SS7 Network and Common Channel Signaling

- all control signals in the wireline domain are handled by the SS7 signaling network
- acronyms: STP - signaling transfer point, SCP - service control point, SSP - service switching point, LSTP - local STP, RSTP - regional STP
- SSP, MSC and VLR are functionally colocated
- SCP and HLR are functionally colocated
- registration update point of view, all base stations connected to the same MSC represent one RA
- Signaling between the mobile in the current RA and the HLR passes through SSP, LSTP, RSTP and then SCP

SS7 signaling network

- each SSP serves one RA
- SSPs of different RAs are connected to a two-level hierarchy of signaling transfer points, comprising a regional STP connected to all local STPs
- STPs are installed in pairs to ensure robustness, perform message routing and other SS7 functions
- RSTP connected to an SCP which contains the functionality associated with and HLR
- SS7 network carries out network signaling exchange operation using common channel signaling (CCS)
- CCS is a digital communications techniques that provides simultaneous transmission of user data, signaling data, and other related traffic throughout a network

- using out-of-band signaling channels that logically separate the network control data from the user information on the same channel
- CCS is used to pass user data and control signals between the MS and BS, between BS and MSC and between MSCs
- In brief, identify mobile RA, then location update and call setup
- on moving into a new RA, it must update the registration with its HLR
- Mobile is identified by Mobile Identification Number (MIN)
- registration request contains MIN
- base station in RA periodically broadcast beacon signals

Location update

- Mobile listens to pilot signals from base stations in RA and uses these to identify its current RA
- in new RA, mobile sends registration request to the base station of the current cell
- base station forwards the request to MSC which in turn launches a registration query to its associated VLR
- VLR adds an entry in its records on the location of the mobile and forwards the registration request to the HLR
- HLR performs the necessary authentication routing and records the identity of the new serving VLR in its database entry for the mobile and HLR sends a ACK to new VLR
- HLR sends registration cancellation message to old VLR
- old VLR removes the record and sends ACK to HLR

Call Setup

- when network (network access point) receives a call for a mobile, must locate called mobile and deliver the call to it
- calling mobile sends the call request to the MSC in the registration area via its serving base station
- MSC which handles the call request is referred to as the calling MSC
- calling MSC locates the called MSC/VLR combination through its association with the HLR
- HLR routes the call request to the called MSC which in turn pages the called mobile to set up the call

- calling BS receives a call request having MIN, forwards to the VLR of its RA and VLR forwards the request to its MSC
- calling MSC sends a location lookup request to the HLR of the called mobile
- HLR of the called mobile determines the current VLR of the called mobile and sends a routing request to the VLR and VLR forwards the message to its MSC
- called MSC allocates a temporary local directory number to the called mobile and sends a reply to the HLR together with the TLDN
- HLR forwards the TLDN to the MSC of the calling mobile
- using TLDN the MSC of calling mobile initiates a connection request to the called MSC through the SS7 network

- call setup procedure establishes a linkage between the calling MSC and the called MSC
- the called MSC knows that the called mobile is in the RA under its jurisdiction but does not know in which cell the called mobile is located
- paging procedure is needed to locate the called mobile within a registration area
- polling: called MSC broadcasts a polling message, which contains the MIN of the called mobile to all cells within the RA
- BS of each cells relays the paging message to the mobile terminals
- only the called mobile responds to the called MSC through its current BS with the base station ID of its current cell
- the called MSC then knows where to forward the call

Location Management for PCS Network

- communication by anyone, from anywhere and at anytime
- higher transmission rate and higher frequency spectrum (1.85 to 1.99 GHz)
- smaller cell sizes to enlarge the system capacity, hence smaller registration area and increase in the number of times that HLR is accessed
- large distances introduce signaling delay
- to reduce delay in call setup and delivery
- overlay approach: enhance two tiered architecture reducing the number of HLR accesses using pointer forwarding
- setup pointer from old VLR to new VLR eliminating signaling exchanges between the HLR and the VLR's

- need to traverse the link chain from the initial VLR to the Mobile's current VLR
- disadvantage: chain may be long and delay becomes intolerable
- upper bound on the cost of call setup incorporated
- K limit on length of the link chain; if chain length exceeds K, update to HLR is forced and link chain is reset to NULL
- rate of call arrivals and the rate of RA crossing have impact on overlay approach

$$\text{Call-to-mobility ration} \quad = \quad \frac{\text{rate of call arrivals}}{\text{rate of RA crossings}}$$

- pointer forwarding scheme works well if CMR is relatively low

- Local Anchor Approach: create virtual HLR in the form of a local anchor
- when mobile crosses RA, register with the LA which has an association with the HLR and plays the role of HLR (virtual HLR)
- MSC of the newly entered RA registers the mobile location at VLR called LA
- need to assess performance of both handoff and location management
- rate of boundary crossing by the mobile is an important parameter
- mobility model, network architecture and traffic parameters
- calculate intraswitch handoff rate, interswitch handoff rate and the location update rate

Traffic Calculation

- model based or measurement based
- analytical model constructed based on known distributions
- does not reflect real scenario but provide guidance
- Say, cluster of N hexagonal cells

$$A_{cell} = 2.598R^2$$

$$A_{cluster} \approx N \times 2.598R^2 \approx 2.598R^2_{cluster}$$

$$R_{cluster} \approx \sqrt{N}R$$

- to calculate intracluster handoff rate - number of boundary crossing per cell per unit time
- for intercluster handoff rate - number of cell crossing per cluster per unit time
- calculate handoff rate based on network parameter, traffic parameter and Mobile's movement pattern

- population density of mobiles = ρ (number of mobiles/km^2)
- speed of mobile V km/hr
- traffic load per mobile station = λ_{ar} (Erlangs/MS)
- percentage of powered stations = δ
- percentage of active mobiles among the powered stations = ϵ
- Number of crossing per cell per unit time = μ_{cell}
- Number of crossing per cluster per unit time = $\mu_{cluster}$
- mobile powered - listening mode / active - ongoing connection
- the percentage of the total population that is active is given by $\epsilon\delta$
- number of handoff per unit time is smaller than the number of boundary crossing per unit time

Mobility Model based on active mobiles

- mobiles are uniformly distributed in the cell
- direction of travel of all mobiles relative to the cell boundary is uniformly distributed on $[0, 2\pi]$
- mobile travels with constant velocity V in a particular given direction
- the rate of boundary crossing - the rate at which a randomly chosen mobile crosses the cell boundary time the number of mobiles per cell
- it is function of cell size, ρ, and V
- say, perimeter of the cell $L_{cell} = 6R$

- rate of mobiles departing the cell μ_{cell}

$$\mu_{cell} = \frac{\rho V L_{cell}}{\pi} = \frac{6\rho V R}{\pi}$$

- by the flow conservation law, the number of departing a cell per unit time equals the number of entering per unit time
- rate of mobiles departing the cluster $\mu_{cluster}$

$$\mu_{cluster} = \frac{\rho V L_{cluster}}{\pi}$$

- perimeter of cluster $L_{cluster}$

$$L_{cluster} \approx 6R_{cluster} = 6\sqrt{N}R$$

$$\mu_{cluster} = \frac{6\rho V \sqrt{N}R}{\pi}$$

$\lambda_{ho\_cluster}$ - total handoff rate of a cluster (number of handoffs in the cluster both within the cluster and to neighboring clusters per unit time)

$$\begin{aligned}\lambda_{ho\_cluster} &= \text{number of cells in the cluster} \quad \times \\ &\quad \text{number of crossings per cell per unit time} \quad \times \%\text{active mobiles} \\ &\quad \times\%\text{powered stations} \quad \times \text{ traffic load per MS} \\ &= N \times \mu_{cell} \times \epsilon \times \delta \times \lambda_{ar}\end{aligned}$$

$\lambda_{ho\_intercluster}$ - total handoff rate of a cluster includes both intracluster handoff rate and intercluster handoff rate

$$\begin{aligned}\lambda_{ho\_intercluster} &= \text{number of crossings per cluster per unit time} \quad \times \%\text{active mobiles} \\ &\quad \times\%\text{powered stations} \quad \times \text{ traffic load per MS} \\ &= \mu_{cluster} \times \epsilon \times \delta \times \lambda_{ar}\end{aligned}$$

$$\lambda_{ho\_intracluster} = \lambda_{ho\_cluster} - \lambda_{ho\_intercluster}$$