CS 621
Mobile Computing

Location Management for Mobile Cellular Systems

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Cellular System Architecture

- Each cell is served by a base station (BS)
- Each BS is connected to a mobile switching center (MSC) through fixed links
- Each MSC is connected to other MSCs and PSTN

MSC

HLR

VLR

To other MSCs

MSC

HLR

VLR

PSTN

PSTN
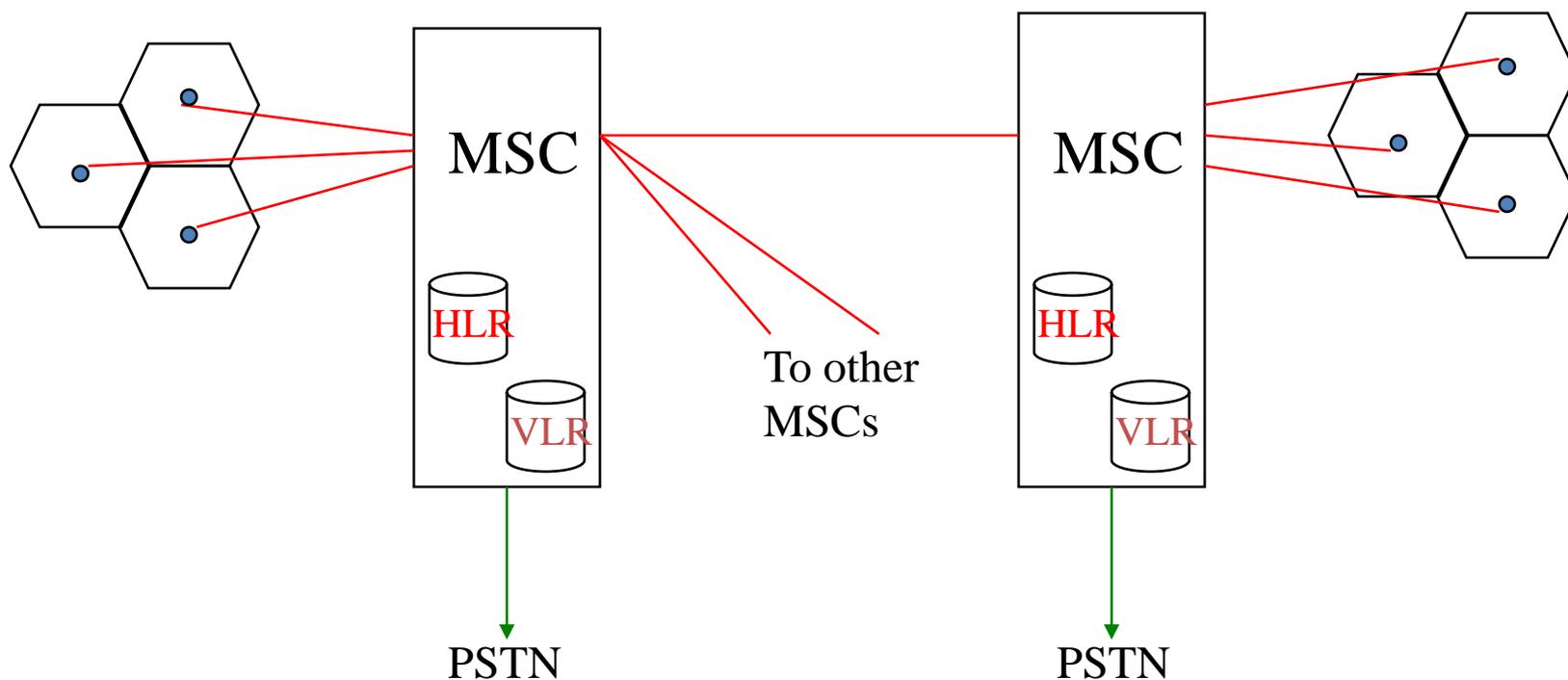
Cellular System Architecture

- Each MSC is a local switching exchange that handles
  - Switching of mobile user from one base station to another
  - Locating the current cell of a mobile user
    - Home Location Register (HLR): database recording the current location of each mobile that belongs to the MSC
    - Visitor Location Register (VLR): database recording the cell of "visiting" mobiles
  - Interfacing with other MSCs
  - Interfacing with PSTN (traditional telephone network)

- One channel in each cell is set aside for signaling information between BS and mobiles
  - Mobile-to-BS: location update, call setup for outgoing calls, response to incoming calls
  - BS-to-Mobile: cell identity, call setup for incoming calls, location updating

Call Setup

- Outgoing call setup:
  - User keys in the number and presses send (no dial tone)
  - Mobile transmits access request on uplink signaling channel
  - If network can process the call, BS sends a channel allocation message
  - Network proceeds to setup the connection
- Network activity:
  - MSC determines current location of target mobile using HLR, VLR and by communicating with other MSCs
  - Source MSC initiates a call setup message to MSC covering target area
- Incoming call setup:
  - Target MSC (covering current location of mobile) initiates a paging msg
  - BSs forward the paging message on downlink channel in coverage area
  - If mobile is on (monitoring the signaling channel), it responds to BS
  - BS sends a channel allocation message and informs MSC
- Network activity:
  - Network completes the two halves of the connection

Bandwidth

Next:

- Location Management in Cellular Networks
  - Concept of Location area
  - Location update procedure
  - Call delivery procedure
- Other location management strategies
  - Location update
  - Paging
  - Database management

Location Management in Cellular Networks has to address the following issues

- When should a MS (or MT) update its location to the network
- How should the exact location of a MS be determined within a specified time constraint
- How should user location info be stored and disseminated throughout the network

Cellular Systems

Where is 9864180075?
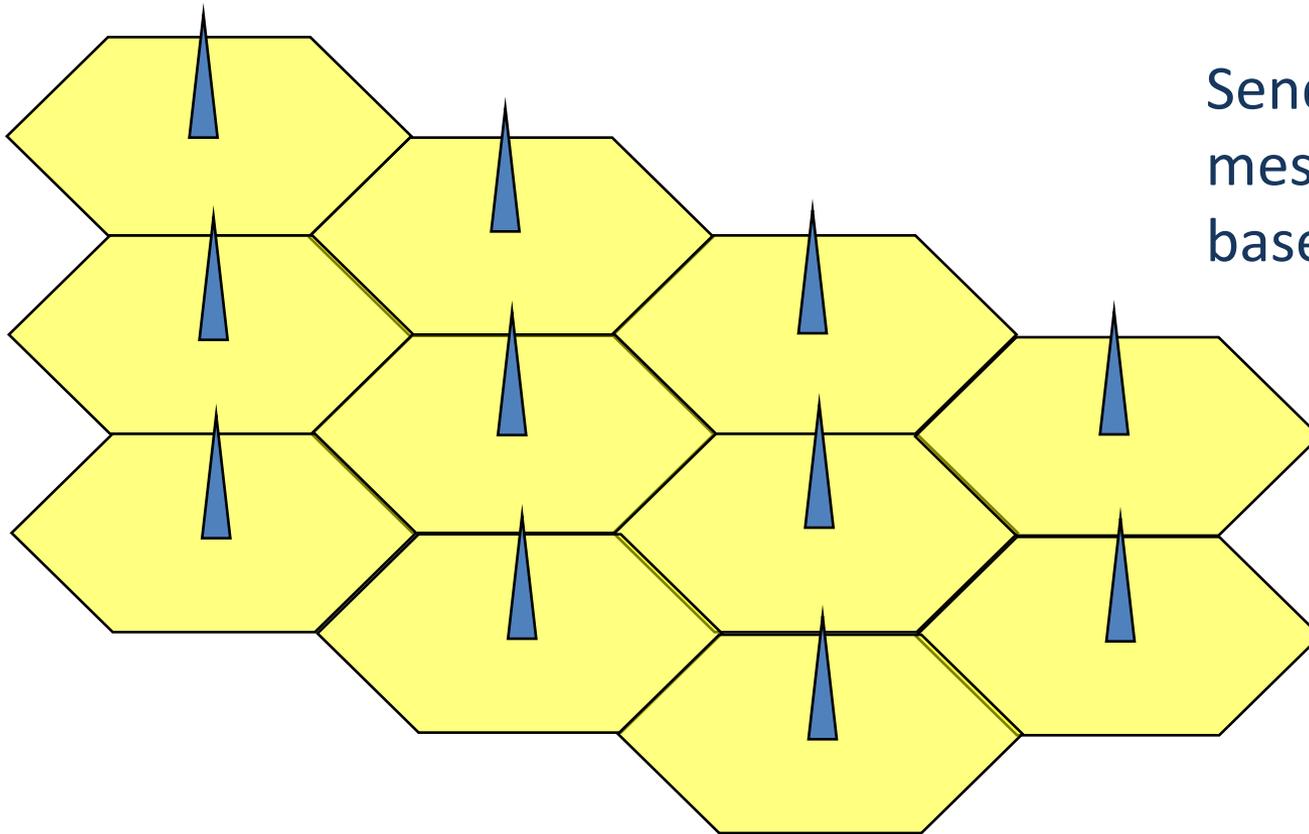
Send broadcast messages from every base station?

Two Major Components in Location Management

- Location Update
  - The operation of informing the **network** about the **current location** of the mobile terminal is known as *location update* or *location registration*.
  - May be static (**based on topology of the network, performed at predefined set of cells**) or dynamic (**based on mobility pattern and call arrival pattern of an user**)
- Paging
  - The operation of determining the **location** of the mobile terminal is called *terminal paging* or *searching*.
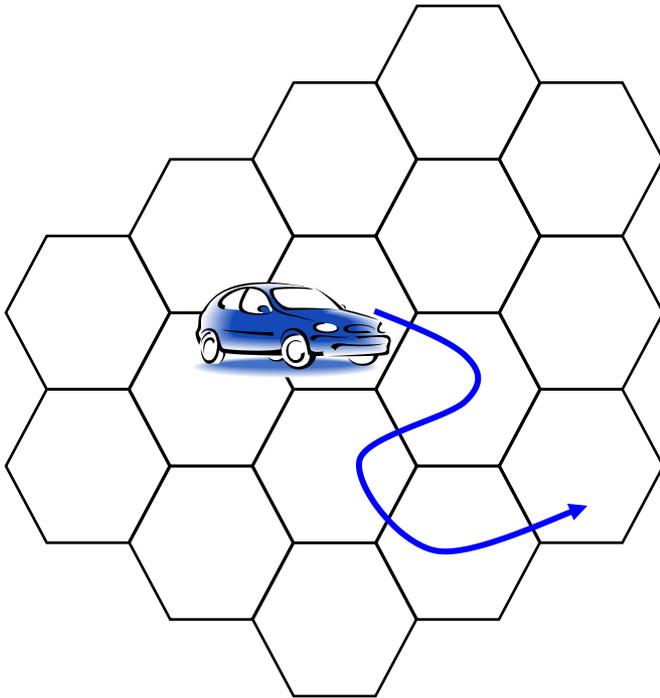 - The system sends messages (from one or more base stations) to find a particular user.
- There is a Trade-off between the costs of location update and paging
- Thus central problem of location management is to devise algorithms that minimize overall cost of LU & Paging
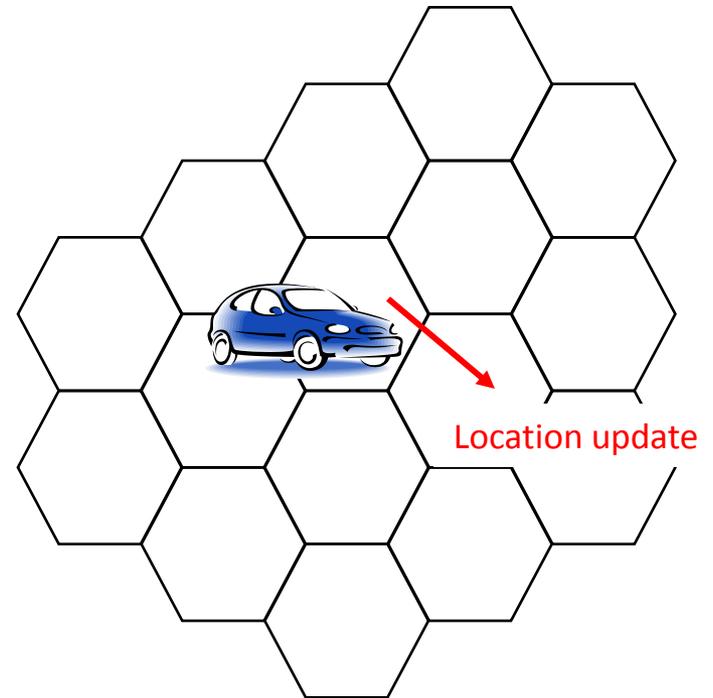
Location never update (no cost).

Need to page every cells (high cost).

Location updates for every cell crossing (high cost).

Need to page only one cell (low cost).

Location update

Location Management Approaches

Maybe – **static** (predefined cells, does not depend on mobility) or **dynamic**, and **global** (all MTs update their locations from same set of cells) or **local** (per-user, allows to decide when and where to perform LU)

1. Location Area approach (Global static), (Time-varying LA ?, Individualized LA?)

2. Reporting Cells (Global static)

3. Time Based (Individualized dynamic)

4. Movement Based (same as 3)

5. Distance Based (same as 3)

6. Profile Based (same as 3)

Location Area Approach

- Service Coverage area is Partitioned into different **location areas** (LAs).

- Each LA consists of several contiguous cells

- The BS of each cell broadcasts the identification (ID) of LA to which the cell belongs.

- Therefore, a MS knows which LA it is in

- A MS will update its location (reports its new LA) whenever it moves into a cell which belongs to a new LA

- When an incoming call arrives for a MS, the cellular system will page all cells of the LA which was last reported by the MS

- *In principle, service area should be partitioned in such a way to minimize both Location-update cost and Paging Cost*

Partition the region into different location areas.
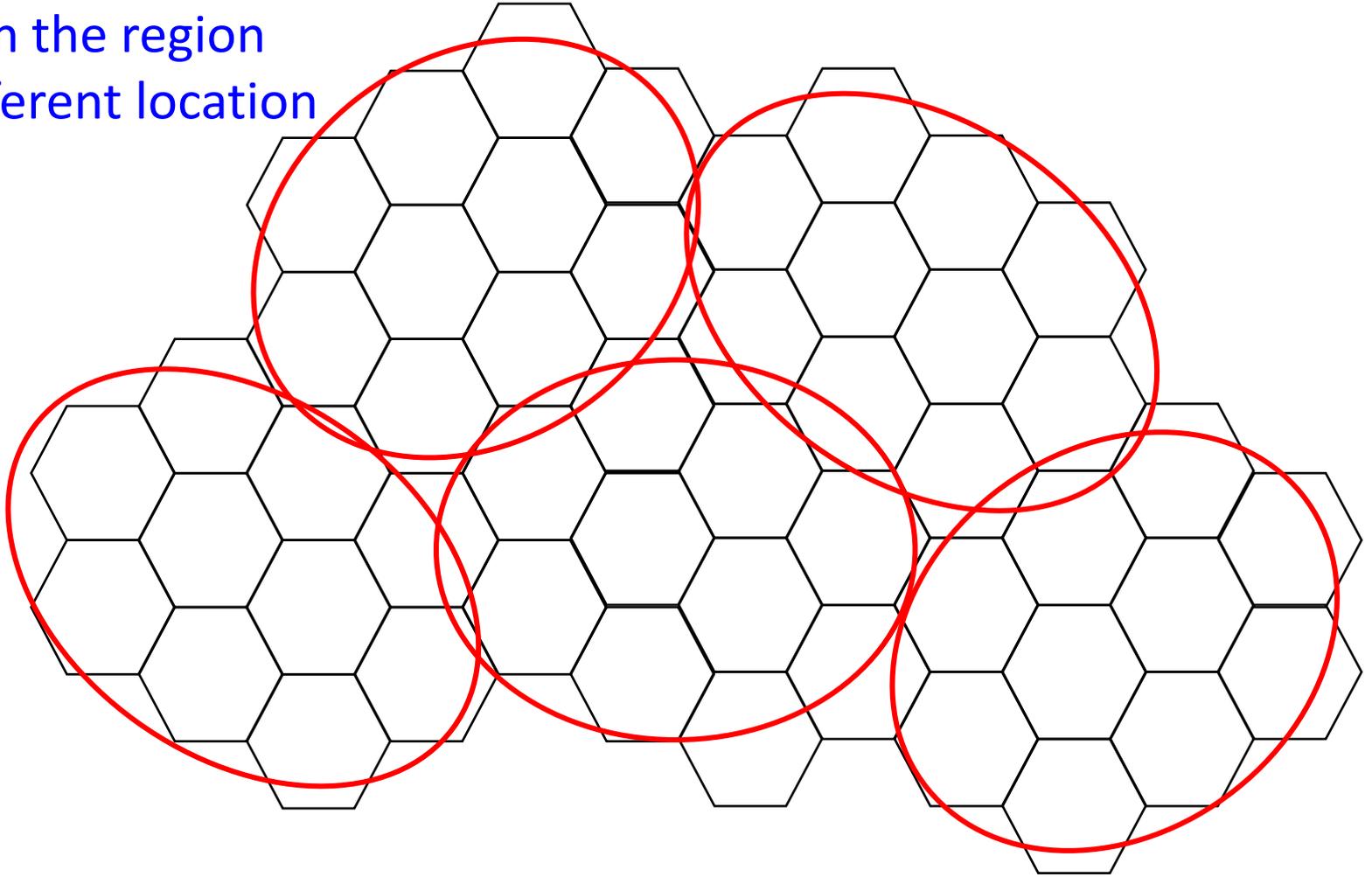
Location Area Approach (Cont'd)

- Trade-off between location update cost and paging cost

- 2-extreme cases – Always-Update and Never-Update

- **Always-Update:** Each cell is a LA, cost of location update is very high, no paging cost (can just route an incoming call to the last reported cell without paging)

- **Never-Update:** Whole service area is a LA, no location update cost, paging cost is very high because the cellular system need to page every cell in the service area to find the current cell of the MS

- In classical LA approach, the most recently visited LA-ID is stored in a MS. Whenever the MS receives a new LA-ID, it initiates a location update.

Location Area Approach (Cont'd)

•Two Location Algorithm (TLA) allows a MS to store and register the IDs of two most recently visited LAs.

•When a MS moves into a new LA, it checks if the new location is in the memory. If not found, the oldest of the two LAs is replaced by the new one and location update is performed

•This results in **reduction of ping-pong effect**

• Among other techniques to reduce ping-pong effect is defining Overlapped LA

Location Update

LA-1

LA-2
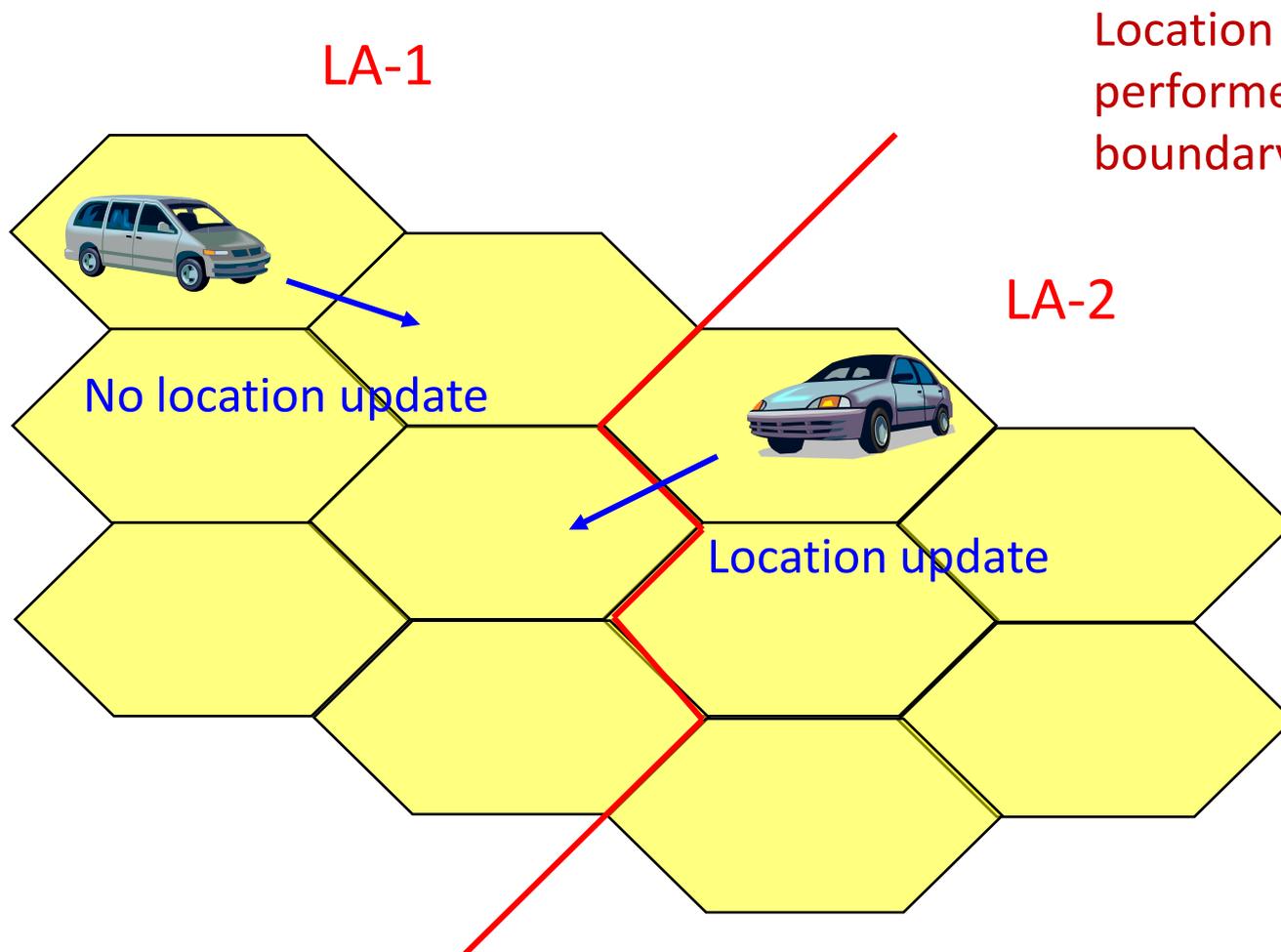
Location update is performed when there is a boundary crossing.

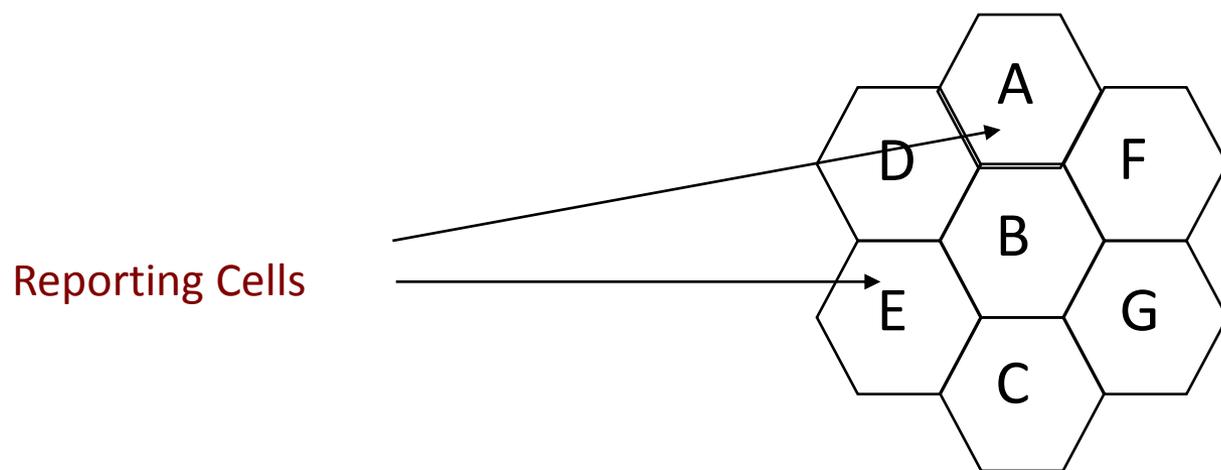No location update

Location update

How to determine the size of a LA?

Reporting Cells/Centers

• A subset of cells have been selected from all cells as reporting cells.

• Other cells are called non-reporting cells.

• BSs broadcast a signal to indicate whether the cell is a reporting one or not. So a MS knows whether it is in a reporting cell or not

• For each reporting cell i, its *vicinity* is defined as the collection of all non-reporting cells that are reachable from cell i without crossing another reporting cell.

• The reporting cell belongs to its own vicinity.

• A MS will update its location (i.e. Cell ID), whenever it moves into a new reporting cell.

Reporting Cells/Centers(Cont'd)

- When an incoming call arrives for a MS, the cellular system will page all cells within the vicinity of the reporting cells which was last reported by the MS
- 2-Extremes: Always-update & Never-update
- The goal is – how to select a subset of reporting cell to minimize the total location management cost (sum of location update cost and the paging cost)

Reporting Cells

Time Based

- Given a time Threshold T, a MS updates its location every T units of time.

- The corresponding paging strategy is also simple.

- Whenever there is an incoming call for a MS, the system will first search the cell the MS last reported to, say i. If it is not found there, the system will search in cells $i+j$ and $i-j$ starting with $j=1$ and continuing until the MS is found.

- Here a ring cellular topology is assumed

Movement Based

- Each MS keeps a counter which is initialized to zero after each location update.

- Whenever a MS crosses the boundary between two cells, it increases the counter by one.

- The boundary crossing can be detected by comparing the Ids of those 2 cells.

- When the counter reaches a **predefined threshold**, say M, the MS updates its location (i.e. cell ID)

- Guarantees that the MS is located in an area (*residing area*) that is within a distance M from the last reported cell.

- When an incoming call arrives for a MS, the system will page all the cells in *residing area. (Easy to impl due to simplicity)*

Distance Based

- Each MS keeps track of the distance between the current cell and the last reported cell (distance is defined in terms of cells).

- When the distance reaches a predefined threshold, say D, the MS updates its location (cell ID).

- Guarantees that the MS is located in an area (*residing area*) that is within a distance D from the last reported cell.

- When an incoming call arrives for a MS, the system will page all the cells within a distance D from the last reported cell.

- Hard to compute the distance between 2 cells or it requires a lot of storage to maintain the distance info among all cells.

- *Although, if cell IDs can be assigned properly, the distance between 2 cells can be computed very easily.*

Profile Based

- Cellular System keeps individual subscriber's mobility pattern in his/her *profile*. This info will be used to save the costs of location update and paging

- The idea behind this strategy is that the mobility pattern of a majority of subscribers can be foretold.

- For each time period $[t_i, t_j)$, the system maintains a list of LAs, $(A_1, p_1), (A_2, p_2), \ldots, (A_k, p_k)$. Here, A_f is an LA and p_f is the prob that the subscriber is located in A_f. Also $p_1 > p_2 > \ldots\ldots p_k$

- If a subscriber moves within the recorded LAs during the corresponding period $[t_i, t_j)$, the subscriber does not require to perform location update, otherwise the subscriber reports its current location, and the system will trace the subscriber as in classical LA approach.

- So, location update is significantly reduced

Location Databases

These two databases communicate with each other to authenticate and update each other about the location of an MS.

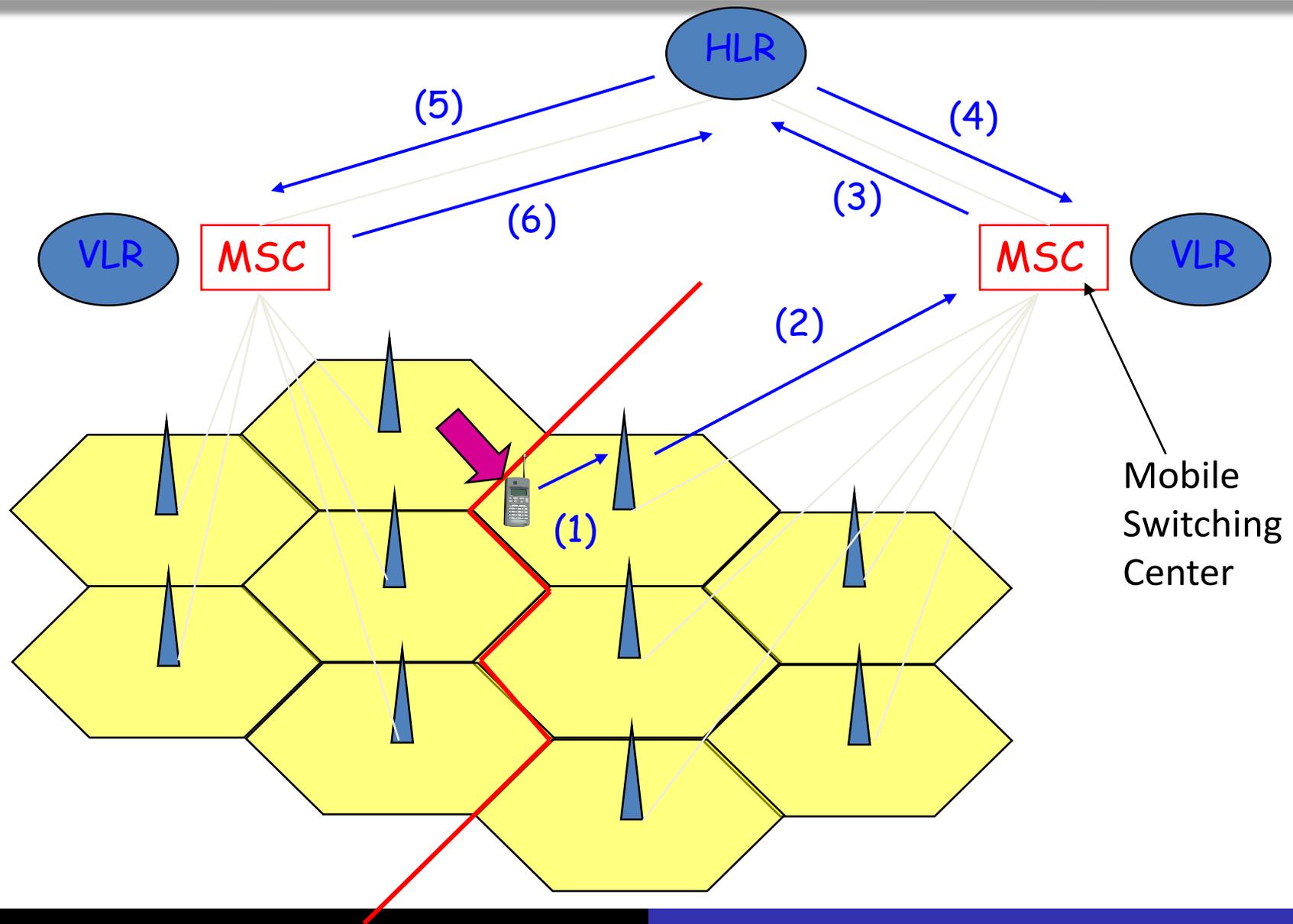Home Location Register (HLR)
Visitor Location Register (VLR)

- Home Database
  - Every MS is permanently associated with a home database
  - Keep track of the profile of the MS
    - Mobile ID, authentication keys, location, etc.

- Visiting Database
  - Keeps track of the MSs in its service area.

GSM Example: Location Update

HLR

(5)   (4)

(3)

(6)

VLR   MSC   MSC   VLR

(2)

(1)

Mobile
Switching
Center

Location Update Procedures

1. MS transmits a Location Update (LU) to the new BS
2. The BS forwards the LU to the MSC
3. MSC sends LU to the HLR and updates VLR
4. HLR does the following:
   authenticate the MS
   record the ID of the new VLR
   send an ACK to the new VLR
5. HLR sends a registration cancellation message to the old VLR
6. The old VLR removes the record of the MS and returns an ACK to HLR
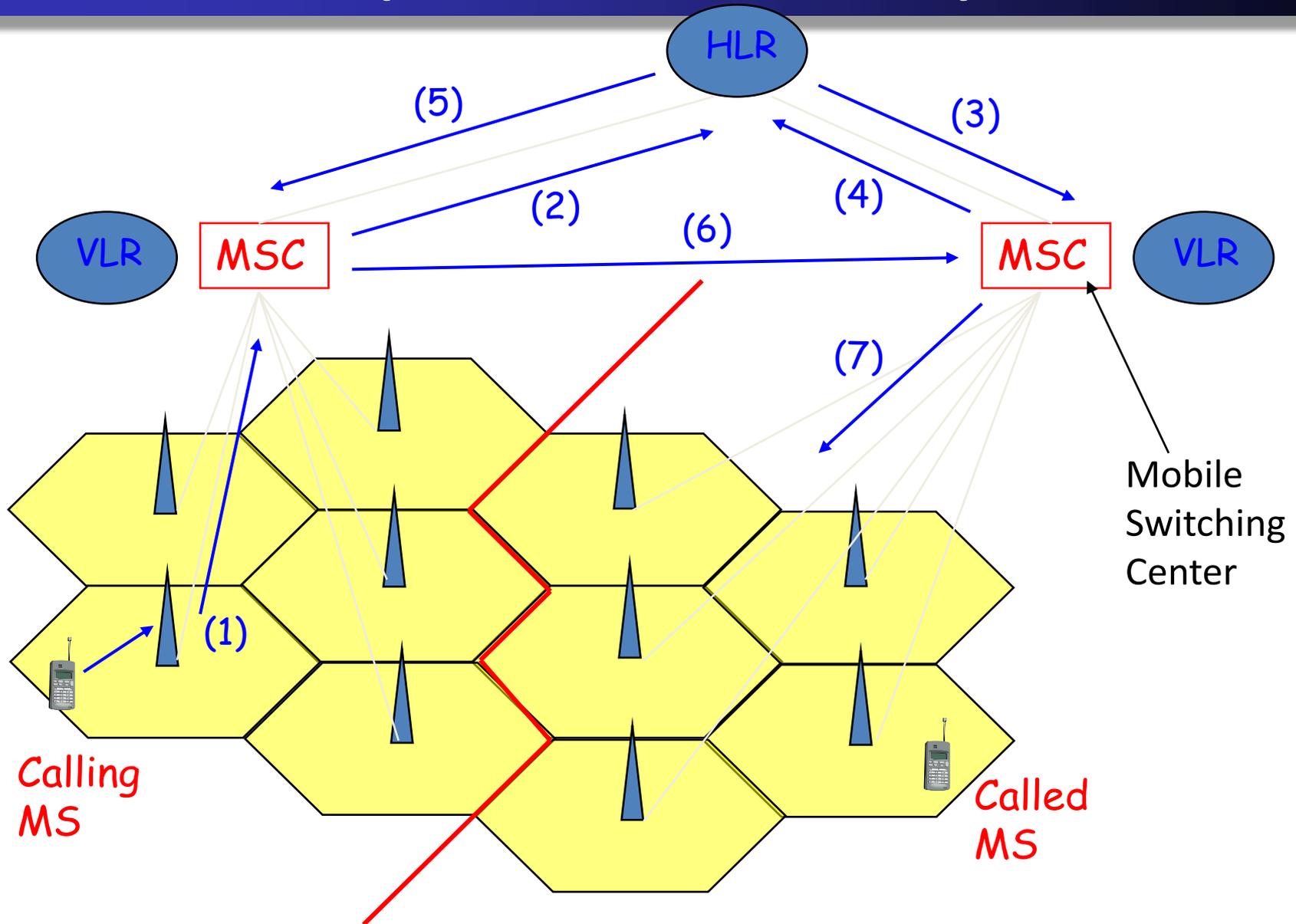
Call Delivery Procedure

1. Calling MS sends a call initiation signal to MSC through BS.
2. MSC sends a location request to HLR of the called MS
3. HLR determines serving VLR of called MS and sends a route request message to it.
4. MSC allocates a temporary ID to MS and sends this ID to HLR
5. HLR forwards the ID to MSC of the calling MS
6. Calling MSC requests a call set up to the called MSC
7. Paging messages are sent to cells within the LA.

THANKS!