Outline

- LM in PCS networks
- Improving the performance of LM
  - The update/search trade-off
  - Update improvements
    - e.g. Forwarding pointers, location anchors
  - Search improvements
    - e.g. Location caching, profile replication
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.
  - 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.
Location Management Problem

- In static networks, a terminal’s network address serves two purposes:
  1. End-point identifier
  2. Location identifier
- Mobility prevents using a single address for both purposes
  - Both end-point identifier & location identifier are needed.
- Location management keeps mapping between an end-point identifier and its location identifier
  - Basically a directory problem.
Location Management: Basic Operations

- Two primitive operations:
  1. **Lookup** (a.k.a. search/find/page/locate) operation: is the procedure by which the network finds the location of the mobile.
     - required when a call (message) to a user is placed (to be delivered)
  2. **Update** (a.k.a track/move/register) operation: is the procedure by which the network elements update information about the location of the mobile.
     - required when a user changes its “location”
     - The information gathered during updating/tracking is used during the locating operation
Hand-off, registration and call delivery

Hand-off, registration and call delivery

LR 1

MSC

LR 2

MSC

PCS backbone

LR 4

(HLR to Mobile A)

MSC

Mobile A

Mobile B

Mobile C

Hand-off

Hand-off + registration
Abstract LM cost model

- infrastructure-based mobile networks
- maintains location information of mobile elements
- Location information is used to properly route data and calls to mobile elements
- Two basic operations
  - Location information update (set info)
  - Location information search (acquire info)
- Cost-based description
  - Cost, as a metric of resource use.
- Load of Location management
  \[ L = f_s c_s + f_u c_u \]
Improving performance of LM

- Registrations during a hand-off are “expensive” (high cost)
  - HLR has to be updated
  - Time-critical
  - Chance of call loss

- Trends of mobile networks
  - Smaller cells, smaller RAs, larger number of RAs
    - Registration operations will significantly rise
  - Mobile terminal population growth
    - Mobile users will double in a few years
  - Immense effect to LM overhead

- Registrations are important to be kept low
  - Scalability
  - Low overhead

- If registrations happen not during a hand-off, then they can be cheap (soft registrations)
  - Not time-critical
  - Little chance of call loss (no channel reallocation)
LM improvements

- Update/search trade-off optimizations
  - Principle of update/search trade-off
    - The more effort spent in updating the information, the less effort needed to seek the information
    - And vice versa
  - Redistribute rates of updates and searches to overall load reduction
    \[ L = f_c C_S + f_m C_u \]
    \[ \downarrow L = f_c \downarrow C_S + f_m \uparrow C_u \]
    Profile Replication, Forwarding Pointers etc.
  - Characteristic: optimal point depends on call to mobility ratio (CMR = $f_c / f_m$)

- Non-trade-off optimizations
  - Do not conform to the update-search trade-off principle
  - Unilateral reduction of one (or more) load components
    \[ L = f_c C_S + f_m C_u \]
    \[ \downarrow L = f_c \downarrow C_S + f_m C_u \]
  - Predictive registration, predictive paging
  - Characteristic: optimal point depends on knowledge of the terminal mobility and/or call model.
Abstract LM protocol and “cost”

- **Update**
  - VLR: Notify HLR of moving mobile
  - HLR: update location of mobile and send acknowledgement

- **Search**
  - Caller: Ask mobile’s VLR from HLR
  - HLR: search in database and respond with mobile’s VLR
  - Caller: contact mobile’s VLR and set up call.

- **Cost of LM**
  - $f_m d_V + f_c (d_H + d_L)$
Protocol typical timelines

- Updates:
  - mobile (REG, ACK, UPD, ACK)
  - caller (LKU, RES, CAL, ACK, PAG, ACK, DAT)

- Searches:
  - mobile
  - callee
Search cost improvement: Profile replication

- **Technique**
  - Report the mobile’s location to another “HLR” (in addition to the HLR)

- **Update cost**
  - $2d_V$

- **Search cost**
  - $d_H/2 + d_L$

- **LM cost**
  - $2 f_m d_V + f_c (d_H/2 + d_L)$
  - $N f_m d_V + f_c (d_H/N + d_L)$

- **Profitable when**
  - $f_c/f_m > N (d_V/d_H)$

- **Optimal N**
  - $N = \sqrt{\left(\frac{f_c}{f_m}\right) \left(\frac{d_H}{d_V}\right)}$
Update cost improvement: Forwarding Pointers

- Technique
  - Leave a forwarding “note” at the old location informing to be reached at the new location

- Update cost
  - \( (k \cdot d_M + d_V)/k \)

- Search cost
  - \( d_H + d_L + k \cdot d_M/2 \)

- LM cost
  - \( f_m(k \cdot d_M + d_V)/k + f_c(d_H + d_L + k \cdot d_M/2) \)

- Profitable when (if \( k \gg 1 \))
  - \( F_c/f_m < (2/k) (d_V - d_M)/d_M \)

- Optimal value of \( k \)
  - \( K = \sqrt{2(f_m/f_c)(d_V/d_M)} \)
Search cost improvement:
Updated location at the callers

- **Technique**
  - Report the mobile’s location to the caller (in addition to the HLR)
- **Update cost**
  - $d_L + d_V$
- **Search cost**
  - $d_L$
- **LM cost**
  - $f_m (d_L + d_V) + f_c d_L$
- **Profitable when**
  - $f_c/f_m > d_L/d_H$
    - If the caller is stationary
  - It is higher if caller is truly mobile
Search cost improvement: Location caching

- **Technique**
  - Cache the location of a mobile when you establish the call

- **Call setup cost (search cost)**
  - $d_H + d_L$ (no caching)
  - $d_L$ (cache hit)
  - $d_H + 2d_L$ (cache miss)

- **Cost of searches**
  - $f_m \left[ d_H + 2d_L + \frac{f_c}{f_m} \cdot d_L \right]

- **Cost of LM**
  - $f_m d_V + f_c \left[ \frac{(d_H+2d_L)}{f_m} \cdot \frac{f_m}{(f_m+f_c)} + d_L \cdot \frac{f_c}{(f_c+f_m)} \right]

- **Profitable when**
  - $\frac{f_c}{f_m} > \frac{d_L}{d_H}$