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Mobility Aspects in 4G Networks - White Paper

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Abstract

The fourth generation mobile system is a collection of radio networks providing access to IP based service. In this environment roaming is seamless and users are always connected to the best network. Although this vision is common for many actors in the mobile research community, mobility and network architecture remain two of the critical issues to solve and their feasibility has not yet been demonstrated. The Network and Mobility project has a mandate to study these issues.

The purpose of this paper is to provide high-level insights into different mobility related problem areas within 4G. It also summarises assumptions and conclusions so far reached by the Network and Mobility project.

Contents

Preface

This white paper was written to provide a simplified view of what technical issues the “Nett og Mobilitet” project addresses. It also serves the purpose of providing a description of main research areas for 4G networks.

This paper is intended for a large public within Telenor as well as for external organisations. However some technical background is needed to understand some of the concepts and discussions formulated in this paper.

1 Introduction

Cellular operators have been thus far limited to coping with one cellular technology which purpose is to provide a single service in a wide area. With the advent of 3G this telecommunication landscape will evolve. In densely populated urban and suburban areas, for example, 3G will provide higher bit rates and means for enhanced services. Similarly, in hot spots where usage is high, Wireless Local Area Networks (WLAN) will complement 2G/3G service offering by providing access to the same services, but with even higher bandwidth. Technologies with other coverage vs. capacity properties, such as satellite networks, fixed wireless access (e.g. IEEE 802.16) and PAN (Bluetooth, 802.15), might further complement current operations.

Native technologies for radio access networks differ in many regards. However there is a general industrial trend to migrate the networks towards an IP based solution. This allows for easy and cost effective service creation through reuse of application software as well as straightforward interoperability with existing Internet services. In addition IP is technology independent and can thus work on any underlying access technology. As such it represents the glue between the different radio networks. A network that uses the Internet Protocol to combine different radio access networks is hereafter referred to as 4G network.

2 Problem Definition

Deployment of 4G networks is not far from reality, and these networks will exist for a long time. There exist several tools, or so-called proposals, to solve mobility issues, and surely a great deal of them could work fairly well in a closed, non-interoperable, and low scale network. However, worldwide deployment cannot afford technologies to be working fairly well. They have to be close to optimality. This will ensure that services will satisfy users and will allow for cost efficient operation and management of networks.

We see mobility as a critical aspect of 4G. In this context we deal with three main issues that should be dealt with rather independently to accommodate an easy work split. Interactions between these aspects should however not be overlooked.

The first issue deals with optimal choice of access technology, or how to be best connected. Given that a user may be offered connectivity from more than one technology at any one time, one has to consider how the terminal and the network choose the technology suitable for services the user is accessing.

The second issue regards the design of a mobility enabled IP networking architecture, which contains the functionality to deal with mobility between access technologies. This includes fast, seamless handovers (IP micro-mobility), quality of service (QoS), security and accounting.

The third issue concerns the adaptation of multimedia transmission across 4G networks. Indeed multimedia will be a main service feature of 4G networks, and changing radio access networks may in particular result in drastic changes in the network condition. Thus the framework for multimedia transmission must be adaptive.

This paper provides further insight into these issues, which are explored by the Networks and Mobility project of the Future Wireless World (DTV). In the third section we provide a high level description of optimal choice of access network as well as some initial results. The fourth section provides further problem definition with regards to IP mobility and the fifth section deals with adaptivity in multimedia transmission. In the last section we conclude on these issues and provide perspective on further work.

This paper mainly deals with terminal mobility, however, interactions with personal mobility needs to be understood as well.

3 Best Connected

Today's cellular industry is evolving to offer higher data rate mobile Internet services. Other technologies are also suited for these types of services. Many cellular operators see WLAN technology as a competitive technology that will gain some market shares for Mobile Internet services. Other technologies such as Bluetooth® and satellite communications should neither be underestimated.

As these technologies are being deployed one could take another approach and view these technologies as complementary. Indeed WLAN is best suited for high data rate indoor coverage for low mobile users. GPRS or UMTS, on the other hand, are best suited for nation wide coverage and can be regarded as wide area networks.

With mobile multimedia services being not far ahead one needs to be concerned with terminal mobility as well. To illustrate this need one could think of a user starting a video streaming session in a train station covered by WLAN. When the train leaves the train station WLAN is not available any longer and UMTS or GPRS should be used.

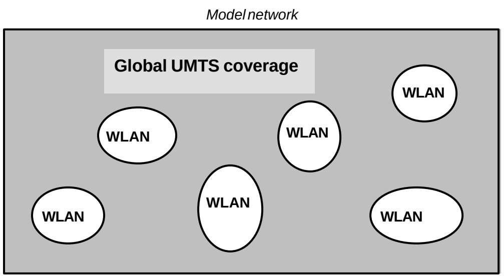

Figure 1 - 4G Coverage model

The aforementioned scenario requires that the terminal itself is able to choose the appropriate technology at any given time and that mobility procedures ensure the recovery of connectivity. More generally speaking it is an advantage for the system to take control over these procedures as it renders mobility transparent to the user. In addition the system could use both technologies for load balancing purposes so as to have a more spectrum efficient system.

The optimal choice of radio access network is thus an important question for future mobile Internet systems as well as it is important to the end user. In this section we report our preliminary results on this issue.

The problem is quite complex when dealing with many possible access networks. Thus we have first restricted our study to two radio access networks i.e. UMTS and WLAN. The former offers a wide coverage area and thus supports a high degree of mobility, while the latter offers higher bandwidth in limited areas only.

In scenarios where both types of access networks coexists, frequent decisions must be taken regarding which network to connect to. A handover algorithm should both determine which network to connect to as well as when to perform a handover between the different networks. Ideally, the handover algorithm would assure that the best overall wireless link is chosen, but different

behaviours can be expected. In our study, we have investigated how different handover algorithms influence the user's perception of his communication services.
Two different scenarios were studied, a scenario with users on the move and a scenario with users at work within an office building, with two alternative handover algorithms:

- Always connect to WLAN when it is available.
- Connect to WLAN when available only when no real-time or streaming sessions are active. (To avoid interruptions due to handovers)

Our study showed that always giving priority to WLAN is not the best strategy. The network selection strategy should take into consideration the type of bearer service used at the time of handover. This ensures stability as well as optimal bandwidth for interactive and background services. By considering active sessions as well as available access networks, we found that a perceivable better user satisfaction was achieved for both scenarios. The study is explained in more details in [1,2].

There are still a number of unresolved issues regarding optimal wireless network selection and further work should be carried out in the following topics:

- Improve the mobility models and apply other models for user movement.
- Study other, more complex handover strategies
- Study more than two radio access networks
- Consider network load and load balancing to illustrate operator benefits

4 IP Mobility

It is expected that mobile IP [3,4] will become the standard mechanism for mobility in any IP-based inter-network. It is often termed 'macro-mobility' since it will be global, and independent of mechanisms (such as routing protocols, link-layers technologies and security architectures) of different administrative IP-domains. But generality has a price; mobile IP is not optimised to take advantage of specific mechanisms that may be deployed in different administrative domains. Instead, Mobile IP provides mobility in a manner that resembles only simple portability.

To enhance Mobile IP, so-called 'micro-mobility' protocols have been developed for seamless handovers i.e. handovers that result in minimal handover delay, minimal packet loss, and minimal loss of communication state. Micro-mobility protocols should be deployed only in the administrative domains and access networks where they are required (hence the term 'micro').

The Internet community has gradually realized that routing-table driven micro-mobility proposals, such as Cellular IP [5] and Hawaii [6] are immature and their prospects uncertain. Hence, research and development on such proposals have been moved from Internet Engineering Task Force (IETF) to the more long-termed, research-focused Internet Research Task Force (IRTF). Hierarchical Mobile IP [7], on the other hand, is based on Mobile-IP itself, and is still under development in IETF.

Other proposals to enhance mobility take advantage of mobility features of the underlying technology. It is assumed that a handover at the underlying technology may result in handovers at the IP-layer. The link-layer can for example trigger the IP-layer to perform an IP handover to speed up the IP-handover process [8]. Furthermore, context transfers, as proposed by the Seamoby WG [9], may reduce packet loss and minimize loss of communication state during handovers.

At the time of 4G deployment it is anticipated that Internet Protocol Version 6 (IPv6) and Mobile IPv6 (MIPv6) will be in widespread use. In this scenario Hierarchical Mobile IPv6 (HMIPv6) is a promising technology to enhance mobility in the access network. Furthermore, the mobility anchor points introduced by HMIPv6 can be useful for mobility management in a 4G access network, since MIPv6 have no router (i.e. foreign agent) for network centric mobility management in the access domain.

It is also expected that a substantial number of networks will be mobile at the time 4G is deployed. Access networks will be located in buses, trains, and cars, and users may also carry and roam with their own small Personal Area Networks (PANs). Thus, mobility management of roaming networks is an issue that should be addressed by 4G.

In conclusion, IP-mobility should be enhanced and optimised for 4G scenarios, and HMIPv6 is anticipated to form a cornerstone in this effort. The Networks and mobility project is therefore increasing the understanding of HMIPv6 in the context of 4G, and the last version of Mobile IPv6. It is particularly important to see how HMIPv6 integrates with requirements obvious to 4G networks, such as the AAA security architecture [10, 11, 12]. It has often been mentioned that 4G should also be able to accommodate roaming PANs (in addition to roaming terminals), and the project also explores if HMIPv6 will be able to deal with this task.

5 Adaptation in Multimedia transmission

In cellular networks such as UMTS, Users compete for the scarce and expensive bandwidth. Variable bit rate services provide a way to ensure service provisioning at lower costs. In addition the radio environment has dynamics that renders difficult the possibility to provide a guaranteed network service. This requires however that the servic es are adaptive and robust against varying radio conditions.

The issue of robustness and service adaptation in a 4G environment is a subset of the aforementioned problem. Indeed one may consider that switching between WLAN and UMTS is similar to going from a low congested micro UMTS cell to a highly loaded macro cell. In theory the aspects of quality of service variations during a multimedia session are similar but the properties of the variation are different. In figure 2 we provide a summary of the available bandwidth in case of mobility between radio access network, e.g. UMTS and WLAN. There are two types of variations. Relative low but frequent amplitude variation and a at times a sudden large variation. High variations in the network Quality of Service (QoS) leads to significant variations of the multimedia quality. The result could sometimes be unacceptable to the users.
In our study we have assumed that the subjective value of being mobile is higher than the perceived negative effect of quality of service variations.

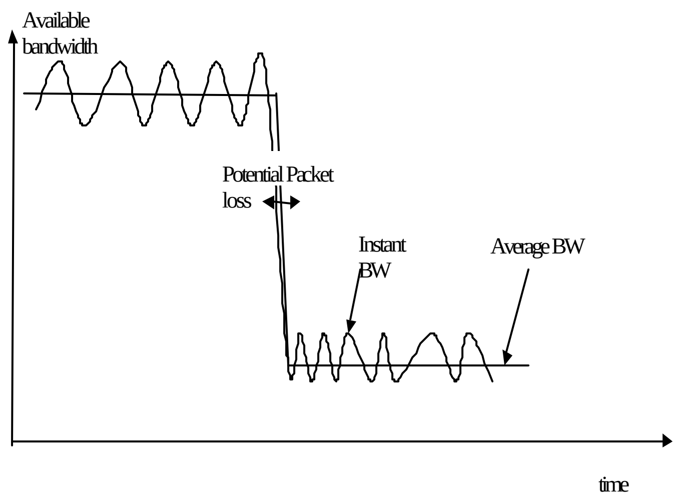

Figure 2 - varying network conditions in 4G environment

We have also adopted an Internet based Multimedia transmission framework [13] provides a certain level of flexibility able to cope with the frequent low scale variations. This is because the Internet also has the property of being a dynamic environment in terms of network Quality of Service. However this framework was probably not designed to cope with variations in network QoS as high and rapid (i.e. almost infinitely rapid as we are dealing with in a 4G environment.
Extending this framework to optimally handle rapid and drastic variations of the network conditions in a manner that is user friendly is one of the main discussion topics for 4G networks. The related issues are :

- The choice of an optimal adaptive encoding framework.
- Signalling QoS variations to allow the application to be aware in real time of the network conditions.
- Behaviour of the application when changes of network conditions occur.
- User interactions to ensure personalised adaptation of the multimedia presentation.

We have thus far in the Network and mobility project focused on the first two points.

The Fine Granular Scalability of MPEG4 [14] is a good contender since it provides a high level of granularity. However, the advantage in terms of spectrum efficiency of this scheme, compared to an optimal encoding mode switching, remains to be seen in a 4G environment. The network and mobility project intends to further consolidate a general understanding on performance issues through comparative analysis of existing results.

We enhance transport protocols such as RTP/RTCP [13] to include fast and selective retransmission capabilities to cope in a localised manner with inter access handover. However we believe that efficient solutions would benefit from a general end-to-end QoS signalling framework.

Further work is needed to ensure that the whole adaptive framework takes into account 4G requirements.

6 Conclusion

In this paper we have motivated the rationale for 4G networks and identified the main problem areas regarding mobility in these environments. These are central with regards to providing an optimal 4G platform for customers and thus operators. We have also provided some insight into the current status of the network and mobility project in DTV.

Optimal choice of access network impacts the user's satisfaction. The project has defined a model for evaluating different strategies and recommends an access selection scheme that takes into consideration the type of service being used (e.g. voice or dat). Further work is needed to refine the model and to study further the impact on operator's benefit in terms of spectrum efficiency (cost) and revenues.

IP mobility is a major issue since 4G networks are based on the IP protocol to glue the different radio networks together. Interactions between efficient IP mobility schemes and other functions, such as security and Quality of service, are required for 4G. The Mobility scheme of Hierarchical Mobile IP is thus far identified as the most promising one for offering mobility in a 4G network.

Adaption of multimedia transmission framework is a prerequisite in a heterogeneous environment. We have reviewed some main aspects such as adaptive encoding and real time end-to-end QoS signalling. Some enhancements to the general Internet Transmisison framework re needed to ensure smooth and scalable solutions.

Further work is needed within the different problem areas to provide further understanding and improved solutions. In addition further interactions between these areas are necessary to ensure a future proof and scalable solution.

The Networks and mobility project of the Future Wireless World (DTV) is working with these issues. The method of work includes both a theoretical approach that interacts with a test-bed implementation and a testing phase to ensure that practical issues are not overlooked. Cooperation with University of Oslo (UiO) on certain topics has allowed profitable exchange of thoughts. These include:

- Mathematical modelling of the optimal choice of radio access network problem. (PhD)
- Interactions between SIP and Mobile IP. (Master's thesis)

Significance for Telenor

4G networks are intended to be realized in a near future. However many technical problems remain to be solved. It is thus important for Telenor to understand potential problem areas that may affect the timing of deployment. IN addition solutions may affect the way the services are perceived by our customers. We need to make sure that these solutions take into consideration what the customers are willing to pay for.

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