* 5-layer TCP/IP Stack

Interworking devices

2 sub layers

(1) Media Access Control (MAC)

(2) Logical Link Control (LLC)

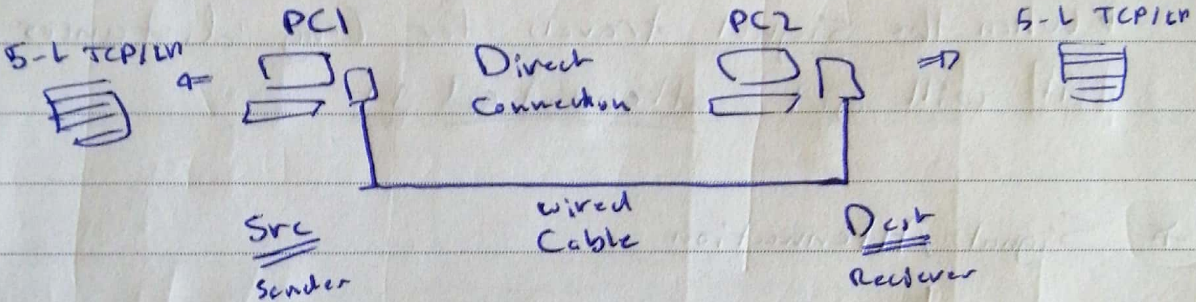
(5)	Application layer
(4)	Transport layer
(3)	Network layer
(2)	Data link layer
(1)	physical layer

Routers — understand IP addresses — 24 / 48 - ports

Switches — understand (physical addresses) ||| MAC Addresses

Repeaters, Amplifiers; Hubs

Channel (Media)
- Wired (cables)
- Wireless (Air transmission)



⇒ Channel limitations :- (1) Noise

Router يفصل شبكات

Interface2 Router Interface1

PSUT —(X)— JU

↳ local Internet Service Provider (ISP)

we have 2 separate networks connected to the router

(IP Addresses) — IP Address Pool * Global ISP

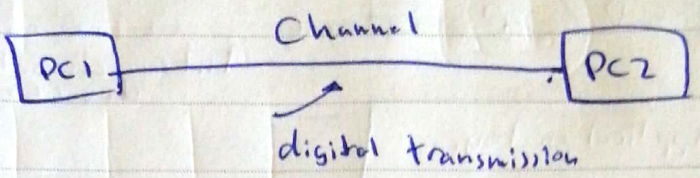
Hierarchy

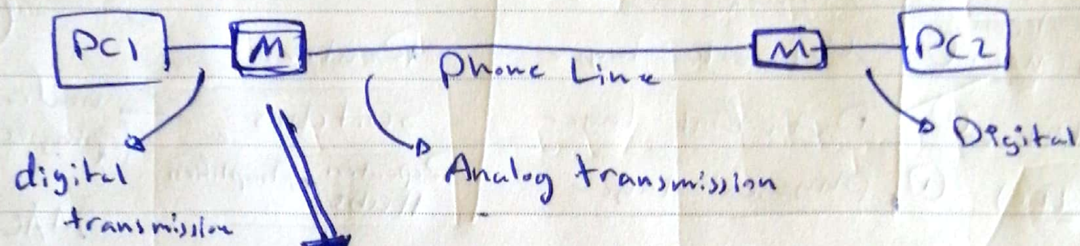
Global ISP
↳ Regional ISP
↳ Local ISP
↳ Customers

No.

Modem ≠ Router

 # Note :





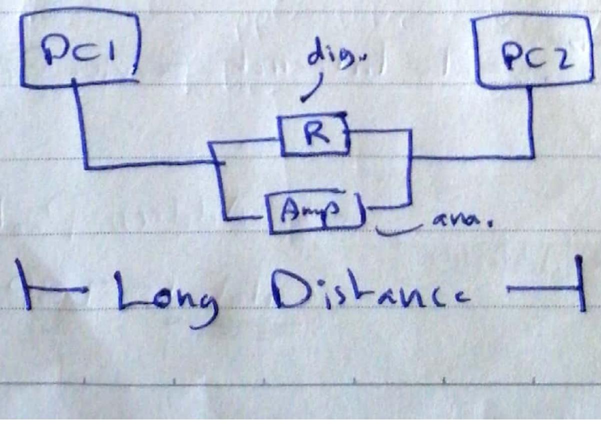
Modem (Modulation / DeModulation)

⇒ When the <u>signal</u> travels for long distances it will get <u>attenuated</u> !!

* Signal Attenuation

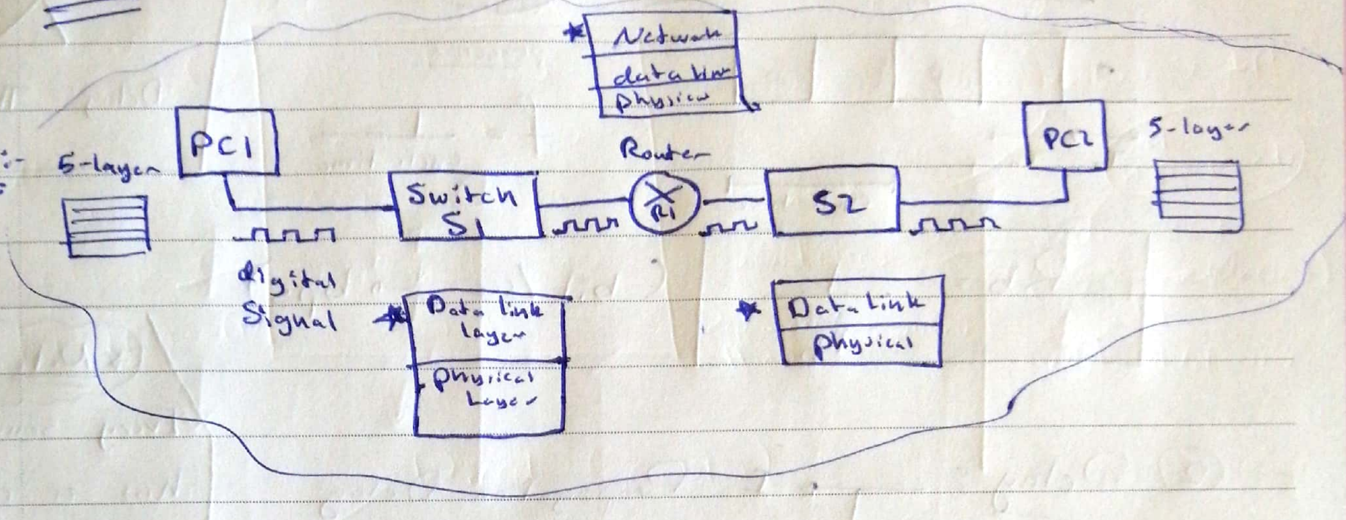
Analog	Digital
• Amplifiers ↳ including noise	• Repeaters (better) ↳ regenerates signal <u>excluding</u> noise

 # Note :-



layer-1 device (physical) * Hubs :- multiple ports repeaters

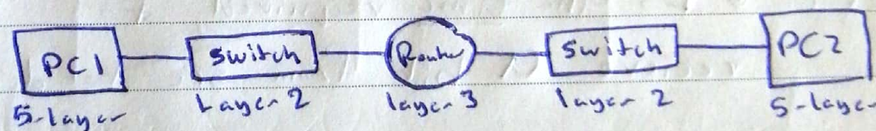
#Note :-



* Protocols :- a set of rules adhered by communicating devices for the purpose of having timely, recognizable and reliable transfer of data

- timely: synchronous
- recognizable : format (syntax) of data
- reliable : Accuracy of data

* Communicating devices :-



- Sender
- Source

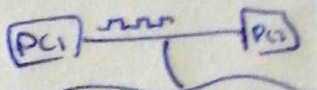
- Recievers
- Dest.

processor — Server ← terminals

Server
program
machine
high performance

* Computing → Centralized (master/slaves model) (limited space)
→ Distributed (client / server model) (open space unlimited)

programs

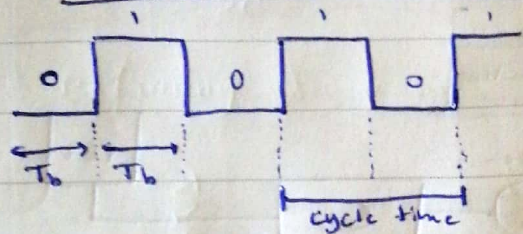


link ≡ channel ≡ media

Performance

Delay | Throughput

1) Bit Rate (data rate) — Rb



processor

$$f = \frac{1}{\text{cycle time}}$$

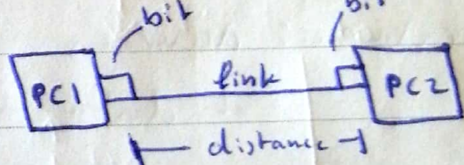
$$\boxed{R_b = \frac{1}{T_b}}$$ (bit/sec → bps)

*** Note ***
Every Source has a certain data rate R_b

2) Delay :-

- I Propagation Delay
- II Transmission Delay
- III Processing Delay
- IV Queuing Delay

I Propagation Delay (T_{prop}) :-



Def :- • Is the time required to recieve a bit from src to dest.

$$\frac{m}{m/s} = s$$

$$\boxed{T_{prop} = \frac{\text{Distance}}{\text{Velocity}}}$$

Velocity → relies on the channel
≡ link velocity
≡ propagation speed of a bit

⇒ **Note:**
- Copper wire $v \approx 2.3 \times 10^8$ m/s
- fiber $v \approx 3 \times 10^8$ m/s

No.

$\boxed{II}$ Transmission Delay (T_{trans}) :

Def :- • Is the time elapsed from the moment the 1^{st} bit is transmitted (from the Src) till the last bit is transmitted

$$\boxed{T_{trans} = \frac{\text{Msg length (bits)}}{R_b \text{ (bps)}}}$$

depends on the efficiency & speed of Src

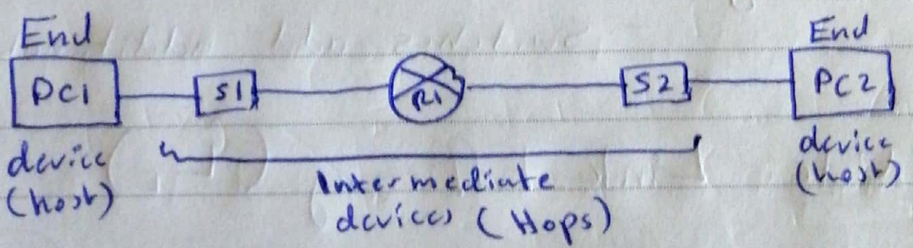
Note :- ① T_{prop} & T_{trans} are deterministic delays

② Processing & Queuing delays are undeterministic

★ End-to-end delay (T_D)

$= T_{prop} + T_{trans} + T_{proc} + T_{queue}$

Note :- End-to-end?

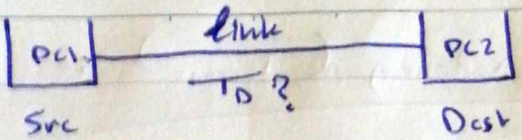


Def :- Time elapsed from the moment the 1^{st} bit is transmitted till the moment the last bit is recieved.

E-to-E Delay

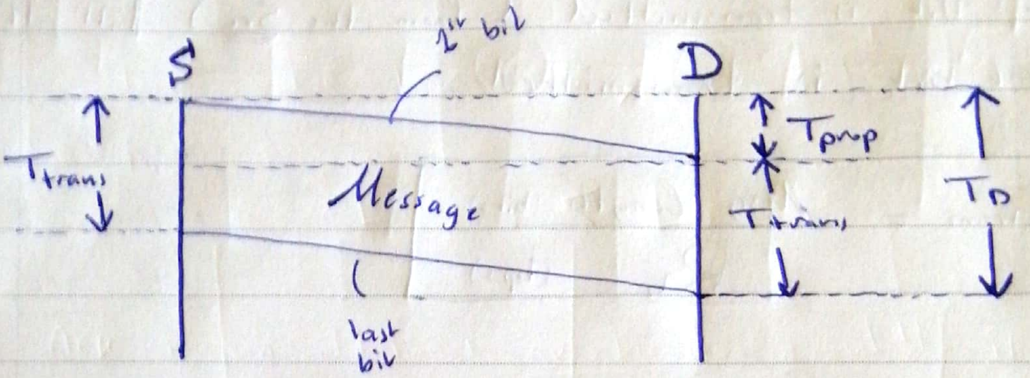
smile for life

Case 1

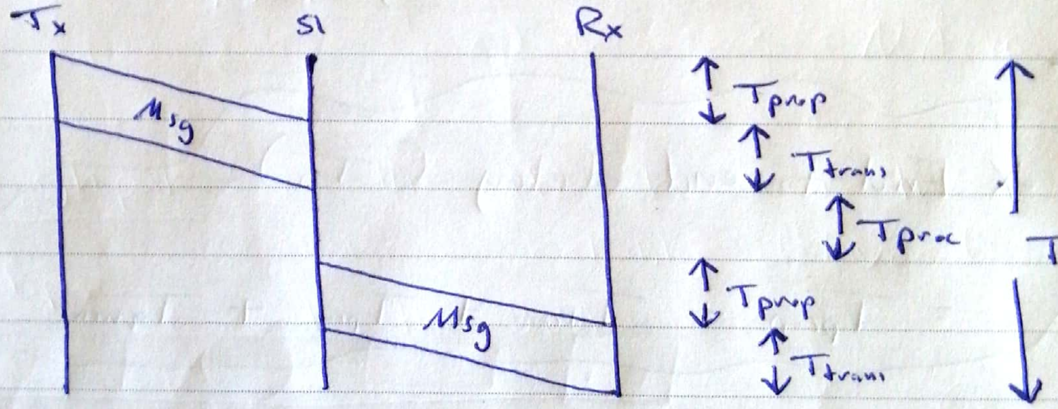


Ideal Case
(No switches)
direct links

⇒ timing diagram



Case 2



⇒ **Summary:-**

- Switches add additional <u>overhead</u>

but without switches we need direct links which is impractical so we use switches

Note:- Link Efficiency (L_E)

$$\boxed{L_E = \frac{T_{trans}}{T_D}}$$

my mission is to keep the link busy

$\Rightarrow$ for case 1 :- $L_E = \dfrac{T_{trans}}{T_{trans} + T_{prop}} = \dfrac{1}{1+\alpha}$, $\alpha = \dfrac{T_{prop}}{T_{trans}}$ ($T_{prop} = \frac{D}{V}$)

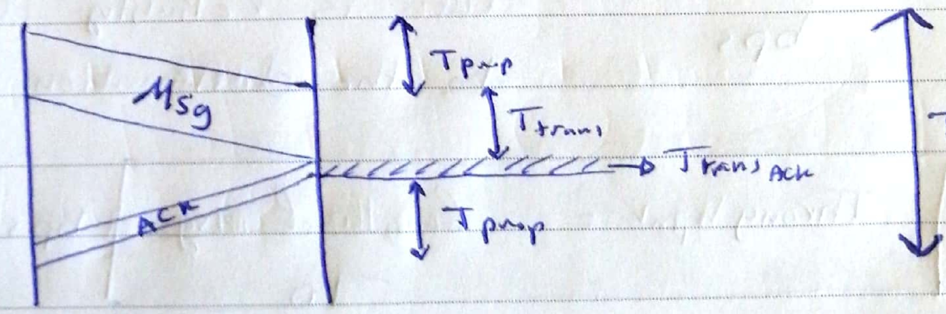
to maximize L_E : $T_{prop} \downarrow$ minimum & $T_{trans} \uparrow$ maximum $\rightarrow$ to keep line busy

$\Rightarrow$ for case 2 :- $L_E = \dfrac{T_{trans}}{2T_{trans} + 2T_{prop} + \cancel{T_{proc}}}$ $\rightarrow$ for simplicity T_{proc} very small

$\therefore L_E = \dfrac{1}{2(1+\alpha)} << \dfrac{1}{1+\alpha}$, ideal case

Case 3 ☆ Handshaking Scheme :- (Protocol)

ACK :- Acknowledgement



let us assume that ACK is very small msg length ≈ 0

$$T_D = T_{trans} + 2T_{prop} + \cancel{T_{trans\,ACK}}$$

$$\therefore T_D = T_{trans} + 2T_{prop}$$

No.

⇒ Differences between Cases 1 & 3

$T_{o c1} = T_{trans} + T_{prop}$, $L_{E1} = \frac{1}{1+\alpha}$

$T_{o c3} = T_{trans} + 2T_{prop}$, $L_{E3} = \frac{1}{1+2\alpha}$

$\therefore \quad L_{E\,case3} < L_{E\,case1}$

 # Note:- ACK is an additional overhead But!! it can't be ignored as the reliability is achieved :

2 Types of **ACK** :- 1) Positive (ACK) +
2) Negative (NACK) −

---

(3) Throughput :- is the rate at which the data is reliably delivered to the destination

bps

$$\boxed{\text{Throughput} = \frac{\text{length of msg}}{T_D}} \text{ bps}$$

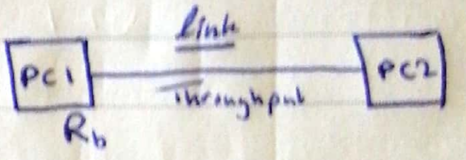
To end-to-end delay

⇒ our objective is to maximize the throughput of link

⇒ Throughput is directly connected to the capacity of the link

No. Rb → Bit Rate

$\checkmark$ * Throughput, R_b? Throughput $\geq R_b$



if throughput < R_b, we need a Buffer

we are still in the physical layer!!!

if throughput > R_b, we need Multiplexing to optimize the usage of the high throughput

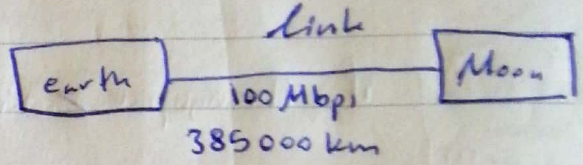
Questions:- [Q1] Consider a LAN with a maximum distance of 4 km, at what bit rate would the propagation delay (at a propagation speed of 2.3×10^8 m/s) be equal to the transmission delay for 512-byte packet?

Soln.

$$T_{prop} = T_{trans} \Rightarrow \frac{d}{V} = \frac{L}{R_b}$$

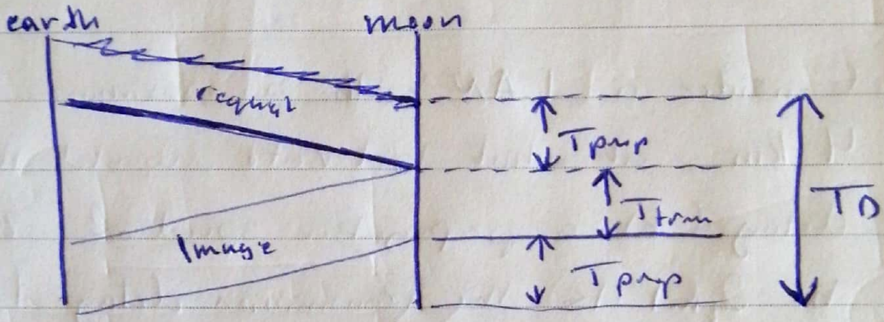
$$\frac{4\times10^3 \text{ m}}{2.3\times10^8 \text{ m/s}} = \frac{512\times8 \text{ bit}}{R_b \text{ bps}} \qquad \therefore R_b = 235.52 \text{ Mbps}$$

[Q2] Suppose there is a 100 Mbps point-to-point link between the earth to the moon. The distance from moon to earth is approx 385,000 km and data travels over the link at the speed of light (3×10^8 m/s) A camera on the moon takes pictures



- timing diagram

Assume having very small request msg ($T_{trans} = 0$)



Soln $T_D = 2T_{prop} + T_{trans}$

$$T_{prop} = \frac{3.85 \times 10^8}{3 \times 10^8} = 1.283 \text{ sec}$$

$$T_{trans} = \frac{40 \times 10^6 \text{ bits}}{100 \times 10^6} = 0.4 \text{ sec}$$

$$\therefore \quad T_D = 2(1.283) + 0.4 = 2.97 \text{ sec}$$

a) 2075 μs
b)

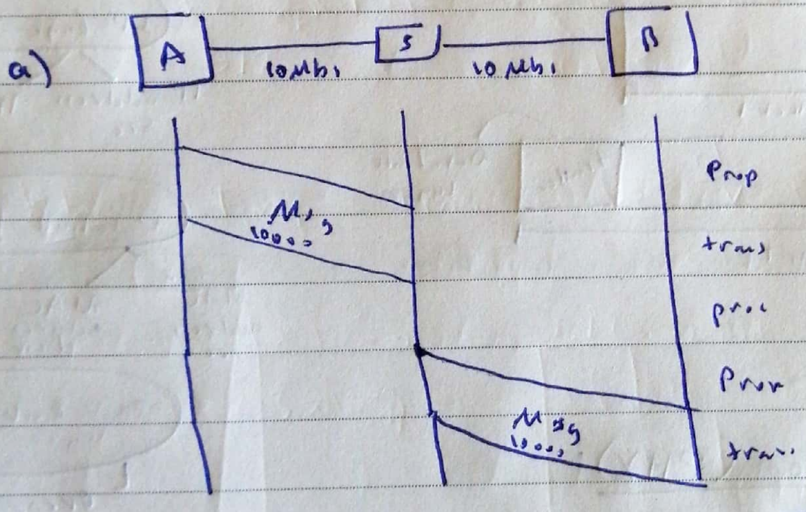
No.

Q3 Hosts A & B are each connected to a switch via 10 Mbps links, the propagation delay on each link 20 μs. Switch is a 'store and forward device, it begins retransmitting a recieved packet 35 μs after it finishes recieving it. Find the total time required to transmit 10,000 bits from A and B

a) as a single packet
b) as two 5,000 bit packets sent one right after the other

* Ideas!!
① Store & forward device
② dividing the packet into fragments

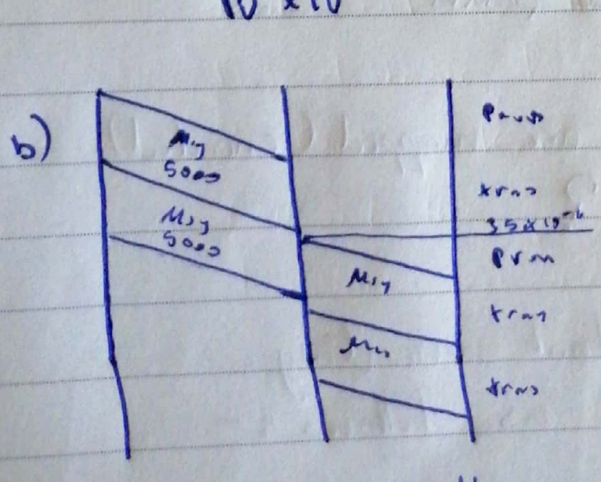
a)



$$T_{trans} = \frac{10000}{10 \times 10^6} = 1000\ \mu s$$

$$T_D = 2(20 \times 10^{-6}) + 2(1000 \times 10^{-6}) + 35 \times 10^{-6}$$
$$= 2075\ \mu s$$

b)



$$T_D = 2(20 \times 10^{-6}) \quad \text{prop}$$
$$+ 3(500 \times 10^{-6}) \quad \text{trans}$$
$$+ 35 \times 10^{-6} \quad \text{proc}$$
$$= 1575\ \mu s$$

$$T_{trans} = \frac{5000}{10 \times 10^6} = 500\ \mu s$$

Dividing the msg reduces End-to-end delay

* Raw bits < Digital Signal / Analog Signal

No.

Inter networking devices	TCP/IP Stack	Data Unit
—	Application layer	Message ⇒ (will be split into)
—	Transport layer	Segment 1, Seg 2, Seg 3 ...
Routers	Network layer	Packet 1, Packet 2, Packet 3 ...
Switches	Data link layer	Frame 1, Frame 2, Frame 3 ...
Repeaters, Hubs as [Amps	Physical layer	* Raw bits 1, Raw bits 2, Raw bits 3 ...

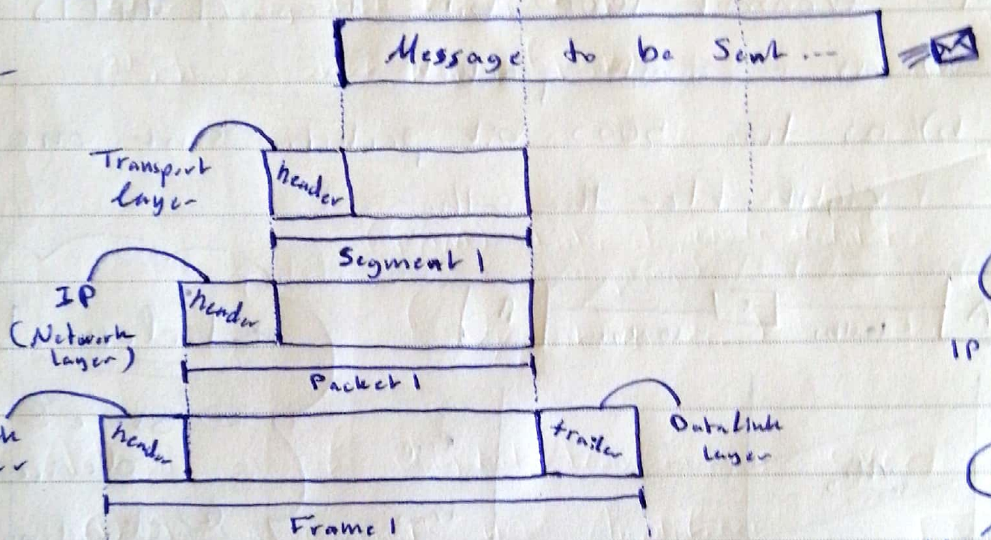
Link

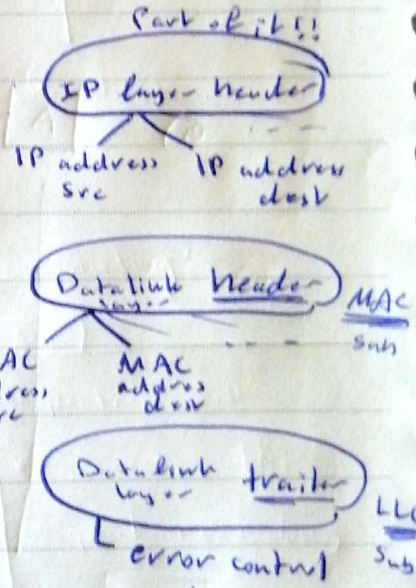
7 Jul Sun
1st exam

why split?
- delay
- practicality (storing / buffering)

Note :-

every layer introduces certain services





1 Physical Layer (PHY) :-

- is responsible of transmitting raw bits between 2 points

question: How bits "0" & "1" are mapped (encoded) into a digital signal?

⇒ we have 3 important encoding schemes, detailed as follows :-

No.

① Non-return to zero (NRZ):-

"1" ↔ high level , "0" ↔ low level

Synch with clock

② NRZ-Inverted (NRZI):-

"1" ↔ Transition of the current state, "0" → No Transition

Synch with clock

③ Manchester Encoding:-

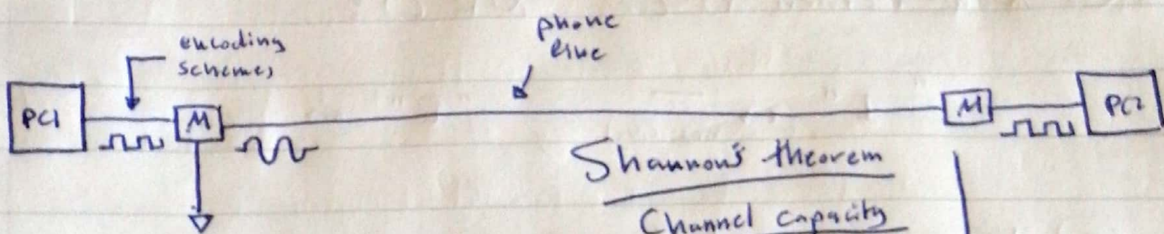
"1" → , "0" →

Question

A wants to send the following raw bits to be:-

001011110100

How these bits are mapped into a digital signal?



Shannon's theorem

Channel capacity

⇒ Modulation / Demodulation :-

1) Amplitude Shift keying (ASK)
2) Frequency Shift keying (FSK)
3) Phase Shift keying (PSK)

Pulse Code Modulation (PCM)

- (PAM) Pulse Amplitude Modulation (Sampling) (Nyquist theorem)
- Quantisation
- Coding

* Advantages of digital transmission over analog:-

why Digital over Analog ?

① Analog circuits use Amplifiers
Digital circuits use Repeaters

Note
Repeaters will regenerate the signal excluding noise

② Easy to apply encryption to digital data

③ Higher Bandwidth

④ Lower error rate

⑤ Easy to multiplex large channel capacities with digital

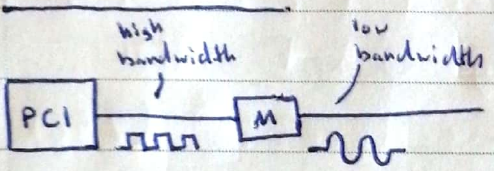
No.

* Link Types :-

1. Simplex : signals travel only in one direction

2. Half Duplex : signals travel in both directions **but** one signal at a time

3. Full Duplex : signals travel in both directions and at the same time



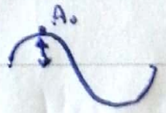
R_b (bits/sec) — Symbol rate (symbols/sec)

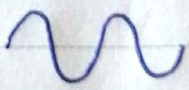
Grouping or Signaling → to solve bandwidth asymmetry

to avoid using a buffer !! → delay

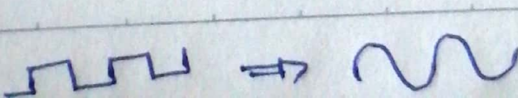
X (symbols/sec) * N (bits/symbol)

$$R_b = XN \text{ (bits/sec)}$$

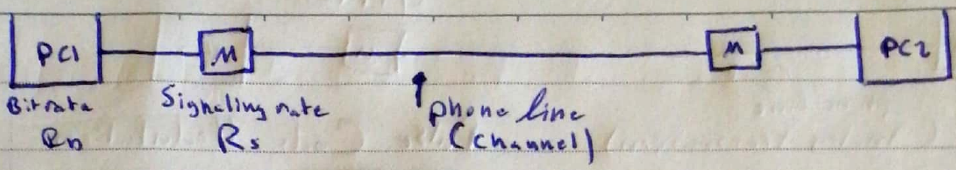
1) ASK :- "1" →  , "0" →

2) FSK :- "1" →  , "0" →  same amplitude

3) PSK :- "1" →  , "0" → 



*



* **Channel Bandwidth :-** Is the range of frequencies that can pass through this channel without degradation

  W (Hz)

* **Signal Bandwidth :-** Is the range of frequencies available in the signal

  B

* **Channel Capacity :-** Is the maximum data rate supported by channel

  C (bps)

$$\Rightarrow \boxed{R_b \leq C = W \log_2(1 + SNR)}$$

* SNR :- Signal-to-Noise Ratio $= \dfrac{\text{Signal Power}}{\text{Noise Power}}$

SNR: the Higher the Better

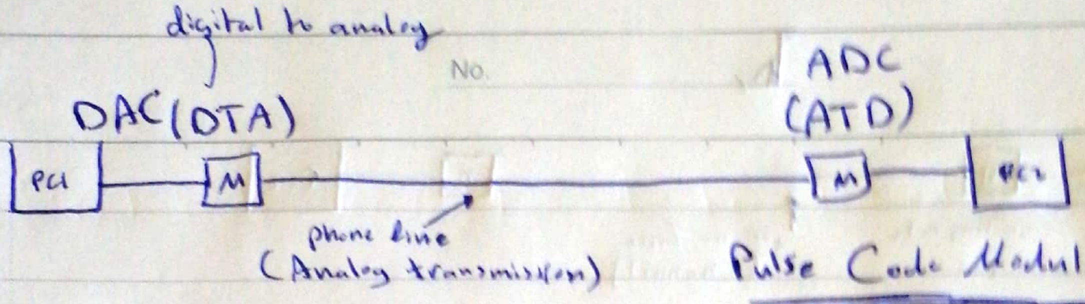
Ex If we want to send data at a rate of 8000 bps through a link that has a bandwidth of 1000 Hz what is the minimum SNR required?

Soln. $R_b \leq C = W \log_2(1 + SNR)$

$$8000 \text{ bps} = 1000 \text{ Hz} \log_2(1 + SNR)$$

$$1 + SNR = 2^8 = 256 \quad \therefore SNR = 255$$

#



Pulse Code Modulation

① Sampling (PAM) Nyquist thm ② Quantization ③ Encoding

① Sampling (PAM) :-

Nyquist thm

Sampling freq لازم تكون ضعف freq of Signal

$$\underbrace{f_s}_{\text{Sampling freq}} \geq 2\underbrace{f_m}_{\text{freq of signal being sampled}}$$

② Quantization :- Assume having 8-bit ADC,

⇒ means that we have 2^8 (256) Quantization levels

Summary 8-bit ADC

$\boxed{2 \times \underbrace{4\,KHz}_{\text{phone line freq}}}$ → Sampling Rate = 8000 samples/sec

× 8 bits/sample

= 64 kbps —— must be ≥ src data rate

⇒ This is the basic data rate of public switched telephone Network (PSTN)

* Multiplexing :-

1) Frequency division multiplexing (FDM)
2) Time division multiplexing (TDM)

① FDM :- Conditions to be statisfied :-

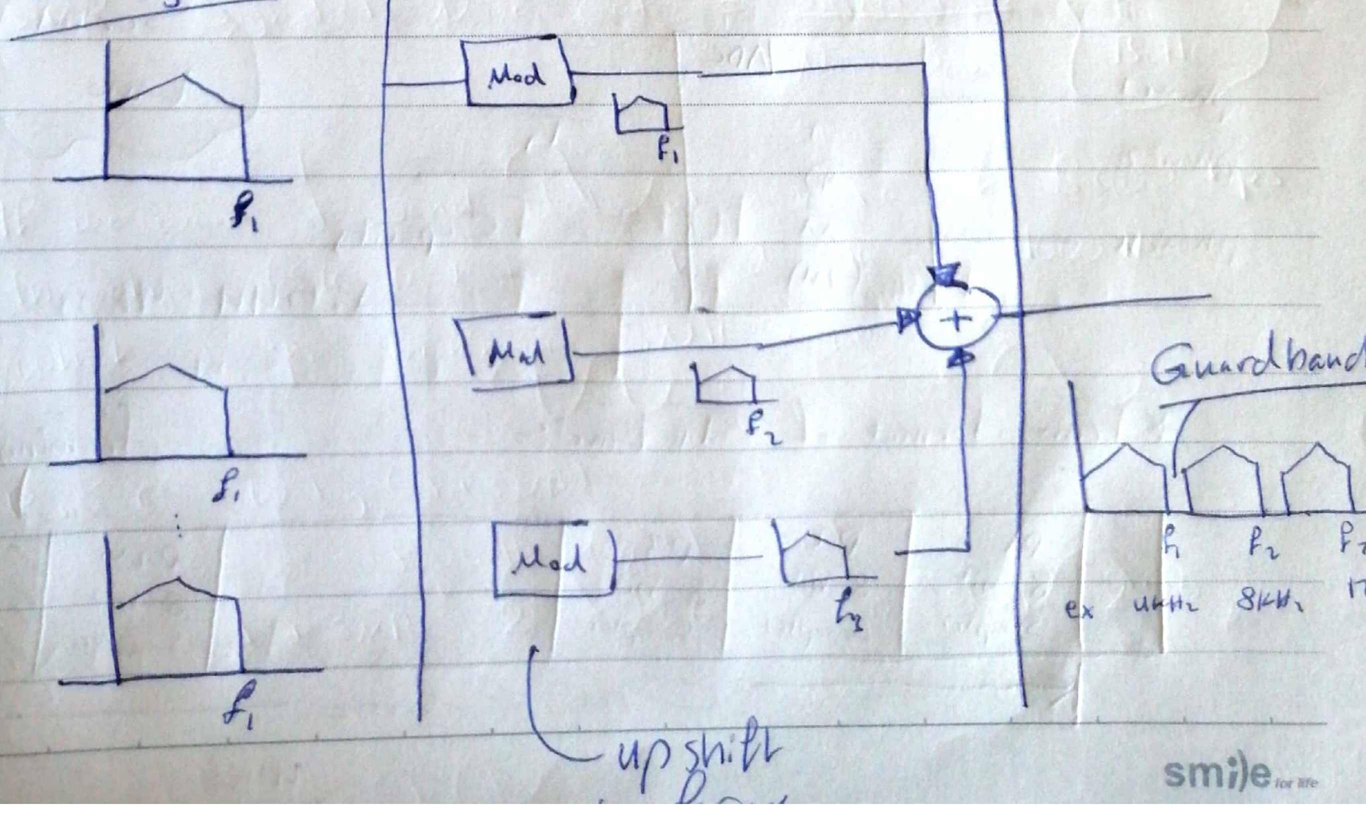
- The bandwidth of the medium (channel) exceeds the bandwidth of the signal to be retransmitted

Procedure :-

1) Each signal is modulated into a different Carrier frequency

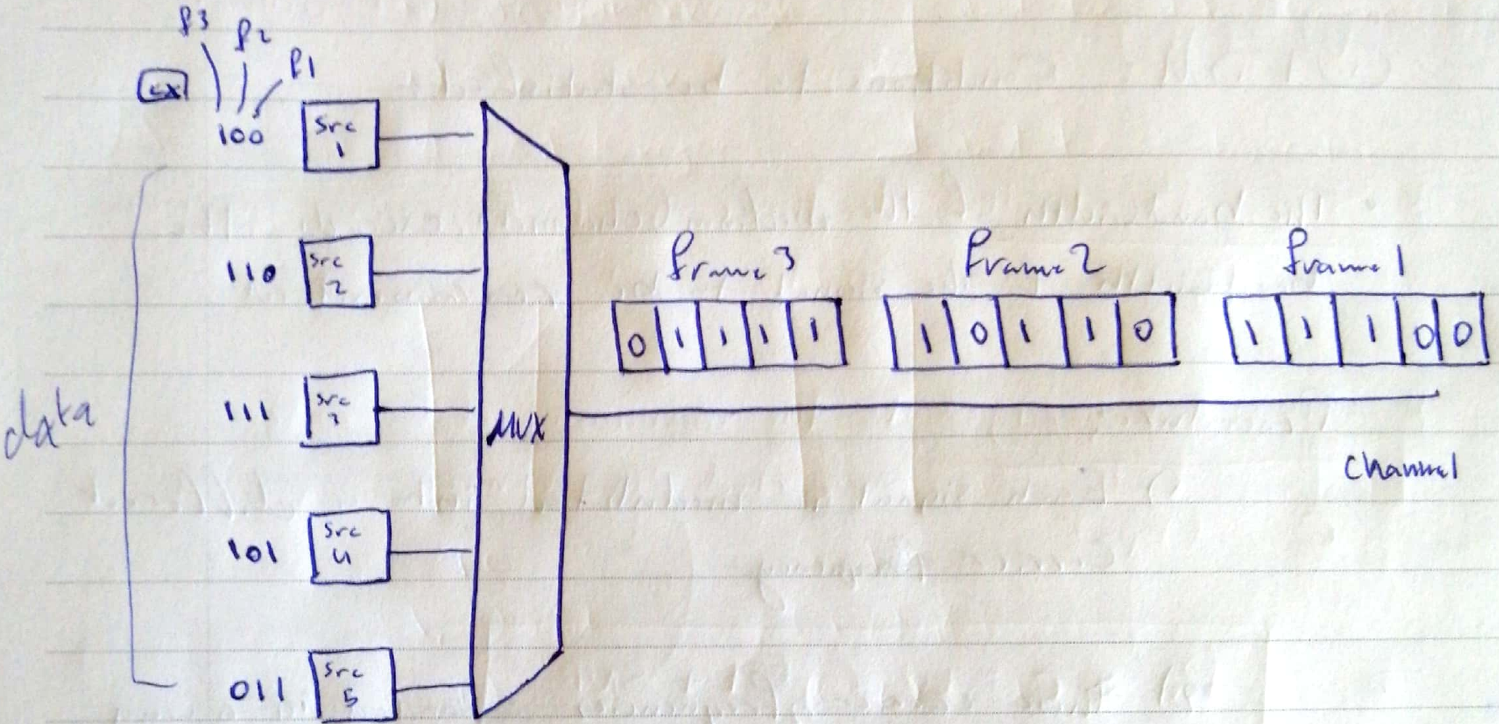
2) these carrier frequencies expanded in a way that will not be overlapped

Voice Signals :-

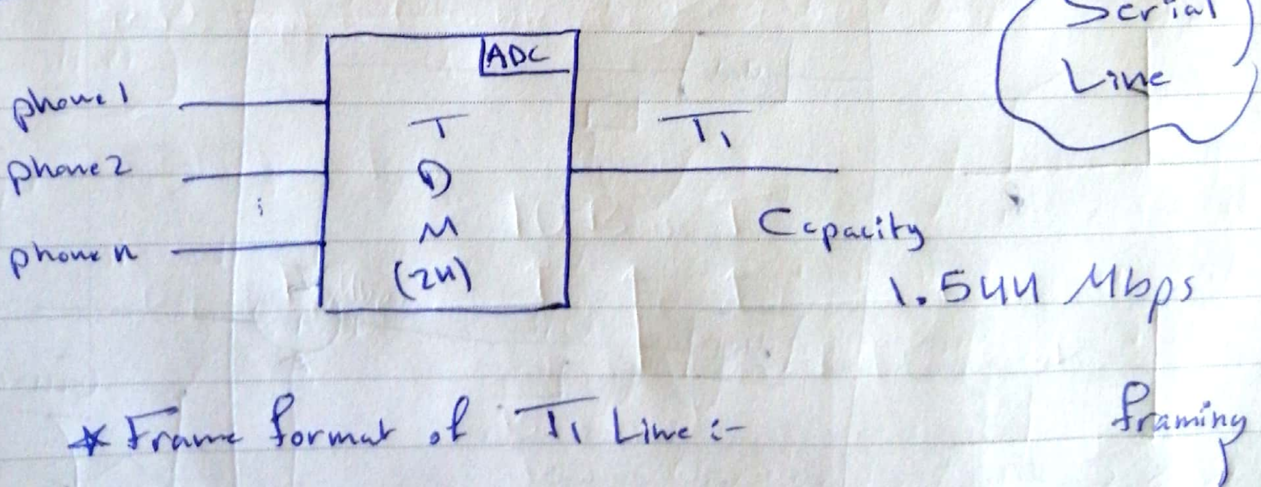


② TDM :- Condition to be satisfied :-

- Data rate of the medium exceeds the data rate of the signal to be transmitted

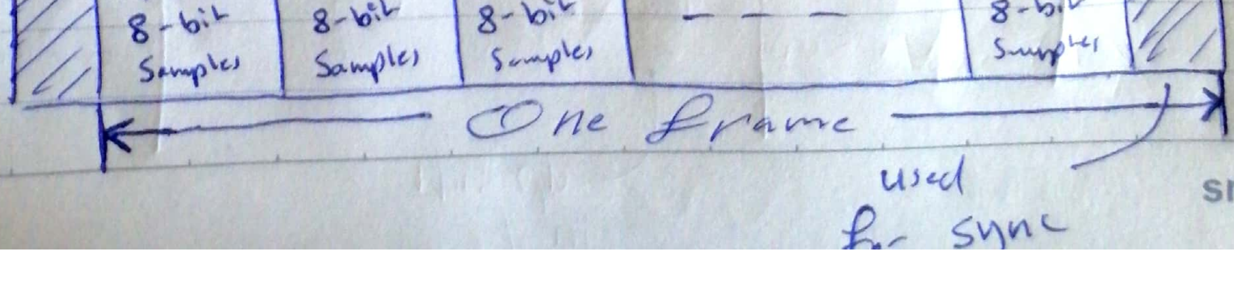


Real Example Digital Carrier System → T_1 Line



Capacity
1.544 Mbps

* Frame format of T_1 Line :-



No.

8 bits/sample * 24 + 1 bit/sample

= 193 bits/sample * 8000 samples/sec

= 1.544 Mbps Bandwidth of Serial Line

$\boxed{Ex}$ Assume you are ~~required~~ requested to design a TDM carrier that supports 30 voice lines using 16-bit samples at a sampling rate of 8000 samples/sec. Determine the required bit rate?

Soln (30 * 16-bit samples + 1) * 8000 samples/sec

= 3.848 Mbps

eacademic.ju.edu.jo/kdarabkeh

→ Materials

No.

★ Transmission Media :-

SHH in PHY

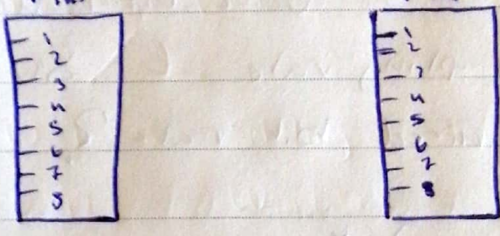
⇒ UTP Cable Type :-

1) Straight Through
2) Cross Over
3) Roll Over

1) and 2): used for data communication

3): used for configuration

Pins | Pins



PC | Switch

(1,2) Send | (1,2) Recieve

(3,6) Recieve | (3,6) Send

⇒ Description of cable (ex)

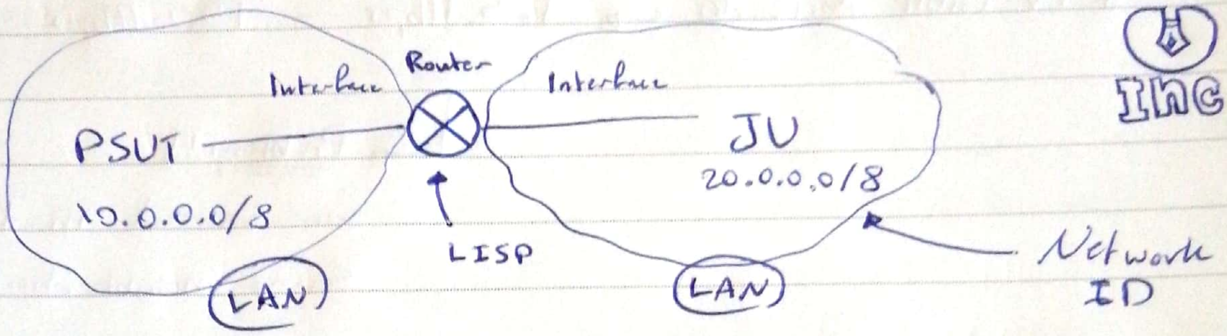
10 Base T

10 Mbps → 10

Base → Baseband transmission

T → Twisted-Pair Cable

table 7.1 X

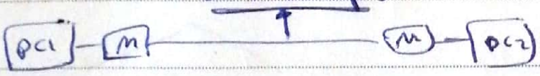


Inc.

IP Address belongs to PC not network

- basic data rate of (PSTN)

64 kbps



- Dial up → 56 kbps (one service at a time phone or internet)

*ISDN

Basic rate interface

- 2 B channels → 64 Kbps each

128 kbps Combined

- 1 D channel → 16 kbps used for control data info

Primary rate interface

- 23 B channels → 64 Kbps each

∴ 1.472 Mbps combined

- 1 D channel → 64 kbps

Error Control → LLC (Data Link Layer) < error detection, error correction

*DSL

128 kbps, 256 kbps → 1 Gbps

No.

* TV-Cable Networks → 1.5 Mbps – 150 Mbps

→ **Problem!!** was shared in the same neighborhood

★ Data Link Layer:-

unit ↓ Frame

LLC

must operate together

Flow Control: Stop-and-Wait (Send-and-Wait), Sliding Window

Error Control: Error detection, Error correction

Automatic Repeat reQuest (ARQ)

ACK: positive (ACK), negative (NACK)

- Stop-and-Wait ARQ
- Sliding window ARQ ✓ link utilization

* Data Link Layer Protocols:-

▷ Ethernet:- a set of networking technologies - introduced for LANs - available at both data link & physical layers

→ Ethernet cabling system

No.

⇒ OSI Model $\xrightarrow{\text{is replaced by}}$ TCP/IP Stack

7 layers → used HDLC

5 layers → uses Ethernet

---

not used anymore (Ethernet, FDDI, Token ring] for groups

Token ring — 16Mbps

HDLC

SLIP, PPP] for individuals

⇒ **Old Ethernet** :-

1) Shared media
2) Half duplex links
3) CSMA/CD → channel access protocol

old Ethernet 10Mbps

Ethernet Segments
LANs
slide #4

old Ethernet Cabling System

10Mbps ← 10 Base 5 → Coaxial cable (500m)

Base → Baseband transmission

main Problem was Collision

* used repeaters between segments to regenerate signals
