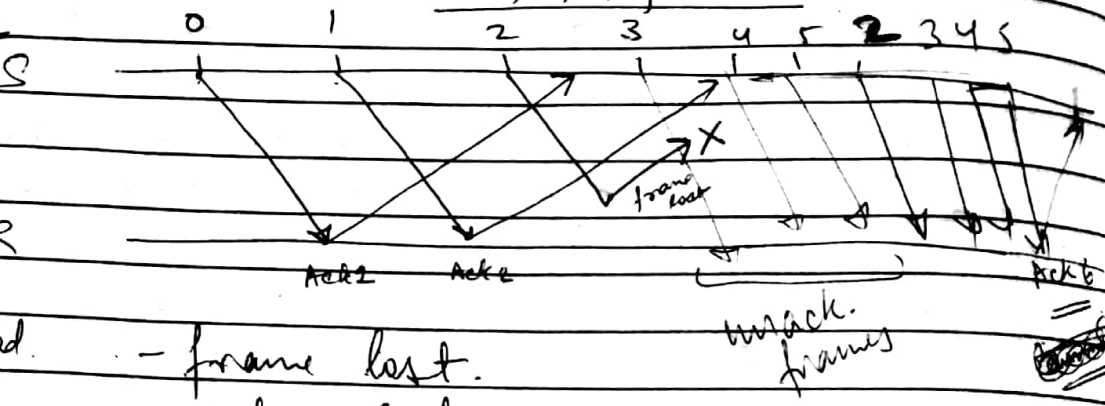
Efficiency of GBN :

$m = 3$

- Window size $\Rightarrow$ 0, 1, 2, 3, 4, 5, 6, 7 frames

$W = 3$

Max. window size = 7.



η_{GBN}

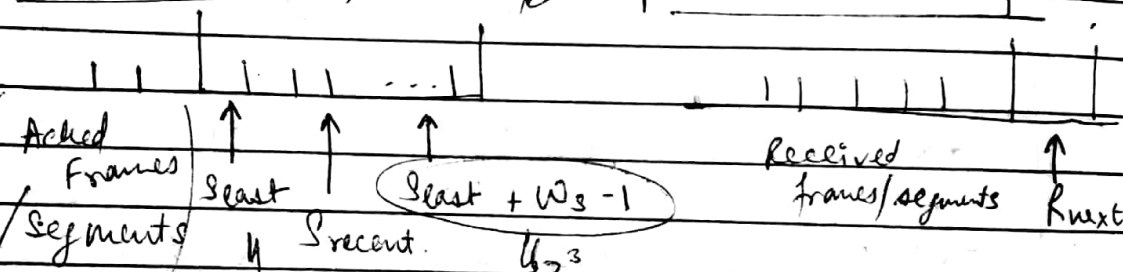
we can forward upto 7.

$(S_{last} + W_S - 1)$

$(2^3 - 1)$

- frame lost.
- ack. lost

$S_{least} = 2$ ∈ not acked.



$t_{out} = 2 t_{prop} + 2 T_f^{max} + T_{process}$

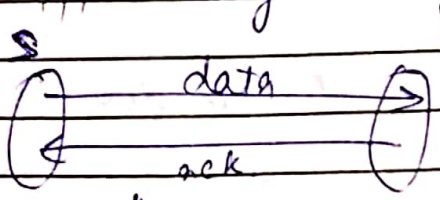
T^{max} = 2 max. length frames transmission time on reverse channel : $2 \times T_f^{max}$

$$\eta_{GBN} = \frac{\frac{n_f - n_0}{t_{GBN}}}{R}$$

SWARQ → only discussed for half-duplex.

→ full duplex → forwarding channel, receiving channel.

efficiency changes.



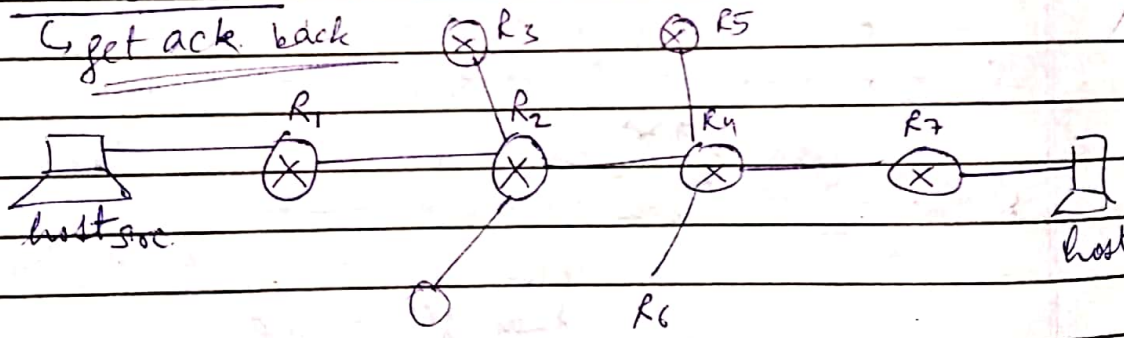
↓
simultaneously.

→ Response time is going to be different, time out is diff.

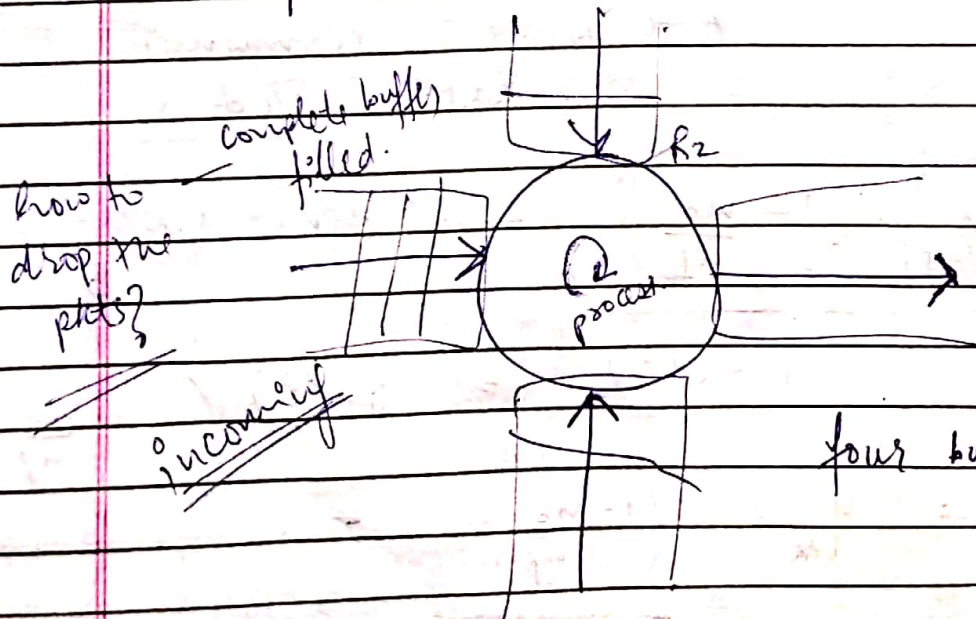
for Congestion Control, first we need to discuss Resource Allocation.

(end to end communication - reliable - ARQ ③)

↳ get ack back



we need to reduce retransmissions, i.e. reduce drops.



If it is a bidirectional link → 2 queues with each interface.

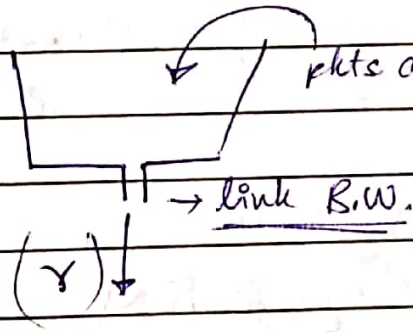
Total 8 queues — to know what is incoming pkt, what is forwarding pkt.

→ Seq. No. is limited, pkts can have identical seq. no.s.

How to drop the pkts? when queue is full.

Traffic Shaping mechanism:

① Token Bucket ② Leaky Bucket.



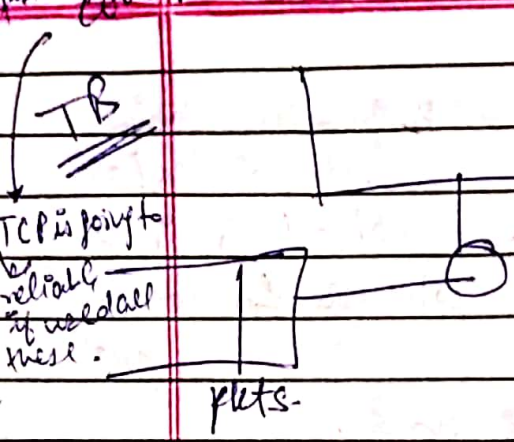
If $R = r$ or $R < r$ ⇒ no delay at buffer level. (no congestion)

But if $R > r$ ⇒ bucket will be filled with pkts. — when max. size of bucket is full, pkts will overflow → top surface pkts will drop

Drop Tail Concept

If some priorities are there then less priority pkts will drop.

(3) fast retransmit, fast recovery concept (1) additive increase multiplicative decrease / (2) slow start



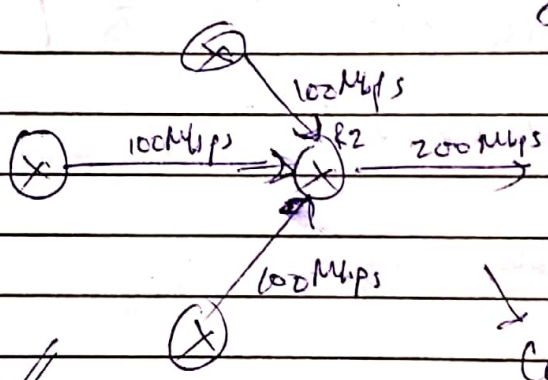
4 pkts . . . = error happens Come back to 1 pkt

⇒ tokens will be lost, not pkts.

Queue the pkts when the token is not available.

If pkt rate ↑ then increase your token rate.

→ Leaky Bucket — at the gateway level.



100Mbps everything will close.

Congestion at R2

feedback mechanism to know the amt. of pkts being dropped then use the rate. → Congestion Avoidence

top ← (3) Congestion Control.

→ TCP tow | reno | S-ACK. — Congestion Control

{additive multiplicative} Use pkts which are sent +1, +1, — if error happens, come back to $\times \frac{1}{n}$ pkts

8) mobile pic HTTP

After Midsem:

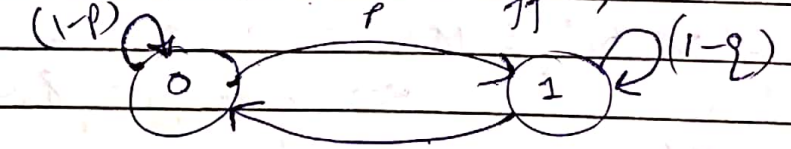
17/3/19 TCP, UDP

① Analytical model - throughput, other parameters
② Simulate the model.

Congestion can happen at any node / router.
End to end communication - intermediate nodes.
- functions. (Eg: Home to school : Traffic light)
depends on traffic { If traffic more ↑, no traffic light, : accident
" less ↓, there is " " : delay.

Markovian Chain model : Discrete / Continuous slide 66

two states : 0 : off, 1 : on



Initial state : off. : not transmitting
To trans we need to go to on state.
p : prob reqd to move from 0 to 1.
↓
if we are ready to trans but all links busy
↳ so we remain in initial state
↳ (1-p).

After transmitting pkt, go back : q
more pkts to transmit
↳ remain in (1) → (1-q)

- Add. Inc, mult. dec.
- TCP Reno, Vegas

Arrival rate ↑ , departure rate ↓ ⇒ Congestion

If arr. rate < dep. rate : No Congestion
if " > " : Congestion ✓

Eg: Weekends : at shopping mall : 7 counters are open.
weekdays " : 5 counters are enough.

If delay → saturation, then beyond saturation we need to drop the pkts.

→ Additive Inc. , multiplicative dec.
↳ arr. rate ↳ dep. rate

Slide 66 Throughput = $\frac{W \times MSS}{RTT}$ bytes/sec.
(MSS: seg. length)

rate v/s window concept.

→ segment size } if buf. > seg. : ✓ no drop
→ buffer size } else drop (retransmission, more time).

Two phases :
- Slow Start
- Congestion avoidence ←

Congestion control: when you have enough resources and when you don't have resources

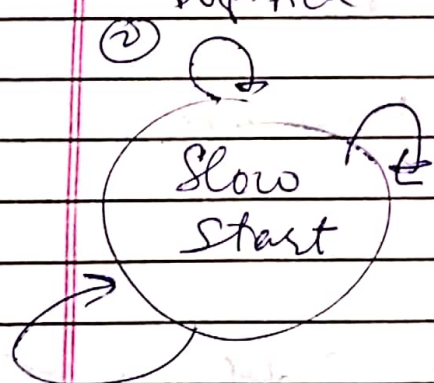
Date
Page

⇒ TCP Slow Start :

Ack is there, we know pkt delivery is successful or not, if success, tt & whenever any congestion is there we will get retransmission req, - NACK or time out.

slide 68 Cong. wnd = max. window size (MSS).
(cwnd)

max. threshold value : ssthresh.
↳ once you reach that, cong. wnd size drops to half



Cong. Control/Avoidance

Q) What is Congestion?
Q) Algo on Cong. Control
Q) " " & Avoidance :→ RED Rand. Early Detection. (no detail study).

TCP Pkt format : (47) slide

Length of Headers :

Src Port Add., Dest. → TCP does not provide any multi° tasking → only point to point

DNS : 53 port no.

Dest port # → what appln. service you req.

B/w 2 nodes : pt. to pt. connection.

In order pkt. delivery : Seq No. is req'd. (2^{32})

Ack No. → if pkt. drop then Seqd.

(never use all zeros or all ones ($2^{32}-2$))

Flags → F: Finish : Release Connec.

Checksum : Errors detection / mechanism. (CRC) (if there is any header change)

↳ How TCP achieves its each objective.

UDP : connec. less.

Reliability : ~~F~~low control, Cong. control, ACK, Seq No.

Ch-4 Network Layer (routing layer) → Total performance of n/w depends on n/w layer only.

How to divide the existing n/w ?

- Data plane
- Control plane

Control plane → Software part – Control plane
underlying H/w part (Routers) – Data plane

Objectives :

- Addressing scheme (routing) – primary.
-

IP v4, v6

v4 → 32 bits

v6 → 128 bits → no classes.

Why IPv6 ?

2 add. scheme

1 device : 1 add.

1 mobile, laptop, desktop → devices which connect to internet requires 1 IP add.

pivot existed applns. — more sensors.

IPv4 limits the no. of addresses.

→ Japan developing IPv7 also.

IP Spoofing :

Rand. IP add. - bypass proxy : anonymizer.com

→ Attacker wants to hide his identity : secret agent : try to attack on China's IP add, won't use India's IP add. → Spoof IP add from other country - with no link with India. - use fake IP add.

IPv6 → IP security ✓

from a particular router, where to move?

Events - drop the pkt
- store the pkt / forward.
- send pkt
- receive pkt

Spread info. where? — might not find any destination.

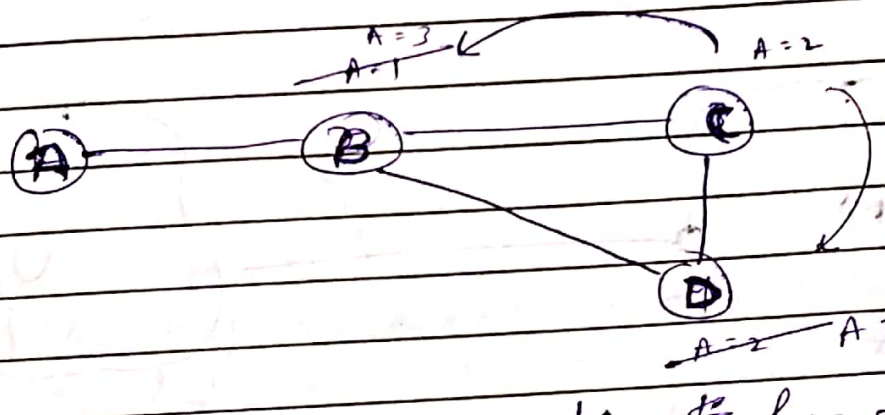
↳ keep on moving in the network.

↳ Consumes n/w bandwidth : need to control it.

- maintain timeouts.

DVR : hop counts — distance based routing.

LSR : how many links are supposed to be used, if not there, kill the port.
(no. of links



DVR

=> It will cont. till ∞ (count to ∞ problem)

Distance as a parameter for timeout.

A : B (1 hop neighbours) → then it updates it to be 3 hop neighbours.
A : C (2 hop neighbours)
A : D (2 hop neighbours)

How to solve count to ∞ problem?
(Split Horizon

Instead of distances, we move to #links
(LSR) : outgoing links (send) / incoming links (receive)

→ RIP — (DVR) — 2 versions.
Routing — right now, v2 is being used

→ OSPF — (LSR)

CDMA

- Freq-Div Multiple Access
- Time-Div " "
- C " "

TDMA — problem : I have a slot and if I'm not using it then waste.

same problem with FDMA.

Phy. layer → frames consisting of (0,1)
↓
analog signals (modulation technique)
- phase based
- amplitude "
- freq "

Quadrature Phase → modulation.

WIRELESS COMMUNICATIONS :

1. Satellite n/w / cellular : 1G | 2G | 3G ---
2. Top of the building : cell towes : mobile communication
3. N/w sensors (5 blue blocks)
4. Vehicular n/w.
5. Road side units

IoT — one of the big n/ws.

maldives car / volkswagon car.

Augmented Reality / Virtual Reality

Licensed Band Spectrum / Unlicensed.

Heterogenous N/W.

Jio - cell towers - less - compression of cellular and ——— (Heterogenous)

more sim cards : more radiations

future will be Software Defined Radio.

~~Attenuation~~ Attenuation, Fading

once freq will not interfare with other freq.

Interference, Attenuation

Wireless

Infrastructure Based N/W
↳ Satellite

Infrastructure-less N/W

Wireless → less / limited Bandwidth
↳ limited spectrum

WLAN – WiFi (upto 100 m.)
W-PAN – Bluetooth (upto 10 m.)

6/4/18

→ Wireless N/w : we need a transmitter and a receiver. – what is medium used? – AIR
(T,R) They should have same freq. to communicate.

→ IOT – Big Data Analytics
– many devices – processing – storage.

→ Jio → short span of time – billions of users.

→ Disturbence signal is generated when mobile is near TV or PC. – wireless n/ws.

→ Ad-hoc N/w: Purposefully created n/w.

→ Cognitive radio N/w: next generation n/w, does it exist – limited spectrum – TV channels

→ Federal communication – USA. (AI is reqd., Eg: radio automatically switches from 1 freq to another)
(US Agencies to handle radio/wifi)

↳ Underwater, undermine, underground n/w.
↳ terrorism

→ Vehical Adhoc n/w → Future transport sys.
↳ drivers-less car (AI)

→ Body Area Sensor N/w. – Future stuff.

SDN, CDN

walkie-talkie → MIMO

laptop.

Single device provides access to multiple devices → no. of antennas
↳ multiple ports
↳ so that no interference b/w ports

transmitter

broadcast

if there is interference, then call gets disconnected.

Uplink → many transmitters - one receiver.
↳ (MAC)

FM → all users are able to access it.

WIFI → " " " not able " " .
↳ limited spectrum. → [two users can't use the same freq, if they use same freq then interference]

Out of multiple channels - only 2 you are able to use - to avoid interference. - limited spectrum

Problem

Solution: Spectral Reuse

cause

TV, Radio → Licensed bands
Bluetooth, WIFI, → Unlicensed bands.
UWB - ultra white band.

Why hexagon representation? (Licensed)

distance of centroids - equidistant

② Some area remains uncovered.

① centroids may not be equidistanced.

Lic. band - structured	Unlic band - not structured — Btooth, Wi-Fi, UWB

Hexagon different colours - diff. colours will not interfere with each other.

green surrounded by pink/purple.

F_1, F_2, F_3 → ~~or~~ three frequencies (limited spectrum being reused efficiently)

Eg: Cellular, Wimax (wireless ~~to~~ metropolitan Area N/ws)

TDMA
FDMA
CDMA
wireless

Reuse introduces interference → bit error rate

Signal to Noise Ratio Theorem : $SNR = \frac{P}{N+I}$

Noise, Interference, bit error rate

→ 1G, 2G, 3G, 4G, 5G. — Hong Kong (China) launched it.

orthogonal freq. DM, MIMO

↓

no two signals interfere

→ LTE, Small cells

→ one cell - one freq. — now we need to break it.

Cellular - Stringent N/w.

Ad hoc - Mesh N/w → ① Mobile Ad hoc N/w (MANET)

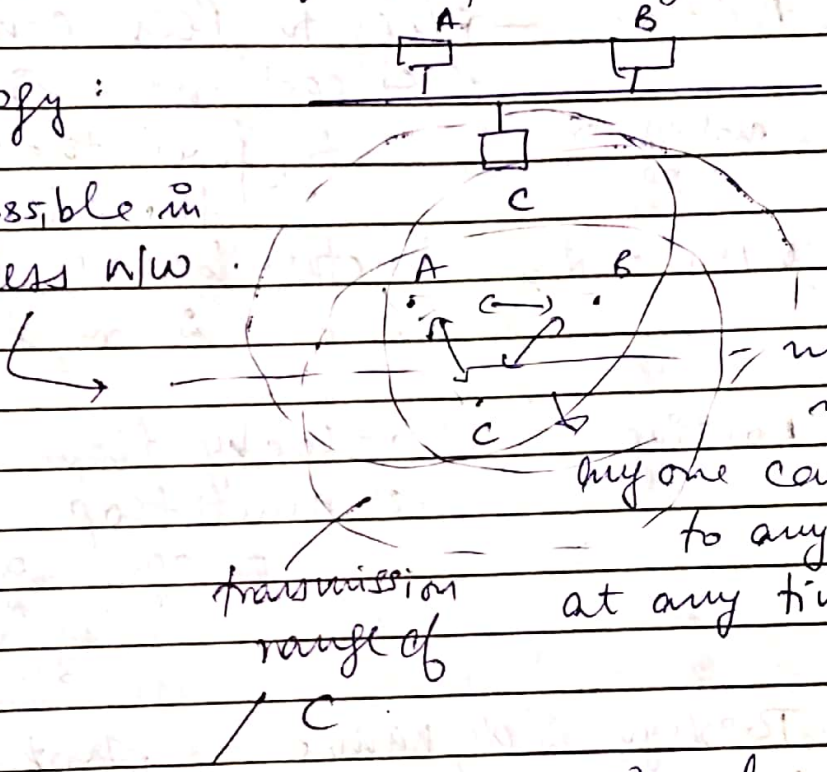
② Wireless Mesh N/w (WMN)

Zigbee Sensors

WLAN - IEEE 802 11
WPAN - IEEE 802 15.4
WMAX - IEEE 802 16 - wireless & service provides.

MANET → have to connect to other nodes.
if n/w fails - gets disconnected.

Bus topology:
↳ not possible in wireless n/w.



C sending some signal, if other node is within the range, then it will be able to listen.

Mesh n/w
↳ each node has to maintain at-least 2 connections with other nodes.

Fully mesh - n nodes, each node has to maintain (n-1) links
(connected graph)

Ad-hoc.
↳ not the same scenario.

→ Indoor wireless n/w - home automation
→ outdoor " " - signals travel bit far away than indoor.

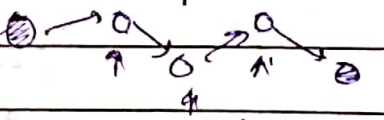
Propagation models - Free Space Parse Model.

Adhoc - 2 types
① Pees to Pees communication (MANET)
↳ each node is responsible to send the data as receive the data as transmit it.
(not infrastructure based)

② WiFi - Infrastructure based, because wifi access pt. is reqd. (WMN)

Routing - 2 types
① Hop by Hop
② multi-hop

(Sensor Node ↕ Gateway)



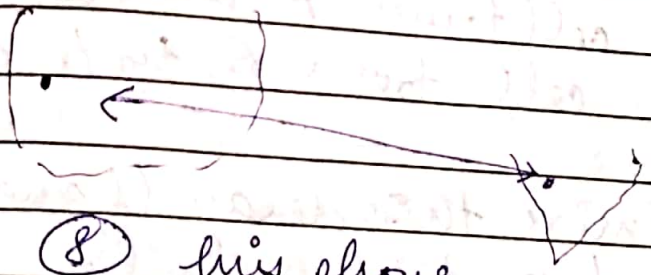
Topology is dynamic - not static nodes. (mobile nodes)
Need N/w Routing table which also changes
(Moving nodes changes ↳ Topology changes)

SINR - Signal Interference Noise Ratio.
CINR - Channel " " "

5/4/19

Cellular N/w Architecture :

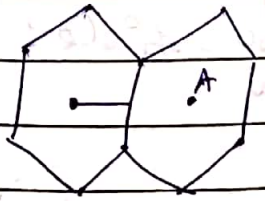
Type Ph. No. → Dial → how is call connected from India to San Francisco?



① your phone
② fwd call → reaches the cell tower nearest to you → connect to
③ Mobile switching centre
④ main switching centre (India)
⑤ Satellite
⑥ main switching centre in US
⑦ cell in which he belongs that cell tower
⑧ his phone.

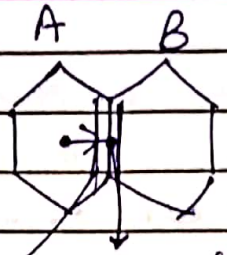
* If you are moving to one cell tower area from another cell tower ! → So now, that cell towers will find and receive my calls.
↳ Hand out mechanism. — 2 types

① Horizontal – 2 cell towers maintain same technology.
② Vertical → diff. tech. → Eg. vertical → ex. BSNL cell towers ↳ next cell is vodafone, it will provide me services.



Threshold dis. is there → to initiate handout process – it is called handout delay.
If delay is too long → then call disconnects else if its not long → call continues.

to wifi → once registered, then they switch acc to the strength of wifi



Handout

this time period → if more → call disconnect

threshold value of A

threshold value of B

threshold → cell tower A dis connects and cell tower B tys to connect

→ minimize this delay (handout) so to cont. the call.

cell

- Base Station
- mobile users
- air interface

Pt to pt. connection b/w mobile ~~station~~ and base station.

Mobile Switching Center (MSC) :

↳ it identifies that you are moving towards another cell tower.

it is an intermediate node. → it will fwd. the call to main station.

Eg: 2 phones kept side by side:

Ph 1 → cell tower → Ph 2

mobile switching center → main station

cellular → infrastructure Based NW

Ph. if not currently being used, then also, mobile keeps on communicating with MSC. Every time period, mobile keeps on sending its location.

In Skype call → a little delay is there.

ATM card → takes few moments to process - ask pin code → we are not able to hear those fraction of seconds. → we will move from that place to some where else. Delays, however small, are not heared.

Combined FDM / TDM.

CDMA.

GSM → Global Sys. for Mobile Communications.

2G → Voice channels / digital tech started.

CDMA 2000 → brilliance tech - micro tech.

BSC: ~~Base Switching Centre~~ — MobileSC.

Base station Controller.

Gateway

& add on to the prev. one.

(why is it needed?

↳ to distribute the load / traffic.

Before moving to 3G, 2.5G sys. was created: voice and data channel.

E → 2G
H → 2.5G
3G → 3G
4G → 4G

GPRS - evolved from GSM. (115Kbps)

EDGE → " " " " (384Kbps)

CDMA 2000 → reduced usage after 2.5G

clear diff. b/w 1G, 2G, 3G ?
(IP based technology) ?

SGSN → Serves GPRS Support Node
GGSN → Gateway " "

GPRS → exact location you are able to find.

→ 3G : radio n/w controller
↳ first priority is given to voice calls.
↳ whenever voice calls are initiated, data n/w is stopped.
↳ (voice calls) comes first then (video calls) (v-calls)

Q) 2G v/s 3G ?
↓ ↓
no data in 2G — we introduced data (parallelly transmitting both)

Q) 1G : also voice calls.

Q) then after 3G : advancements in speed and quality.

Q) Jio uses purely packet switching mechanism
↳ IP based

→ UMTS → 14 Mbps → huge compared to 2G

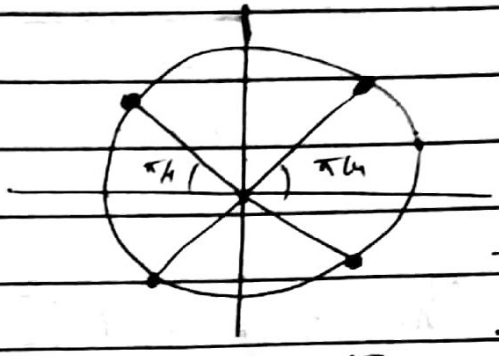
Digital Signals.

Aim:- Analog ← convert (MODEM)

Modulation techniques — Amplitude (1), Base (2), Freq (3).

If we have Digital to Digital modulation then we would have more quality. - No modulation.

QPSK
Quadrature Phase Shift Key

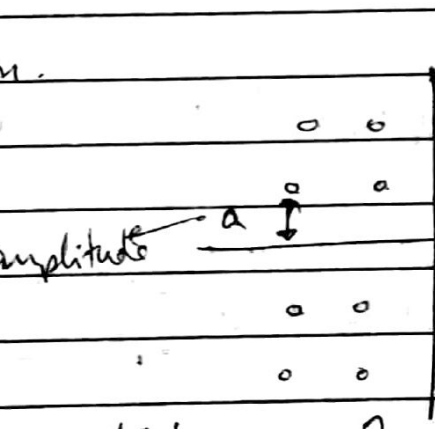


4 QPSK

π/4 QPSK

4 bits

QAM
modulation.



16 QAM

Each one 4 digital values

16 bits

we require distance?

$$d = a(2i - k + 1) + a(2j - k + 1)$$

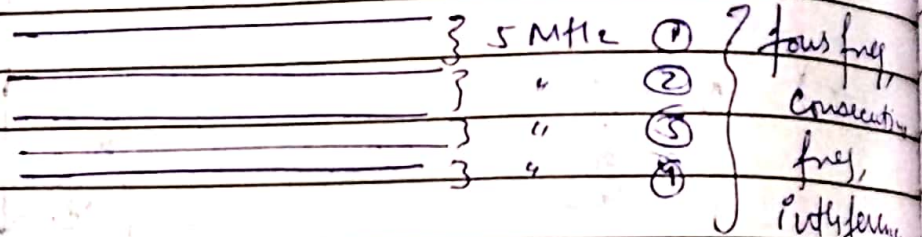
(y axis value, x-axis value)

$$k = \sqrt{m} = \sqrt{16} = 4$$

Cellular n/w → all airtels vodafone, BSNL, what technologies are they using? QPSK, QAM...

g) CDMA v/s FDMA ?

4) OFDM : Orthogonal freq. DM.



In Phy layer - BW - Hz.
Data link / N/w - bps

we need orthogonal freq : OFDM
used for wireless n/w

Suppose we have 4 users, CDMA v/s FDMA ?

f) TDMA - div. into time slots (4)

20 MHz

div. freq by the no. of users.

4 channels

to min. the interference.

every user send data in their own time slots.

both TD / FD has its own drawback

Carries Sense Multiple Access.

CSMA back off time ?

Common shared medium → 4 nodes if access at same time collision can occur.

Detect collision.

Avoid collision.

Back off : whenever collision occurs, those nodes go to back off time.

↳ if those nodes have same back off time, collision will occur again.

Node with min. back off time will go early

Expoential back off time. — whenever it reaches max — it starts with initial value. (min.)

LTE Frame : 10 msec. → div. into 10 (1msec) sub frames

4G + LTE → both available.

1 sub frame → 2 slots (.5msec)

pt. to pt. communication : are req. to maintain frames

7 OFDM symbols → 1 sub frame (: 1 slot)

(0.6) short cyclic prefix.

802 frame : | preamble | Src MAC add. | Dest MAC add | Data IP Page payload |

wh + LTE

LTE → designing wst. time frame.

① Each frame : 10 msec

⑩ subframes : 1 msec.

② slot : .5 msec

⑥-⑦ OFDM symbols

Phy. Resource Blocks (PRB) — 12 consecutive sub carriers

(6/7) symbols × 12 subcarriers (15kHz BW. - 1 slot)

diagram Each cell : resource element

⑦ OFDM symbols : 2 slots : 1 sub frame : 12 subcarriers

[R] → Reference symbol.

Imp ① Pt. to Pt. connec. : we need frame.
② Construction of frame.

Digital data → Contruct frame → remove header → get IP layer / MAC layer → fragmentation

Cellular technology - 1G, 2G, 2.5G, 3G, 4G, 4G + LTE (3G + LTE = 4G)

8) LTE structure.
9) 5G → diff. from 1G, 2G ... .

Date
Page

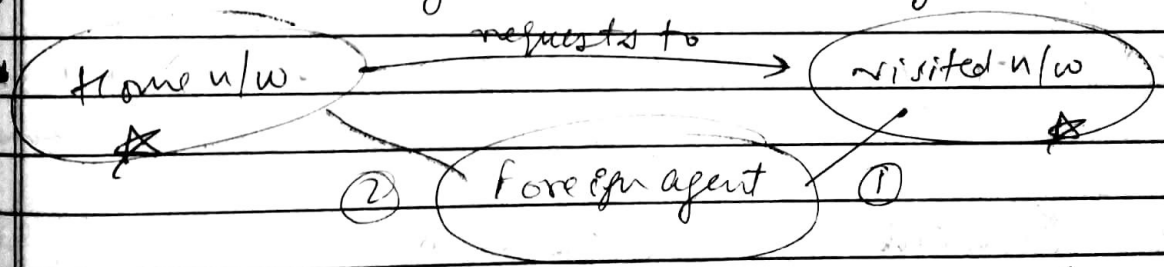
Mobile Wireless N/W:

Mobility - No, high, medium.

While driving → cell battery dries out faster?
↳ due to mobility → constantly cell tower finds your location.
Static state : periodically update location
Mobility : faster " "

Home n/w : India.
No roaming charges now a days. - Foreign agent
(1 Nation = 1 Call)

indirect routing ↔ direct routing



Home Agent
Foreign Agent
} Terminologies

WIRELESS NETWORKS

Trans-receives : Transmit as well as receive.
↳ Eg: Mobile.

① To communicate : 2 devices should contain transmitter / receives.
② Signals reach receiver → when both devices are in same freq. and are in same region : transmitter in range of receives and receives in range of transmitters.

→ RFID : Radio Freq. ID — In shopping malls, tags → which are removed when purchased. ↓ big stands means the fate.

→ MACAW
multiple access carries — —

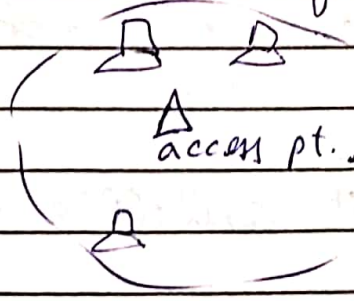
→ DIFS, SIFS, TIFS, RIFS

LAN, WLAN, WSN
wireless sensor n/w

→ 802.3 ⇒ family. Ethernet (LAN) (CD)
→ .11 a/b/g/n → Wireless LAN, WiFi (CA).
→ .15.4 → WPAN : ZigBee
lower data rates — lower powes.
→ Bluetooth → TDMA

→ WBAN → Body Area N/w. → WBASN
sensor.

★ Elements of Wireless N/w



responsibility? → whenever it receives req, it creates an ethernet frame. (802.11 frame)
wireless
if wired: 802.3 frame.

802.2 : error detection and error control.

.4 — token bus
.5 — token ring
.11 — wireless LAN.
.15 — PAN
.16 — WiMAX — Accessing n/w (wireless metropolitan)
.17

IEEE 802.11 — Slide 12 — Important Qns
.11b — unlicensed bands — 2.4 GHz, 5 GHz
— all channels - orthogonal — no interference. (1) (2)

a and g separated

5 GHz | 2.4 GHz

have better data rate than b.

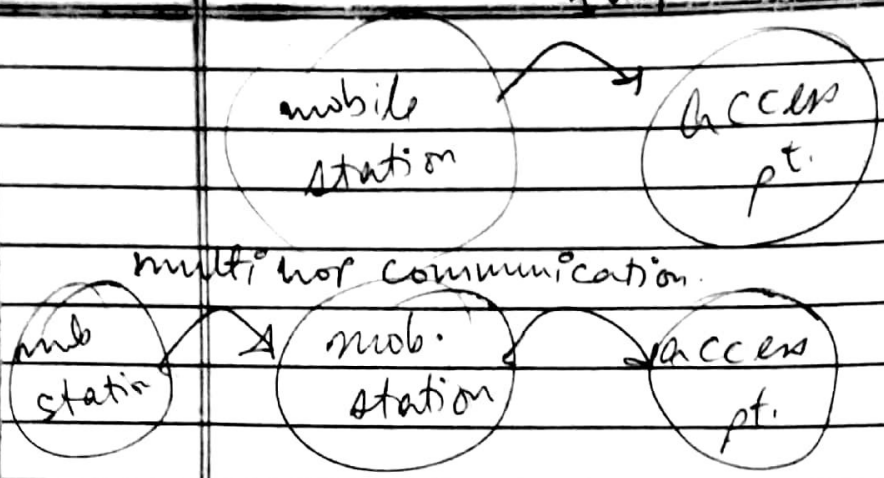
Mbps

Indoor | outdoor | Mid | Long

→ Decreased signal strength : Air : particles
obstacles.
as dis. ↑ → the strength ↓ (external noises)

→ Wifi → access pt. is reqd.
→ MANET → 2 devices → 1 access pt., 1 client
(peer to peer)

INTERNET OF VEHICLES — IOV
↳ Company will know about you.
↳ If car broken : but issue is privacy!



Bluetooth: 1 hop, no infrastructure is reqd
MANET / VANET → multi-hop.

Phy layer
- ~~Infrared~~
- FHSS
- DSSS
- OFDM
- HR-DSSS - High Rate - Direct
- OFDM

lower bound

802.11 Structure - Slide 24

Architecture of MAC.
(Slide 40 future)
- Point - PCF - Infrastructure based
- Distributed - DCF - Infrastructureless
- → Phy layer - SDM.

802.11 MAC frame Format.

BSS → Basic Service set : Each of it has 1 access pt.

management fun
1. Channel, find it
2. If not available, go for scan.

Login

User Authentication & Assoc.

Beacon management → how is it (pc) going to connect to wifi?

Power management

↳ ① scan for available wifis.

(Howscan is possible)

② select one (AP)

Laptop broadcasts the message → "who are near me"?

AP → will respond to this message - "I'm here"

(Beacon frames)

firewall : ms connection page → automatically appears

power saving mode : disables that =)

: 2.4 GHz - 2.48 GHz : upper bound

11 channels

Only 3 are able to use at a time

non-overlapping channels.

Why not more than 3?

↳ there are overlapping channels → interference

C. Mode 38 (same colour → at one time)

↓

others are overlapping.

Passive / Active Scanning.

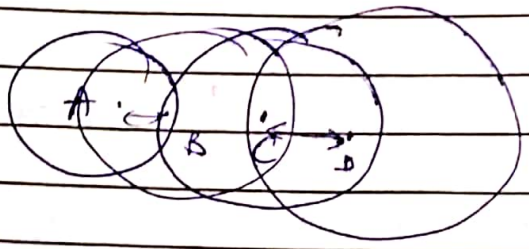
A is hidden node to C. (B-C) Interacting

(A) wants to send to (B)

↳ common node

Whenever (A) starts transmission → Collision happens

→ Exposed station problem.



A – B are communicating
C – D → wants to communicate, is there a problem?
↓
not possible, because they are exposed nodes to A – B communication, so they won't communicate.

slide 53

20/4/19

→ RTS – CTS
|
Ready to Send clear to send

Collision Avoidence mechanism.

CD → possible full duplex method

WIFI → ~~mostly~~ half duplex → CA.

→ If any node wants to send – first they send RTS pkt.
→ If collision → back off time → both nodes (exponential)
A and B → hidden nodes → in G/w they is AP.
↓ ↓
sends CTS pkt to both A and B

CA

NAV defes.

RTS - 20B

CTS - 12 B

MPDU → max. pkt data unit : 2300 B

DIFS time → RTS pkt.

data

SIFS

ack

CTS pkt.

+NAV = time

Cellulas - Hexagonal structure ?

- 1G, 2G, 2.5G, 3G, 4G
- Wireless N/w - Phy. layers prop - OFDM (F)
- modulation techniques BPSK (F)
- antenna prop. - 3 types
  - unidirec
  - bidirec
  - omnidirec.

Phy prop of wireless - freq ✓ ✓
- Bands - 2.4, 5 GHz
- licensed spectrums (5) 9 MHz below
- unlicensed spectrums - medicinal (ISM) industrial scientific purpose.

Mobile Phone - check wireless prop.
(some versions use 2.4 GHz others use 5 GHz.

Now a days, more than ISM applns. are using these bands only!

By end of 2020, it is expected that each person will have more than 20 sensors!

WSN, Adhoc, Underwater Aquatic Sensors, Nano sensors (n/ws), Body Area Sensors.

Date
Page

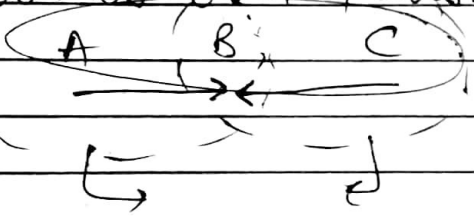
All are n/ws (wireless) – where is the difference?
↳ n/w structure pt. of view, they are different
↳ n/w device " " " " "

802.11 → CSMA/CA

Ethernet → CD
why CD is not in wireless? CA is used.

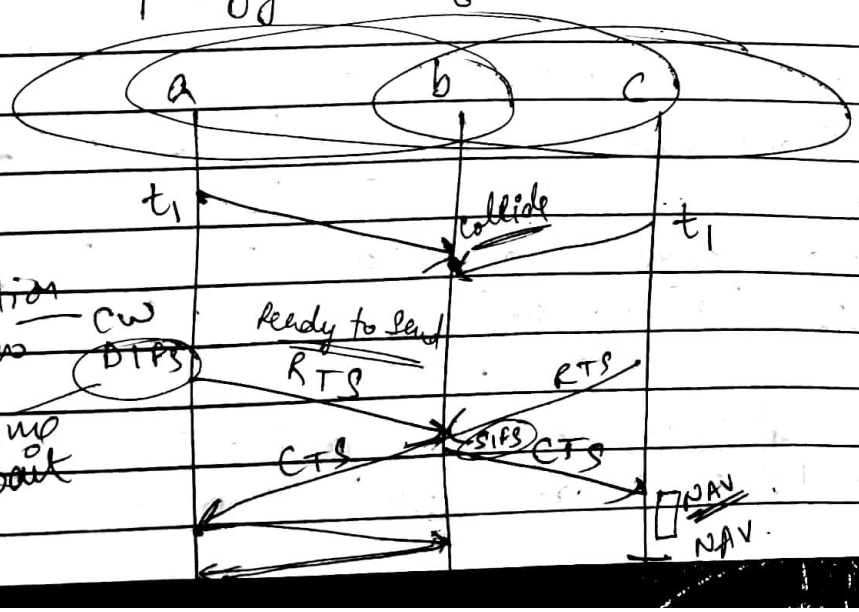
Wired tech. → full duplex

half duplex mechanism, every node has its own transmission rate,



A and C are not able to transmit with each other → hidden
→ from B, both A and C are recognizable

we can't say what topology is it? – in wireless it is not possible.



hidden terminal problem

Pkt drop → retransmit.

Date
Page

If a and b are transmitting, c doesn't know about that, so c can transmit the data.

Use contention window:

whenever trans. occurs, wait till IFS.

DIFS — Frame Services.
SIFS
PIFS etc.

802.11 → Distributed Coordination Function (DCF)
→ pt. to CF (PCF)

Both 'a' and 'c' sends RTS pkt, both have to wait.
SIFS time is over, then both will receive CTS pkt (Clear to Send)

NAV → Network Allocation Vector.

'b' will send 'c' a time till which it needs to wait so that 'a' and 'b' can communicate with each other.
'c' will not comm. with 'b' till NAV time is over. ('c' will not interfere for NAV time) After NAV time, 'c' will send pkt (RTS).

if 'a', 'b' are communicating, is there any problem with 'c', 'd' communication ?

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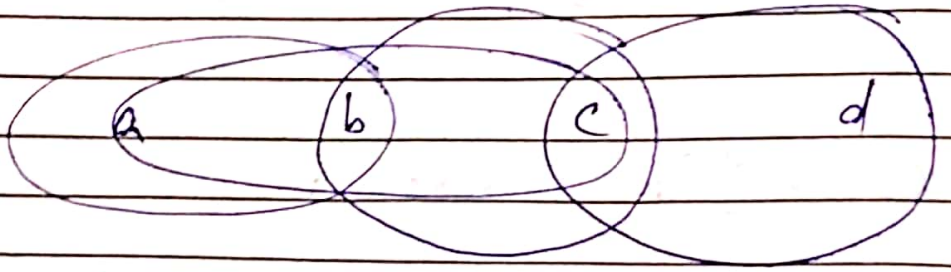
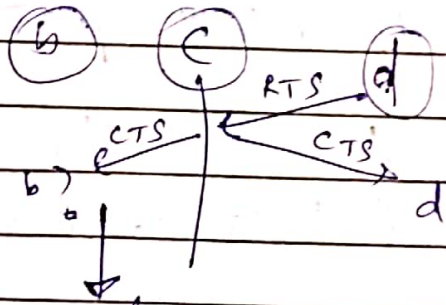
Exposed terminal problem :-



wrt. 'c', 'b' and 'd' are hidden nodes.
'c' will not communicate with 'd'.
c :- (avoid other comm. th.)



b is already in communication so it will collide

Multi° Radio - Multi° Channel

MIMO - Multiple Input Output.

Wireless

Phy layer, MAC layer
(8.2.11)

Q/ Why sensors are imp. to us?

→ AC - switches off as it reaches the reqd. degree.
→ fire detection
→ Smart City

Sensors - tiny device. RO, Kent: pH measurement
(Environmental, traffic based, etc...
sensor is inside.

Process the signal ⇒ provide info to sensor
(cycle)

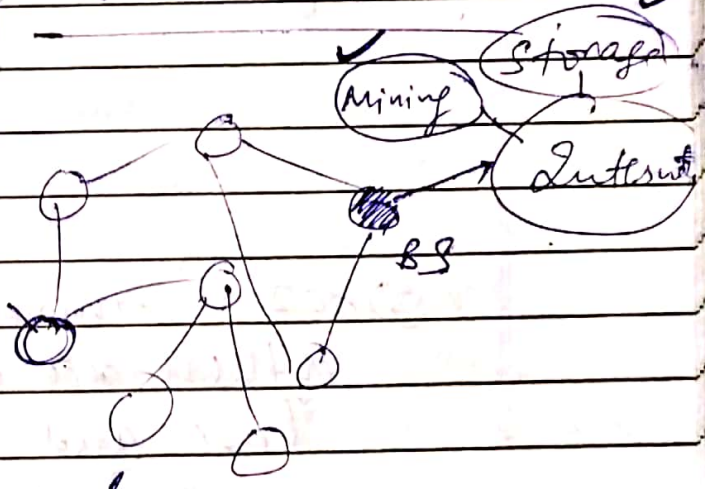
Large no. of sensors will provide more accurate info. → avg.

Sensors
Active Passive.

Eg: smoke sensors.

→ Weather report →

heat wave in Rajasthan



Mining and Storage → Exp.
(last 100 yrs. of the data, similar heat wave) : - Deep learning

(WSN)

Sensor n/w → diff. components ? - Sensor
- RS
- Internet
- Analysis - Processing
- Mining - Storage

⇒ IOT v/s WSN
↓ superset ↓ subset of IOT (Applⁿ.)
↓ internet is necessary ↓ internet is optional

Slide 11 Sensors → battery powered device - energy constrained sensors.
(very small devices)

2 types of MAC : 802.11 → 100m. → it requires ① more energy
- 802.15.4 → 10m. not more than that.
↓
it is more used. why?
② more problems of hidden terminals in 11 than 15.4.
③ 802.11 → most of these die very soon. (use and throw). - save energy to make battery life more - 15.4

Small energy (eg li

Challenges in WSN : Energy

$E_{CPU} = E_{switch} + E_{leakage}$

Layer wise how much energy is used?

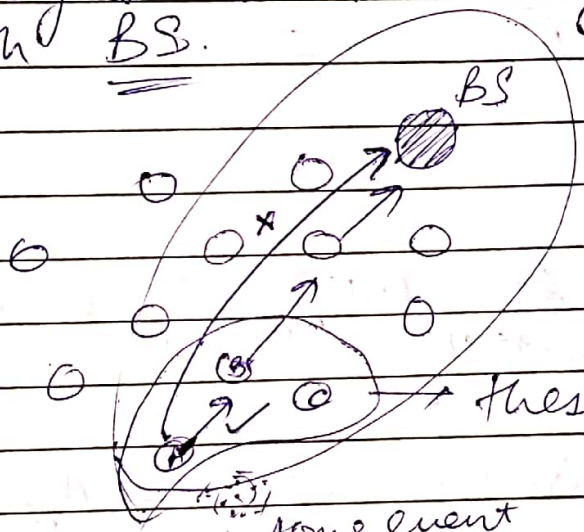
Token mechanism - Access internet or sit idle if you have token.

① Direct comm., ② Multi hop

→ Data distribution :

Cellular - 2 way → Sensor and BS - same range (or maybe more trans. range than sensor)
Radio - FM. → Direct. (one way comm.)

Every sensor is directly/indirectly able to communicate with BS.



→ these sensors detected the event.

if (A) has transmission range where (BS) is within it, then it will directly transmit to (BS). Where is the problem in this?
↳ not energy efficient. → ① device internal operational energy ② transmission and reception energy, (A) will die soon because it will transmit directly to (BS) → so multi hop is preferable here.

(small energy negligible)

(huge)
while transmitting, receiving requires less energy

Huge event → 100 sensors are giving/ sending info. to BS, 100 pkts are generated which will be processed, all those will die soon (sensors)

Data Aggregation → instead of 100 pkts, just send 1 pkt.

Routing for WSN.

Sensors:

✓ – Active State

/ – Sleep State : to save energy, if you don't have any

x – Idle State activity

Q) Why sensors is directly connec. to App. layer?

need to send some info. – digital info. formulate to some other place – comm. subsys (direct comm. – do not req. (hidden trans. layer)

trans. layer)

if every sensor is directly comm. with BS. → no trans. layer

pt. to pt. comm.

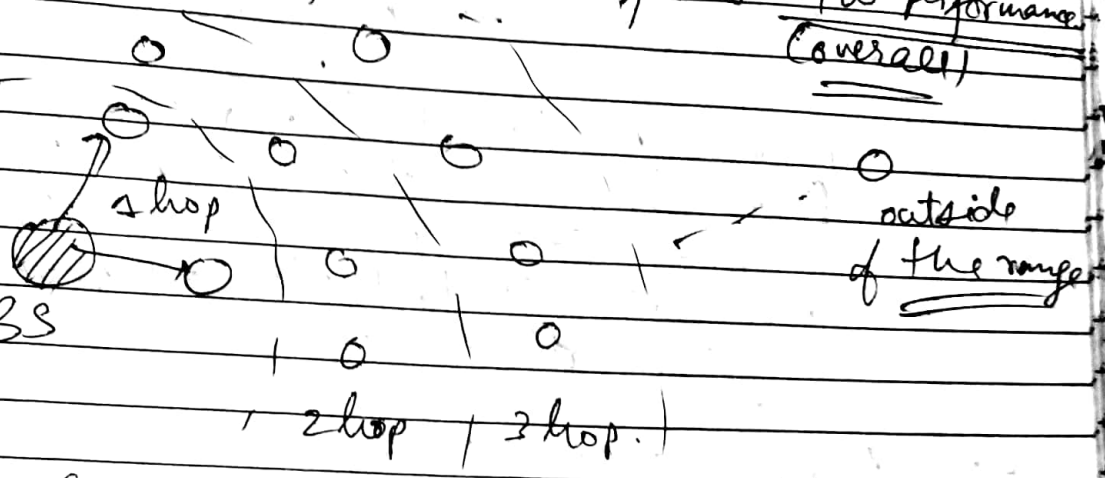
multi hop → trans. layer is req.

802.4, 802.15.4 } Content based MAC layer.

Content free → S-MAC, B-MAC

MAC layer

N/w layer performance – defines N/w performance (overall)



Deployment of sensors:

(1) Manually need to deploy

(2) Dropped in - deep forest - when manually can't be deployed.

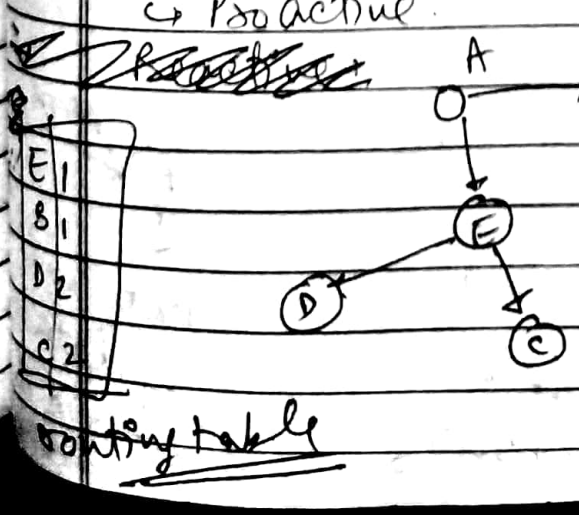
Far away sensors are not going to be in transmission range.

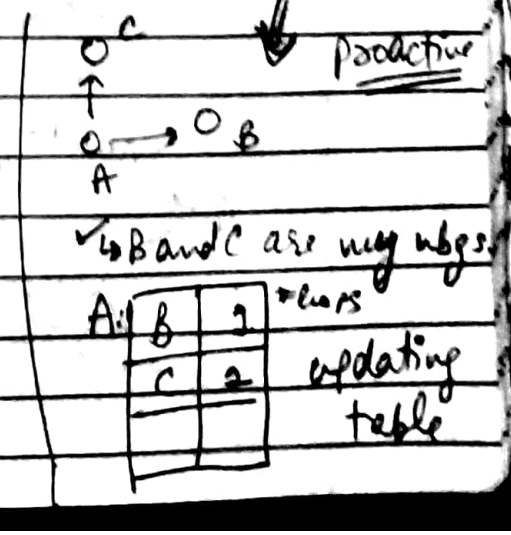
Upcoming Applications of sensor. Slide(green)

Blue slides : Properties.

→ Botocd Classification:

→ First compute all the routes → then route
↳ Proactive





Enquiries ĉ1

ADV, DATA, REQ : SPIN

Date
Page

↳ messages are sent in DD :
- Interest : only particular region user is interested (weather forecast.
- Data : need not involve all the nodes data
- Gradient
- Reinforcement

Hierarchical routing → LEACH
↳ CDMA / TDMA based MAC protocol

Clusters based protocol
↳ Deploy the sensors
↳ Dropping the sensors.

Rotation info.

How will you know the location? - GPS.
Stationary sensor nodes. - BS collected all nodes - remaining energy, location, data (sensors)

Clusters should not have heavy loaded clustes head!

Randomly select the clusters.

Periodically, we need to change clustes head.
→ Residual energy and
→ location.

How many clusters need to be form?

If an event happened → all nodes in the clusters send it to cluster head where data is aggregated and send to BS.

Cluster head will exhaust a significant energy - running data & then it will transmit data to BS which is far away, that the way, this cluster head will die soon, hence we will change cluster head based on residual energy and location.

↳ randomly select the new cluster head.

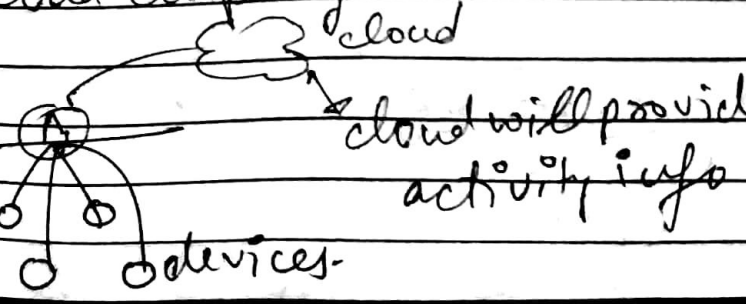
→ Maximum energy node has to selected as cluster head? → what is the problem with that.? → Depends on location as well! if max. energy node is far away from the rest of the nodes then not the optimal case.

exam

Routing for wireless sensor n/w?
Classification. (multiple)
- proactive, reactive, hybrid (topology based) n/w
- flat, hierarchical, loc based (n/w struct) - use
- (protocol op. based): DoS, Query, ---

IOT?

Apply layer concepts - will req. internet always.
cloud computing



NFV, SDN, cloud-RAN
distributed cloud.

Date
Page

→ Want to switch on the AC. → forgot to mention the temp°. → cloud will automatically take care of it and put the avg. temp°. that you are most likely to use.

↓

Cloud has to process that: time taking
↳ cached some of the processes → priority
↳ fog log → immediate response
↳ like cache (RAM).
and cloud → HD.

to send same time

SDN for Wifi?

Layerwise — Unified Control Plane.

(wiping) all H/W. devices connected (switch, routers...)

WiFi cellular Ad-hoc

If any req. is processed → pkt is fwd to first → controller → it will select the shortest path which is not much loaded. (view of n/w complete)

→ Data plane
→ Control Plane

n/w optimization

& computing layer

→ Horizontal Hand off → moving from one wifi to another.
→ Vertical Hand off. (when technology differs ie there, moving from wifi to wimax)

OFDM
Orthogonal freq - non-interfered freq.

Cognitive Radio Paradigms

Q) How many TV channels? - subscribe to channels but you may watch only 3-4 channels daily.

Under-utilisation
↳ most of the TV channels are under-utilised. → opportunistically, we need to utilize them
→ some bands are over utilised. - overlay, underlay
→ Vacant spectrums (white holes).

NCR
unlicensed bands: 2.4 GHz, 5 GHz

SDN
CDN
ICN
} next class

Day to day, new applications are growing, need more bands.

Min. interference with primary user: underlay

IoT devices directly comm. to Gateway & connect to cloud

fog computing
cache some responses (saves time)