Location management in Mobile Networks

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Location Management: Context

- **Mobility Management**: Enables users to support mobile users, allowing them to move, while simultaneously offering them incoming calls, data packets, and other services.
  - Types of mobility:
    1. **Terminal mobility**: ability of terminal to retain connectivity with the network so that all on-going communication services remain active despite terminal’s migration.
    2. **Personal mobility**: disassociates user from the terminal (e.g. in GSM a mobile station = mobile terminal + smart card with subscriber identification module (SIM)).
    3. **Service mobility**: provides continuous service to mobile clients across multiple administrative domains.
  - Consists of:
    1. **Location management**: tracking mobiles and locating them prior to establishing incoming calls (delivering pending messages).
    2. **Handoff management** (a.k.a. automatic link transfer): rerouting connections with minimal degradation of QoS.
The Problem

• To track the mobile user
• Maintaining the binding between the logical identifier and physical location of the user
• The location of the terminal cannot be deduced from its endpoint address, like in wired networks
• Additional addressing schemes protocols needed to locate the mobile terminal
• Being mobile, user creates uncertainty of the exact location of the mobile terminal which is tried to overcome by the network
Issues

- Cost of Communicating with mobile user is augmented by “Cost of Searching for the Current location of the user”.
  - Paging cost
    - Number of calls arrived & Number of cells paged
  - Update cost
    - Number of times mobile updates
  - Trade-off: More the paging, less the update
- Requirement for an optimal algorithm
  - Call routed with allowable time constraint
  - Less information exchange
Location management

- Involves two basic operations
  - Paging
    - Search by system to track the mobile
    - MSC broadcasts message
    - Target replies in the reverse channel
  - Update
    - Upper bound on the location uncertainty
    - Mobile sends update message on the reverse channel
Mobility Management Basics

Mobility Management based on pure Paging:
- If a call arrives, terminal is paged in all cells of the mobile network
- Location update is not required
- As paging must be executed in all cells of the network for each arriving call/SMS/data-packet
  - high signaling overhead
  - high delay in call/SMS/data-packet delivery

Mobility Management based on pure Location Update:
- Each time the user crosses cell boundaries a location update is triggered
- Paging is not required
- As location updates must be initialized whenever crossing cell boundaries
  - high signaling and database update overhead
  - high power consumption in the terminals
Location Areas

- Several cells are combined to a location area (LA).
- Subscriber location is known if the system knows the LA in which the subscriber is located.
- When the system must establish a communication with the mobile, the paging only occurs in the current LA where called user resides.
- Resource consumption is limited to the respective LA: paging messages are only transmitted in the cells of this particular LA.
- Location information are stored in databases (generally, a home database and several visitor location databases are included in the network architecture).

Design of Location Areas

- Size of LAs is determined in dependence on:
  - the cell radius
  - the mean mobile velocity
  - the cost of LUs (in terms of the number of LU messages required to update the location of a mobile)
  - the cost of paging (in terms of the number of paging messages required to find a mobile)
- Goal: minimizing location management cost (LU+paging traffic and processing).
Update Schemas

• The vicinity of the last update information gives the most probable location of the mobile terminal
• When to update?
• Static
  – Partition of cells in LAs
    • Non-overlapping grouping of cells
    • Mobile updates when it crosses an LA boundary
    • Drawback: traffic generated only on the boundary cells, reducing BW availability for other calls
Update Schemas

– Selection of designated reporting cells
  • Mobile must update in some designated cells
• Dynamic – based only on user’s activity
  – Distance based
    • Updates when Euclidean distance crosses a threshold D
    • Distance can be specified in terms of cells covered
  – Movement based
    • Updates when number of cell boundaries crossed reaches a threshold M
• Time based
  • Mobile sends periodic updates
Selection of LM Schemes

• Cost of location updates and lookups
• Maximum service capacity of each location database =
  – the maximum rate of updates and lookups that each database can service
• Space restrictions (size of the location database)
• Type and relative frequency of call to move operations (call-to-mobility ratio (CMR))
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

1. Home Location Registrar
2. Find m
3. Page m
4. Base-station (cell c)
5. Is mobile m in your cell?
6. Where is mobile m?

(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 Management (cont.)

• Periodic Location Update
  – Each mobile is require to regularly report its location at a set time interval

• Random 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
Location Databases

- Distributed DBs used to store the location of mobile users
- Types of Architectures
  - Two-tier
  - Hierarchical
  - Regional Directories
Two-Tier Architecture

- Used in GSM
- A home DB called “Home Location Register (HLR)” is associated with each mobile user
- “Visitor Location Register (VLR)” is maintained at each zone
- HLR
  - Located at a pre-specified zone for each user
  - Maintains the current location of the user as part of the “User Profile”
  - To locate user ‘x’, x’s HLR is identified and queried
  - When ‘x’ moves, contacts HLR and updates it to “New Current Location”
Two-Tier Architecture (contd..)

- VLR
  - stores profiles of users not at home location and currently located inside it’s area.
  - When call is placed from zone ‘i’ to user ‘x’
    - Query for ‘x’ in i’s VLR
    - If ( not found )
      contact x’s HLR
  - When ‘x’ moves from zone ‘i’ to zone ‘j’
    - Delete entry ‘x’ from i’s VLR
    - Add new entry ‘x’ to j’s VLR
    - Update x’s HLR
Drawbacks of HLR/VLR

• Assignment of HLR to a mobile is permanent
  – users permanently shifted to different region still contact the same HLR

• Scalability
  – Not scalable to highly distributed systems
### HLR

<table>
<thead>
<tr>
<th>USER</th>
<th>INFO</th>
<th>CL</th>
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<tbody>
<tr>
<td>A</td>
<td></td>
<td>MSC2</td>
</tr>
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</table>

### MSC 1

\[ \text{User Info} \]

### MSC 2

\[ \text{User Info} \]

### MSC 3

\[ \text{User Info} \]

### Fixed Network

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**VLR**

**To other MSCs**
Location Management in GSM

- The Mobility Management layer (MM) is built on top of the RR (Radio Resources Management) layer.
- Handles the functions that arise from the mobility of the subscriber, as well as the authentication and security aspects.

- **Design Choices**
  - Page each cell in the network for each call
    - Waste of Bandwidth
  - Page exactly one cell but requires the mobile to send updates each time it changes cell
    - Results in a large number of updates
Design Choice in GSM

• compromise solution used in GSM is to group cells into “Location areas”

• Updating messages are required when moving between location areas, and mobile stations are paged in the cells of their current location area.
Hierarchical Architecture

- Extend the two-tier scheme by maintaining a hierarchy of location DB
- Location DB at higher level contains location information for users located at levels below it
- Types
  - Static
  - Adaptive
Static LMT

• Location mgt involves
  – Updates
  – Searches
  – Search-updates

• A LMS is a combination of all the above strategies

• Cost of LMS includes number, size and the distance message needs to travel

• An efficient LMS should attempt to minimize the above cost
System Model

- Mobile networks comprise
  - Static backbone network
  - A wireless network
- Two distinct set of entities exist.
  - Mobile hosts
  - Fixed hosts
- Notion of Mobile Support Station(MSS) is there which stands as a gateway between wireless and static network.
- A Mobile host can communicate with only one MSS at a time.
Adaptive LMT

• System designers do not always have prior knowledge of the call-mobility patterns for a particular host.
• In these cases, there is a need for a mechanism which can dynamically adapt most suitable LMS from time to time.

DATA STRUCTURES

\[ M(h) : \{m_1, m_2, m_3, \ldots, m_n\}, m_i = \{t_i, src, dest\} \]—sequence of moves

\[ Cu(h) : \{c_{u_1}, c_{u_2}, \ldots, c_{u_n}\}, c_{u_j} = \text{cost of update upon move } m_j \]

\[ S(h) : \{s_1, s_2, \ldots, s_n\}, s_i = \{t_{si}, h_1\} \text{ there is call from } h_1 \text{ at } t_{si}. \]

\[ Cs(h) : \{c_{s_1}, c_{s_2}, \ldots, c_{s_n}\} \]—sequence of costs.

HOW THESE DATA STRUCTURES ARE OBTAINED?
Finding mobility and call frequencies

- FINDING MOBILITY.
  A system parameter MTMI (Maximum Threshold Move Interval) is defined. Let Delta be the average time interval b/n successive moves.
  Then if Delta<MTMI, the host is fast moving otherwise slow moving.

- FINDING CALL-FREQUENCY.
  Again here, MTCI (Maximum Threshold Call Interval) is defined. Let Delta1 be average time interval b/n successive calls for the host.
  Then if Delta1<MTCI, then the host is frequent caller otherwise infrequent caller.
Pros and Cons of Hierarchical Approach

<table>
<thead>
<tr>
<th>(+)</th>
<th>No need for life-long numbering (no pre-assigned HLR)</th>
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<tbody>
<tr>
<td>(+)</td>
<td>Support for locality</td>
</tr>
<tr>
<td>(-)</td>
<td>Increased number of operations (database operations and communication messages)</td>
</tr>
<tr>
<td>(-)</td>
<td>Increased load and storage requirements at higher-levels</td>
</tr>
</tbody>
</table>
What is a Handoff?

- Handoff refers to a process of transferring an ongoing call or data session from one channel connected to the core network to another.
- Process of transferring a MS from one base station to another.
- Also called as ‘Handover’.
Hard handoff between the MS and BSs.

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Reasons for a Handoff to be conducted

• To avoid call termination: call drops
• When the capacity for connecting new calls of a given cell is used up.
• Interference in the channels.
• When the user behaviors change.
  – Speed and mobility.
Types of Handoffs

- Hard handoff: “break before make” connection
  - Intra and inter-cell handoffs
Types of Handoffs

• Soft handoff: “make-before-break” connection.
• Mobile directed handoff.
  – Multiways and softer handoffs

Soft Handoff between MS and BSTs
Intra-frequency handover

- The new carrier frequency is the same as the previous carrier frequency
- Deployment: CDMA (as neighboring cells usually use the same frequency range)

Inter-frequency handover

- Carrier frequency of the new radio access is different from the old carrier frequency
- Deployment: GSM, handover between different UMTS operators

Inter-system handover

- Happens between two different radio access networks (e.g., GSM and UMTS)
- Special kind of inter-frequency handover
- Deployment: areas where GSM and UMTS coexist and overlay networks
Types of protocols

• 4 types of handoff protocols which help in providing continuous and QOS-guaranteed service.
  – Network-controlled handoff (NCHO)
  – Mobile-assisted handoff (MAHO)
  – Soft handoff (SHO) and
  – Mobile-controlled handoff (MCHO)
Network-controlled Handover (NCHO)

- Network measures the transmission quality via base stations and decides when handover should be executed
- Mobile terminal makes no measurements
- Intense signaling between the base stations and the node that decides on handover
- No handover signaling at the air interface
- Handover process (including data transmission, channel and network switching) takes 100-200ms

Mobile-assisted Handover (MAHO)

- Mobile terminal continuously measures signal strength from serving and neighboring base stations and sends the recorded values to the serving base station
- On the basis of these values, the network decides when handover should take place
- Unlike NCHO, the terminal's situation is taken into account, as the terminal itself does the measuring
- Handover time between handover decision and execution is approximately 1 second
- Increased signaling across the air interface
Mobile-controlled Handover (MCHO)

- Mobile terminal is completely in control of the handover process, i.e., it measures signal strength and decides on handover
- Very short reaction time (on the order of 0.1 seconds)

### Overview

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<tr>
<th>Method</th>
<th>Measurem.</th>
<th>Decision</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network-controlled handover (NCHO)</td>
<td>Network</td>
<td>Network</td>
<td>Analog systems</td>
</tr>
<tr>
<td>Mobile-assisted handover (MAHO)</td>
<td>Network and mobile</td>
<td>Network</td>
<td>GSM, UMTS</td>
</tr>
<tr>
<td>Mobile-controlled handover (MAHO)</td>
<td>Mobile</td>
<td>Mobile</td>
<td>DECT, 802.11</td>
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</table>
Handoff Detection

- The plane wave amplitudes, phases, and angles of arrival relative to the direction of motion are random.
- These plane waves interfere and produce a varying field strength pattern.
- The MS's received signal fades rapidly and deeply as it moves through this interference pattern.
- By reciprocity, the BS receiver experiences the same phenomenon as the MS due to the MS motion.
Shadow Fading

• As the MS moves, different scatterers and terrain change the plane waves incident on the MS antenna.

• Therefore, superimposed on the rapid multi-path fading are slow variations in the average field strength of the interference pattern due to these new reflection and diffraction paths.

• This slower fading phenomenon is called **shadow fading**.