CPET 565/CPET 499
Mobile Computing Systems
Lecture 5
Mobility Management
2 of 2

Based on the Text used in the course: Fundamentals of Mobile & Pervasive Computing, 2005, by Frank Adelstein, et. al, from McGraw-Hill

Fall 2012

A Specialty Course for Purdue University's M.S. in Technology Graduate Program

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Mobility Management (cont.)

- Mobile Location Code
  - Mobile Country Code
  - Mobile Network Code
  - Local Area Code
  - Routing Area Code
  - Cell Identity
- Location Update Procedure
  - A mobile device inform a cellular network whenever it moves from one location area to another
  - Mobiles are responsible for detecting location area code

Mobility Management (cont.)

- Periodic Location Update
  - Each mobile is require to regularly report its location at a set time interval
- Radom Location Update
  - When a mobile moves from one location area to the next while not on a call
  - A stationary mobile that selects coverage from a cell in a different location area because of signal fading
- Roaming
  - A Mobility management procedure of all cellular networks

Mobility Management (cont.)

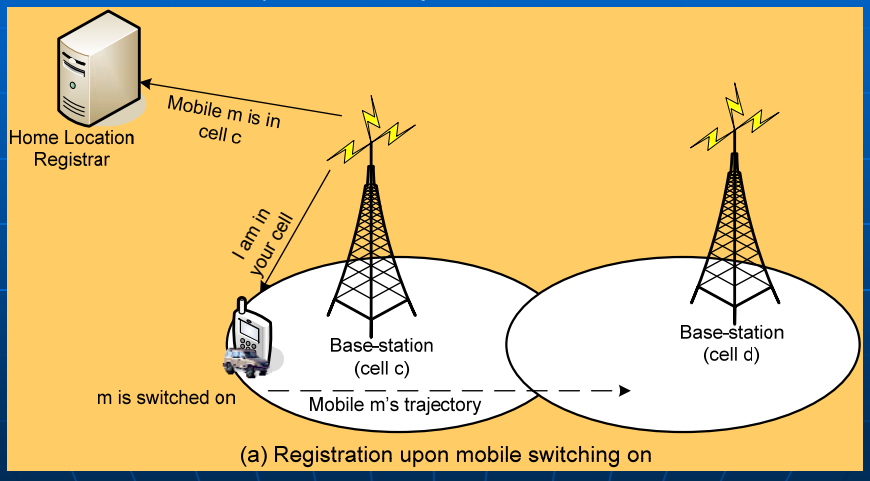
- TMSI (Temporary Mobile Subscriber Identity)
  - Given to the mobile, the moment it is switched on
  - Local to location area
  - Has to be updated, each time the mobile moves to a new geographical area
- IMSI (International Mobile Subscriber Identify)
  - A unique number associated with GSM and UMTS network mobile phone users
  - The number is stored in SIM (Subscriber Identity Module) card

Mobility Management (cont.)

- Location Management Principles & Techniques
  - Location Registrars (databases)
  - Location Area
    - A set of base stations (10s or even 100s)
    - Grouped for optimized signaling
  - Search Operation
  - Update operation
    - Static Update Schemes
    - Dynamic Update Schemes

Simple Location Management Scheme (cont.)

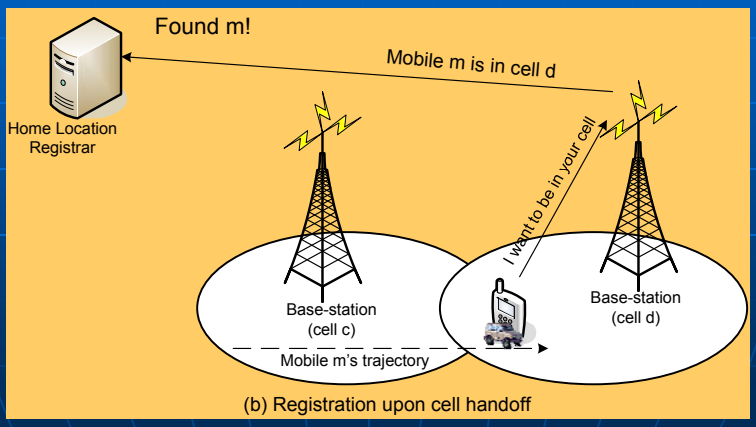
- Search and Update Operations (mobile node m is switched on) – Static Update



(a) Registration upon mobile switching on

Simple Location Management Scheme (cont.)

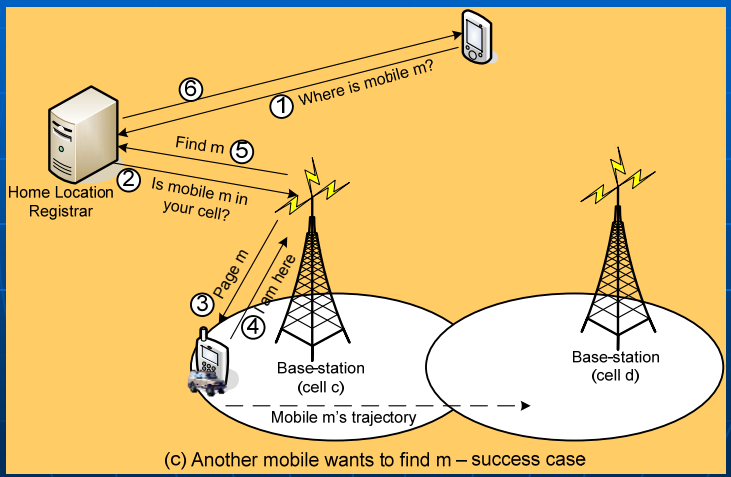
- Search and Update Operations (mobile node moves from cell c to cell d)



(b) Registration upon cell handoff

Simple Location Management Scheme (cont.)

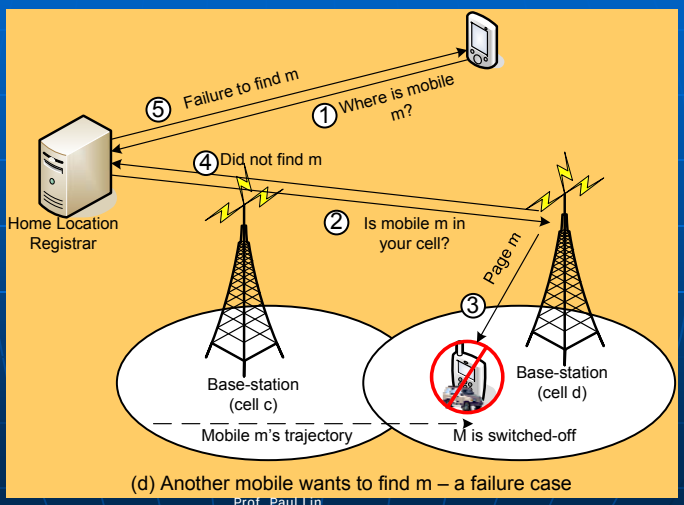
- Search and Update Operations (m in cell c & ON)



(c) Another mobile wants to find m – success case

Simple Location Management Scheme (cont.)

- Search and Update Operations (find m location; m is OFF)



(d) Another mobile wants to find m – a failure case

Mobility Binding of a Mobile Node

- How to reduce the probability of failure (1 – max, 0 – min)?
- Enhancement 1 – reduce search cost through the # of updates performed at HLR (Home Location Registrar - <mobile,cell> bindings) per mobile node
  - t_U – the time when the binding was last updated
  - ttL – the time to live (how long the binding is valid)
  - t_P – periodically update time < ttL

Mobility Binding of a Mobile Node (cont.)

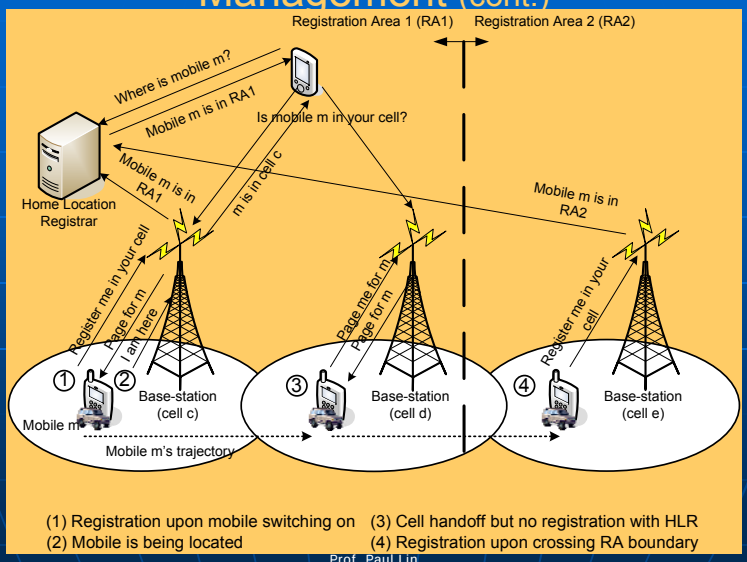
- How to reduce the probability of failure (1 – max, 0 – min)?
- Enhancement 2 – page neighbor cells
  - Increasing areas/cells for a maximum of k rings
  - If the speed of mobile node m is a maximum of v_m cells per second, then k (rings) can be set to

    $k = v_m \times t_p$, where t_p – periodical update time

Registration Area-based Location Management

- Used by Personal Communication Service – GSM (Global System for Mobile Communication)
- Service areas of PCs – the set of all cells (the union of coverage area of all the cells)
  - Partitioned into several Registration Areas (RAs) or Location Areas
  - Each RA consists of several contiguous communication cells

Registration Area-based Location Management (cont.)



Registration Area-based Location Management (cont.)

- Cell c & d – in RA1
- Cell e – in RA2
- Node m moves from cell c to d
  - Average update cost is reduced, because the HLR is not informed when handoff involves cells belonging to same RAs
  - Search cost is increased, because all the cells in the RA have to be contacted for the exact location of the mobile node

Registration Area-based Location Management (cont.)

- 2-Level Hierarchy of Location Registrars
  - Local Location Registrars
  - Remote Location Registrars
- Used in GSM to avoid contacting all the cells in the RA to locate a mobile node
  - One Location Registrar ↔ 1 RA
  - One Location Registrar ↔ several RAs (in practice)
  - N Registration Areas (RA1, RA2, …, RAn)
  - N Local Location Registrars (LR1, LR2, …, LRn)
  - LRi is the Local Location Registrars of RAi
  - All others location registrars as Remote Location Registrars

Location Management

- Home Location Registrars
- Visitor Location Registers
- Forwarding Pointers
- Per-user Caching

Actual Address vs. Forwarding Pointer

- Alice – a resident of New York
  - Temporary move to Texas, in & moves quite often (every week) – Texas: Dallas → El Paso → Austin → Houston
  - Maintaining a forwarding location pointer: reduce the burden of Local Updating cost for Alice
- Bob – a resident of Arizona
  - Wants to contact Alice
  - Increasing the Remote Search Cost
  - Contact NY Registrar first, then contact Texas Registrar
- Which Method is better?
  - Actual Address at Home Location Registrar
  - Forwarding Pointer (Location pointer)

Actual Address vs. Forwarding Pointer (cont.)

Alice:
If Never Change address in TX
***Maintain the Actual addr at Home LR: NY Is better!**

Bob:

→ NY LR

Figure 2.3 (1) Maintaining actual address at HLR (courtesy: http://www.infoplease.com/atlas/unitedstates.html)

Actual Address vs. Forwarding Pointer (cont.)

Alice moves often: Dallas, El Paso, Austin, Houston

*** Maintain a location pointer at NY**

Bob: contact Tx-LR for subsequent loc. info

Figure 2.3 (2) Maintaining forwarding pointer at Home Location Registrar (HLR)
(courtesy: http://www.infoplease.com/atlas/unitedstates.html)

A Chain of Forwarding Pointers

- Alice
  - Maintaining Forwarding Pointers of length 3
  - New York → Texas → Alaska → Alabama
- Bob
  - Trying to locate Alice
  - Start with New York registrar then follow the forwarding pointers
  - For 4 location registrars New York → Texas → Alaska → Alabama

A Chain of Forwarding Pointers (cont.)

Figure 2.4 Location management using a chain of forwarding pointer (courtesy: http://www.infoplease.com/atlas/unitedstates.html)

Static vs Dynamic Update Schemes

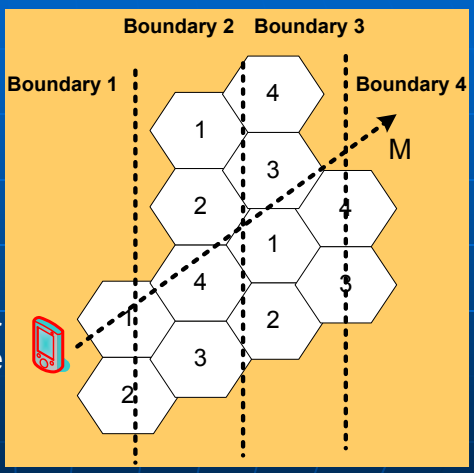
- Static Update Scheme
  - RA-based Location Update
  - Ignore dynamic behavior of mobile nodes
  - Boundaries of RAs are predetermined (static)
  - Cost: a lot of location update due to mobile nodes moving between two adjacent RAs in quick succession
- Dynamic Update Schemes
  - Time-based (periodic) Updates
  - Movement-based Updates
  - Distance-based Updates

Dynamic Update Schemes

- Time-based (periodic) Updates
  - Update Control Timer
  - The simplest method to implement

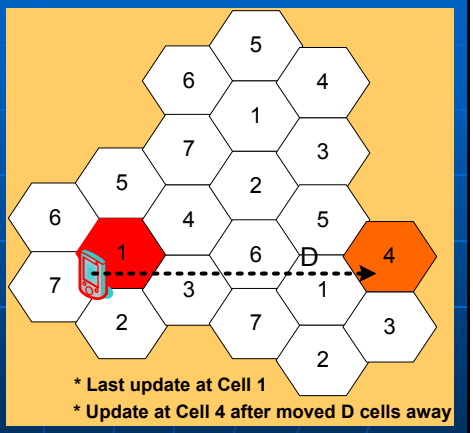
Dynamic Update Schemes

- Movement-based Updates
  - A mobile node update its location
  - When?
    - It crosses a certain number of cell boundaries M since it last registered
  - Mechanism
    - Counting the number of Handoffs since the last update
  - Suitable for stationary users



Dynamic Update Schemes

- Distance-based Updates
  - A mobile node updates its location
  - When?
    - It moves a certain number of cells D away from the last cell at which it last updated its location
  - Need to know the topology of cellular network
  - Difficult to implement
  - Suitable for mobile user who moves within a locality



Dynamic Update Schemes (cont.)

- Per-User Location Caching (on the mobile)
  - Used to avoid accessing a roaming mobile's location frequently
  - CMR (Call-to-Mobility Ratio) =
    (Avg rate at which a user received calls) / (Avg rate at which the user moves)
  - LCMR (Local CMR) =
    (Avg rate at which a user receives calls from a given Registration Area) / (Avg rate at which the user moves)
  - RCMR (Regional CMR) =
    Same definition as that of the LCMR

Replicating Location Information (cont.)

- Location info stored at one of the n Location Registrars
- Load balancing of Registrars
- Replicating info & methods
  - Redundancy – failed registrars (for example, hit by the storm)
  - How many replicas?
    - Full replication – increase the cost of updates
    - Partial replication – preferable
  - Methods of replication
    - Flat Organization
    - Hierarchical Organization

Replicating Location Information (cont.)

- Flat Organization
  - Given n Location Registrars
  - If a mobile node info can be stored at any LR, without any penalty in terms of access cost
  - An Example:
    - n = 16 LRs
    - k Replication Factor = 4 ($k \leq n$)
    - Update starts at the randomly selected LR6 → LR10 → LR14 → LR2
    - Search for the same mobile node starts at randomly selected location registrar, sequentially, LR12 → LR13 →LR14 (found it)

Replicating Location Information (cont.)

- Flat Organization

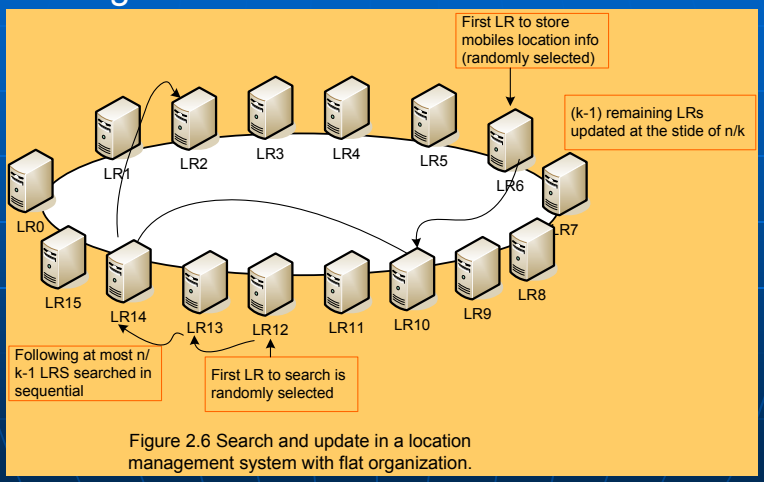


Figure 2.6 Search and update in a location management system with flat organization.

Replicating Location Information (cont.)

- Hierarchical Organization
  - Multi-level (tree) of LRs
  - Leaf LR: has info on all the mobile nodes in the RA(s) associated with it
  - Root LR: stores info on all the mobile nodes in the system
- An Example
  - 15 LRs: LR0 … LR15 formed a balanced tree
  - 8 RAs (RA0, RA1, …, RA7)
  - Caller – LR4
  - Callee – LR1 (before move), LR2 (after move)
  - Location Info maintained at LR1, LR6, LR12, and LR14

Replicating Location Information (cont.)

- Hierarchical Organization

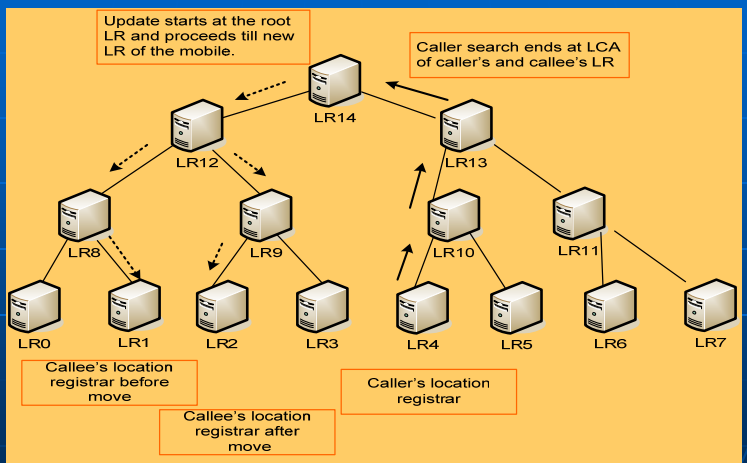


Figure 2.7 Update and search in a hierarchical (Tree) location management system.

Replicating Location Information (cont.)

- The Search Scenario (in Fig. 2.7)
  - Caller – LR4 in RA4
  - Callee mobile node – in RA1
  - Search operation
    - In the order: LR4, LR10, LR13, and LR14 (root)
    - Callee moves from RA1 to RA2
    - The Location info needs to be updated in: LR14, LR12;
    - Added to LR7 and LR2
    - Deleted from LR6 and LR1