

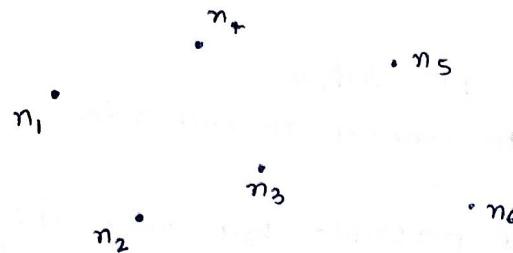
17th March (Ppt also)

host (receiving or sending but not forwarding)

router (receiving and forwarding)

Ad-hoc network

① MANET (Mobile Ad hoc network)



→ nodes and routers both present

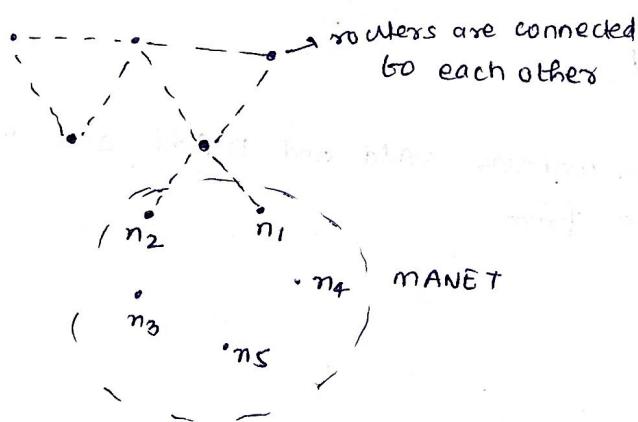
→ mobile nodes - constant speed

- stop for some time
(pause time)

- move in random direction

→ any node can work as host or a router

Mesh



Mesh routers → stationary nodes mostly

- connected to nearby routers wirelessly
- with each router a Ad-hoc network may be connected.

• 3G, 4G, 5G not involved in Adhoc

• To DS and from DS are 0 then its Ad-hoc

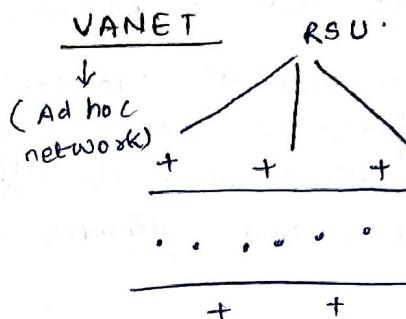


n_3 , n_4 can not send directly

→ so since n_1 is in range of n_3 , n_3 can send it to n_1 and then to n_2 and n_2 can forward it to n_4 .

n_4

Adhoc



RSU - Road side unit

- direction along road
- speed - high

Variation of MANET

• 2' way of communication:

① v2v (vehicle to vehicle)

② v2x (vehicle to roadside)

(possible one or two are connected to internet)

- nodes almost stationary (less motion)

- Act as routers of nodes
- find some value and pass to other
- Battery power

Adhoc Networks →

if the subnets are same, we have to forward (Routing) / broadcast)

→ There are different forms of Ad-hoc network (+ types)

- General Application of Ad-hoc network

- Some kind of 'Disasters'
- Infrastructure not working
- Situations where it's difficult to put Infra
- where two equipments wants to connect to each other.

Routing Protocols (There are around 40-50 protocols but only 4 have RPC)

→ DSR (Dynamic source Routing)

→ AODV (Adhoc on demand Distance Vector Routing) } for both we will be considering MANET

→ OLSR

→ TBRPS (Topology broadcast based on reverse path forwarding)

Two standard

- ① IEEE
- ② Internet engineering task force

We will be seeing DSR and AODV

* AODV

• Table driven (packet going out, packet contains s-Add and D-Add and during forwarding it reaches from - - - - -)

• source routing

* DSR

(contains the whole path, address of immediate nodes)

inside packet

→ proactive Routing

→ Reactive Routing (overhead reduces, delay increases) (No root)

* In wired, change of topology were very rare, but in Adhoc network, the root and topology changes frequently.

- If topology changes frequently overhead increases.

Reactive routing → "jab pyaa lagta kaha shuru kia"

- When packet received, reaction starts

AODV and DSR are both reactive routing

if node changes so does route changes
 (If route is not used in that time interval hence overhead is useless
 hence why overhead reduces in Reactive)

Ques- How does overhead reduce in Reactive?

Ans- In reactive routing nodes location frequently changes, and since the route is given beforehand. when sending packet if the route is not used in time interval the node location changes hence, its useless, the overhead is useless. Hence why overhead reduces but delay increases in Reactive Routing

- i)- Route discovery
- ii)- Route maintenance

DSR

1)- Route Discovery :- A node only try to find a route if it has same packet to send to destination and currently no known route to destination.

→ if a node has a packet P to send to destination

let 1 to 8.

i)- node(1) search its route cache. If route is present, send packet P to 8 through route.

ii)- if no route in route cache of 1.

Broadcast a Route request with unique id & DA
 $<1, 8, 42>$

iii)- A node which receive route request do following ↑
 - check if node already received same route request

Request - if so discard it

- if DA is own address of node then R-Request reached to target, send route reply

- if node has route to destination send Route Reply.

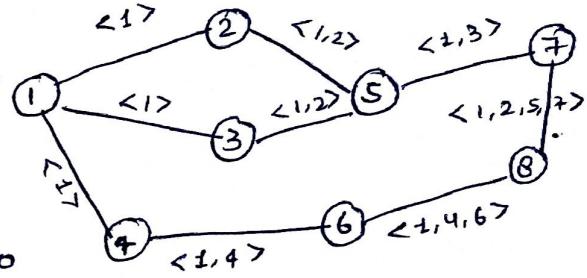
iv)- otherwise node append its own address to list of traversed nodes in packet + rebroadcast Route request.

$\langle R\text{-}Reply \rangle$
 $\langle 8, 7, 5, 3, 1 \rangle$
 unicast back

Route error msg

i^d
 $\langle 1, 8, 3, 4, 2 \rangle$

$\langle 1, 8, 3, 4, 4, 2 \rangle$. append its own address in
 t^d list



AODV: Ad hoc on Demand Distance vector Routing

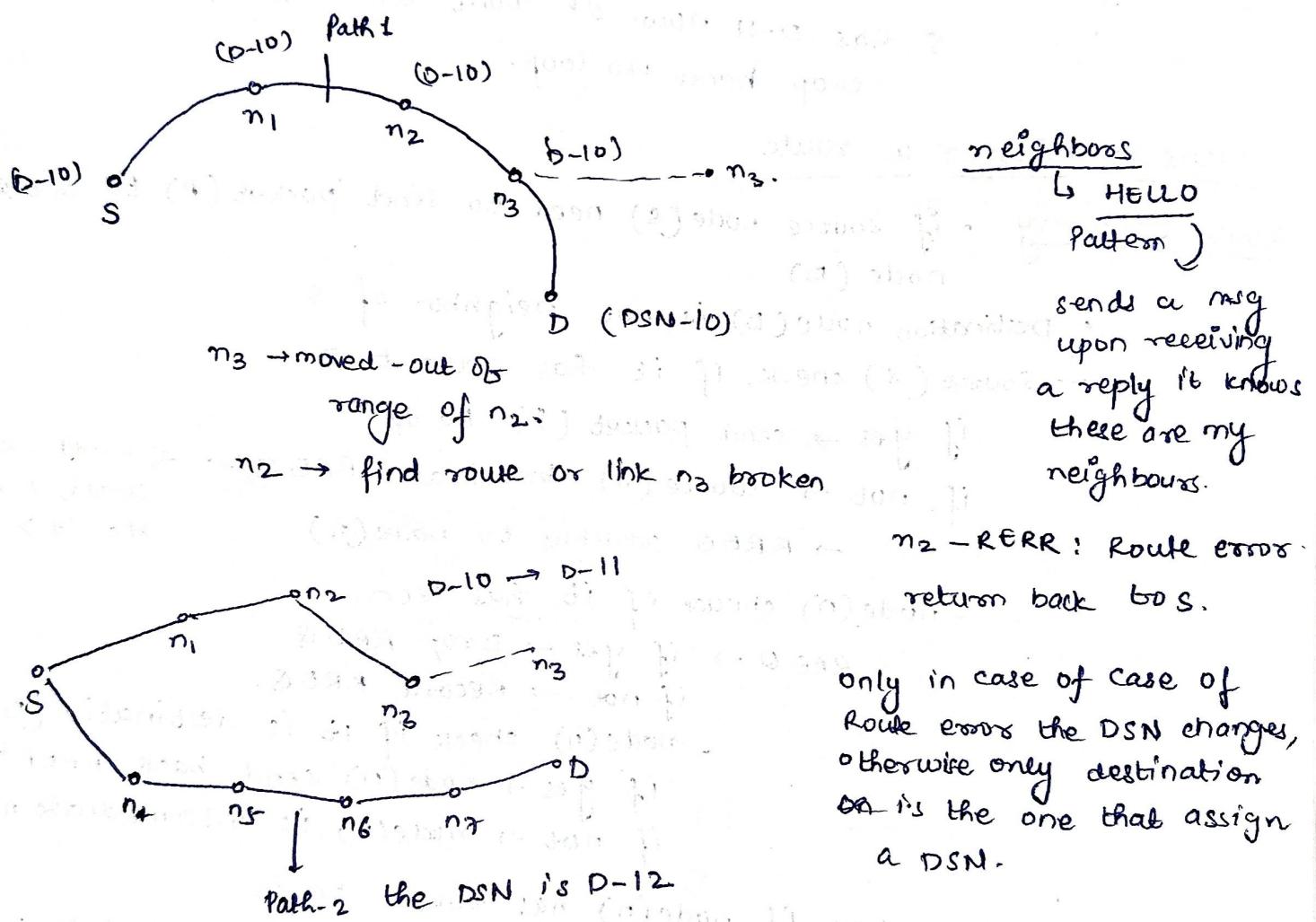
19 march

DSN - Destination sequence number

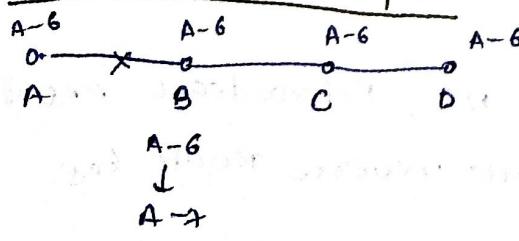
↓
To tell if a route is fresh or old.
And if the DSN is low then the route is invalid and it high then valid
(in case of 2 DSN)

→ contain only one route in route cache

- i) checks if the packet has already been seen or not upon receiving.
- ii) if a request that has already been processed is received. It drops the request.
- iii) To tell a route is new/fresh route DSN is used, DSN is assigned by the destination.
- iv) the one having the greater DSN is valid.
- v) Route request carries the DSN



How it avoids loops

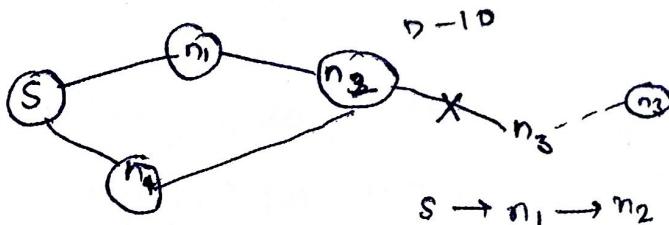


B notices route is broken and changes the DSN A-6 to A-7

now: if C → send A-6 - for node A

B → will ~~reject~~ reject it

Because A7 > A6.



$S \rightarrow n_1 \rightarrow n_2 \rightarrow n_3 \rightarrow D$ ($n_2 \rightarrow RERR$ to S)

if msg is last S will assume the route is working but n_2 knows that path is broken so it will send a new path to D so sends a request which is received by n_4 and n_4 sends it to S.

$n_2 \rightarrow$ RERR to S
↳ lost

$n_2 \rightarrow$ search new path for D
RREQ

S \rightarrow get RREQ from n_4

S \rightarrow RREP
↳ coop
 $n_2 \rightarrow n_1 \rightarrow S \rightarrow n_4 \rightarrow n_2$
 $n_2 \rightarrow n_4 \rightarrow S \rightarrow n_1 \rightarrow n_2$

DSN at n_2 = D-10

n_2 - link b/w n_3 broken so,

D-11

$n_2 \rightarrow$ RREQ

D-11

n_2 sends RREQ D-11.

S has D-11 now. It won't tell that if has a new loop hence NO loop.

Steps to discover a route

Route Discovery • If source node(S) need to send packet(P) to another node(D)

• Destination node(D) is not neighbor of S

- Source(S) check if it has route to D

if yes \rightarrow send packet(P) to D

if not \rightarrow source(S) broadcast RREQ \rightarrow < S-add, S-seqno, D-add, D-seqno, HC, id >

\rightarrow RREQ reaches to node(n)

- node(n) checks if it has seen

RREQ \rightarrow if yes \rightarrow Drop RREQ

if not \rightarrow Record RREQ,

- node(n) check if it is destination(D)

if yes \rightarrow node(n) send back RREP to S

if not \rightarrow node(n) is intermediate node

- check if node(n) has route to D

if yes \rightarrow node(n) send RREP to S + D both

if not \rightarrow node(n)

increases HC, Rebroadcast RREQ.

and route reverse route to S.

RREP

originator-add

Dest-add

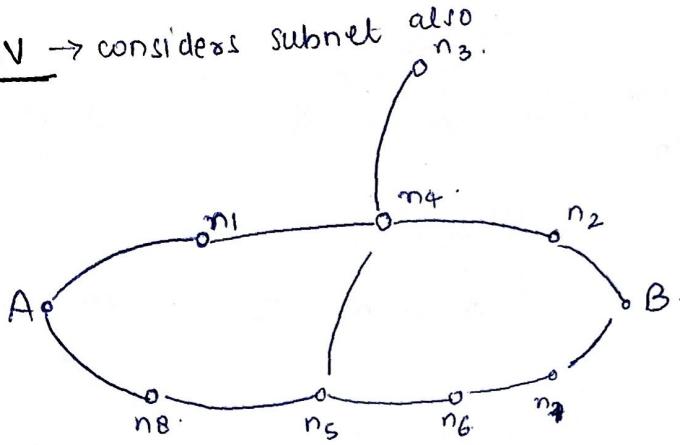
Dest-seq no

HC

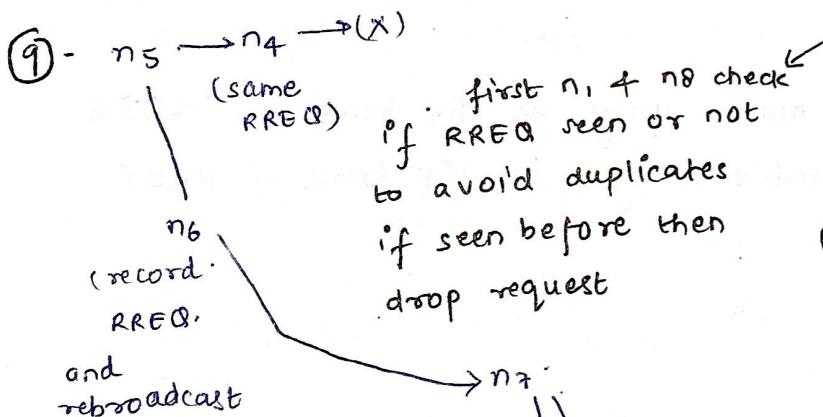
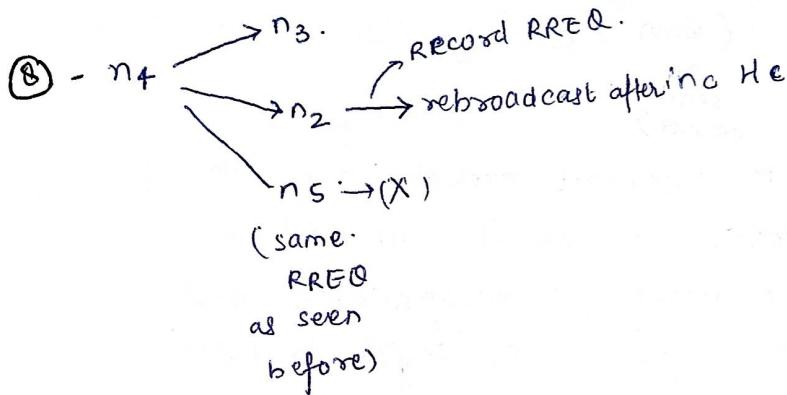
id

24/03/2025

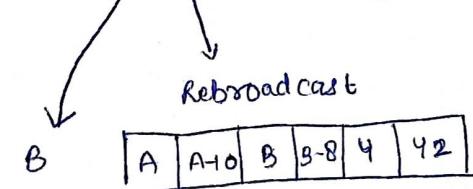
AODV → considers subnet also.



* A → originator (sending a route request)



| | | | | | |
|---|------|---|-----|---|----|
| A | A-10 | B | B-8 | 3 | 42 |
|---|------|---|-----|---|----|



⑩ - n₂ → B after inc HC → 4.
make _____

ns. rebroadcast

* At every node at the time of broadcasting a reverse route is also recorded for route reply.

P - packet

① A → B

(B is not neighbour of A)

② A → RREQ to B.

(UDP packet)

| | | | | | |
|----|----------|----|----------|----|----|
| A | A-10 | B | B-8 | 0 | 42 |
| SA | S-Seq no | DA | D-Seq no | HC | Id |

③ Broadcast by A and this RREQ reaches to neighbours of A

* (at the time of broadcasting packet is encapsulated with ethernet layer, link layer)

IP broadcast → 255.255.255.255

Hardware broadcast → ff:ff:ff:ff

④ RREQ → n₁ & n₈.

n₁ & n₈ → no route to B.

n₁, n₈ → Record route request

⑤ - n₁ → Rebroadcast RREQ.

| | | | | | |
|---|------|---|-----|---|----|
| A | A-10 | B | B-8 | 1 | 42 |
|---|------|---|-----|---|----|

⑥ - n₁ → RREQ → n₄

⑦ - n₄ → check RREQ → seen or not, record it

→ no route to B

→ rebroadcast RREQ after increasing HC = HC + 1

| | | | | | |
|---|------|---|-----|---|----|
| A | A-10 | B | B-8 | 2 | 42 |
|---|------|---|-----|---|----|

Reverse route at each node is recorded (Routing tables at each node)

n₁

| dest | nexthop | met | (DSN) | seq no | time |
|------|---------|-----|-------|--------|------|
| A | A | 1 | | A-10 | 10 |

n₈

| | | | | |
|---|---|---|------|----|
| A | A | 1 | A-10 | 10 |
|---|---|---|------|----|

n₅

n₄ Keep reverse route

| | | | | |
|---|----------------|---|------|----|
| A | n ₁ | 2 | A-10 | 10 |
|---|----------------|---|------|----|

n₆

| | | | | |
|---|----------------|---|------|-----|
| A | n ₅ | 3 | A-10 | 10. |
|---|----------------|---|------|-----|

n₂ reverse route

| | | | | |
|---|----------------|---|------|----|
| A | n ₄ | 3 | A-10 | 10 |
|---|----------------|---|------|----|

→ B
(when
n₂
send
packet)

| | | | | |
|---|----------------|---|------|----|
| A | n ₂ | 4 | A-10 | 50 |
|---|----------------|---|------|----|

- ⑪ - B → RREP to A. *(RREP → unicast packet in which if
↓
packet is sent it will add or

< originator, Add, dest-Add, dest seq no, HC=0, id >
UDP packet is encapsulated with
IP layer + link layer in which
S-IP → (B-IP)
B-IP → (A-IP)

Note - All intermediate node make entry at the time of RREQ
and RREP so routing table changes at the time of RREP.

⑫ at B

↗ greater sequence

| | | | | |
|---|---|------|---|----|
| A | B | B-12 | 0 | 42 |
|---|---|------|---|----|

B checks its routing table and send
packet to n₂

(reverse routing path)

- ⑬ at n₂ → check its routing table and send packet to n₄ and also
make a forward entry for this. also

| | | | | | |
|--------|---|---|------|---|----|
| RREP - | A | B | B-12 | 1 | 42 |
|--------|---|---|------|---|----|

↗ n₄

| | | | | | |
|----------------------|---|----------------|------|------|----|
| <u>n₂</u> | A | n ₄ | 3 | A-10 | 10 |
| B | B | 1 | B-12 | 50 | |

③ Now n_4 → checks its reverse routing path and sends packet to next hop n_1

| | | | | | |
|------|---|---|------|---|----|
| RREP | A | B | B-12 | 2 | 42 |
|------|---|---|------|---|----|

at $\underline{n_4}$ (Routing table)

A n_1 2 A-10 10

B n_2 2 B-12 50

④ Now n_1 → checks its reverse routing path and sends packet to next hop A.

| | | | | | |
|------|---|---|------|---|----|
| RREP | A | B | B-12 | 3 | 42 |
|------|---|---|------|---|----|

at $\underline{n_1}$ (Routing table)

A A 1 A-10 10

B n_4 3 B-12 50

⑤ Now A receive this packet and make entry for B.

A (Routing table)

B n_1 4 B-12 50

Case-II → Intermediate node have route to B.

A → B RREQ

+ n_4 has route to B.

(A → n_1 → n_4
RREQ RREQ (have route to B)

at $\underline{n_4}$

B n_2 2 B-10 50



> RREQ(B-8) (here B-10 > B-8
RREQ seq no have
it is valid state to send reply)

Now n_4 send reply to A (sends RREP) (* intermediate node send RREP to both source Add + dest Add)

• $n_4 \rightarrow A$

RREP:

| | | | | |
|---|---|------|------|----|
| A | B | B-10 | HC=2 | 42 |
|---|---|------|------|----|

• $n_4 \rightarrow B$ (Assume A fictitious RREQ from B to A)

RREP (B-9 A-12 seq)
seq check

| | | | | |
|---|---|------|------|------|
| A | B | B-10 | HC=2 | (42) |
|---|---|------|------|------|

RERR (Route maintenance)

RERR

$\rightarrow 2 \rightarrow \text{generate RERR}$

($DC = 2, 3, 3-11, D-11, D-10, D, D-10$)

Destination
unreachable
count

(node 2, change PSN
of unreachable node
and increase by 1)

RERR → (may be Broadcast or
unicast)

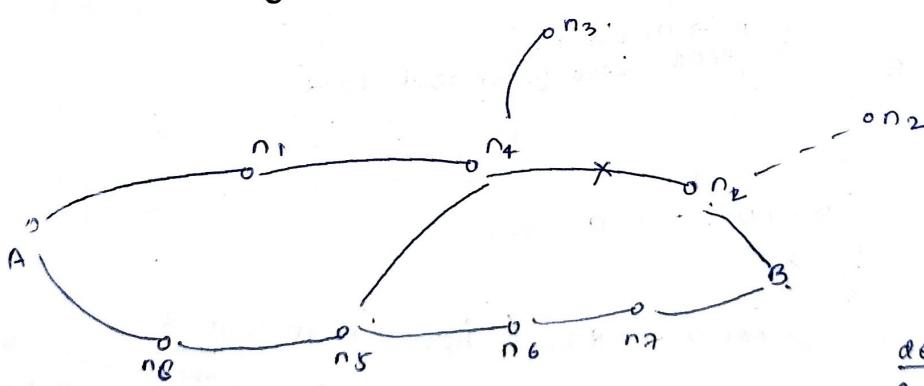
precursor node, or nodes.

A node maintains list of precursor
nodes that may be forwarding packet
on this route.

- List of precursors in a routing table
entry contains those neighbouring nodes
to which RREP forwarded or generated.

Now let us suppose in previous diagram if n_2 reaches move to another
location now generate RERR

for n_4 , ($n_1, n_3, n_5 \rightarrow$ precursor
node)



n_4 generate route go error
 $\rightarrow (DC = 2, 2, 2-11, 2-10, B, B-8)$

$\rightarrow (n_4 \text{ broadcast to } n_3, n_5, n_1)$

now n_3, n_5, n_1 delete entries for path B.

$n_5 \rightarrow n_8, n_6, n_8 \rightarrow A$

$\rightarrow n_1 \rightarrow A$

$\rightarrow 2 \rightarrow \text{generate RERR}$

$\rightarrow S \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow D$

but when 3 move to
different location

now $3 \rightarrow$ out of reach of 2

($2 \rightarrow$ routing table entry).

| dest | next | met | seq |
|------|------|-----|---------|
| D | 3 | 2 | D-10 50 |

(as 2 know that 3 is
unreachable and now 2 checks
its routing table and came
to know 3 is next hop of
D so, D is also
unreachable for 2.)

(more than one
precursor node
so RERR will
be broadcasted.)

so all the node
receiving RERR will
delete entry to destination
from table).

Also entry of precursor node
is added to routing table.

* (Seq-no detection will)

26 March (RPL side notes)

UDP - Packet loss is not an issue in UDP.

TCP → Packet loss wireless link

- bit errors on wireless medium
- mobility

TCP deal with

Packet loss:- Detect via - time out, no Ack.

- goes to slow start

Assume congestion

- unable to find loss is -

- due to congestion

- due to bit errors on wireless medium

- due to mobility

(TCP "day
read
amount")

" Read PPT + side Notes
for Tuesday
TCP."

Socket Transfers in I-TCP

CN → FA (AP) → MN

< MN-IP, MN-P, CN-IP, CN-P >

< FA-IP, FA-P, MN-IP, MN-P >

PA2 → FA2

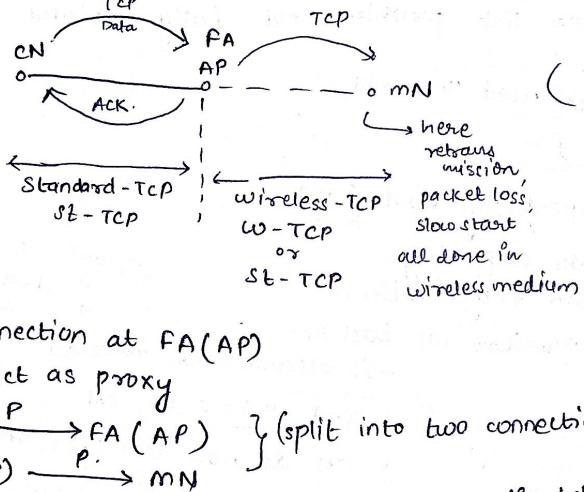
as it is transferred
to FA2 when MN moves

to FA2

Result - performance degrade

Cannot change - TCP - because of large installation base

I-TCP
(Indirect TCP) //

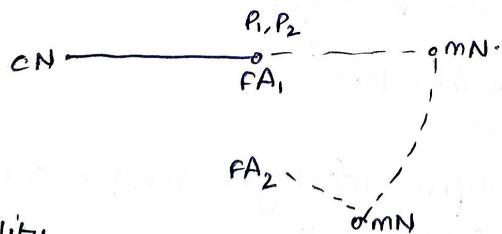


(TCP connection is established b/w CN & MN which is virtual and we split connection at AP.)

→ There is a violation of end-to-end connectivity because acknowledgement is sent by AP not MN (where packet actually need to sent) and on the behalf of MN all packets.

- FA (AP) buffer packet, send Ack to CN, now forward buffered packet to MN & Receive Ack from MN.

II.

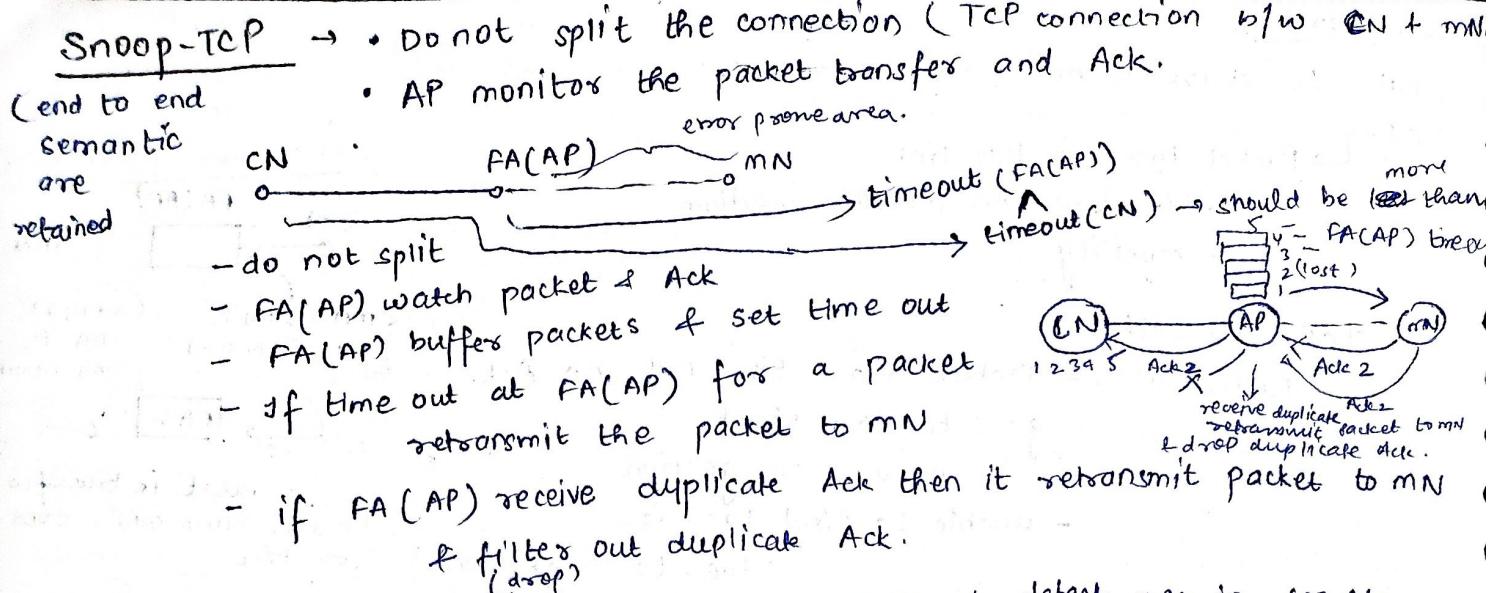


* chances of AP crashing can lead to permanent loss of data.

Mobility

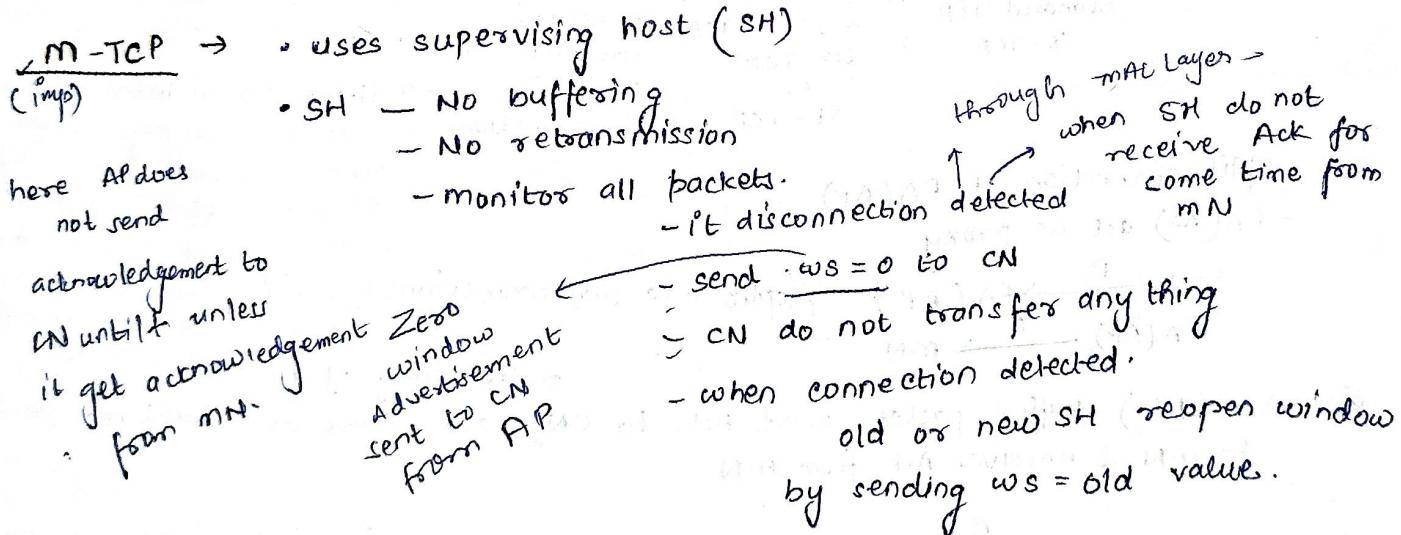
- MN moves from FA₁ to FA₂
- FA₁ received packet P₁, P₂ & Ack send to CN
- Now FA₁ unable to send packet to MN
- when MN register with FA₂
- FA₂ can inform FA₁ for location update of MN
- FA₁ transmit P₁, P₂ to FA₂

- socket transfer from FA₁ to FA₂ to maintain TCP connection.



MN to CN - FA(AP) snoop packet stream & detect gap in seq. No.
send N-Ack to MN & MN retransmit missing packet.

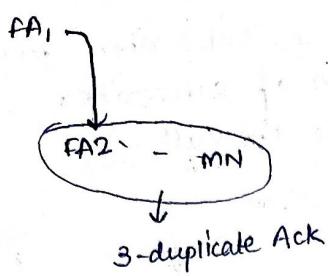
- Adv → E-T-E connection
- disadv
- NO handovers of state on change of FA
 - wireless link problems not fully isolated from wired link
 - N-Ack need on MN.
- { disadvantage of indirect TCP. }



Transmission / Time out freezing:

- mobile host drive into tunnel
- cross layer
- MAC layer inform TCP layer about interruption
- TCP freeze current state
 - timer & congestion window
- when MAC layer detect connection Again it inform TCP
- TCP resume connection from same point.

- Fast retransmit / Fast recovery



* hold or last acknowledgement at AP is used to send ZW ACK to CN if there is chances of disconnection.

- Selective Repeat

T-TCP - Transaction Oriented TCP.

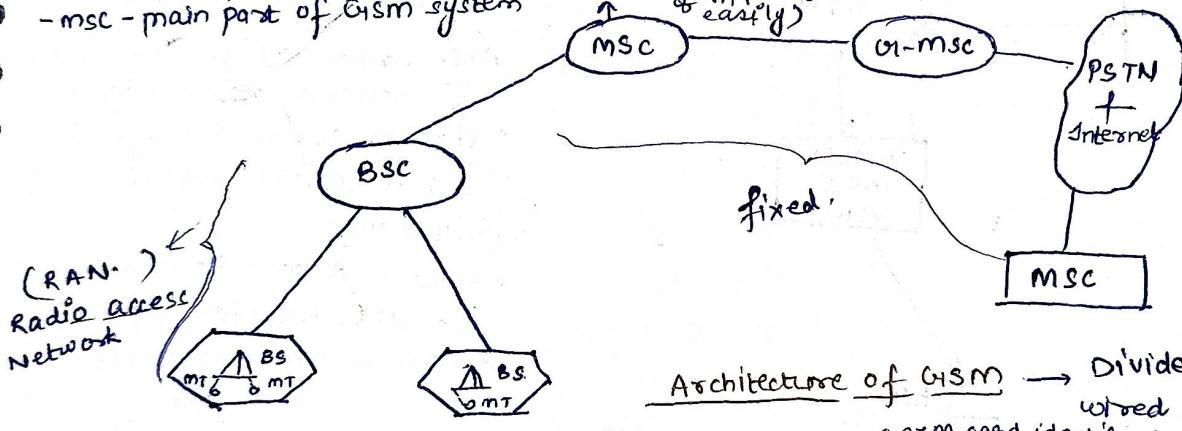
- connection setup & break
- ↓
- 7 packets → 2 to 3 packets.

2/04/2025 (unseen - edition 1)
(in edition 0)

GSM 2G, 3G → Global System for mobile communication

- certain no. of Base Station are connected to BSC.
- msc - main part of GSM system

(should know the exact locations & MT so that can route call easily)



BS — Base station

BSC — Base Station Controller

MSC — mobile service switching centre

G1-mSC — Gateway mSC — we will refer it as home MSC.

(related to concept of Home network)

Architecture of GSM → Divided into two parts wired & wireless.

(SIM card identify by this number)

SIM, ISM → identification

Home PLMN → Home public land mobile network

Visited PLMN → Visited Network.

MSC → - Contain several BSC

↓
(keep locations)

- Connecting all connections upto MT control

- Database Integration < HLR } databases, vLR } present at msc

- Call forwarding

- location management

- registration of MT with msc (this info use in call for warding)

- forwarding reg information to home network.

→ SIM card attached with ISM number and registered with locality called as home network

HLR → database at home msc (G1-msc)

- Home Location Register

- Permanent Phone number of subscriber & subscriber profile.

- information about current location of subscriber

- address of visited network to route the call

(msc contain
VLR)

VLR → Visitor Location Register

- database at visited msc

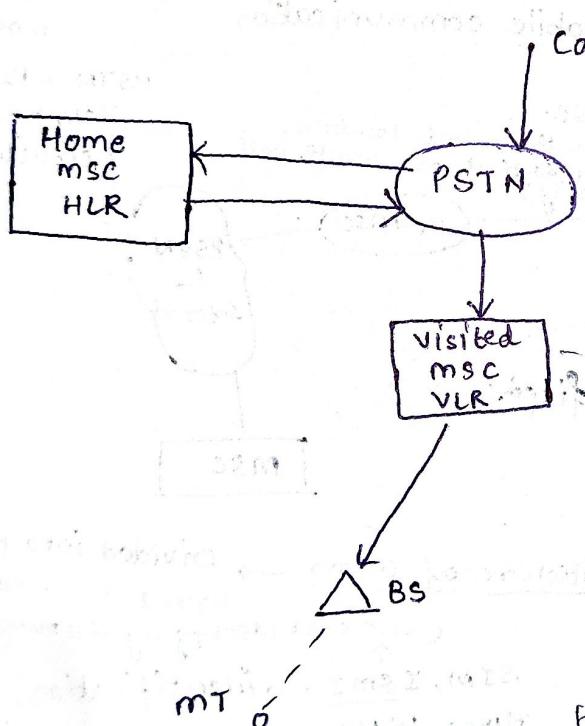
- contain entry for each mobile user currently in the network served by VLR (present with particular msc)

- VLR entry come & go as mobile users come & go

(Dynamic database) - VLR is usually co-located with visited msc.

* Call Forwarding (in 2G networks)

3G networks



How HLR get Roaming numbers? or VLR add.

- when MT goes to visited network covered by VLR
- through signal exchange b/w MT & VLR. MT registers with visited msc.
- Now VLR send location update to HLR, location update contain - roaming numbers or VLR add

• VLR get info at subscriber from HLR.

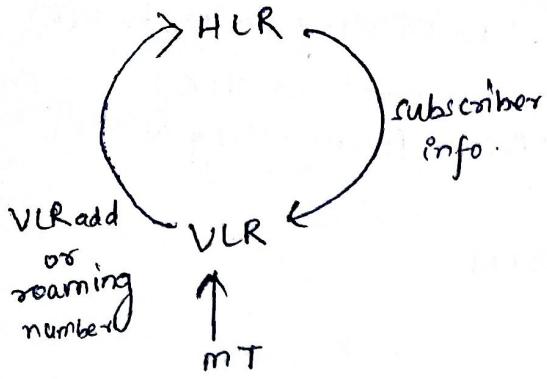
1- Correspondent dial MT permanent number, Through permanent number call goes to Home msc (G1-msc) via PSTN.

2- Home msc (G1-msc) receive call - querying to HLR to find location of MT.

3- HLR return - address of VLR - if G1-msc get address of VLR - it obtain roaming number from roaming numbers (not visible to user) VLR

to Home msc (G1-msc)

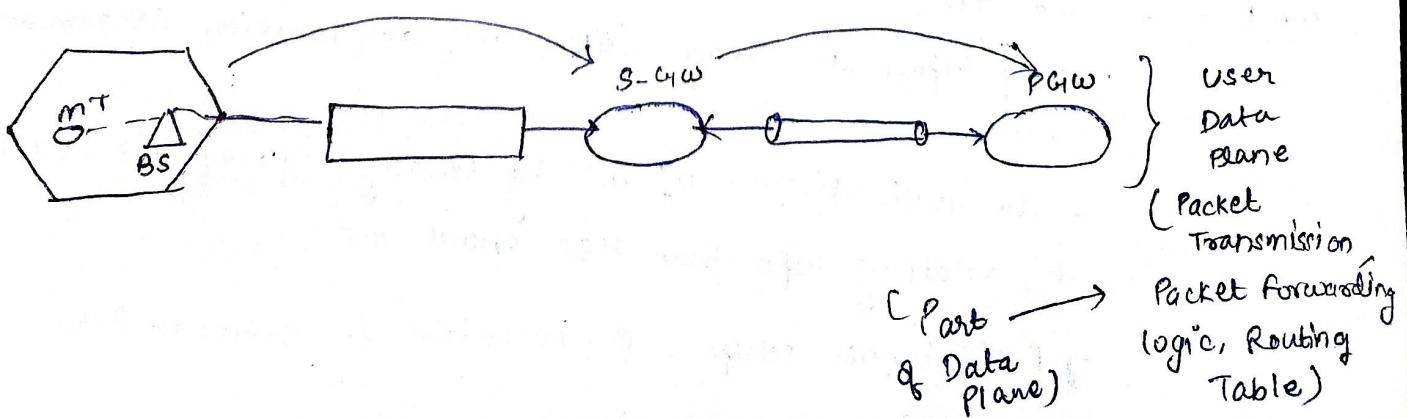
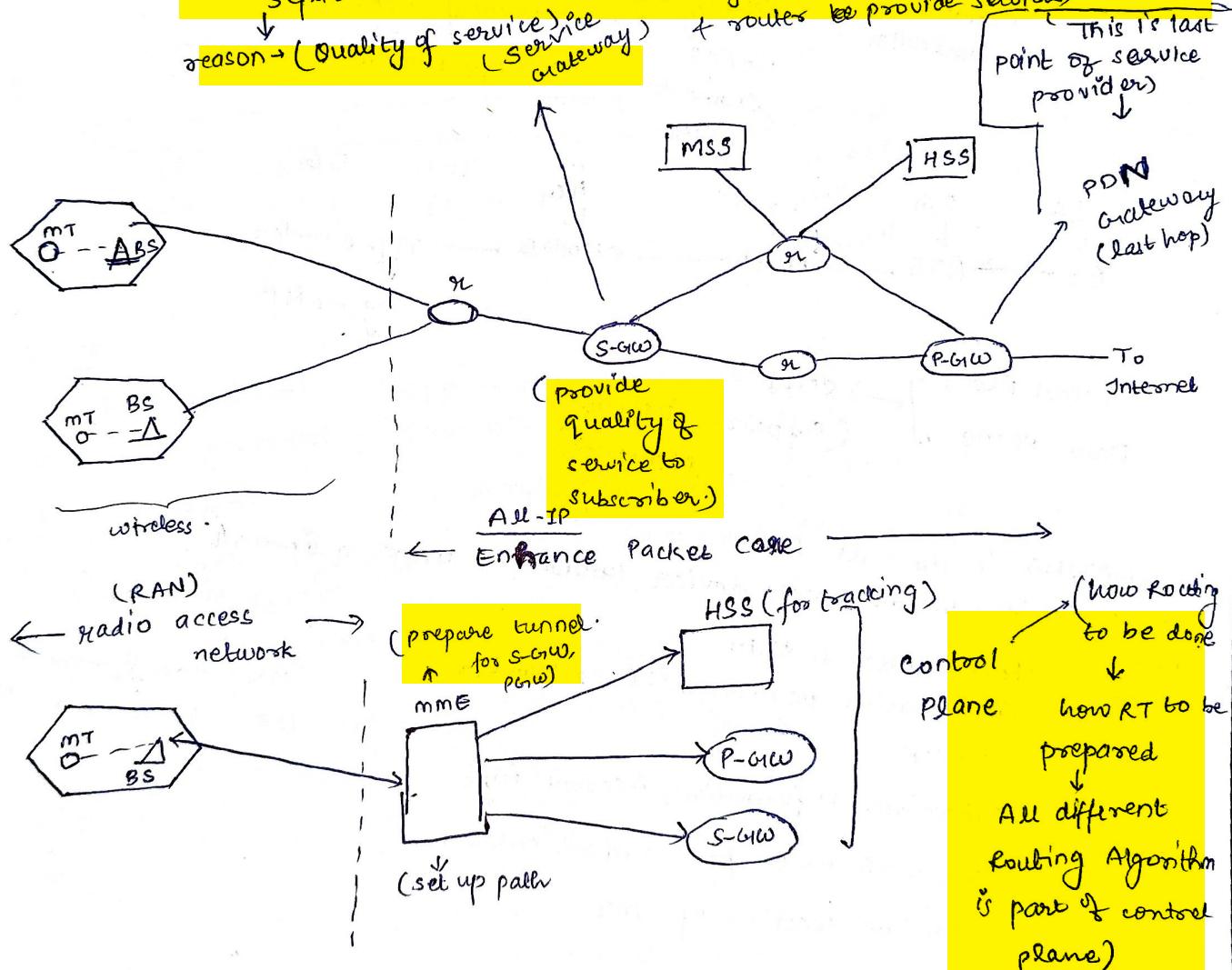
4- Home msc (G1-msc) set up second leg of call to visited msc. Visited msc transfers call to BS serving MT.



7/04/2025

4G - LTE

Data Transmission and call forwarding (voice call) done on separate tunnels? → It goes to internet keeping requirement
 reason → (Quality of service) (Service gateway) + routers to provide services



GPRS → Generalised Packet Radio Service

HSS → Home subscriber server/service → (functionality similar to HLR)

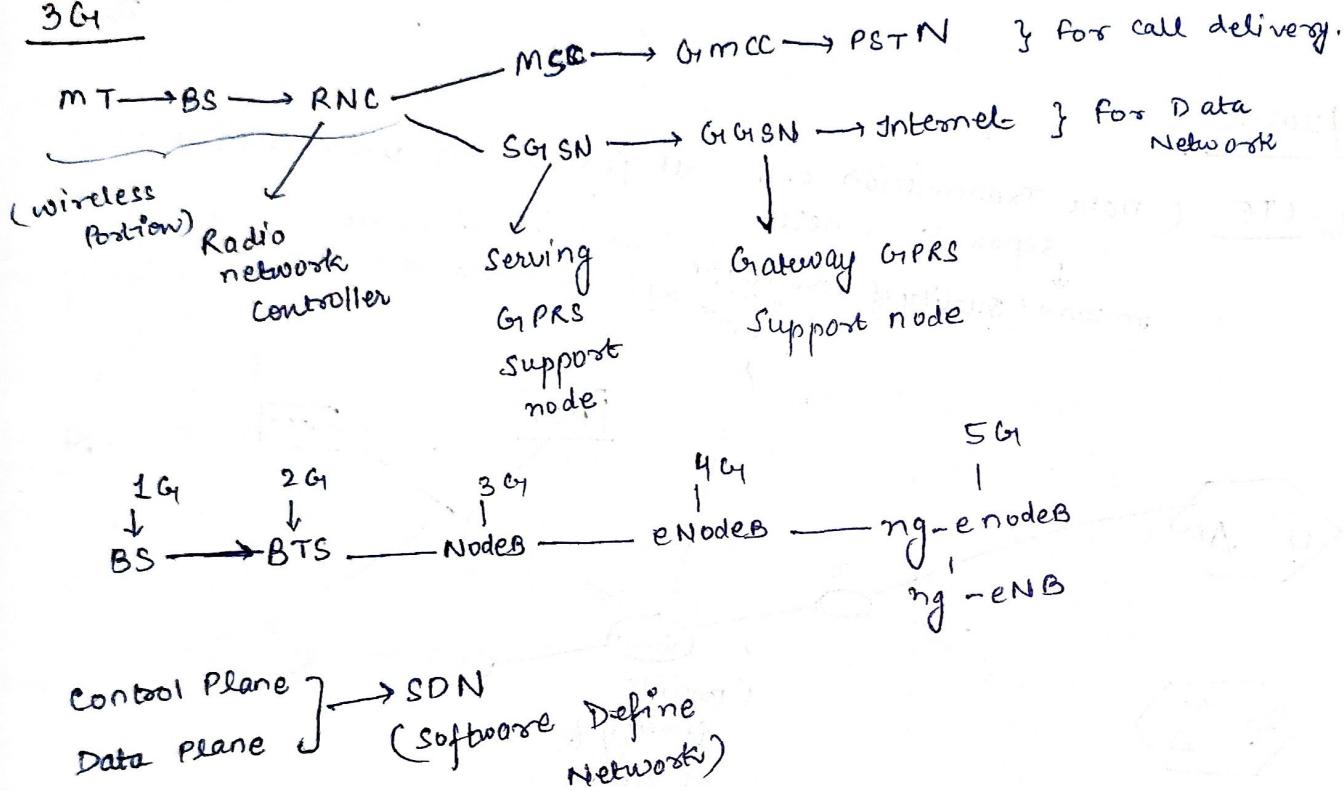
MME → mobility Management Entity (it is related to VLR)

Similar functionality as VLR

2G

MT → BS → BSC → MSC → GmSC → PSTN

3G



* NATING is done at P-GW

as user equipment

* In 4G, 5G mobile devices known as user equipment

HSS - store IMSI + SIM

information, permanent phone number

- like HLR

- subscriber information, account info

- use with MME for authentication

- contain location of MT

at some point

HSS - store dynamic entries

HLR - store static entries

MME - - like VLR

- keep information about visited MT, cell location in carrier's network

- do authentication of MT by sending info of MT to HSS
+ obtaining info from HSS about MT

- Path, tunnel setup - BS to S-GW + S-GW to P-GW

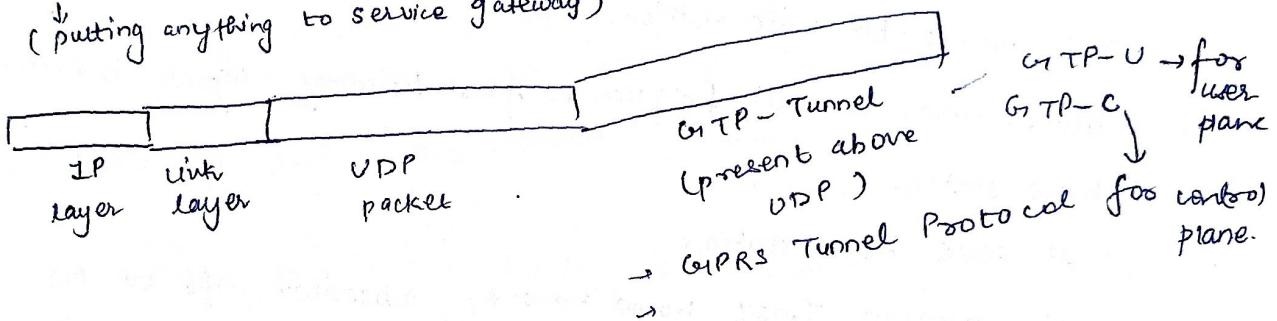
P-GW → (PPN-Gateway)

- Last LTE element that a datagram originating from mT encounters before entering to larger internet
- Provide NAT IP to mT & perform NAT functions.
- mobility of mT is hidden behind P-GW of cellular carrier.

S-GW

- control QoS
- manage local mobility when mT move among different Base stations
- Tunnel from BS to S-GW change as mT moves
- mME control this change of tunnel b/w S-GW & BS.
(putting anything to service gateway)

packet →



For voice

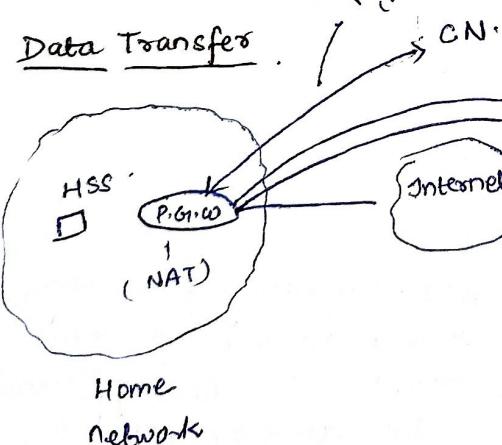
4G use RTP protocol
5G use SCTP protocol

SIP is also use by 4G, 5G.
(Session initiation Protocol)

For data transfer

TCP, UDP (Simple)
Public-IP (destination when NAT used)

* Triangular routing is used for Data Transfer + call transfers.



MT → IP,
Permanent
Phone no

PON will be able
to know for
whom this
packet is -

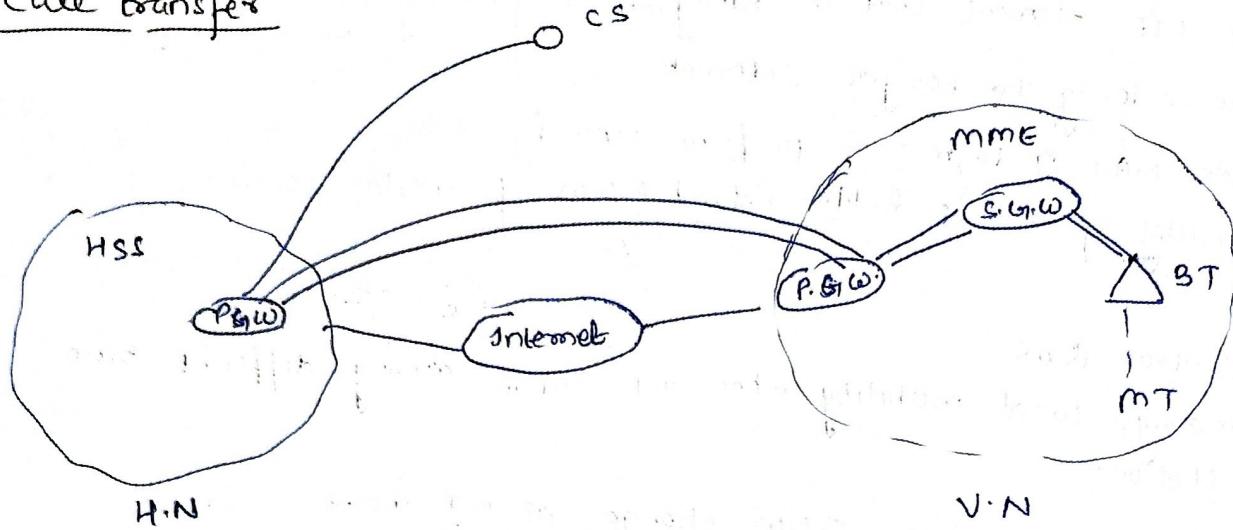
Public-IP)

(Separate Tunnel created to give ~~traffic~~ priority to
voice traffic.) within network.

priority

Answer to question 10: In visited network, separate tunnel is created to give priority to voice traffic.

Call transfer



Major steps

MT moves to base station.

- MS - listen to all frequencies for primary signal transmitted by base station.
- It selects base station.
- It provides IMSI, home network, subscriber info to BS

Associate with MME

- BS controls MME
- MME gets authentication & subscriber info from HSS
- MME authenticates MT
- MME informs HSS about MT
- MME configures tunnels.

09/04/2025

Hand-off

2G1, 3G1

(connection ongoing)

- during call when MT changes BS
- when signal strength deteriorates or when cell overloaded

- MT associated with BS1, finds signal strength of BS2 + signal strength of BS1
- if is sent to BS1 - 2 times in one second
- handoff indicated by BS1

BS1 → currently providing service to MT so BS2 decide either handoff should be done or not.

Things done during handoff:

i) - BS1 message to visited msc - Handoff to BS2 of mT

ii) - visited msc setup path to BS2 & inform
BS2 for handoff of MT.

iii) - BS2 allocate channel to mT and inform
(all main act done by BS2)
visited msc & BS1 about path setup &
information needed by mT to attach with
BS2

iv) - mT is informed by BS1 to perform
handoff to BS2

v) - mT & BS2 exchange message to activate new channel.

vi) - mT send handoff complete message to BS2 which is forwarded to
visited msc. Now visited msc start re-route call to mT via BS2.

vii) - Resources along path to BS1 released (channel or anything should be
released by BS1)

(within same BS) → mT handoff can happen if BS change

→ In only one Base Station
channel.

→ whatever is required for
mT to attach to BS2
inform by BS2.



→ channel change

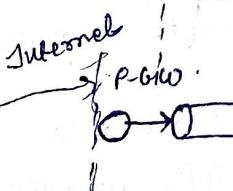


→ when signal strength decreases beyond minimum value (min-ss) then
call delivery is not possible. so either
call termination. ✓ (talk to
VLR and
all registration
done)
handoff.
location
management)

$$\rightarrow \boxed{\text{handoff value} > \text{min-ss}}$$

4G (Handoff)

EPC



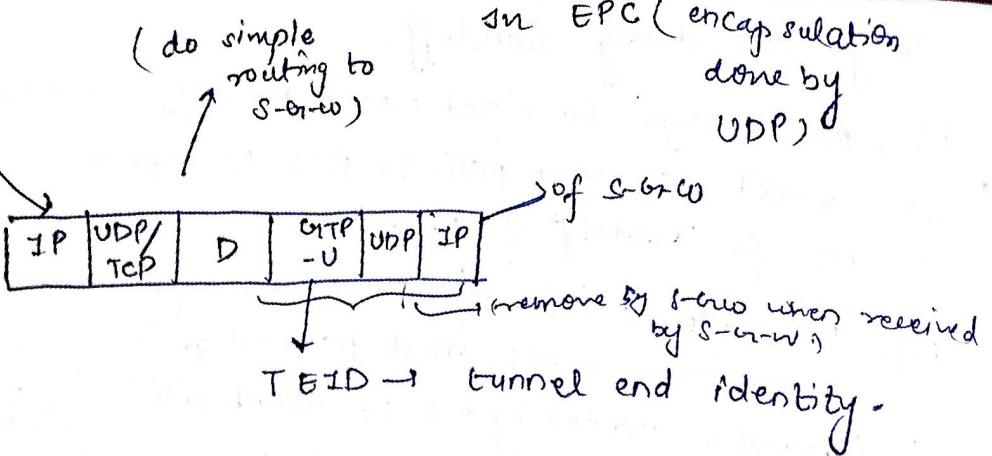
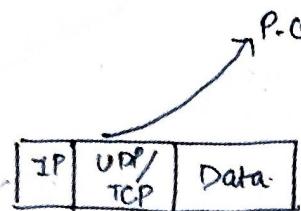
S-GW

BS.

mT

• Let's suppose a packet is coming from internet to P-GW (PDN network)

Packet Transfer



→ S-GW check this encapsulated packet & check 'tunnel end identity' remove extra headers & Add its own GTP-U, UDP & IP. and sends this new packet to base station (mT)

→ Now from Base station, we do radio interface to transfer packet to mT.

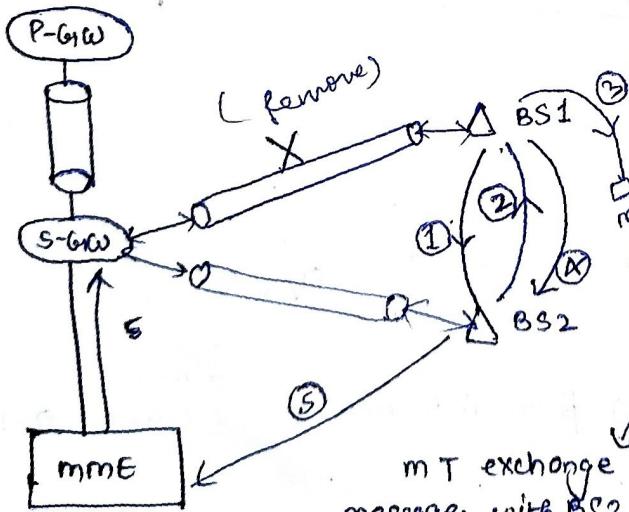
→ From internet it receives IP → public-IP of P-GW

but when transferring from PDN gateway to S-GW it changes IP (from public IP to private IP of mT)
PDN Gateway do NATing)

→ When voice msg or packet is not going to internet, then IP will be private IP.

→ (In calling packet (Data → permanent phone no.) & iPDN gateway use SIP protocol to find its IP address)

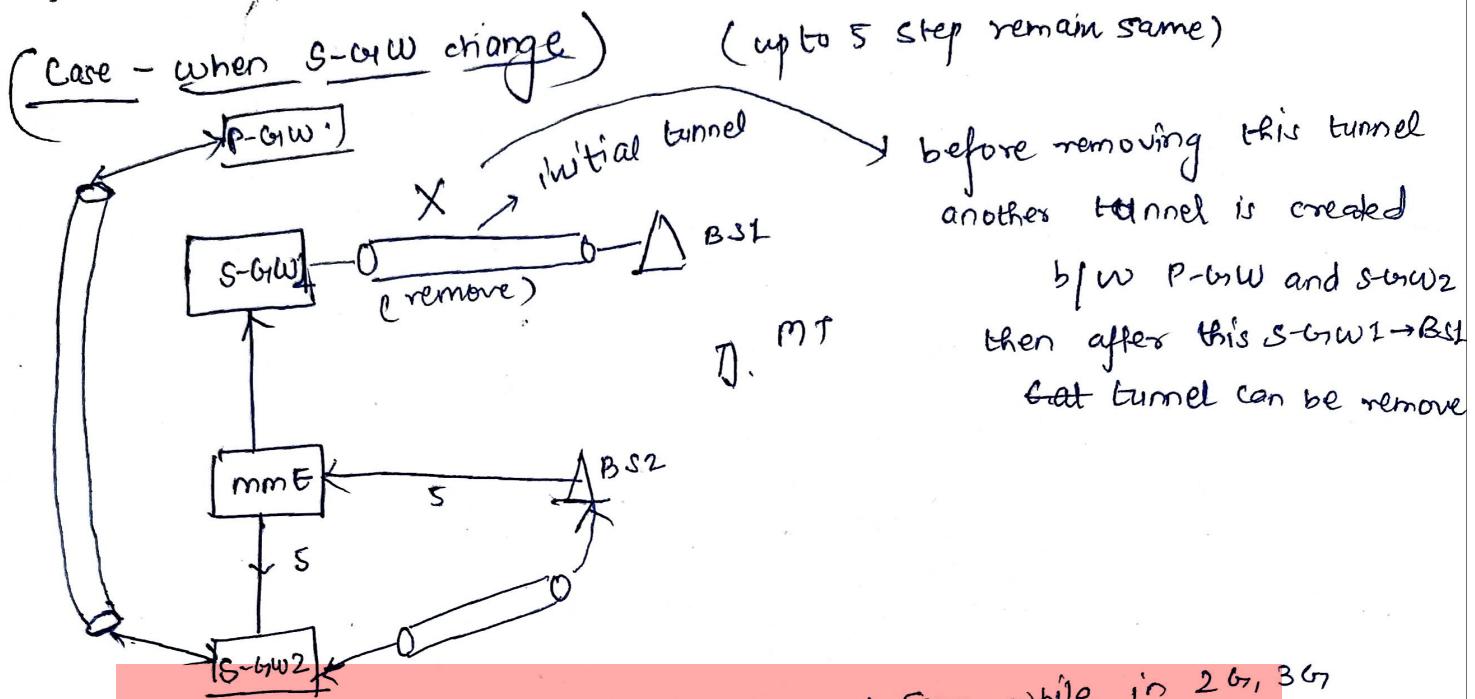
4G (Handoff)



mT exchange messages with BS2 & inform BS1 handoff complete.

- ① → BS1 select BS2 and send handover Req to BS2
- ② → BS2 allocate channel for mT and BS2 send handover Req-Ack. confirm info required to associate with BS2
- ③ - BS2 inform mT about BS2 identify & channel info now mT can send/receive datagram to/from BS2.
- ④ BS1 stop forwarding datagram to mT & redirect them to BS2.
- ⑤ BS2 forward these datagram to mT

- 5) - BS2 inform to mMME.
 mMME signals to S-GW for creation of new-tunnel between S-GW & BS2 for MT.
- 6) - BS2 inform BS1 to release resource associated with MT.
- 7) - BS2 & MT exchange datagram through new tunnel →



In 4G, 5G call is transferred in packet form while in 2G, 3G call is transferred through circuits. When MT moves from BS1 to BS2 then packet chan. coming from MT it can be buffered at BS1 due to packet switching which can not be done on circuit switching (2G, 3G). This is only advantage of 4G, 5G over 2G, 3G.