- → Physical topology (Star, Bus, Star, Ring, Mesh)
- → Hardwares (Repeaters / Hubs)
- → Transmission mode (Simplex, Duplex)
- → Multiplexing
- → Encoding

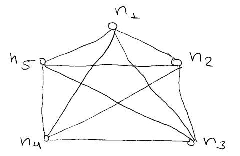
from Data link layer   To Data link layer



Physical layer converts bits to signal (at sender's side)
and signal to bits (at Receiver's side)

* Topology

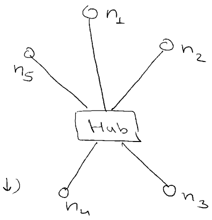
(1) Mesh Topology



n = number of node

- → No. of cables → $^{n}C_2 = \frac{n*(n-1)}{2}$
- → No. of ports → $(n-1)*n$
- → Reliability → High ↑
- → Cost → High ↑
- → Security → Yes. High ↑
- → Point-to-point (or Dedicated) Communication

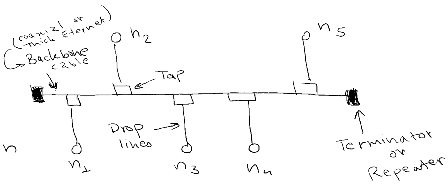
(2) Hub (or Star) Topology



Multiport device

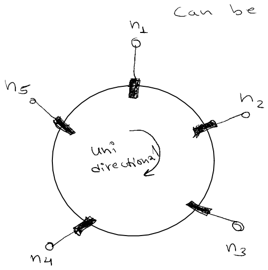
- → No. of cables → n
- → No of ports → $n \times 1 = n$
- → Reliability → Single point failure (Less ↓)
- → Cost → Less than Mesh
- → Security → Low ↓
- → Supports Point-to-point comm.

(3) Bus Topology



- → No. of cables ⇒ n + 1
- → No. of ports ⇒ $n * 1 = n$
- → Reliability → single point failure (Less ↓)
- → Security → Low ↓
- → Cost → cheap
- → Multipoint network / communication → Collision = n (max) (high↑)
  can be reduced by token bus concept

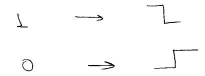
(4) Ring Topology



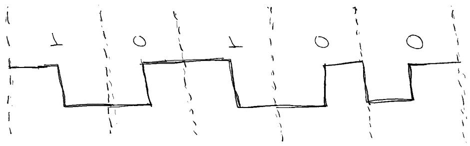
- → No. of cables ⇒ n + 1
- → No. of ports ⇒ $n * 1 = n$
- → Reliability → Single point failure (Less ↓)
- → Security → Low ↓
- → Cost → Cheap
- → Collision is high. can be reduced by Token Ring Concept
- → Multipoint network / communication

* Manchester Vs Differential Manchester Encoding

→ Manchester Encoding:

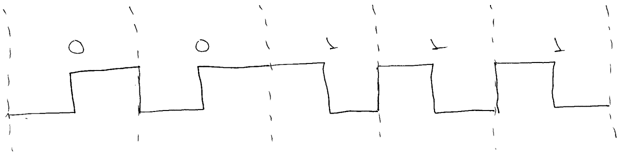


Eg.:



Eg.: 0 0 1 1 1

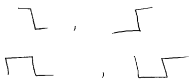
E.g. :



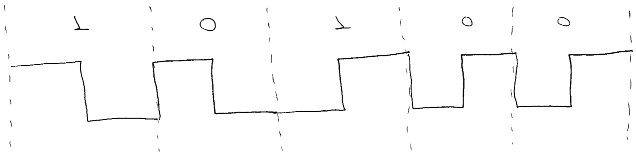
→ Differential Manchester Encoding.

1 →

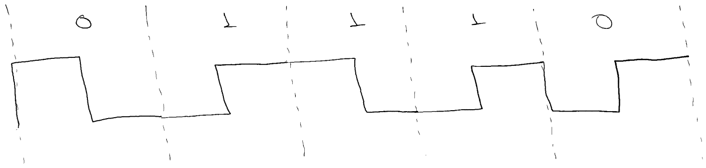
0 →



E.g. :



E.g. :



* Various Devices in Computer Networks :

1) Cables
2) Repeaters } Hardwares
3) Hubs
4) Bridges
5) Switches } Hardwares and Softwares
6) Routers Modem
7) Gateway
8) IDS } Seurity
9) firewall

(1) Cables : Physical Layer

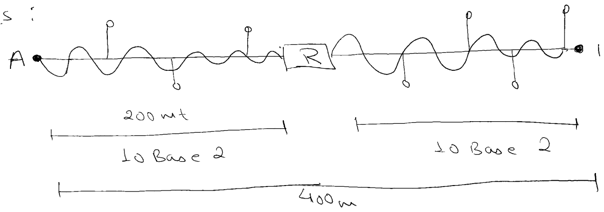
→ Unshielded Twisted Pair Cable
↳ $\underbrace{10}_{10\text{Mbps}}$ $\underbrace{\text{Base}}_{\text{Base band / Broad band}}$ $\underbrace{T}_{100m}$, 100 Base T

Used as Ethernet LAN

→ Coaxial Cable
↳ 10 Base $\underbrace{2}_{2t = 2\times100m = 200 m}$, 10 Base $\underbrace{5}_{5t = 5\times100 m = 500 m}$

→ Fibre Optic Cable
↳ 100 Base $\underbrace{Fx}_{\approx 2km}$

(2) Repeaters : Physical Layer



→ 2-port device
→ forwarding
→ No filtering

→ forwarding
→ No filtering
→ Collision Domain → Collision = n (max)

Repeater vs Amplifier.
- If initial signal strength is x.
  - → Amplifier can amplify signal to $> x$.
  - → Repeater cannot amplify signal to $> x$.
  - → Repeater can only amplify signal upto x.

∴ Repeater is generally used where or when attenuation occurs
- Amplifier is/can be used at source even when attenuation does not occur

(3) Hubs

Physical layer
→ Multiport
→ forwarding
→ No filtering (hence, high traffic)
→ Collision Domain. Collision = n (max)

(4) Bridges :

Physical and Data link layer
→ Used to connect two different LANs.
→ Forwarding (MAC and Port Table)
→ Filtering (Source MAC and Port MAC)
→ Collision Domain (No/Less Collision because Bridge uses Store and forward)
→ Bridge Data Unit Protocol

Types
- Static (Not self learning)
- Dynamic (or Transparent) (Self learning) (Better)

(5) Routers :

Physical, Data link and Network layer
→ Forwarding (Routing Table)
→ Filtering (IP Address and ARP)
→ Routing
→ Flooding
→ Collision Domain (No/Less collision. Store and forward)

* Collision Domain vs Broadcast Domain

			Collision Domain		Broadcast Domain
1.	Repeater	→	No Change	→	No Change
2.	Hub	→	No Change	→	No Change
3.	Bridge	→	Reduce	→	No Change
4.	Switch	→	Reduce	→	No Change
5.	Router	→	Reduce	→	Reduce

* Circuit Switching :

→ Physical layer
→ Contiguous flow
→ No Headers (because, dedicated path)
→ Efficiency → less ↓
→ Delays → less ↓

E.g.: Telephone line Exchange:

- Total time = Setup time + Transmission Time $\left(\frac{\text{Message}}{\text{Bandwidth}}\right)$ + Propagation Delay $\left(\frac{\text{Distance}}{\text{Speed}}\right)$ + Tear Down Time

* Packet Switching :

→ Data link and Network Layer
→ Store and forward
→ Pipelining used
→ Efficiency ↑ (because it uses store and forward method)
→ Delay ↑

Types

Delay ?

Types

Datagram ↳ Switching Network layer

Virtual ↳ Circuit Data link layer.

- Total Time = (n * Transmission Time) + Propagation Delay

DataGram Switching	Virtual Circuit
→ Connectionless	→ Connection oriented
→ No Reservation	→ Reservation
→ Out of order	→ Same order.
→ High overhead	→ Less overhead
→ packet loss is less ↓	→ packet loss is high ↑
→ Used in internet	→ Used in ATM, X.25
→ Efficiency ↑ Cost ↓	→ Efficiency ↓ Cost ↑
→ Delay high	→ No delay (or less)

* Message Switching :

→ Precedecessor of Packet Switching → i.e., Circuit switching → Message Switching → Packet Switching
→ Store and forward
→ Hop by hop delivery

* Data Link Layer

1) Hop to Hop or Node to Node Delivery.
2) Flow Control
   - → Stop and Wait (S/W)
   - → GoBack N (GBN)
   - → Selective Repeat (SR)
3) Error Control
   - → CRC (Data link layer)
   - → CheckSum (Transport layer)
4) Access Control
   - → CSMA/CD
   - → Aloha
   - → Token Ring/Bus
5) Physical Address (MAC)

* Stop and Wait ARQ :

→ Send one frame, then wait until acknowledgement is received.
→ Sender's window size = 1
Receiver's window size = 1
→ One frame at a time.

* Go-Back-N ARQ :

→ Uses Sliding Window Protocol.
→ Sender's window size = $2^m - 1$, where m is sequence representation bit number.
Receiver's window size = 1 (always) ↳ example, 0-3 = 2 bit, so $m = 2$
→ Sender's window size must not be equal to 2^m. 0-7 = 3 bit, so $m = 3$
It should be less than 2^m. 0-15 = 4 bit, so $m = 4$
Therefore we take w.s. as $2^m - 1$.
we can take it lower than that, 2^m-2, 2^m-3... but 2^m-1 is the best take.
→ Does not accept out of order packet/data frame (ie, only accepts in sequence).

* Selective Repeat ARQ :

→ Uses sliding window Protocol.
→ Sender's window size = 2^{m-1}
Receiver's window size = 2^{m-1} } same
→ Accepts out of order packet/data frame.
→ Sends NAK (ie, negative acknowledgement) for the frame dropped.

* Flow Control in Data Link Layer :

Stop & Wait	Go Back N	Selective Repeat
→ Transmits 1 frame at a time. Efficiency ↓	→ Transmits Multiple frames Efficiency ↑	→ Transmits Multiple Efficiency
→ Sender window = 1 Receiver window = 1	→ Sender window = $2^k - 1$ Receiver window = 1	→ Sender window = 2^{k-1} Receiver window = 2^{k-1}
→ $\eta = \frac{1}{1+2a}$	→ $\eta = (2^k - 1) * \frac{1}{1+2a}$	→ $\eta = (2^{k-1}) * \frac{1}{1+2a}$

Receiver window = 1	Receiver window = 1	Receiver window = 2^{k-1}
→ $\eta = \frac{1}{1+2x}$	→ $\eta = (2^k - 1) * \frac{1}{1+2x}$	→ $\eta = (2^{k-1}) * \frac{1}{1+2x}$
→ Retransmission = 1	→ Does not accept out of order packet → Cumulative ACK → Retransmission = $2^k - 1$	→ Accepts out of order packet → Cumulative & Independent ACK → Retransmission = 1

η is efficiency

$x = \frac{T_p}{T_t}$

T_p is propagation delay

T_t is transmission time.

Also, $\eta = \frac{T_t}{T_t + R_{tt}}$

R_{tt} is round trip time.

$R_{tt} = 2 * T_p$

K is the number of bits to represent window size.

2^k is the available sequence number.

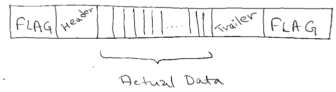
* Framing in Data link layer:

↳ Fixed-Size framing.

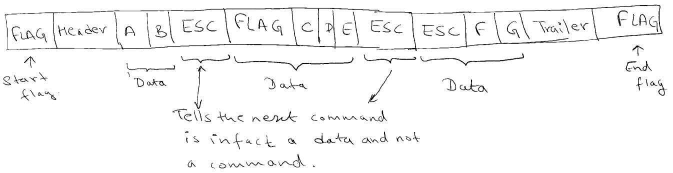
↳ Variable-Size framing

Bits are packed into frames, so that each frame is distinguishable from another.

→ frame in a character-oriented protocol



→ Byte Stuffing and unstuffing.



* Error Detection and Correction

↳ Single bit Error

↳ Burst Error

Detection:

→ Simple Parity (Even, Odd)

→ 2D Parity Check

→ Check Sum

→ CRC (Cyclic Redundancy Check)

Correction:

↳ Hamming Codes

* Single Bit Parity

→ m+1 bits, m is number of msg bits

→ Even Parity, i.e., num. of '1' should be even

→ Also used Odd Parity, i.e. num of '1' should be odd.

→ Can detect all single bit errors in code word

→ Can detect all odd no. of errors also.

↳ only detects. Cannot correct.

Better we with Even Parity only.

E.g.: Code word: 1 0 1 0 __

Even parity: 1 0 1 0 0

Transmitting msg 10100.

Received msg: 1 0 1 1 0

Check for even parity → −ve

Therefore, error occurred.

Odd Parity: 1 0 1 0 1

Transmitting msg 10101

Received msg: 1 0 1 1 1

Check odd parity → −ve

There fore, error occurred.

- Hamming Distance.

Given two codewords: 0 1 0 1 and 1 1 1 0

Perform XOR op.:

$$\begin{array}{r} 0\ 1\ 0\ 1 \\ 1\ 1\ 1\ 0 \\ \hline 1\ 0\ 1\ 1 \end{array}$$

Count no. of 1's in obtained XOR result 1011
∴ Hamming distance = 3

from 0000 to 1111, the minimum hamming dist = 2.
or, $d = 2$

And, $d-1 = 2-1 = 1$.
that means, for codewords from 0000 to 1111,
it can detect only 1 bit error.

* CRC (Cyclic Redundancy Check):

- → Based on Binary division
- → total bits = $(m+r)$. m is message bits, r is redundant bits.
- → Polynomial should not be divisible by x. and $(x+1)$
- → Can detect all odd errors, single bit errors, burst error of length equal to polynomial degree. (e.g. x^4+x^3+1, degree = 4)

Eg.: x^4+x^3+1 is divisor.
1010101010 is divident.

Number of Redundant bits, r = 4 (degree of polynomial).
So, new divident = 1010101010 $\underline{0000}$ (Adding 4 redundant bits to original msg bits)

Converting polynomial to binary
Given polynomial is divisor $x^4 + x^3 + 1$

$$1x^4 + 1x^3 + 0x^2 + 0x^1 + 1x^0$$
$$= 1 \quad 1 \quad 0 \quad 0 \quad 1$$
$$= 11001$$

So, perform XOR division.

Here, r = bits − 1
= 5 − 1
= 4

↑ If given direct binary form instead of Polynomial,
No. of redundant bits = divisor bits − 1

```
11001 ) 1010101010 0000
        ⊕11001
         011000
         ⊕11001
           00001 1010
              ⊕11001
                00011000
                  ⊕11001
                    000010   ← Take 4 bits from LSB
```

∴ Valid Data CodeWork = 10101010100010
Sent to Receiver.

If no error occurred, when receiver checks using same method, then remainder received is 0.

And if error occurs during transmission, be it single bit or burst error, the remainder does not come to be 0.
This will mean, there has been error.

→ Only detects error, does not correct it.

→ Efficiency = $\frac{m}{m+r} \times 100\%$, in above case, $\eta = \frac{10}{14} \times 100\% = 71.4\%$

* Hamming Code for Error Detection and Correction

Position	7	6	5	4	3	2	1
Bit	d_3	d_2	d_1	p_2	d_0	p_1	p_0

How? to find parity?

→ By default, Even Parity

→ Corrects only single bit error

2^n , $n = 0, 1, 2 \dots$
So, 2^0 = 1st position
2^1 = 2nd position
2^2 = 4th position
2^3 = 8th position, which is not in the above table of 4 data bits and 3 parity bits

XOR

$p_0 = d_3 \oplus d_1 \oplus d_0$
$p_1 = d_3 \oplus d_2 \oplus d_0$
$p_2 = d_3 \oplus d_2 \oplus d_1$

} How to know? In table, P_0 is at 1st position. so take data (if present) skipping 1 column.
i.e., 1, 3, 5, 7, ~~8~~, ~~10~~ …
Since 1 is P, we take d from 3, 5, 7

P_1 is at 2nd position, so take data skipping 2 columns.
i.e, 2, 3, 6, 7, 10, 11 ….
2 is P, we take 3, 6, 7 d.

P_2 is at 4th pos, so take data skipping 4 colums,
i.e. 4, 5, 6, 7 …. 12, 13, 14, 15 ….
i.e. 5, 6, 7 d

P_2 is at 4^{th} pos, so take data skipping 4 colums,
i.e, 4,5,6,7.... 12,13,14,15....
4 is P, we take 5,6,7 d

E.g.: Initial given data: 1011 to be transmitted.

Converting to Hamming Code:

1	0	1	_	1	_	_
d_3	d_2	d_1	p_2	d_0	P_1	P_0

$p_2 = d_3 \oplus d_2 \oplus d_1 = 1 \oplus 0 \oplus 1 = 0$
$P_1 = d_3 \oplus d_2 \oplus d_0 = 1 \oplus 0 \oplus 1 = 0$
$P_0 = d_3 \oplus d_1 \oplus d_0 = 1 \oplus 1 \oplus 1 = 1$

So, valid codeword = 1010101
this is transmitted to the receiver.

On receiver's side, this codeword is broken down as d_3, d_2, d_1, d_0 and p_2, p_1, p_0 and parity (p_2, p_1, p_0) is checked again.
If there is no error, the received codeword matches rechecked/generated codeword.

If there is error, suppose, 1010101 is received with error as 1110101
So,
Received codeword = 1 1 1 0 1 0 1
d_3 d_2 d_1 p_2 d_0 P_1 P_0

Checking:
$P_2(0) = d_3 \oplus d_2 \oplus d_1 = 1 \oplus 1 \oplus 1 = 1$ (error)
$P_1(0) = d_3 \oplus d_2 \oplus d_0 = 1 \oplus 1 \oplus 1 = 1$ (error)
$P_0(1) = d_3 \oplus d_1 \oplus d_0 = 1 \oplus 1 \oplus 1 = 1$ (correct)

So,

P_2	P_1	P_0
✓	error	error
0	1	1

If error, take 1
Not error, take 0

So, $011 = (11)_2 = (3)_{10}$

i.e, 3^{rd} data, d_2, has error.
d_0 d_1 d_2 d_3
1^{st} 2^{nd} 3^{rd} 4^{th}

Correct it. So, 1010101 is the corrected codeword. which is the valid codeword.

Hence, codeword successfully retrieved.

Removing parity bits and keeping only data bits, we get, 1011, which is the original message data bits.

* MAC (Multiple Access Control Protocols)

Random Access Protocols
- Aloha
  - Pure
  - slotted
- CSMA
- CSMA/CD
- CSMA/CA

Control Access
- Polling
- Token Passing

Channelisation Protocol
- FDMA
- TDMA

Data Link
- LLC
- MAC

* Pure Aloha:
- Random Access Protocol
- ACK is there
- LAN based
- Only Transmission Time
  NO propagation
- Vulnerable time $= 2 * T_t = 2 \times \frac{M}{BW}$

No propagation

→ Vulnerable time $= 2 * T_t = 2 \times \frac{M}{BW}$

T_t is transmission time
M is message
BW is Bandwidth.

→ Efficiency, $\eta = G * e^{-2G}$

where, G is no. of stations who want to transmit data

Diff w.r.t. G,

$$\frac{d\eta}{dG} = G \times e^{-2G}(-2) + e^{-2G}(1) = 0$$

$$\text{or, } e^{-2G}(-2G+1) = 0$$

$$\therefore G = 1/2$$

$$\text{So, } \eta = 1/2 * e^{-2 \times \frac{1}{2}} * 100\%$$

$$= 18.4\%$$

∴ Efficiency = 18.4 %

* Pure Aloha vs Slotted Aloha:

PURE ALOHA	SLOTTED ALOHA
→ Any time transmission	→ Predefined transmission time
→ $VT = 2 \times TT = 2 \times \frac{M}{BW}$	→ $VT = TT = \frac{M}{BW}$
→ $\eta = G \times e^{-2G} = 18.4\%$	→ $\eta = G \times e^{-G}$
	diff. w.r.t. G, $\frac{d\eta}{dG} = G \times e^{-G}(-1) + e^{-G}(1) = 0$ or, $e^{-G} \times (-G+1) = 0$ ∴ $G = 1$ ∴ $\eta = 36.8\%$

* CSMA : (Carrier-Sensor Multiple Access)

- → 1-persistent
- → 0-persistent
- → p-persistent.

* CSMA / CD : (CSMA / Collision Detection)

→ No ACK
→ TT > PD
→ TT ≥ 2 * PD (TT is transmission time
PD is Propogation delay).

$$\Rightarrow \frac{L}{BW} \geq 2 * PD$$

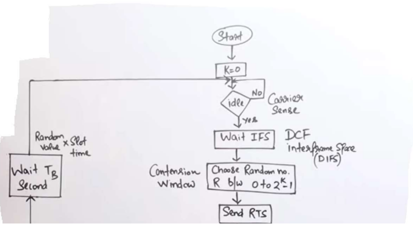
$$\therefore L \geq 2 * PD * BW$$

$$\rightarrow \eta = \frac{1}{1 + 6.44a} \quad ; \quad a = \frac{PD}{TT}$$

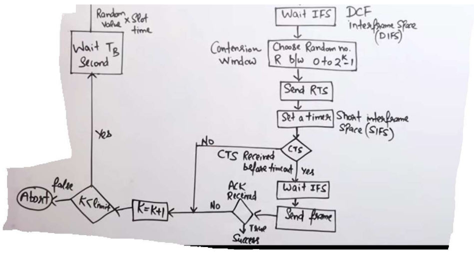
* CSMA / CA : (CSMA / Collision Avoidance)

- → WLAN
- → Interframe Space
- → Collision window
- → ACK

K = No. of attempts
T_B = Back off time.
IFS = Interframe Space



K = No. of attempts
T_B = Back off time.
IFS = Interframe Space
RTS = Ready to Send
CTS = Clear to Send



EXAMPLE: Consider a CSMA/CD network that transmits data at a rate of 100 Mbps (10^8 bits per second) over 1 Km cable with no repeaters. If the min frame size required for this network is 1250 bytes, what is the signal speed (km/sec) in the cable?

Soln:

we have $TT = 2 * PD$

or $TT = 2 * \frac{D}{V}$

or $\frac{L}{BW} = 2 * \frac{D}{V}$

or $V = \frac{2 * D * BW}{L} = \frac{2 * 1 * 10^8}{1250 * 8}$

$= 20000$

∴ Signal speed = 20000 km/sec.