Data Communication Basics

[Chapter 3 & 4 of Stallings]

- Entities: Transmitter, Receiver, Transmitter
- Types: Simplex, Half-Duplex, Full-Duplex.

Data is something that carries meaning. Signal is just the low level electromagnetic signals of the data.

We will talk about Analog/Digital signal carrying digital data

Strength of a Signal

Decibel (dB):

Power of signal P_1 with a reference signal power P_0

Signal strength in dB $= 10 \log_{10}\left(\frac{P_1}{P_0}\right)$.

[Attenuation is usually measured in dB/km]

dBm: $P_0 = 1$ milliwatt

Transmission Impairments

- Attenuation [Loss of strength over distance]
- Attenuation Distortion [higher frequency → higher loss at distance]
- Delay Distortion [Different speed for different frequency]
- Noise [Unwanted signal superimposes]

Signal to Noise Ratio to quantify effect of noise

$$SNR\,(in\ dB) = 10 \log_{10}\left(\frac{S}{N}\right)$$

S: Average Signal Power , N: Noise Power.

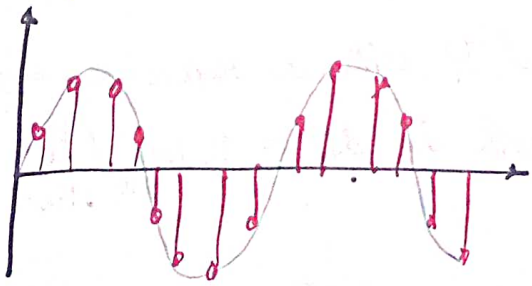
"Signalling Rate can be much higher than data rate"

Channel capacity.

- Each signal can encode more than one bit.

Nyquist Sampling Theorem:

If the maximum frequency of a signal is f, it can be perfectly reconstructed at the receiver if it is sampled at a rate at least $2f$.



Nyquist Theoretical capacity

$$C = 2B \log_2 M \ \text{bits/sec}$$

M ← Number of signal levels

Shannon's Law (with noise)

$$\text{Capacity} = C = B \log_2\left(1 + \frac{S}{N}\right) \ \text{bits/sec}$$

(Theoretical maximum)

$\frac{S}{N}$ ← thermal noise

Transmission Medium

* Guided
  - Twisted pair, Coaxial
  - Fibre optic
* Unguided
  - Wireless communication.

The design factors are : Bandwidth, Transmission Impairments, Interference.

(find out lan cable wire config)

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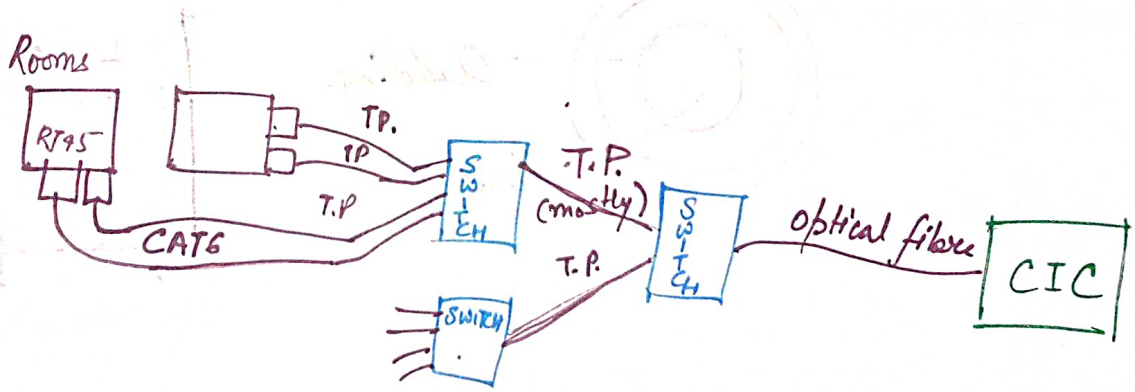


Twisted pair max length ≈ 100m
Multimode ≈ 300-400 m

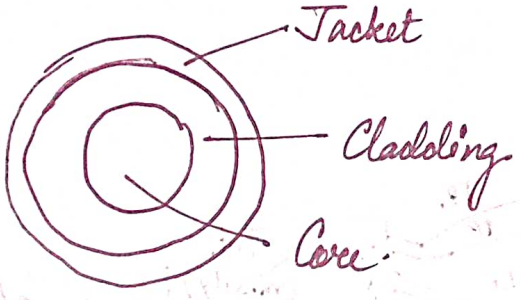
Distance

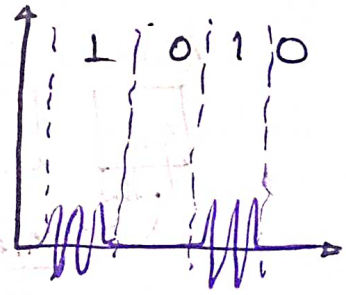
UTP (Unsheilded twisted pair):

- distance ≤ 100m for data rate 1Gbps, 1km for 10G (CAT 6/6A) { < CAT 5 not used }
- cost ≈ 20 ~ 30 Rs/m

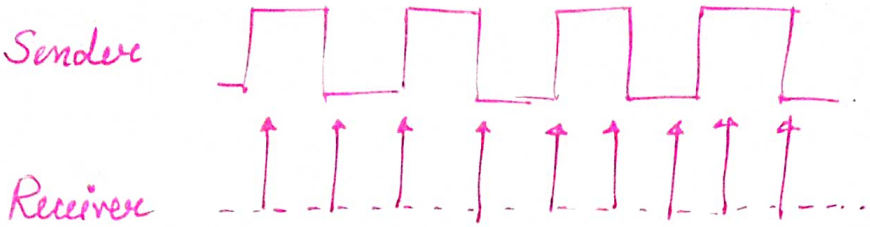
Optical Fibre:

- SMF distance ≤ 10-20 km
  cost ≈ 180 - 200 Rs/km
- MMF distance ≤ 550 m
  cost ≈ 200 - 300 Rs/km.





RELIABLE DATA TRANSFER BETWEEN TWO MACHINES



Synchronization :

- Duration — fixed beforehand.
- Frame — Break up bit patterns into multiple frames.

Frame Synchronization → Asynchronous
→ Synchronous (Mostly used)

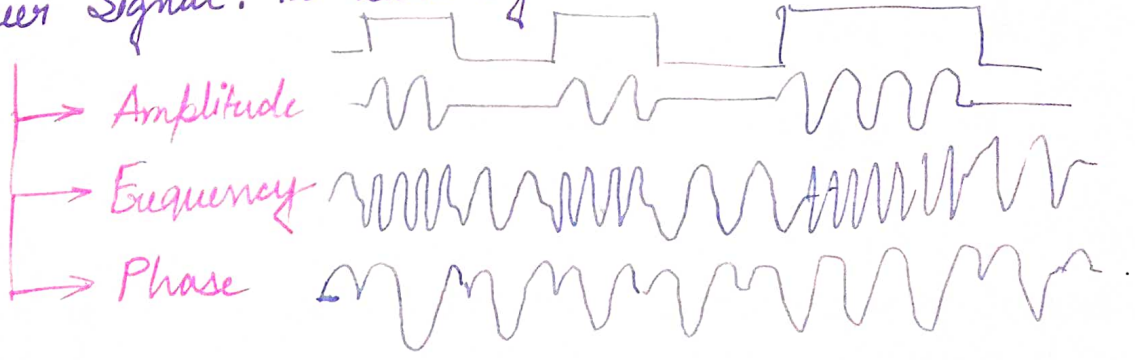
Asynchronous :

Synchronous :

RELIABLE DATA TRANSFER BETWEEN TWO MACHINES

Encoding Digital data with Analog Signals

Carrier Signal: The basic signal that is modulated.



- Quadrature PSK (four phases)
- Quadrature Amplitude Modulation (QAM): 2 levels of amplitudes
  4 phases → 8QAM.

ERROR DETECTION

Transmitter: Add additional bits.

Receiver: seperates data bits, perform same computation, compares with received signal.

Parity Check:

- Odd Parity: #1's → odd
- Even Parity: #1's → even
- Can detect odd number of bit errors.

Cycle Redundancy Check:

- Message M is transmitted appended by some more bits so that it ~~gives~~ is divisible by a known number.

Checksum:

- ~~Add~~ 1's complement sum appended at end
- Sum of everything must be all ones.
- Better than parity check, less effective than CRC.

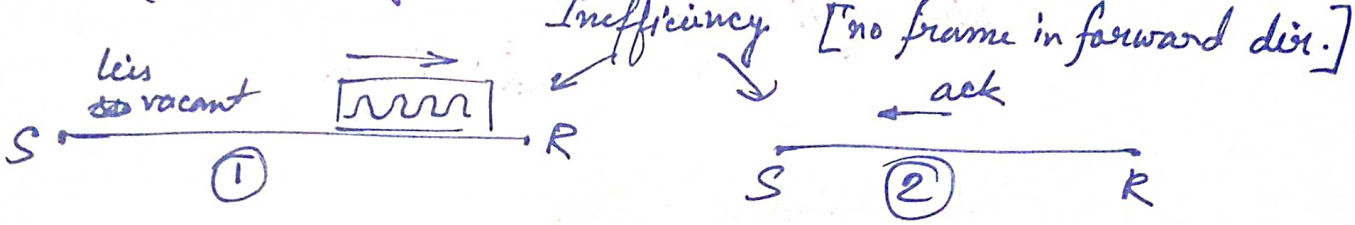
FLOW CONTROL

Technique to control data flow such that sender stops if receiver is slow.

Stop & Wait:

- Sender sends a frame.
- Receiver sends "ack" (if ready to receive another block)

Propagation delay: Time for 1 bit to travel accross the wire



Transmission rate: Data rate = # of bits the transmitter/sender can put in the link per unit time.

- To solve ① → longer frame must be needed.
- However, longer frames are not good (single bit errors can cause retransmission of long frame).

How long should the frame be to resume inefficiency of ①?

$$B = \frac{D}{V} \times R \quad \cdots \quad (R = \text{data rate})$$

B: Bit length of the link.

$\Rightarrow L = B$ [Really bad if R is large or D is large (long high b/w links) — long fat pipes]

Link Efficiency:

~~I could had pumped~~

$$\text{Total time} = \underbrace{\frac{L}{R}}_{\text{frame length}} + \frac{D}{V} + \underbrace{\frac{D}{V}}_{\text{ack}} = \frac{2D}{V} + \frac{L}{R}.$$

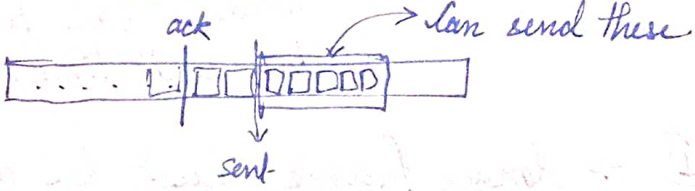
($\frac{L}{R}$: data rate; $\frac{D}{V}$: first bit)

I could had pumped these many bits.

$$\therefore \text{Link Efficiency} = \frac{L}{\left(\frac{L}{R} + \frac{2D}{V}\right) \cdot R}$$

Sliding Window Control

Window size $\rightarrow 2^k - 1$



Assumption: i) No errors; No timeouts

ii) Receiver sends ack only when the frame is delivered to the user, buffer space becomes empty.

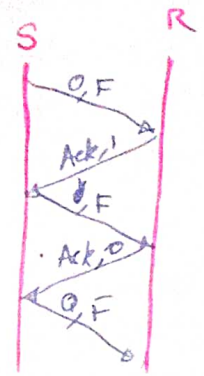
iii) What if not FIFO.

Receiver Expects [0|1|2|3|4],

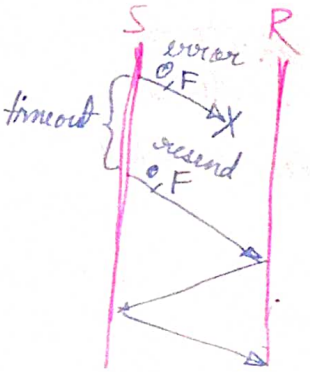
Receives 2, but not 0, 1, what to do:

① Wait for 0, 1; there will be no errors, hence 0 and 1 will eventually arrive.

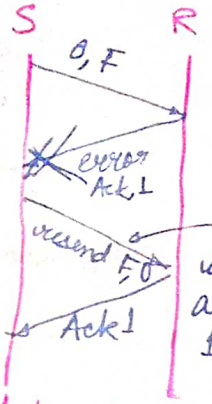
ERROR CONTROL :



error free



Frame in error.



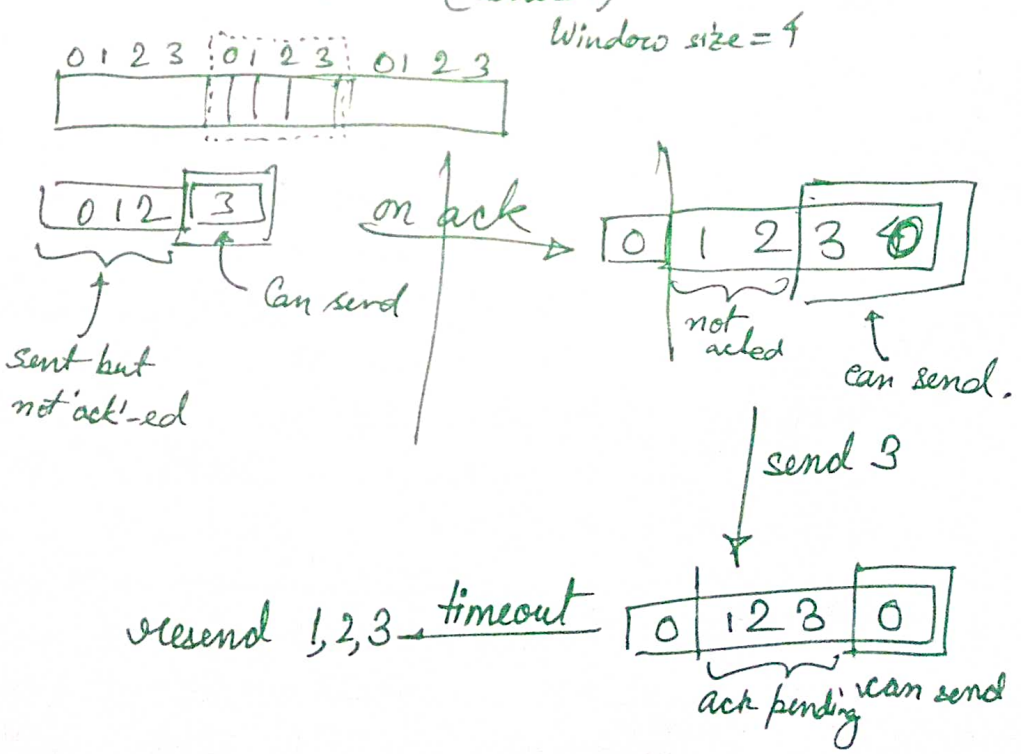
Ack gets corrupted.

Error control on top of the sliding window

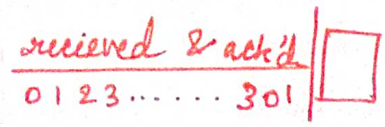
Assumptions:

- A received message can be ~~sent~~ delivered to the user immediately, (so the ack can be sent immediately on recv if needed). So buffer can be freed immediately.

GO-BACK-N ARQ



Receiver ~~side~~ side



receiver buffer size = 1.

only accept 2.

if 3 is received:

- drop
- additionally, can send REJ 2 to ~~indicate~~ ~~indicate~~ allow sender to resend.

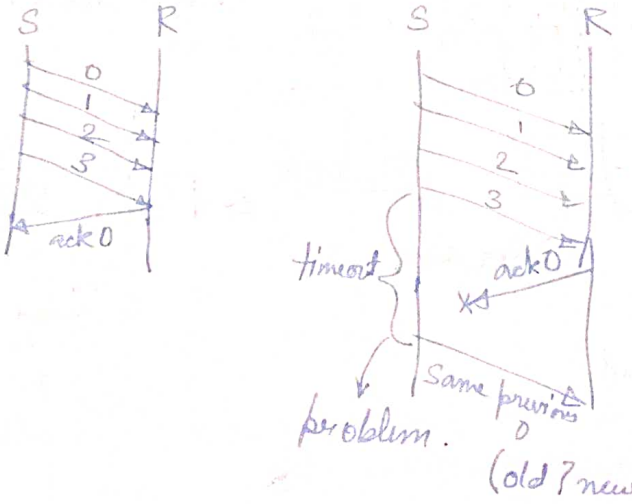
What is the maximum window size if you use k-bit sl. no.

(from 0 to $2^k - 1$)

Max window size = $2^k - 1$

b)

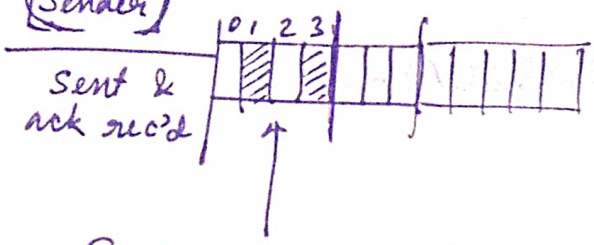
[Assume the opposite, k=2, W=4,



~~Selective~~ ~~accept~~ ~~repeat~~

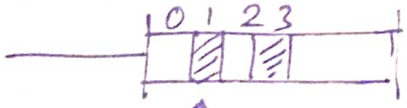
Selective Repeat:

[Sender]



Received 1 & 3 but (~~rec~~ ack'd)
not 0 and 2
(no cumulative ack)
↓
~~recv~~ ack 0
↓
Now window can be shifted by two places.

[Receiver]



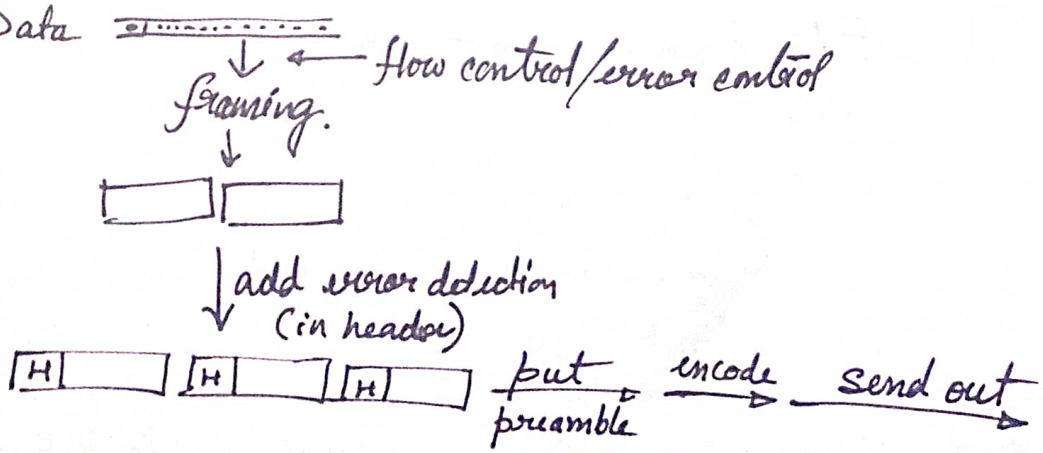
recv'd 1 → ack 1

when 0 is recv'd send ack 0.

- Max window = 2^{k-1} (lower window size)
- More complex buffer management.

Summary:

- Data → Framing. ← flow control/error control
  - add error detection (in header)
  - put preamble → encode → send out



COMMUNICATION BETWEEN MORE THAN TWO DEVICES SHARING A COMMON LINK

LAYERS IN NETWORKING

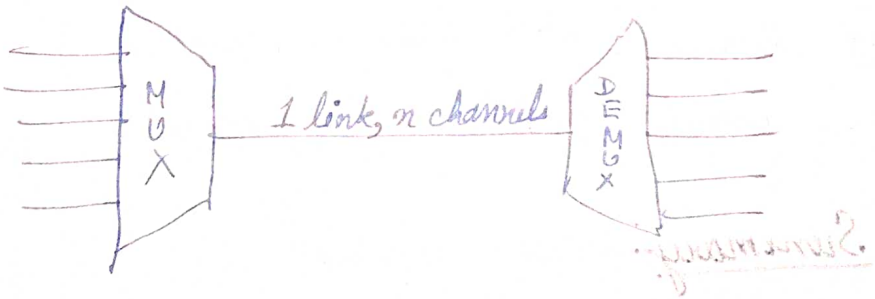
Data Link Layer (Access of sender/Breceiver to transmission channel, reliability, frame, error, flow ctrl)

Lowest → Physical Layer (Raw signal, encoding, decoding, e.t.c)

Multiplexing:

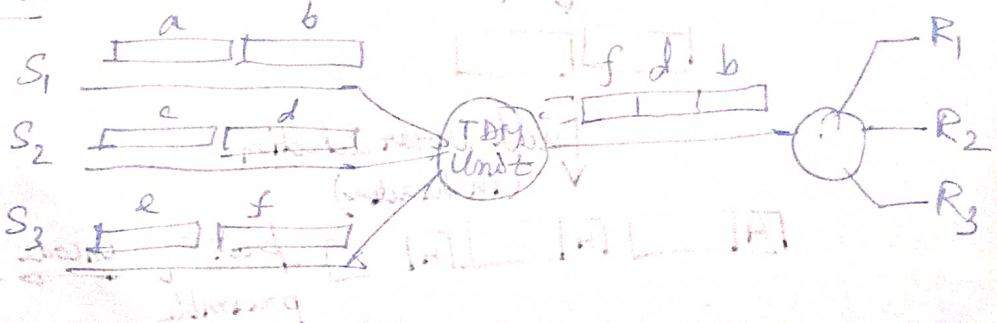
Create more than one "logical" channel out of a link.

- Time division multiplexing (TDM): Each channel is assigned a different time
- Frequency division multiplexing (FDM)
- Wavelength division multiplexing (WDM).



FDM: Guard bands + ~~carrier~~ subcarrier bands.

TDM:



ALOHA

Collision ⇒ Both transmitters send after a random time.

Random time range

- Small → Increase chance of collision.
- Large → Wastage of Channel capacity

Slotted ALOHA

vulnerable time → time for which transmission can cause collision.

Requires clock sync.

What if propagation delay is small

1st bit of any transmitter reaches every other would be transmitter very fast.

Non-persistant

Good at high load.
Bad at low load.

1-persistant

Good at low load.
Bad at high load.

p-persistant

Low p → better for high load
high → better for low load.

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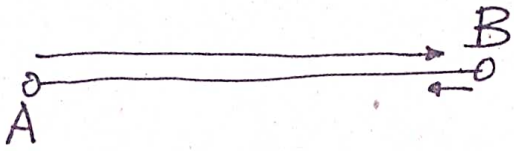
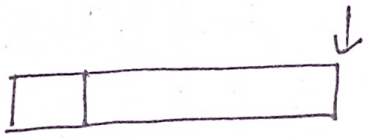
- **Jamming Signal**

A transmitting station detects collision, it stops transmitting and sends a short jamming signal, to let the other stations know about the collision.



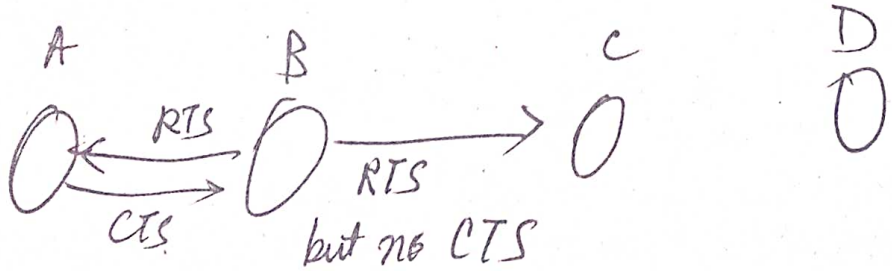
Purpose: Jamming Signal extends duration of collision making it easier to detect.

- CSMA/CD/CA



* **Token Passing**

- Special frame called Token
- Used in 1980's.



Local Area Network (LAN)

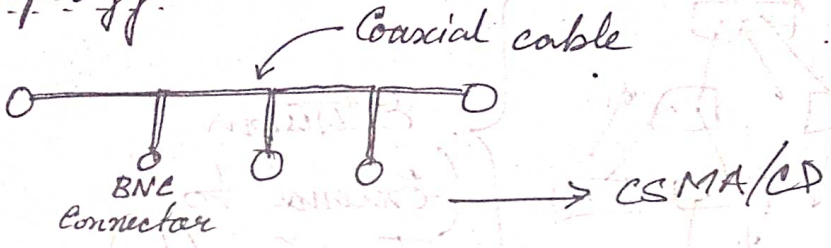
The set of machines receiving a broadcast from one machine is a lan.

- Single administrative management.

Ethernet (Old)

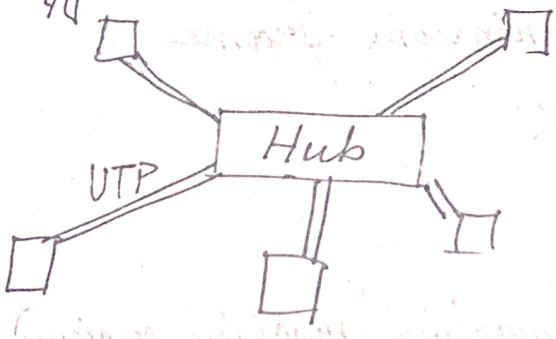
There were 2 topologies

- Bus topology



(Not there anymore)

- Star topology



2 pairs of wires to every machine (full duplex).

Hub → Receives a signal
extract the bits
amplifies
& resends out to all ports.
} No buffer.

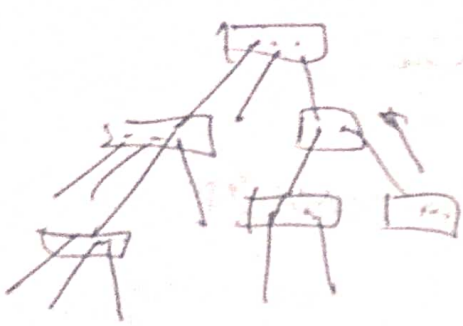
→ CSMA/CD.

(However we use UTP; hence detecting collision i.e = sense a signal receive channel while transmitting something.)

Twisted Pair ——— still there
Star topology ——— (with extension) } still used
Hub ——— Replaced with switches

Problem with star topology

- Extending beyond capacity demands change in hub.
- bandwidth shared by all } · Not good for higher loads.
- medium contention for higher load



Extension (Extend to True Graph)

We know:

- CSMA/CD has a minimum frame size of $L > \frac{2D}{V}R$

Broadcast domain = {machine | machine receives my message}

- bus → all machines
- star → all machines

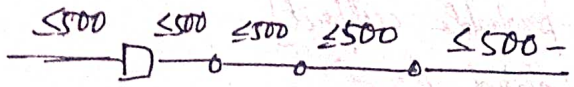
Collision domain = {machine | machine's transmission can collide with each other}

- bus → all
- star → all

Segment → part from one machine to hub

Early Ethernet: Bus

Spec said: max segment length 500m
# of repeaters : 4.



~~minimum length~~ :

$$\text{max delay} = \underbrace{\frac{2D}{V}}_{25\mu s} + \underbrace{4 \times 2 \text{ repeater delays}}_{24\mu s}.$$

So max delay = 49μs

Data rate of 1st LAN = 10 Mbps.

$L > 490$ bits. ≈ taken to be 512 bits.

∴ minimum frame size ≈ 512 bits
≈ 64 bytes.

∴ time to transmit one frame = 51.2μs
(one slot time).

This is the "time unit"

Preamble (+SFD) is not considered to be a part of the frame size.

MAC Address

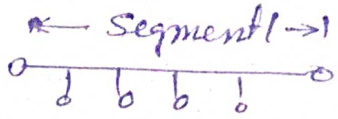
(Basically the Ethernet Address)

- Associated with a NIC (Network Interface Card)
- A PC with a LAN connection & a wifi connection has 2 NICS ⟶ Hence 2 MACS
- The Network Interface "Card" maynot be physical card
- (For the time being) all MAC addresses are distinct.

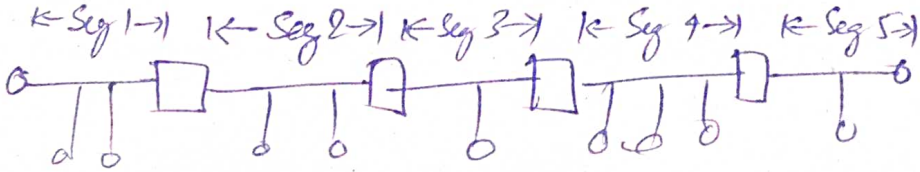
If destination field has ff ff ff ff ff ff (48 1's), then it is a broadcast message, every machine accepts it & sends it to the next layer.

Segment: Part of the medium without any repeater.

Bus (w/o repeater) — (1 collision domain — 1 seg) — all machines in one segment

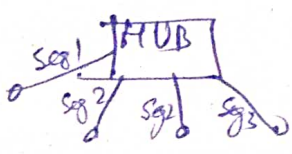


Bus (with repeater) —



(1 collision Domain / 1 segment)

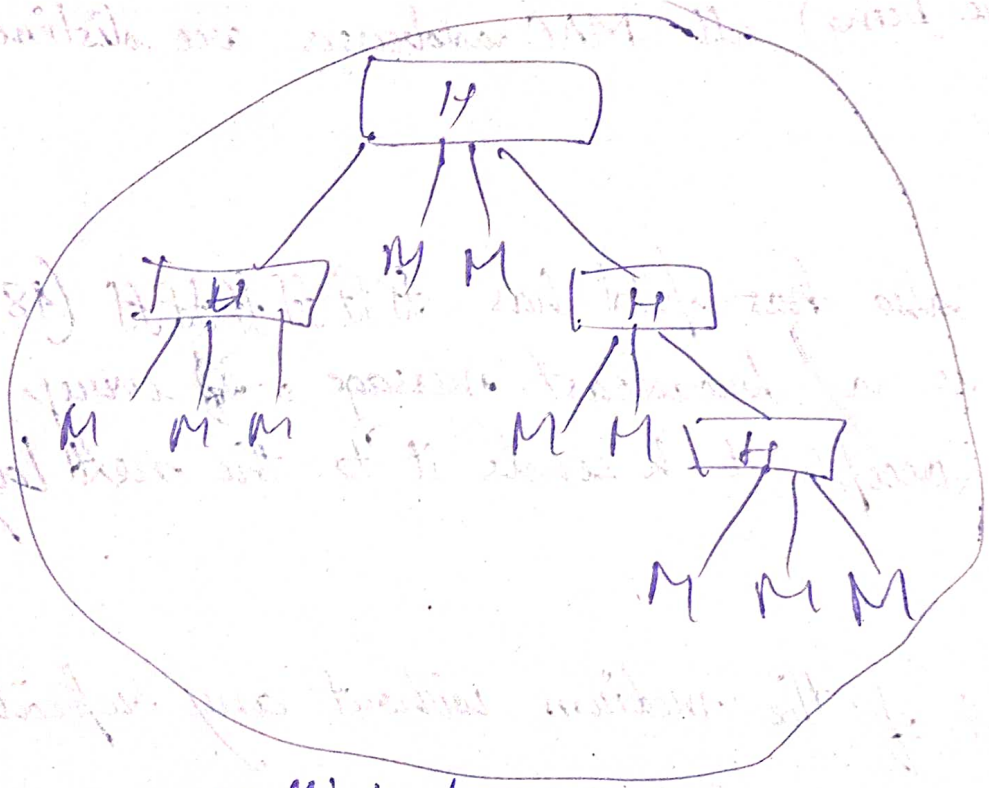
Hub —



(1 collision domain — all segments)

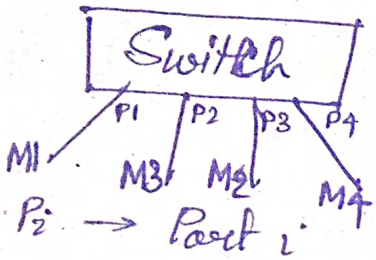
Hub

- Operates a physical layer (doesn't look at headers and stuff)
- Receives the frame bit by bit, amplifies the signal and sends it to all ~~the~~ ports other than the transmitter
- When it detects a collision (transmission on 2 ports), hub sends a 48 bit Jamming signal to all other port



collision domain
& ~~bro~~ broadcast domain.

Switch LAN



- Switch operates a MAC Layer (Data Link Layer) [It looks at MAC headers to make decision]

M1 sends to M4, ⟶ S knows nothing, sends to everyone.
But S gain information that M1 is connected to P1.
(From SA of the ethernet header)

- Will have buffers inside.