Agenda

The lecture contains: Tracking **locations** of **out of session** mobile objects.

- Location concepts.
- General principles behind tracking location of mobile objects.
- Tracking locations of mobile terminals in cellular based wireless networks.

Concept of location

Definition of location

- Location provides meaning to the term "where":
- Mountains, lakes, rivers and oceans, etc., represent continuous geographic terrains on the surface of earth.
- Cities, states, and countries are man made names for certain territories with fixed boundaries.
- Location and navigation are closely inter-related.

Concept of location

General principles behind tracking location

- Location and objects residing there must be associated in some way.
- So, an object can be found by specifying two identifiers:
  - Identifier for the object, and
  - Identifier of the location where the object resides.
- Identifiers work as access points or address to named objects.
- The mapping or the association between two identifiers help in locating an object.

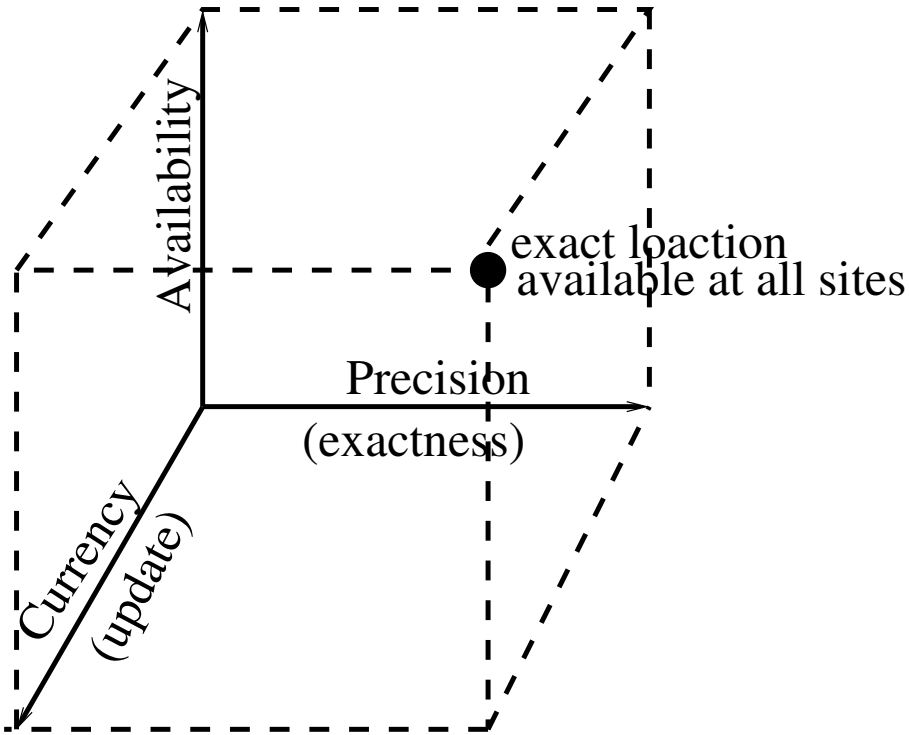
Concept of location

Tracking locations

- It may not be possible to find location of a moving object immediately.
- But, location search becomes easy if footprints of object is stored over time.
- **Update**: invoked each time the object moves.
- **Look up** or **search**: invoked each time a mobile object to be tracked.

Concept of location

Space of location management



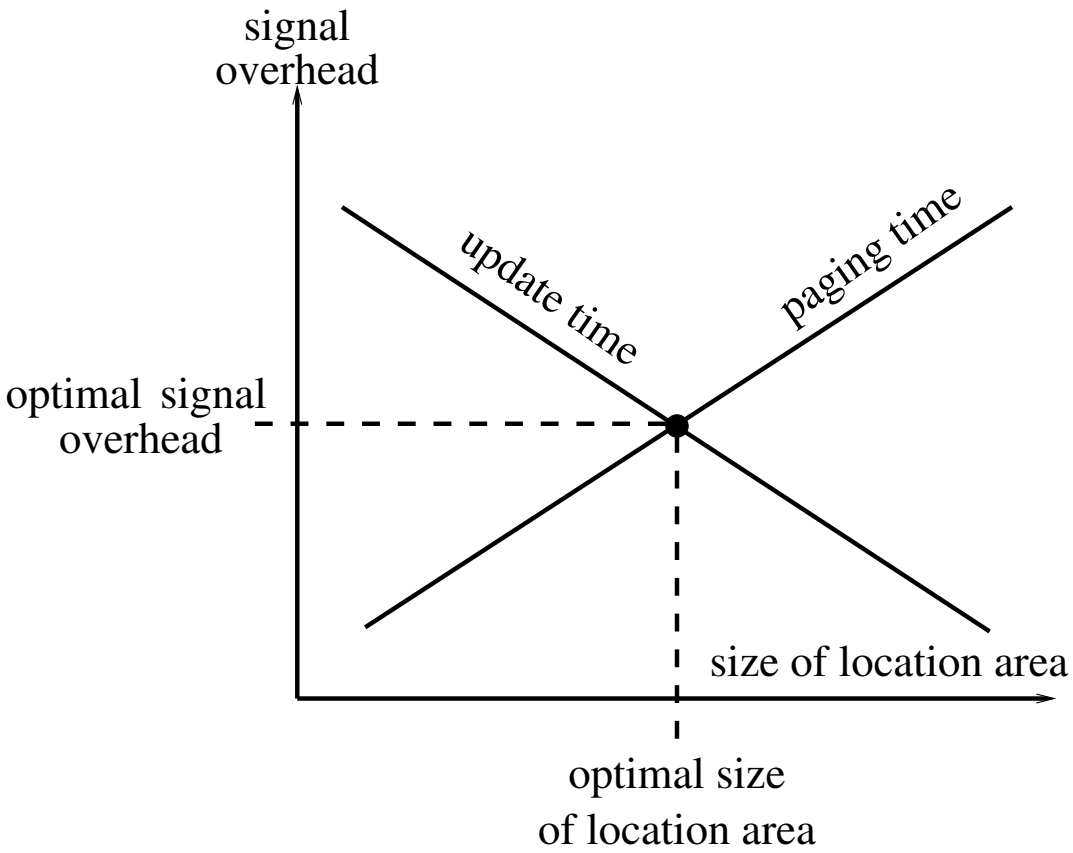
Location database

Update versus paging

- Two extreme ends of location tracking schemes could be:
  1. Update: purely inform based approach.
  2. Paging: purely search based approach.

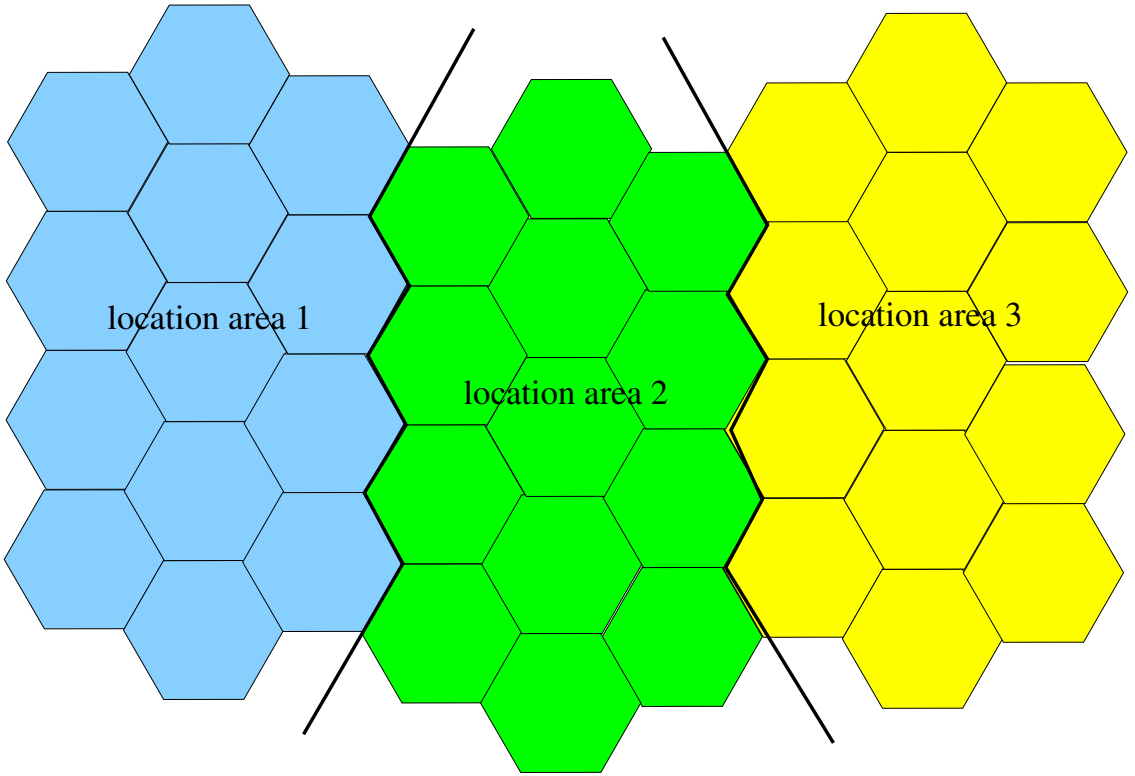
Location database

Update versus paging



Location database

Registration and paging



Location database

Organization of location database

- **Size of database:** huge.
- Database could be **centralized** or **distributed**.
- Inadequacy of centralized database:
  - Size will far exceed a moderately large database.
  - Lead to high access latency.
  - Single point of failure.
  - Can not scale up.
- Distributed database could be a solution.
  - But managing distributed database will need indexing/hashing.

Location database

Paging a mobile terminal

- Paging is sending message to a mobile and establishing a connection.
- Location update provides a location area.
- All basestations belonging to the location area are paged.
- Two different paging schemes can be used
  1. Wide area paging
  2. Selective area paging.
- When the paged mobile responds, connection is established.

Location update

Update schemes

- **Movement based**: MT reports when it enters a new location area.
- **Time based**: MT reports after expiry of a fixed interval of time.
- **Time and movement based**: MT reports either if enters a new LA or on expiry of a fixed interval.
- Theoretical mobility models: fluid flow model, markov model, or random walk model.
  - More appropriate for modeling personal mobility.

Location update

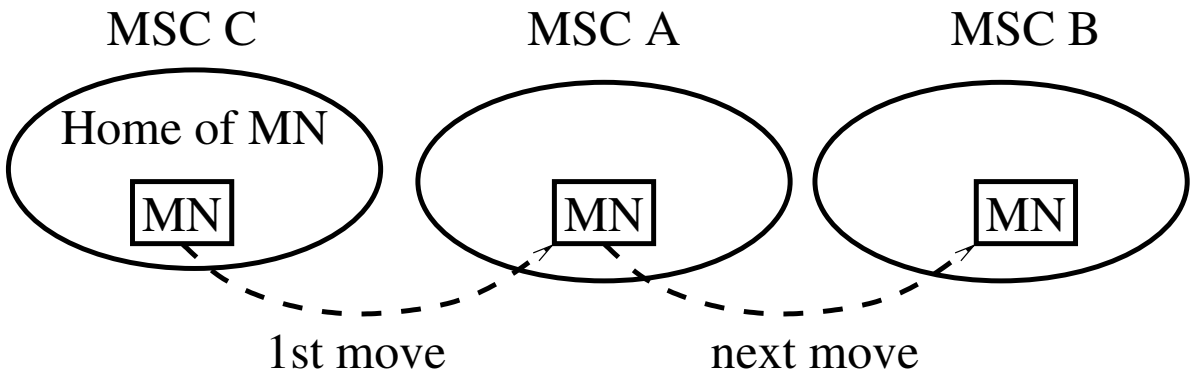
HLR and VLR updates

A user moves from **Cell**$_i$ to **Cell**$_j$

- HLR of user's home MSC gets updated.
- A VLR entry is created for user in MSC of cell **Cell**$_j$.
- Entry for the user from VLRs of **Cell**$_i$ removed.

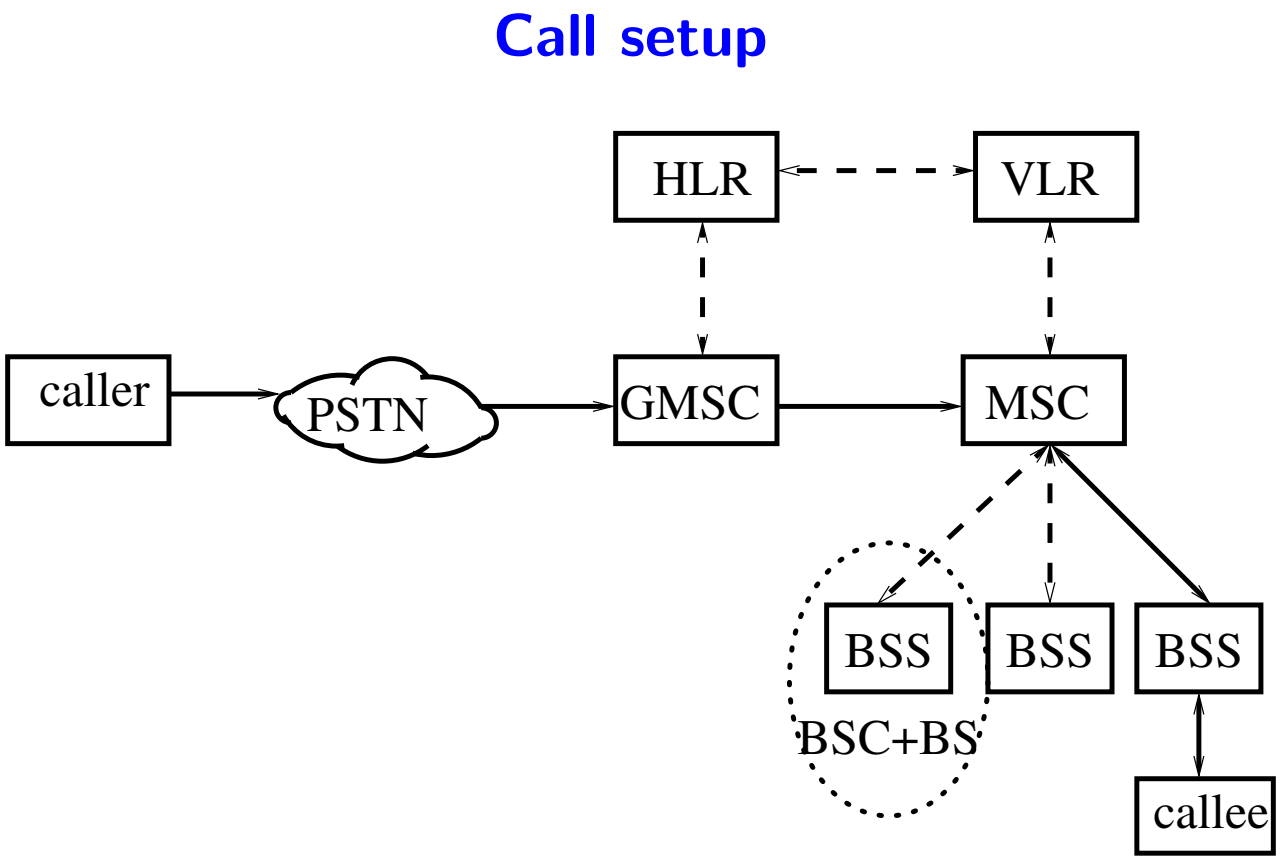
Location update

Movement based update



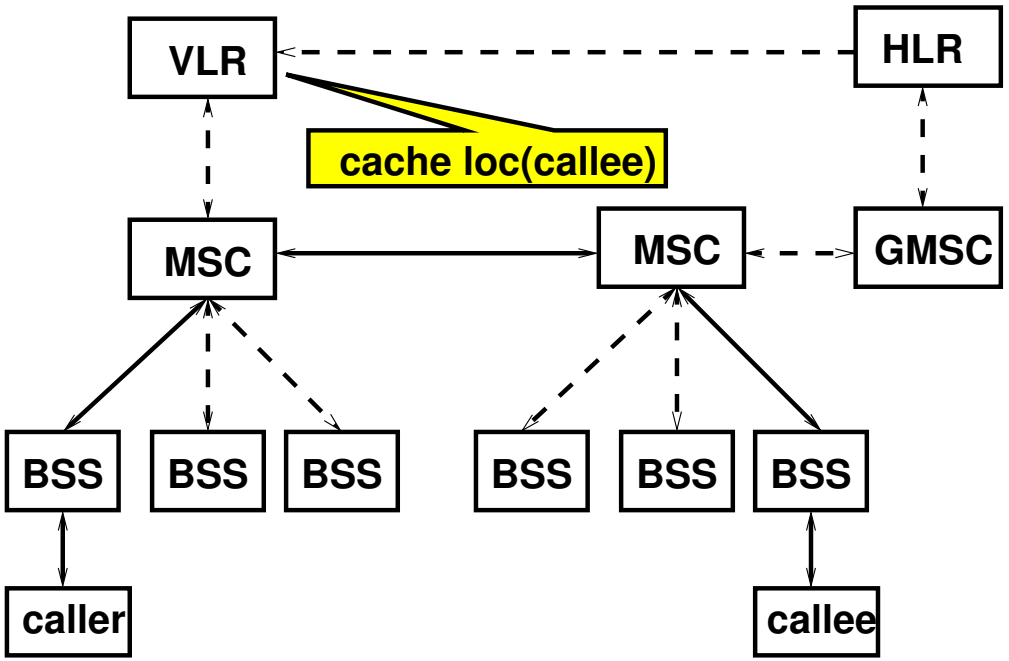
Area	Initial		After 1st move		After 2nd move	
	HLR	VLR	HLR	VLR	HLR	VLR
C	C	––	A	––	B	––
A	––	––	––	MN	––	––
B	––	––	––	––	––	MN

Location update



Caching and replication

Effectiveness of caching



Caching and replication

Effectiveness of caching

- C_B: cost of look up without caching.
- C_H: cost of look up with cache hit.
- Cost with caching: $p_{cache} \times C_H + (1 - p_{cache}) \times C_B$
- Upper bound of the above cost is C_B.
- So $\min\{p_{cache}\} = C_H/C_B$.
- That is probability threshold for caching to be effective: $p_T \geq C_H/C_B$.

Caching and replication

Effectiveness of caching

- Let call arrival times are governed by exponential distribution with mean λ.
- Also inter-LA move times are exponentially distributed with mean $1/\mu$. Then probability of cache correctness:

$$p_{cache} = \text{Prob}[t < t_1] = \int_0^\infty \lambda e^{-\lambda t} \int_t^\infty \mu e^{-\mu t_1} dt_1 dt$$

- The local to mobility ratio for a user is given by LCMR $= \lambda/\mu$.
- LCMR $= \lambda/\mu \geq p_T/(1 - p_T)$

Caching and replication

Replication

- α: cost saving if look up succeeds over to a remote query.
- β: update cost of replication
- c_{ij}: expected number of calls from Cell_j for user i
- Then replication pays if:

$$\alpha * c_{ij} \geq \beta * u_i$$

- Information about replication sites should be kept at HLR of user.

Caching and replication

Per user replication

- Following parameter should be adjusted:
  - r_i: max. # of replicas for user i
  - m_j: max. # of replicas stored at cell j
- Let user i's profile be replicated at cells $R(i)$.
- Then system cost expressed as

$$\sum_{i=1}^{N_{users}} \sum_{j=1, j \in R(i)}^{N_{cells}} (\beta * u_i - \alpha * c_{ij})$$

must be minimized.

Caching and replication

Working set replication

- Working set (WS) is maintained for each mobile.
- WS gets updated if MN moves or gets a call.
  1. For a **call**: $\alpha * c_{ij} \geq \beta U_i$ is evaluated for caller's site, if it is true, the site is included in MN's WS
  2. For a **move**: inequality evaluated for every site in WS, and if inequality becomes false for a site, it is dropped from WS.

Minimizing updates

Forwarding pointers

- When Mobile moves a forward pointer is set from previous VLR to new VLR.
- Forward pointer allowed to grow untill a bound K, after which compression takes place.
- Implicit compression also occurs when a loop is formed. .

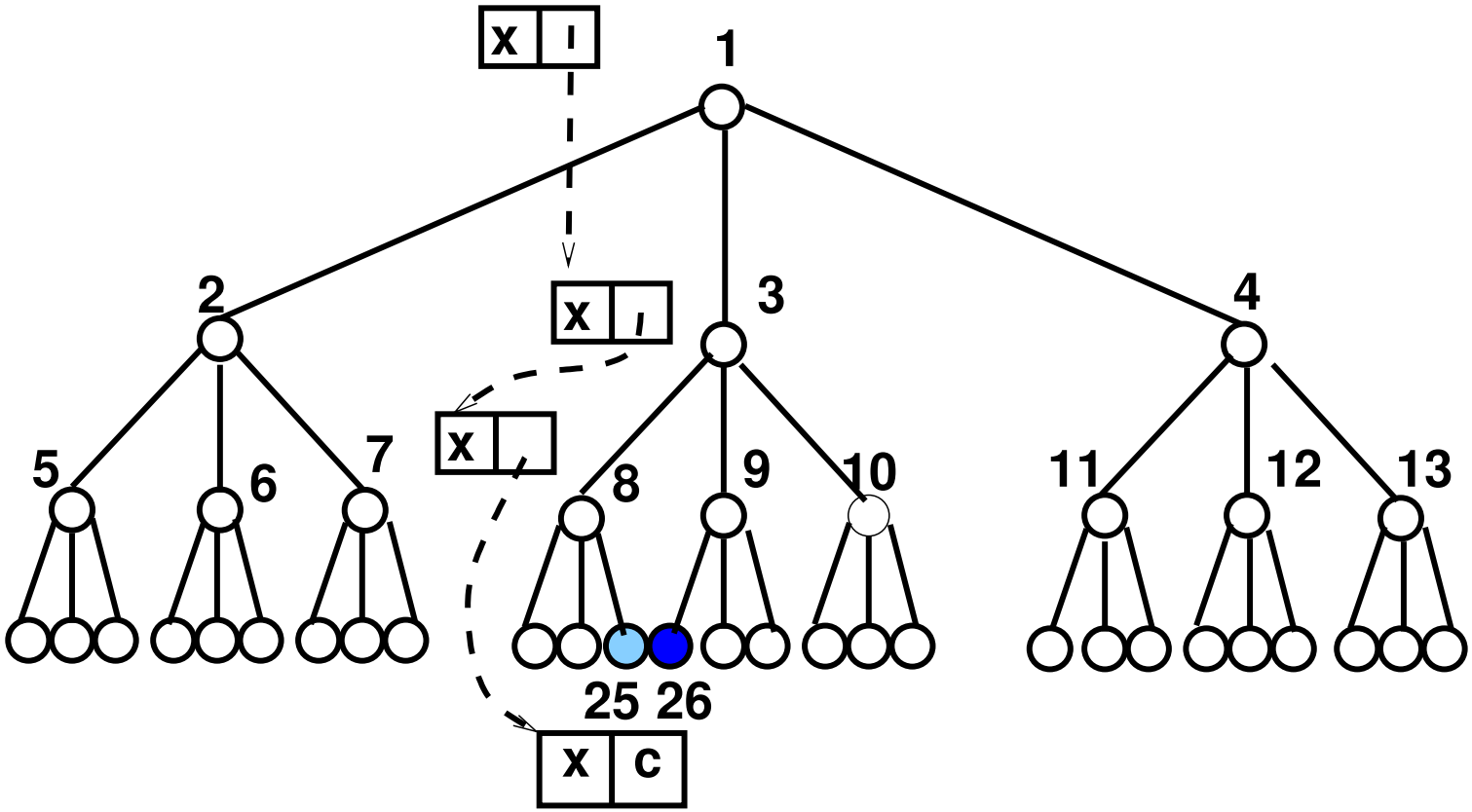
Multi-tier model

Drawbacks of two tier model

- Home location is permanent.
- Two-tier approach does not scale up well.
- Locality of the moves is not captured well.

Multi-tier model

Organization of location database

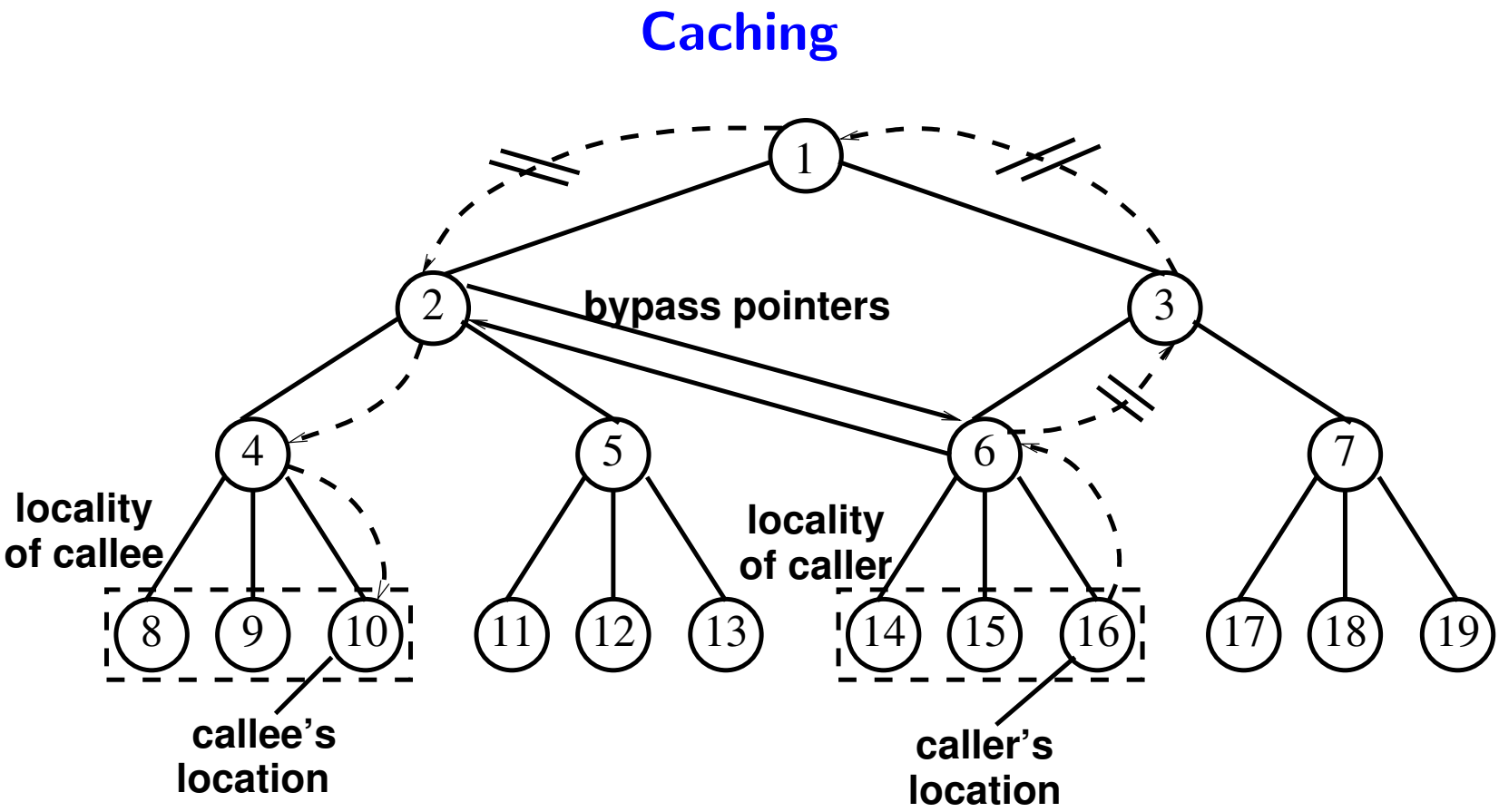


Multi-tier model

Advantages and disadvantages

- Search could be bottom up in the tree hierarchy.
- Does not require HLR and VLR
- Locality is exploited ins a natural way in call setup.
- More updates required compared to 2-tier scheme.
- Update load increases monotonically at internal nodes up the hierarchy.
- Storage requirement also increases at higher levels.

Multi-tier model



Multi-tier model

Replication

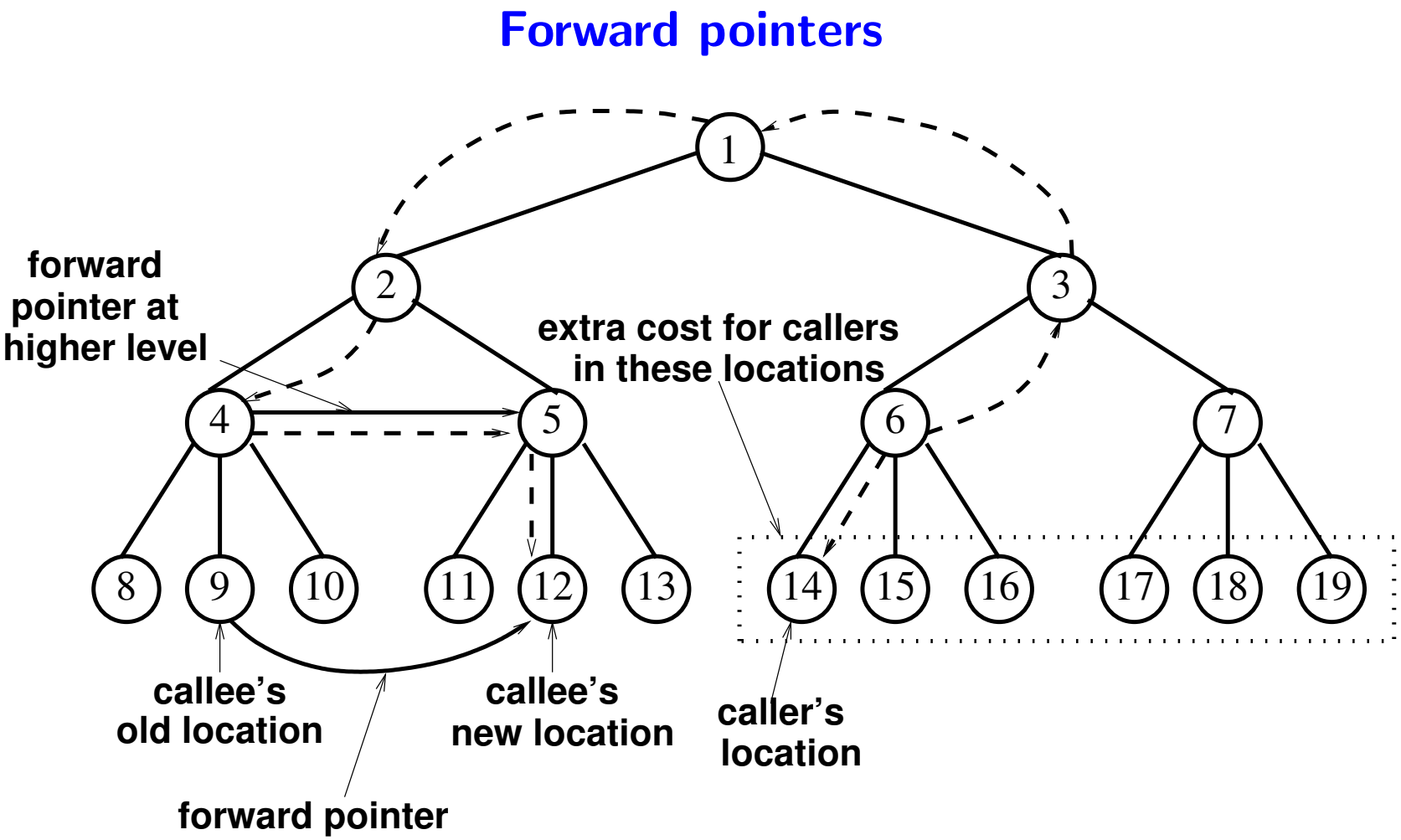
- To minimize cost of lookup, replication of user i may be done in database at node j
  - If the number calls from cells under LA j in far excess to the number i's moves, ie., LCMR_{ij} is high.
- However, two major constraints needs to be addressed:
  - Cumulative storage requirement: a replica at a node leads to placing one at each ancestors.
  - Cost of network communication: update cost would be high.

Multi-tier model

Replication

- Two thresholds R_{min} and R_{max} are used for this.
- Replication is always beneficial if $LCMR_{ij} \geq R_{max}$ if the constraints on L and N are satisfied.
- If $LCMR_{ij} < R_{min}$, then no need to replicate.
- If $R_{min} \leq LCMR_{ij} \leq R_{max}$ then decision will depend on database toplogy.
- Offline algorithm can be designed to decided where replication should be done.

Multi-tier model



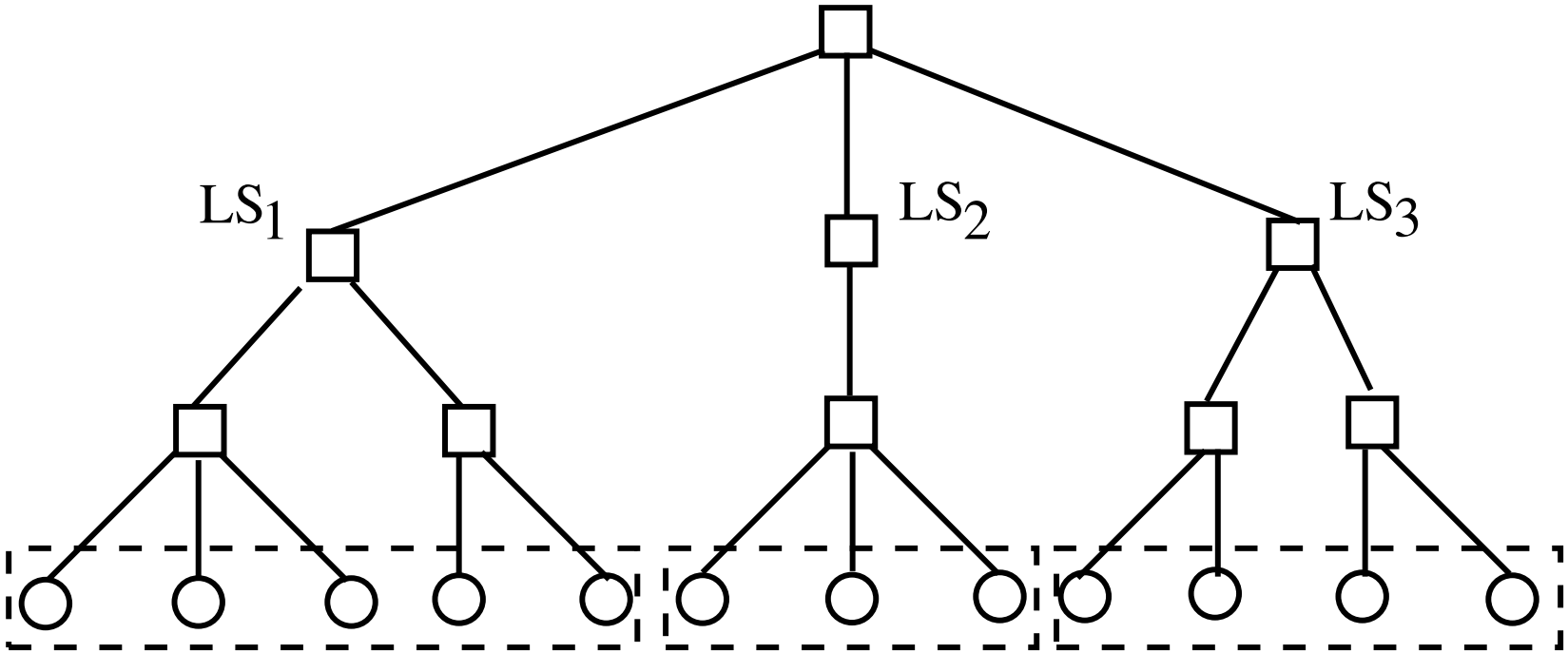
Improving performance

Partition formation

- Combines movement-based with distance-based scheme.
- Defines grouping of (partitions) cells for each user's movements.
- Partitions are formed on basis of the user's mobility pattern over a reasonable period, and possibly captured through **user profiles**.

Improving performance

How it works?



Improving performance

Update and search

- Partition data is stored at LCA of the cells defining that partition.
- LCA maintains location information of user located in the partition.
- Location is not maintained at all the levels.
- A search beginning from root would be guided to particular subtree in which the user is located.
- There is no need to page each children at the lower level to locate the user.

Improving performance

Update

- If a user keeps moving within his/her partition no update is required in the higher level.
- Only the partition representative would know about the moves.
- So, volume of updates can be restricted to lower levels.
- Move to a new partition requires a *de-registration* from previous partition representative.
- So, updates needed at the higher level location databases to record user's new partition.

Improving performance

Search

- Search is proportional to the distance from the caller to the callee.
- Suppose the callee in its home location then cost is proportional to the distance between the LS where the call originated to the home LS.
- In the figure (earlier) this cost can vary from a minimum of 0 unit to a maximum of 8 units.

Summary

- General concept of location
- Maintaining location of out of session mobile by storing footprints.
- Two-tier and hierarchical models for organizing location databases for storing footprint updates.
- Judicious use of caching, replication and forwarding pointers for balancing update and search costs.