A labelling mechanism to support intelligent location updating strategies

Josep Paradells Aspas
Rafael Vidal Ferré

Departament of Telematics
Universitat Politècnica de Catalunya (UPC)
Outline

• Introduction
  – Paging and location updating optimisation strategies
  – Paging and location updating inside IETF world

• Location updating distance-based: labels as a solution
  – Hierarchical labelling
  – Geographical labelling

• Implementation in a real network
  – Problems and solutions

• Conclusions
Introduction

• In Mobile Communications there is a compromise between effort required to locate (paging) and the location updating (LU)
  – **Goal**: minimization of signalling associated to both, paging and LA
  – [WL00] is a good description of strategies & open issues

• Now, this problem is present in IP world
  – IETF SeaMoby Working Group
  ➢ It’s a good time for introducing new solutions
  ➢ We focus in Location Area (LA) design
LU & Paging in current PCNs

- LA-based update algorithm
- Blanket polling paging strategies

MN detects change of $L_{A_{id}} \Rightarrow$ It sends LU

If a call to MN comes
$\Rightarrow$ Paging request is sent to all BSs of LA
PA & LA optimisation – Static LAs

- [TGM88] shows that there is a $N_{\text{opt}}$ number of cells by LA in cellular radio-mobile networks

$$N_{\text{opt}} = \sqrt{\frac{vC_{LU}}{\pi RC_{PG}}}$$

$V = \text{average velocity}$

$C_{PG} = \text{Paging Cost / input call}$

$C_{LU} = \text{LU Cost / input call}$

$N_{\text{opt}} = 7$
PA & LA optimisation – Static LAs

• Pros
  – Easy to implement
    • Operator calculates $N_{opt}$ using traffic and mobility statistics

• Cons
  – Sub optimal solution, users have very different profiles
    • Salesman, taxi driver, housewife, … different call rate, mobility patterns, velocity, …
PA & LA optimisation – Dynamic LAs

- **Time-Based Update**
  - Timer
  - Every timeout a LU is sent
    - Even if MN is static

- **Movement-Based Update**
  - Number of crossed cells
  - When reached, a LU is sent
    - Even there is no absolute movement

- **Distance-Based Update**
  - Distance in number of cells
  - When reached, a LU is sent
    - But, there is no clear procedure to calculate this distance

Distance in cells = 3
PA & LA optimisation – Dynamic LAs

- Dynamic LAs defined by MN
  - LU is a MN decision based on its parameters
- [BKS94] makes analytical comparison of three basic dynamic strategies:
  - Time-Based Update
  - Movement-Based Update
  - Distance-Based Update

⚠️ Distance-based has better results but it is the most difficult to implement!
PA & LA optimisation – Dynamic vs. Static LAs

- [XTG93] explains a method to calculate optimal size of Location Areas (LAs)
  - A labelling mechanism is presented for homogeneous square cells
    - However, this labelling mechanism can’t be extended to be used in a real cellular network
  - A comparison with optimal static LAs is done showing better performance of dynamic over static
    - 21% improvement in the worst case
Dynamic LAs – Distance-Based Update

• We can conclude that:
  – \( A_{\text{opt}} \) can be calculated for static or dynamic LA
  – Theoretical results shows superiority of dynamic strategies
  – Particularly distance-based ones

• But, there are some problems
  – MN profile is needed to find distance
    • Velocity, call rate, mobility pattern, …
  – MN has to be able to calculate distance
    • Number of cells between last LU cell and the current one

➢ Our proposal looks for a solution for distance calculation
Paging and LU inside IETF

- SeaMoby Working Group is working in Dormant Mode Host Alerting ('IP Paging')
  - RFC 3132: Problem Statement
  - RFC 3154: Requirements and Functional Architecture
  - draft-ietf-seamoby-paging-protocol-assessment-01: Protocol Assessment
- Five proposals submitted
RFC 3132: Problem Statement

- There is a need for 'IP Paging'
- It has to be compatible with Mobile IP or other IETF mobility protocols
  - But independent of them!
- It has to take profit of layer two paging protocols
  - Different L2 technologies: WLAN, GPRS, UMTS, …
RFC 3154: Functional Architecture

- Host
- Paging Agent
- Tracking Agent
- Dormant Monitoring Agent

Connections:
- H-TA: Host to Tracking Agent
- H-DMA: Host to Dormant Monitoring Agent
- H-PA: Host to Paging Agent
- DMA-PA: Dormant Monitoring Agent to Paging Agent
- DMA-TA: Dormant Monitoring Agent to Tracking Agent
RFC 3154: Functional Entities

- Host (H)
  - Supports dormant mode and capable to be awakened
  - Determines Paging Area and inform TA

- Paging Agent (PA)
  - Alerts Host in dormant mode
  - Maintains Paging areas (wide cast PA id)
RFC 3154: Functional Entities (II)

- Tracking Agent (TA)
  - Tracks Host active or dormant
  - Determines when enters in inactive mode
  - Notifies DMA about Host location
  - One to one mapping Host ↔ DMA

- Dormant Monitoring Agent (DMA)
  - Detects delivery of packet to Host in dormant mode
  - Queries TA and inform PA to page Host
  - Then it sends packet to Host
  - Host or TA select DMA for a Host when Host enter dormant mode
RFC 3154: Requirements

- More than 20 requirements identified
- Flexibility of Paging Area Design is one of them:

  “The IP paging protocol MUST be flexible in the support of different types of paging areas. Examples are fixed paging areas, where a fixed set of bases stations belong to the paging area for all Hosts, and customized paging areas, where the set of base stations is customized for each Host”
• 'IP Paging' is a good opportunity to introduce dynamic LAs for each host

• Our proposal
  – Combine it with progressive paging and
  – Use labels to allow host to know distance
    • Hierarchical labelling
    • Geographical labelling
Hierarchical labelling - Philosophy

- Hierarchy of 3 cells clusters coded with 2 bits
  - 01 = upper
  - 10 = right
  - 11 = lower
  - 00 = no cluster inside
### Hierarchical labelling – Example

<table>
<thead>
<tr>
<th>Bs_id</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>XXXX0101</td>
<td>0</td>
</tr>
<tr>
<td>XXXX0110</td>
<td>1</td>
</tr>
<tr>
<td>XXXX1001</td>
<td>2</td>
</tr>
<tr>
<td>XXXX0111</td>
<td>1</td>
</tr>
<tr>
<td>XXXX1110</td>
<td>2</td>
</tr>
<tr>
<td>XXXX1011</td>
<td>3</td>
</tr>
</tbody>
</table>

MN sends a LU

Distance_{LU} = 3
Hierarchical labelling – Mapping sample

- Approximation of existing cells to 3 cells clusters

How to map this?
- There are errors
Geographical labelling - Philosophy

- Approximate cell coverage with a circle
  - Centre = BTS position
  - Radius = distance to the cell border
- Label includes (x,y,R)
- If circle overlies
  - Cells are neighbours
  - MN calculates distance vector

MN stores:
- Last Bs$_{id}$
- New Bs$_{id}$
- (ΔX, ΔY)
Geographical labelling – Example

<table>
<thead>
<tr>
<th>(R,X,Y) (ΔX, ΔY)</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R,3,5) (0,0)</td>
<td>0</td>
</tr>
<tr>
<td>(R,2,4) (-1,-1)</td>
<td>1</td>
</tr>
<tr>
<td>(R,3,4) (0,-1)</td>
<td>1</td>
</tr>
<tr>
<td>(R,4,3) (1,-2)</td>
<td>2</td>
</tr>
<tr>
<td>(R,5,2) (1,-3)</td>
<td>3</td>
</tr>
<tr>
<td>(R,5,2) (0,0)</td>
<td>0</td>
</tr>
</tbody>
</table>

Distance_{LU} = 3

MN sends a LU
Labelling - Implementation in a real network

• Existing cells have a very heterogeneous coverage:
  – Different shapes
  – Different sizes
  • From pico to macro cells
Hierarchical - Implementation problems

- Not problem to adapts to different sizes
  - Introduce more levels of hierarchy it’s easy, just some additional bits

- Different shapes and sizes
  - There is a need to do a mapping approximation
  - It is not trivial …

- Label too longer?
  - GSM: LA_{id} = 16 bits, Cell_{id} = 16 bits
  - Hierarchical with 32 bits ⇒ 16 levels of hierarchy, 3^{16} cells
    - It isn’t a problem!
Geographical - Implementation problems

• Not problem to adapts to different sizes
  – Just some bits more to code radius with needed resolution
  – But too much bits if we want good resolution and big areas

• Different shapes
  – Use more complex approximation than circle
    • For example: ellipse with inclination
  – Of course, more bits are needed

\[
\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1
\]
\[
c^2 = a^2 - b^2
\]
Geographical - Implementation problems

- Label too longer?
  - Using 32 bits we can do (for example):
    - Maximum cell radius ($R_{\text{max}}$): 2024 meters
      - 8 bits, 8 meters of resolution
    - Area of application: 4 km x 4 Km
      - 12 bits/coordinate, 1 meter of resolution
  
  \[ \text{Not enough for a national coverage!} \]
  - With 1m resolution, 1000km\(^2\) area and $R_{\text{max}} = 35$km
    we need 56 bits
  - More than GSM but not critical
    - Broadcast
Conclusions

• Distance-based dynamic LAs are the optimal solution
• But, there is no clear procedure to calculate distance
• To solve this problem we propose 2 labelling mechanism:
  – **Hierarchical**: it scales pretty well but has problems of mapping
  – **Geographical**: it solves mapping problem better but needs more bits for labelling
Acknowledgment

- This work is supported by the Spanish CICYT under project TIC2000-1041-C03-01
References


