MOBILITY MANAGEMENT IN MOBILE INTERNET

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ABSTRACT

Efficient mobility management is essential for future communication networks due to evident trend of increasingly mobile users. A number of mobility management schemes are introduced in the literature. However, there seems to be various definitions of mobility management depending on the context of the problem setting.

In this paper, we give a framework that shows how the different definitions of the mobility management relate to each other. Further, we discuss how some existing mobility management solutions map into the new framework.

INTRODUCTION

There have been two more of less separated track of mobility management research. First one emerging from the need to make telephone services mobile and another one from the need to make Internet services mobile.

In the era of fixed telephony and physically big computers, it was more feasible to use devices near the user's current location than carry the device with user. Thus, the research has aimed to provide solutions on convenient usage of devices in the vicinity of the user. Later carrying both computers and phones in the pocket has become feasible and need to provide mobility for Internet and telephone devices have emerged.

While the telephony and Internet research communities have developed solutions for both personal and device mobility for different services, a lot of technologies and terminology have been introduced. Due to a different nature of the fields, there seems to be some mismatches in the terminology used.

Nowadays the ALL IP networks are bringing telephony and Internet tightly together and solutions from Internet and telephony community are used to complement each others also in mobility management. Thus, it is essential to agree on terminology and framework, which allows discussion on and categorisation of different technical solutions in sensible manner. In this paper, we propose such a framework and associated terminology.

The rest of this paper is organized as follows. First, we briefly discuss relation of our contribution to the other work done in the arena. Then, we introduce and discuss novel mobility management framework. Next, we show how existing solutions map into the framework. Finally, we provide summary of the relevant issues.

RELATED WORK

In Integrated Personal Mobility Architecture (IPMoA) work, Thai and Seneviratne (1) have described breakdown of user mobility into personal mobility and terminal mobility, which we call device mobility. Further, the personal mobility, i.e., movement of the user across terminal devices, is split into personal communications and personalising operating environment, and the latter into link, network, and session layer mobility.

TABLE 1 - Glossary

Application Layer Mobility	Mobility is explicitly supported by the application itself.
Continuous Mobility	Users are able to access communication services also while moving
Device Mobility	Movement of the terminal device within network
Link Layer Mobility	Mobility is supported by link layer technology; device's point of attachment to IP network do not change
Localized Mobility	Optimized solution for local movement; avoids global impacts from movement
Macro Mobility	Solution that provides global, network wide mobility
Network Layer Mobility	Mobility is supported by network layer technology; e.g., Mobile IP
Nomadic Mobility	Users are able to access communication services in specific areas; e.g., office, home, and airport
Personal Communica-tions	Provide communication services and ubiquitous reachability for user irrespective of the device she is currently using
Personal Mobility	Movement of the user across terminal devices
Personalizing Operating Environments	Personalizing and maintaining personalization of the operating environment when changing devices
Session Layer Mobility	Mobility is supported in session layer; the sessions are maintained transparently to the applications.
Static Mobility	No movement; included only for the sake of completeness

We have come into similar outcome for the breakdown of mobility management realisations that Thai and Seneviratne. However, we have divided device mobility further into macro and localised mobility. Furthermore, we have noticed that also other aspects than realisations of the mobility management, such as target use cases, must be included into the framework.

FRAMEWORK

In order to develop technology agnostic framework for mobility management, we have examined three different angles of the mobility: use cases, realisation, and functionality. They refer to end user's perception of the provided mobility service, technologies used to provide mobility, and basic procedures that each mobility management technology supports, respectively. Each of the angles will be elaborated below.

Use Cases

From the end-users' view point three different mobility paradigms can be identified: **static**, **nomadic**, and **continuous mobility**. We have included Static mobility only for the sake of completeness. That is an extreme case, where there is no movement at all; other paradigms are discussed further below.

Even though Kleinrock et. al. (3) originally defined nomadicity as "the ability to move easily from place to place and retain access to a rich set of information and communications services while moving, at intermediate stops, and at the destination", nowadays term nomadic mobility usually refers more to portability; i.e., ability to retain access while at intermediate stops, and at the destination. In this paper, we refer to the latter definition, when discussing on nomadic mobility.

Many laptop users today experience nomadic mobility while using their laptops to connect Internet and intranet from different locations (own desk, branch office, home, etc.). However, they are usually not connected to any network while moving between the locations.

Continuous mobility refers to model where users are always reachable and network provides reasonable communication capabilities also for moving users. Network is assumed to provide ubiquitous coverage and users are always reachable. The users of cellular networks (e.g., GSM) experience continuous mobility model today; they are always connected to the network and reachable while on the move.

Realisations

There are two different approached to provide technical realisations of the use cases discussed above: personal and device mobility. While the focus of the former is movement of the user, the focus of the latter is movement of the user's device.

Personal Mobility. One branch of the personal mobility is personal communications, which aims to provide communication services and ubiquitous reachability for user irrespective of the device she is currently using. This is something that, for instance, the personal number concepts in traditional telephony systems have aimed to solve, as described by Saaba (4). Also second generation cellular systems have addressed personal mobility within one system; e.g., in GSM system with SIM card.

Another branch of the personal mobility is personalising the operating environment. This has not been issue with PSTN phones, which have standard user interface, but in more versatile computing environments, personalizing operating environment and maintaining the personalization when changing devices is important issue (1).

Device Mobility. Device mobility can be realized in different protocol layers: link, network, session, and application layer solutions can be identified in practice.

By term link layer, we refer to everything that is below the IP layer; e.g., IEEE 802.11 or GPRS network. Thus, while using **link layer mobility**, device's point of attachment to IP network remains the same. Evidently, the link layer mobility solutions are more or less link technology specific; for instance both IEEE 802.11 and GPRS networks can provide link layer mobility

When device mobility is supported in the network layer, the network routing is able to continue routing packets to and from device even when device's point of attachment to IP network is changed. Thus, the protocols running on top of network layer (e.g., IP) protocol are not aware of the device's movement.

Since we are discussing on Mobile Internet, the **network layer mobility** has to be provided by the IP routing. Johnson and Perkins (5), (6) describe Mobile IP (MIP) solutions for IPv4 and IPv6 that provide network layer mobility solution. Furthermore, several approaches to enhance basic MIP solution have been proposed. Eardley et. al. (2) have introduced a framework for categorizing and evaluating different IP mobility proposals.

The device mobility can be supported also in the session layer; i.e., while the device's point of attachment to IP network is changed, the session layer identifiers are still kept. Thus, the applications running on top of session are not aware of the movement. There are several proposals for **session layer mobility** available; for example, Vakil (7) et. al. describe how session mobility for TCP flows can be achieved.

When the application itself detects the movement of the device and adapts to the new location, we define that as **application layer mobility**. Schulzrinne and Wedlund (8) give an example of application layer mobility in SIP application, which can maintain connectivity even if IP address of the device is changed.

While some device mobility solutions aim to provide global solutions applicable network wide, others aim to provide localized solutions that avoid global impacts of device movement. We call the former category as **macro mobility solutions** and the latter category as **localized mobility solutions**.

More specifically, macro mobility solutions provide support for device mobility without any preconditions; i.e., the device may move between any two point-of-attachments, and the macro mobility is able to support such a movement.

Applying localized mobility solutions imply that also the device movement is local; e.g., between two adjacent access points. When it is known, that in most of cases the device movement is actually local, developing optimised solutions for localized mobility is justified. The localised mobility solutions hide local movements from the macro mobility; therefore reducing the load of the macro mobility.

It makes often perfectly sense to implement macro and localised mobility on different protocol layers. When movement is local, it also very often happens between access points with same link layer technology. Further, handover between access points often involves handling many link technology specific parameters. Thus, link layer solution might be right one for localised mobility, while providing mobility across link technologies calls for network layer macro mobility solution.

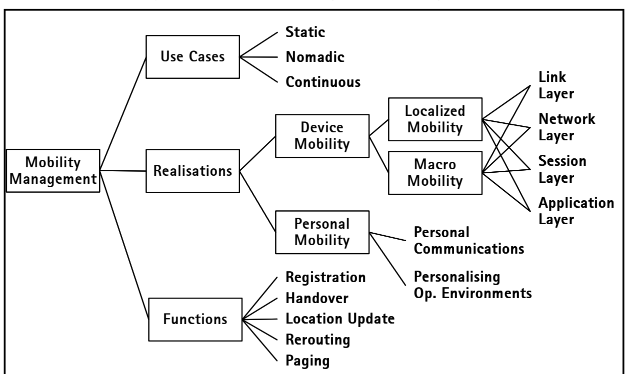

Figure 1: Mobility Management Framework

Note that Malinen et al. (9), among many others, call localized mobility as micro mobility, but we find the term micro mobility misleading in this context. A localized mobility solution may actually provide mobility for large geographical areas.

Functions

Naturally, all mobility management schemes must perform a plenty of functions. There is some variation in terminology; hence, we give here definitions for some of the key procedures common in mobility management solutions.

Registration. In both, personal and device mobility based systems, registration of the user and the used device to the network is needed. Usually registration is done when a device is switched on or the user other vice logs into the device. The purpose of the registration is to inform the network that which device the user is using and that the device is ready to receive communication requests. Usually, registration also implies authentication of the user for usage of the network resources. Registration for personal and device mobility management can be done simultaneously with combined procedure or they can be independent procedures.

Paging. When the mobile device is in power saving mode in cellular systems, the location of the device is known only in the accuracy of location area, which may contain several cells. Thus, paging is needed to find out the cell, where the device is camping and to wake up the device from power saving mode to active mode. Paging is relevant only in device mobility solutions. Moreover, implementing robust power saving features requires tight co-operation of all radio protocol layers; hence, implementing paging may prove to be challenging without support from link layer mobility management.

Location Update. Location update is like registration renewal, which can be triggered by movement or timer. The purpose of the location update is to inform the network on the user's or the device's new location, or to indicate that the device is still in the network, respectively. Like registration, location update can be performed in combined or separated procedure for personal and device mobility.

Handover. When device is in active communication session, handover must be performed when device moves from coverage area of one access point (or base station) to another. The time that is needed to perform the handover procedure is very critical to maintain perceived quality of the communication especially when the session is interactive, for instance, speech call. Usually, handovers are not considered in conjunction with personal mobility. Further, in case of nomadic mobility, the devices are not expected to move across coverage areas while having active sessions; hence, the handover as such is not needed.

Rerouting. Due to requirement for speed of operation, the traffic path in the terrestrial network is often sub optimal after handover procedure. Thus, rerouting may be done to optimise the traffic path in terrestrial network. Since, the handover is already done, rerouting is not that time critical and the procedure does not have to be completely synchronized with handover. As handover, rerouting is typically considered only with device mobility. In case of nomadic mobility, rerouting is needed to establish communication paths for re-established sessions after device movement.

Discussion

In this chapter, we have discussed various aspects of the mobility management, which can be captured into the framework illustrated in figure 1. Naturally, the complete system solution must consider all the aspects of the framework. The designer of the system must consider the use cases for which the system is targeted. If the users expect nomadic experience, building support for continuous mobility might prove to be too expensive. On the other hand, if the users expect to have continuous mobility, the whole system must be designed according to that requirement.

Moreover, mobility management is not the only aspect of complete communication system. The system designer must also consider how mobility management is integrated with AAA infrastructure and procedures, session management, QoS provisioning, etc.

TECHNOLOGIES

In this chapter, we discuss how three case examples can be mapped into the proposed framework. First, we give a look into a state-of-the-art cellular system: UTMS. Second, we elaborate two mobility management protocols developed in IETF. Third, we dig into the combination of these two: 3G ALL IP.

UMTS

The design target of the UTMS was clearly to provide continuous mobility with high QoS. Thus, all the procedures have been designed for high efficiency and speed of operation. Further, management of other system functions such as QoS and AAA has been designed closely together with mobility management.

When UMTS terminal is switched on, it performs registration to the network. While the terminal is in idle mode, it sends location updates when location area changes. When there is communication request for the user, the network pages the terminal that the user is using. During active communication, handovers are performed whenever needed to maintain the session. If the traffic routing in terrestrial network is sub optimal after the handover, rerouting can be done.

In our framework, the UMTS system provides localised, link layer device mobility; the UMTS terminal's point of attachment in the IP network do not change while terminal is moving within UMTS network. However, the system does not need support from any macro mobility solution; UMTS system can provide mobility globally moving terminals.

The UMTS provides also personal mobility. User identity is in the USIM card, which can be inserted into any UMTS terminal. The UMTS system detects which terminal the user is using and directs all communication requests to the right terminal. Further, the USIM card may contain some of user's personal preferences, such as phonebook.

Therefore, it can be said that UMTS system provides also personal mobility, even tough only between UMTS terminals. The Virtual Home Environment (VHE) concept under development in 3GPP aims to provide seamless personal mobility for end users. However, so far the personalising operating environments part of the personal mobility concept is only partially addressed.

IETF

Since the IETF tend to specify protocols not complete solution, there are several protocols specified and discussed in IETF that perform some kind of mobility management. Here we limit our discussion into Mobile IP (MIP) and Session Initiation Protocol (SIP).

In Mobile IP, there is no separation between registration and location update; mobile hosts sends similar message after switching on and movement. The same applies to handover and rerouting; essentially the handover and rerouting happen always simultaneously in MIP. Further, there no concept of power saving mode in MIP; hence, there is no need for separate paging procedures.

According to our framework, MIP provides device mobility; more accurately network layer, macro mobility solution. However, there are various proposals to extend Mobile IP to cover also localized mobility, as elaborated by Eardley et. al. (2).

SIP user agent sends registration when the device switched on or when the user other vice activates the device. During the registration, network associates user with the device in which the user agent is running. Further, the user agent may upload service settings to network and the network may send user preferences to the user agent. SIP has also procedure for location update and it can support rerouting, but do not have direct support for concepts like handover or paging.

In our framework, SIP provides clearly personal mobility solution. While is contains some features, that could be used for personalising operating environment, the focus of SIP is in providing personal communications. Further, SIP can also be utilized for realising application layer device mobility solution, as elaborated by Schulzrinne and Wedlund (8)

ALL IP

We (10) have earlier described ALL IP network architectures, which combine cellular networks and IP technologies together. The target of the ALL IP mobility management design is to provide continuous service as in UMTS, but allow personal mobility to also other than UMTS terminals.

The device mobility solution of the ALL IP is the same than UMTS networks. However, when extending service to other than UMTS networks, there might be need to complement link layer mobility with network layer technology. Thus, Mobile IP based macro mobility solution might be introduced later into ALL IP networks.

In ALL IP, the personal mobility is realised with SIP. ALL IP users register themselves to the network with SIP. After registration network associates user with the device from which she registered.

SUMMARY

In this paper, we have introduced a technology agnostic mobility management framework and associated terminology for discussing different technical realization of mobility management. Further, we have given few examples on mapping of the existing technologies into the framework.

In order to define complete mobility management solution, we need to define: Which use cases it needs to realise; How device mobility and personal mobility aspects are covered; Whether separate macro and localised mobility solutions are needed; In which protocol layers device mobility is realized; and which functions are needed for device and personal mobility.

There are approaches which solve all aspects discussed above in one totally integrated solution; e.g., UMTS. There is also approaches where each protocol solves only one part of the mobility management and many protocols are loosely combined to provide complete solution; e.g., MIP and SIP. The framework described in this paper allows comparing solutions even with different scope in objective manner.

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