Zavod za telekomunikacije

Poslijediplomski studij

za stjecanje doktorata znanosti

Ak.g. 2009./2010.

Projektiranje telekomunikacijskih sustava

Knowledge-based Mobility Management: All-mobile Network & Personal Agent

Prof.dr.sc. Ignac Lovrek

27.4.2010

Outline

- Introduction and Definitions
- Mobility Issues for New Generation Networks
- Mobility Management
- All-mobile Network
- Personal Agents in the All-mobile Network
- Knowledge-based Mobility Management
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Introduction

- New generation networks ask for innovative approach to mobility management.
- Mobile users create uncertainty about their exact location

  → Knowledge-based mobility management?
- The agents offer the advantages for service and application architecture.
- *All-mobile Network*: a network in which mobile and intelligent agents support mobility

  → Personal agent?

Definitions

- *Terminal mobility*: mobility of user's equipment, with wireless access to mobile networks.
- *Personal mobility*: mobility of users, allowing network access from and routing of the communication towards any terminal in a fixed or mobile network, according to user's choice or presence.
- *Service mobility*: service provision for mobile users, including transfer of service capabilities towards them, and service profiling according to their preferences.

Mobility Management

- Registration of current location;
- Location update when location is changed;
- Search when location is unknown;
- The primary goal of registration and location update is to reduce the search costs (paging) under given time requirements;
- Recent works try to exploit user's movement history;

Movement Prediction

- Real-time prediction of the next location;
- The primary goal of movement prediction is to make reservation of network & service resources required for fulfilling (quality of) service requirements;

All-mobile Network (1)

Mobile Agent Network $\{A, S, N\}$

Multi-agent system

$A = \{agent_1, \ldots, agent_k, \ldots, agent_n\}$

$agent_k = \{name_k, address_k, service_k\}$

Set of processing nodes

$S = \{S_1, \ldots, S_i, S_j, \ldots, S_{nc}\}$

S_i, is characterised by a set of services, s_i

All-mobile Network (2)

For *agent*$_k$ hosted by the node S_i or directed toward it *address*$_k$ = S_i and *service*$_k \in s_i$.

The node S_i with a service, *access_service* $\in s_i$, allows user's connection to the network (wireless or wired).

Network

N - connecting processing nodes and allowing agent migration

All-mobile Network (3)

Mobile and wireless environment

- Service provisioning for mobile users in asynchronous and disconnected mode by setting up two connections:
  - (1) for sending a personal agent with a service request
  - (2) for receiving it back with the results
- Related work:
  - interpersonal communication,
  - access to Internet information services,
  - personalisation of the operating environment,
  - integrated terminal and personal mobility .

Personal agent (1)

- User k interacts with the mobile agent network by requesting the services from its personal agent $agent_k$.
- The node at which the user is connected when requesting the services is called the originating node, S_{ok}.
- The node where the user will be connected to collect the response from its personal agent is defined as the terminating node, S_{tk}.

Personal agent (2)

- Mobility is not the only characteristic that personal software agent requires
- Accurate knowledge as possible of a user's location helps a personal agent deliver the results
- In free selection of the server(s), it prefers the ones close to the user,
- Intelligent mobile agent, or the mobile agent co-operating with other stationary or mobile intelligent agents in a multi-agent system is the solution of preference.

Mobility of Users and Agents (1)

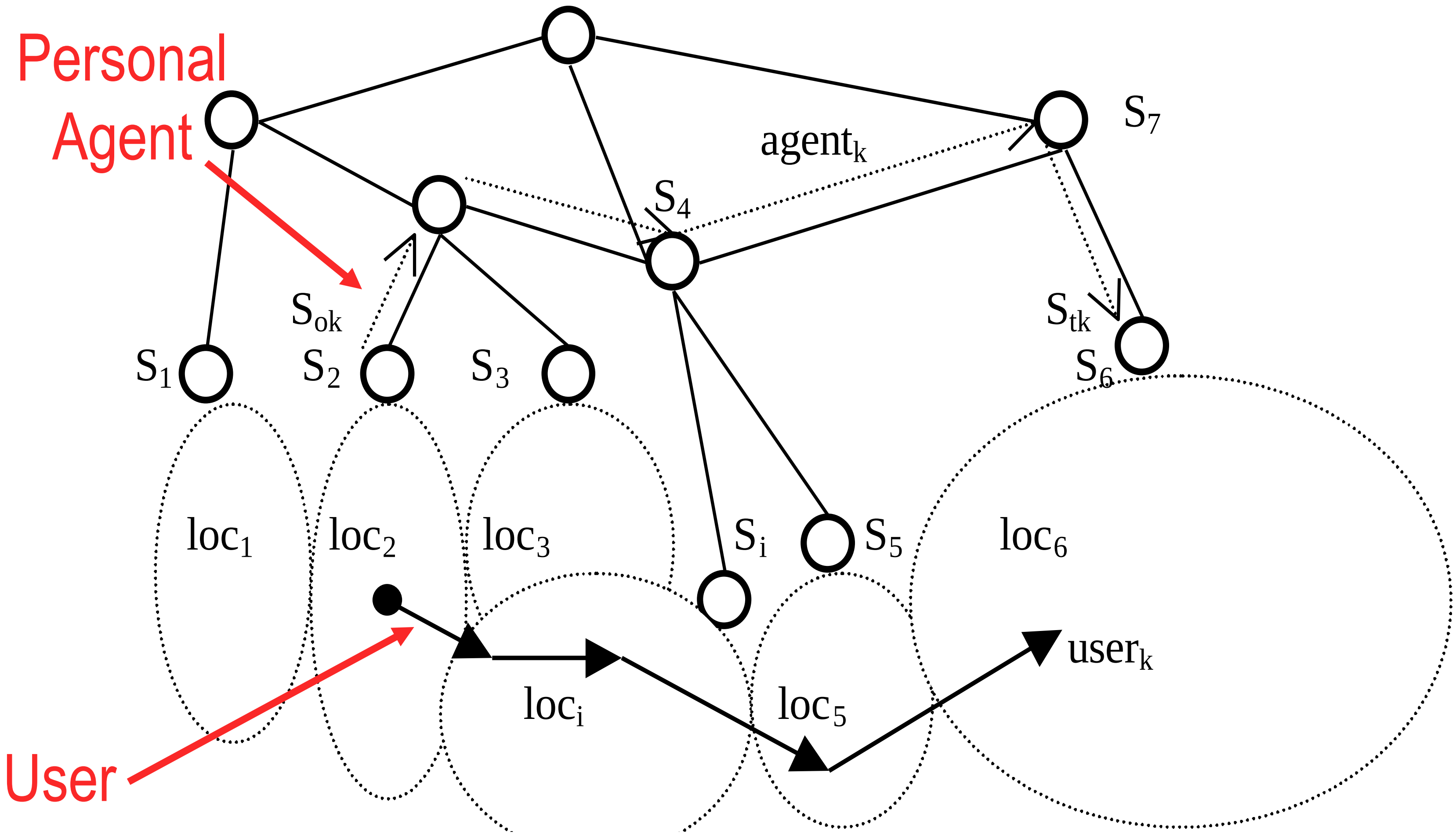
Problem statement

Having started from S_{ok}, personal agent and its owner migrate along different paths and cross different locations.

In order to complete the service, *agent*$_k$ must be directed towards S_{tk} where its owner actually resides .

An intelligent system agent, called mobility management agent, *mm_agent*, is responsible for determining S_{tk} and supplying *agent*$_k$ with S_{tk}.

Mobility of Users and Agents (2)



Knowledge-based Mobility Management

- Definition of mobility events independent of the location update scheme(s).

- Mobility knowledge presentation.

- Learning mobile entity movement.

mm_agent

Location Registration & Update Schemes

Always-Update

- whenever mobile entity changes the location - does not require the search

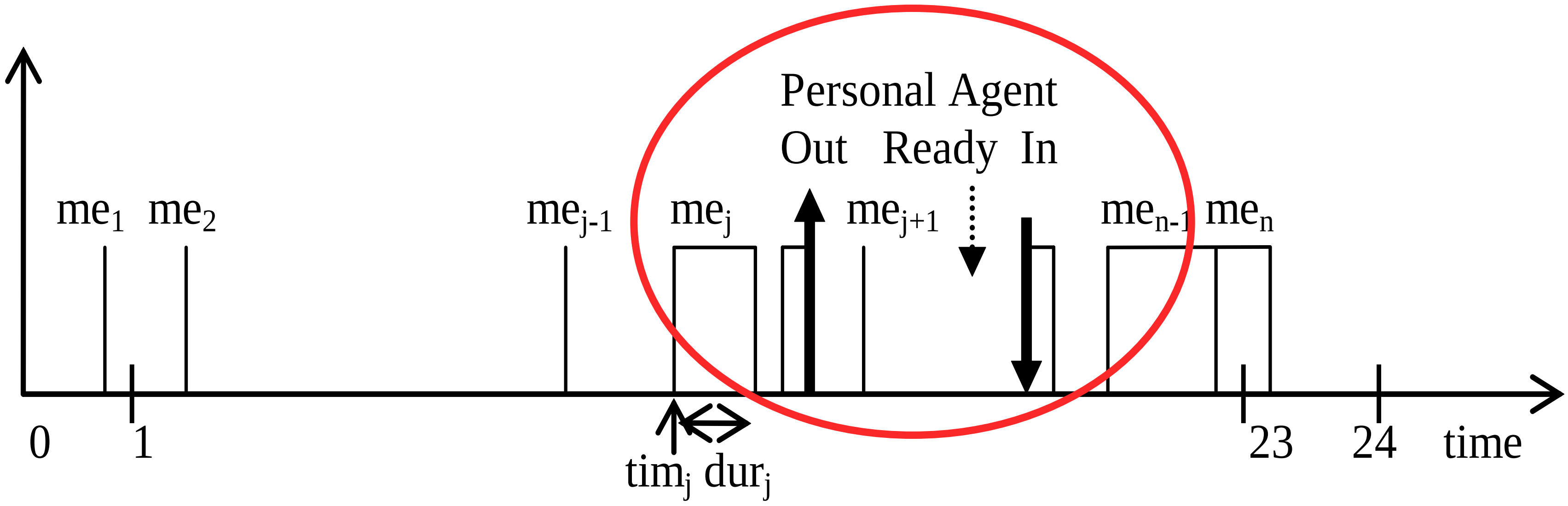
Never-Update

- no location update - the search of the whole network is required

“Reason”-Update

- dynamic mobility management: time, movement, distance, direction, state, ….

Mobility Event and Mobility History



Mobility event: me_j (loc_j, tim_j, dur_j)

Mobility history: ordered sequence of *me*

Mobility Knowledge (1)

- A personal agent serves a human user;
- Mobility knowledge representation should reflect individual user behaviour;
- Mobility history of a specific user is presented by the ordered sequences of events describing daily movement:
  - long-term (weeks, months, season) or
  - short-term (hours, days).

Mobility Knowledge (2)

Long-term mobility history

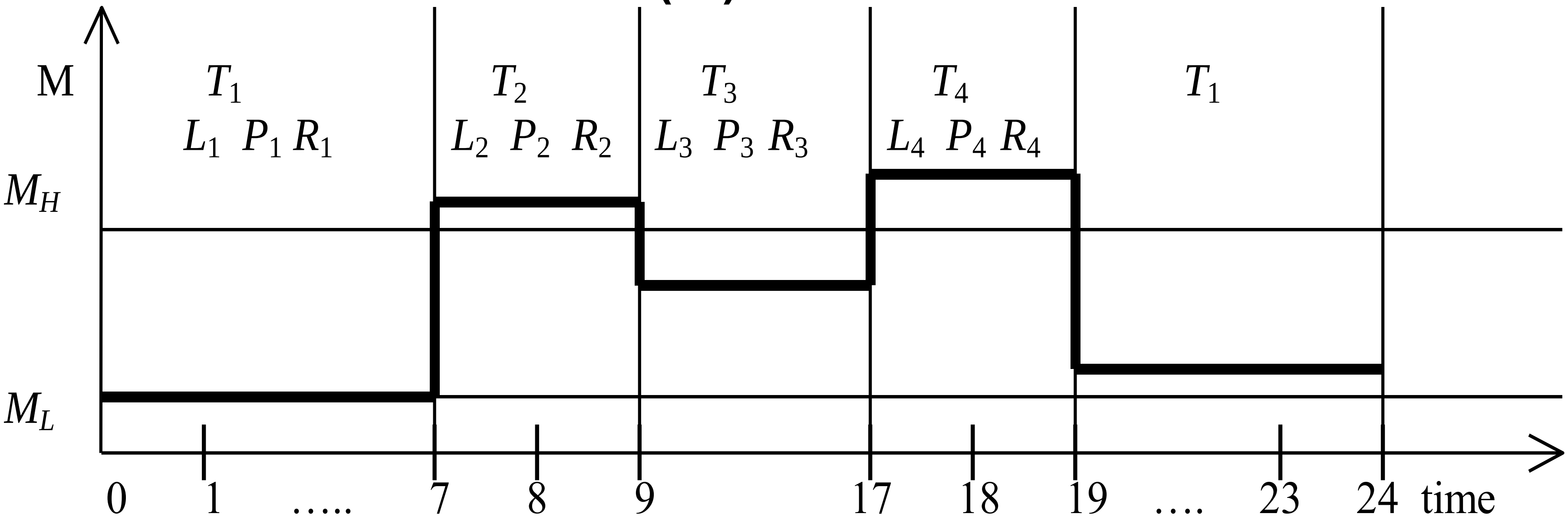
- offers the opportunities to recognize regularities in a user's behaviour and thus, to define daily regular movement.

  Time intervals $T_d = [t_{d1}, t_{d2}]$, $d = 1, 2, \ldots, D$ covering 24 hours of a day.

Short-term mobility history

- can be used for detecting "irregularities", i.e. random movement.

Representation of User Movement (1)



Time interval: $T_d = [t_{d1}, t_{d2}]$

Mobility factor: M_d (location changes/hour)

Locations: L_d

Location probability function: P_d

Resident location: R_d ($\tau_i \geq \tau_{min}$,)

Representation of User Movement (2)

Movement sentence: a sequence of characters representing visited locations.

Movement dictionary: words that define: a) a single location visited by the user, or b) a path, i.e. neighbouring locations passed by the user.

Example: 121211111233333333221 (the user has visited the locations 1, 2 and 3; he/she spent some time at 1 and 3; he/she moved from 1 to 2, from 2 to 1 and 3, and from 3 to 2.

Representation of User Movement (3)

Probabilistic interpretation of movement

- expectation that the user is at specific location(s), or is moving from one location to another.

Fuzzy qualification of movement

- linguistic values for the duration of stay (“just crossing”, “fast driving through”, “longer”, “residential”, etc).

Search Strategy

Questions

a) If the user was located at S_p by the last mobility event, what is (are) his/her current most likely location(s), or

b) Simply, where is the user now?

Answers

Searching strategy based on the principle "most likely locations in the most likely order"

Simulation (1)

- Probabilistic multi-level search strategy to locate the user;
- Location probability distribution, i.e. probability that the user will visit a location, is derived from the movement sentences;
- The search is based on optimum coding:
  - (1) Search the first groups of locations
  - (2) Add search cost to the overall cost
  - (3) If the search fails select the next group and go to 2. Otherwise stop.

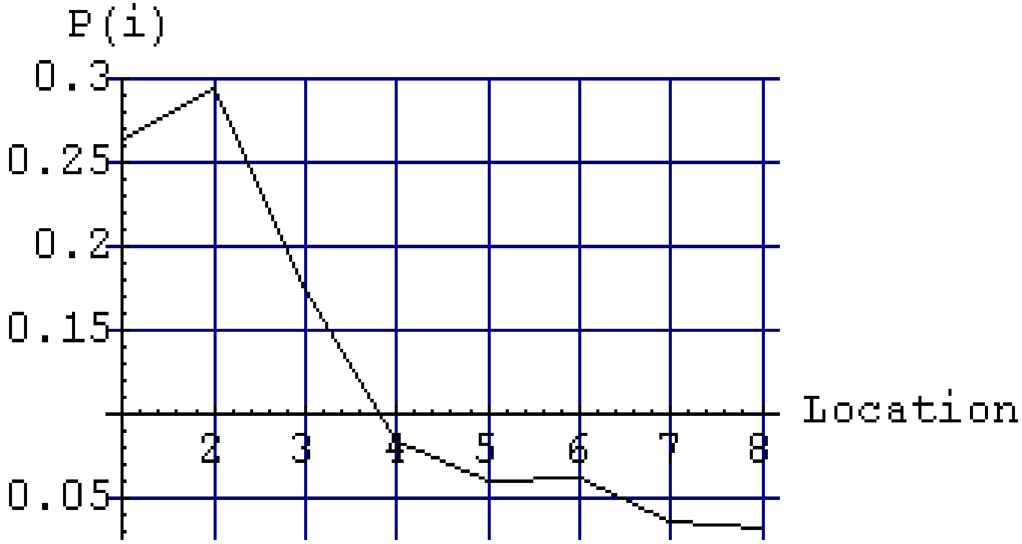
Simulation (2)

The locations sorted in a descending order and divided divided into two groups with as close probabilities as possible:

(2, 1)(3, 4, 5, 7, 8, 6).

“Most likely” locations: 2 and 1

Simulation (3)



If the search fails:

a) search the second group (decision level 1), or
b) re-apply grouping to the non-searched locations

(3, 4, 5) (7, 8, 6)

in order to prepare for decision level 2.

Search Cost (1)

Time cost

- The number of searches, i.e.. paging cycles.
- Minimum: 1 (all locations in the first search)

Space cost

- The number of locations included in a search, i.e.. paged simultaneously.
- Maximum: No. of locations (all locations in the same search)

Total cost = f (time cost, space cost)

Search Cost (2)

Mean search cost

$C = vC_v + kC_k,$

where

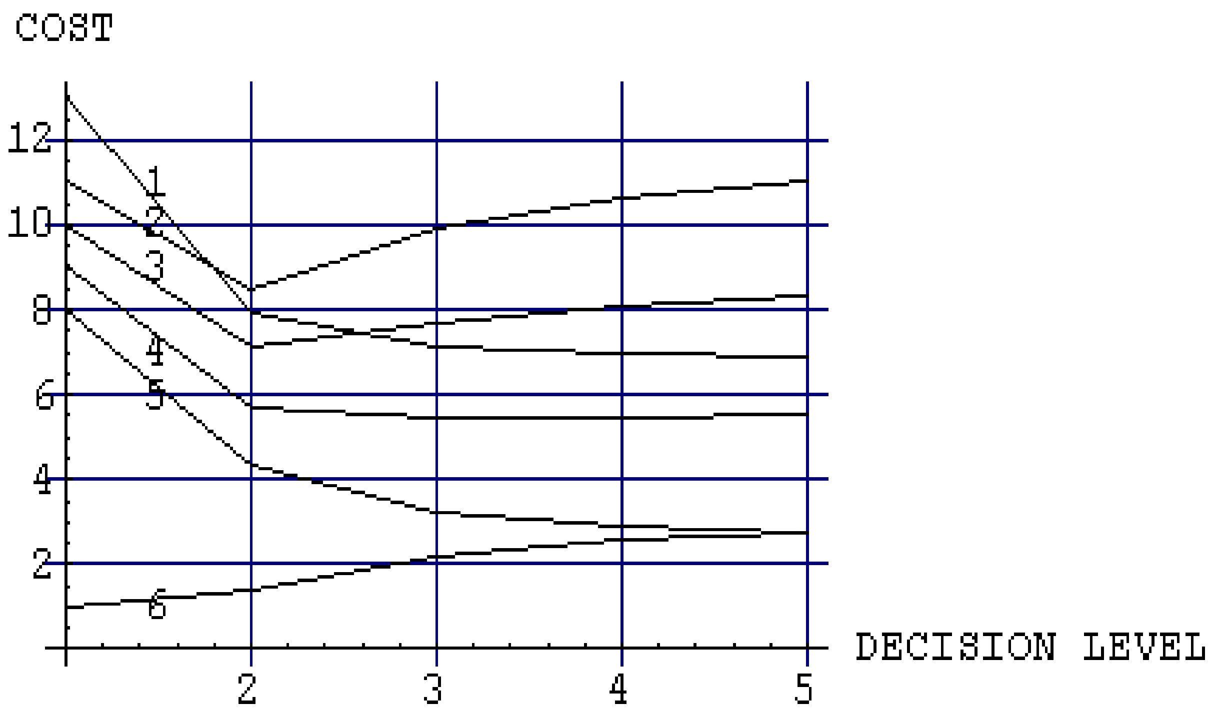
v the mean number of searches,

C_v the cost of (executing) search,

k the number of searched locations, and

C_k the cost of location search.

Search Cost (3)



Cost allocation scheme $i(C_v, C_k,)$

- 1(1, 1.5)
- 2(4, 1)
- 3(2, 1)
- 4(1, 1)
- 5(0, 1)
- 6(1, 0)

Search for the user

Personal agent ready in t_{ready} :

1. Basic regularity check

    If starting *loc* regular & last *loc* update regular

    → regular movement

    If not regular go to 3.

2. Search only the locations that corresponds to the time interval t_{ready}

    If not found

3. Page over the whole area.

Model Analysis

- Simulated events that describe long-term daily movement

  Time interval T_1

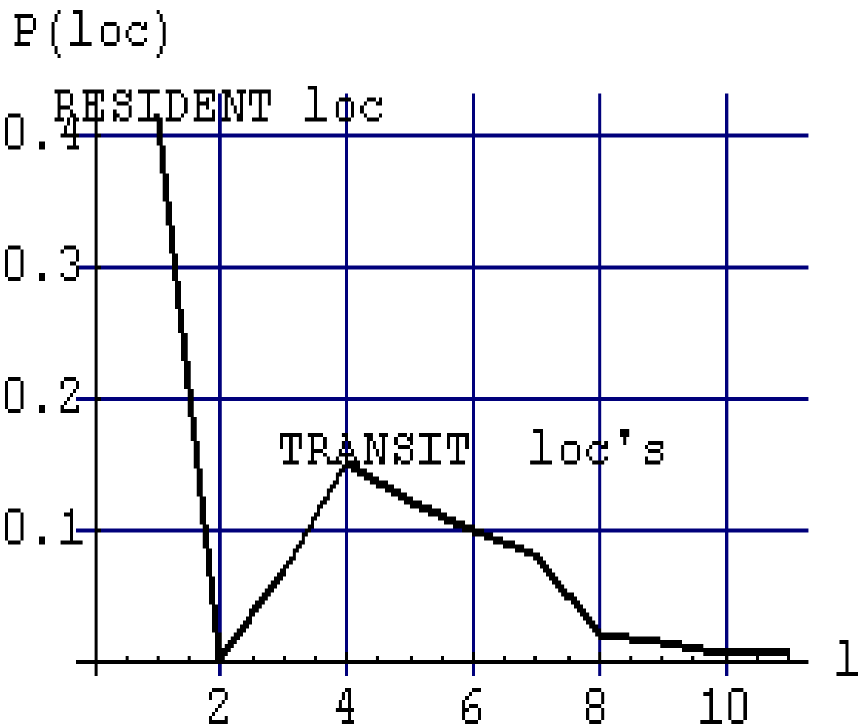
- The user is moving within an area L_1 consisting of 11 locations, one of them (loc_1) being resident; a mobility factor is defined as low.

  Time interval T_2

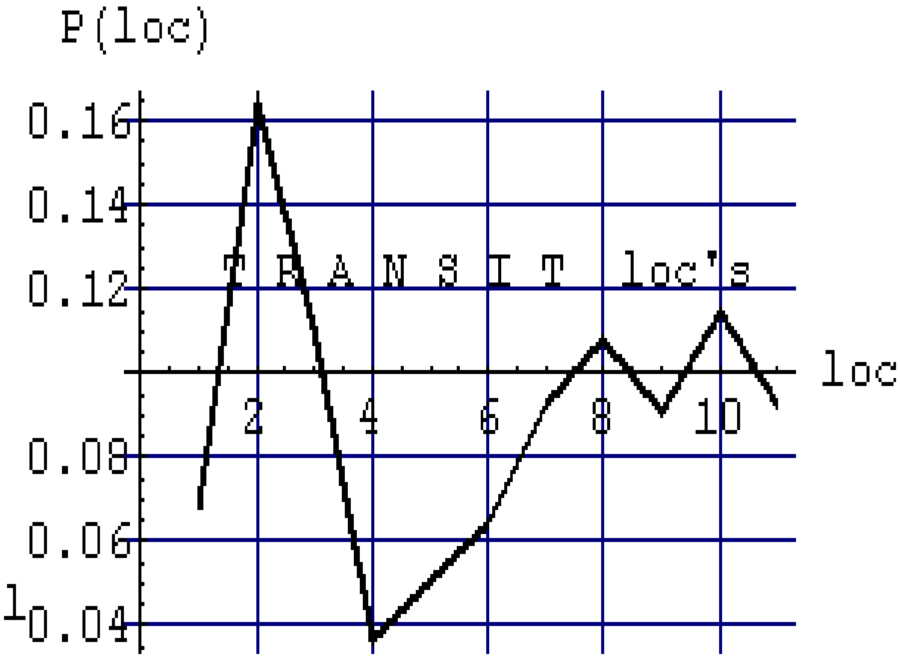
- The user is moving within the same area, i.e. $L_2 = L_1$, but without any resident location; the mobility factor is defined as high. The user's behaviour is characterized as a random movement.

Location Probability Distribution

T1

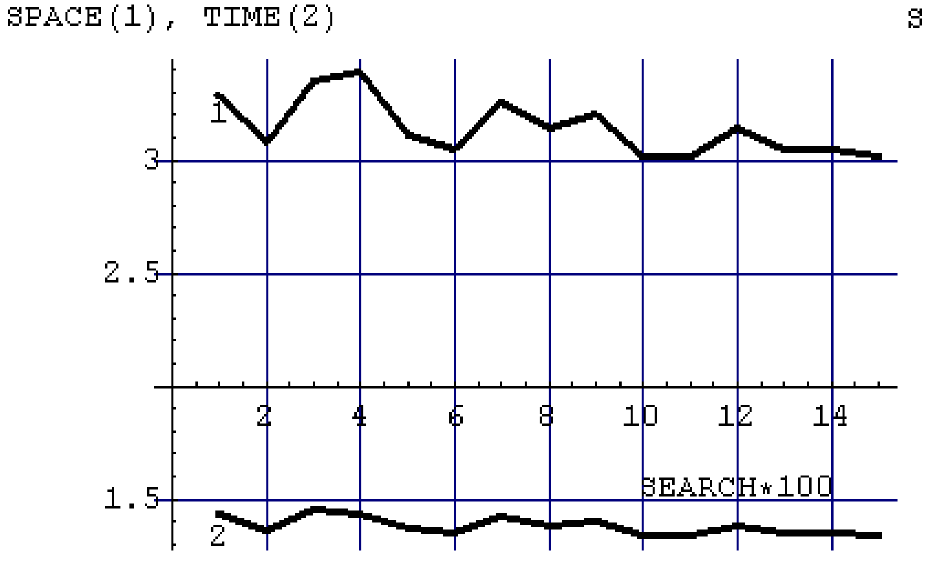


T2

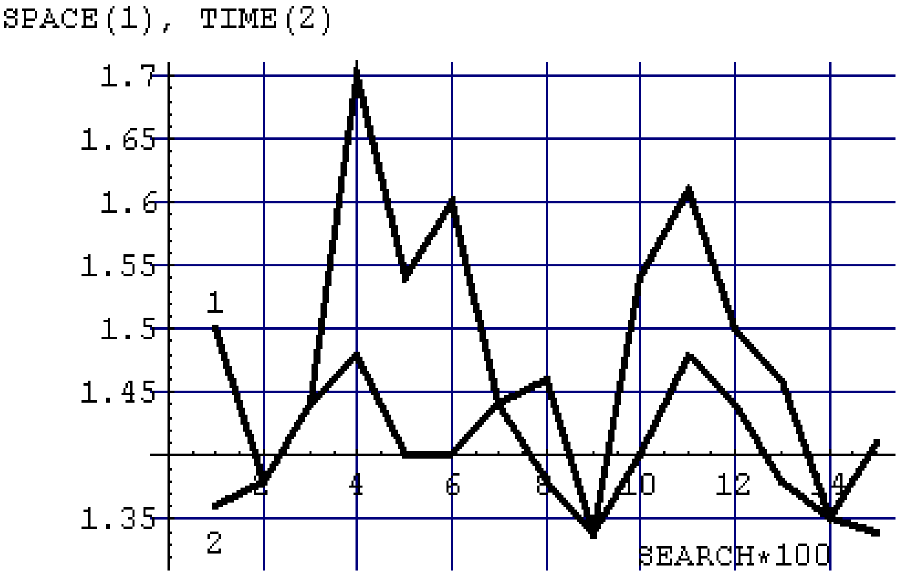


Search Cost

T1



T2



Results

- Overall average time cost is not influenced strongly by the location probability distribution (1.37 for T_1, 1.4 for T_2)
- Overall average space cost depends highly on it, being lower for resident intervals (1.48 for T_1, 3.14 for T_2).
- The model saves network resources used for paging, keeping the number of successive searches acceptable: 1.37 searches over 1.48 locations in T_1, and 1.4 searches over 3.14 locations in T_2.

Conclusions

- Mobility management model that includes user’s movement knowledge
- The movement knowledge, extracted from the mobility events generated by the network and terminal, is used to search for a user (Probabilistic interpretation/fuzzy qualification of movement).
- Investigation of learning models suitable for mobile environments