VOIP MOBILITY OVER HETEROGENEOUS NETWORKS WITH FOCUS ON MOBILITY ISSUE

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Abstract

Multimedia on wireless networks and the integration with other cellular networks requires support for both mobility and quality of service. When mobile nodes move across different wireless networks, current session may be affected by the several factors like handoff delay, jitter and data loss. Voice over IP (VOIP) will be operated seamlessly across different wireless networks and that resulted few issues like mobility, signals and security. Mobile IP is proposed as a network layer host mobility solution. The problem associated with mobile IP makes it unsuitable for real time interactive solution like Voice over IP (VOIP). In this thesis paper we study the VOIP mobility in homogeneous wireless networks and cross layer mechanism for heterogeneous wireless networks which can support mobility in layer 2 of the network stack to get better VOIP performances and mobility. We describe the cross layer mechanism and the experimental results.
Acknowledgements

All my gratitude and thanks to Allah who is heavenly power on earth and store of every information and knowledge.

It is my pleasure to state that the delight earnest and admiration and philosophical esteem to my respectable supervisor Alexandru Popescu and Examiner Professor Adrian Popescu at the school of Computing at Blekinge Institute of Technology, Sweden, for their help and supervision, precious advices and collaboration for doing well with my thesis work.

I also want to thanks my parents and family members. Furthermore, I want to thank all of my associates who assisted me during this period of the thesis research work.
## LIST OF ABBREVIATION

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>IPv6</td>
<td>Internet Protocol version 6</td>
</tr>
<tr>
<td>WLAN</td>
<td>Wireless local Area Network</td>
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<tr>
<td>2G</td>
<td>Second Generation</td>
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<td>3G</td>
<td>Third Generations</td>
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<td>4G</td>
<td>Fourth Generations</td>
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<tr>
<td>AP</td>
<td>Access Point</td>
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<td>IETF</td>
<td>International Engineering Task force</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>VOIP</td>
<td>Voice over Internet Protocol</td>
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<tr>
<td>3GPP</td>
<td>Third Generation Partnership Project</td>
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<tr>
<td>IEEE</td>
<td>Institution of Electrical and Electronics Engineering</td>
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<tr>
<td>IMS</td>
<td>IP Multimedia Subsystem</td>
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<td>QoS</td>
<td>Quality of Service</td>
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<td>MM</td>
<td>Mobility Management</td>
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<tr>
<td>UMTS</td>
<td>Universal Mobile telecommunication System</td>
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<tr>
<td>SCTP</td>
<td>Stream Control Transmission Protocol</td>
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<tr>
<td>SIP</td>
<td>Session Initiation Protocol</td>
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<tr>
<td>FER</td>
<td>Frame Error Rate</td>
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<tr>
<td>HA</td>
<td>Home Agent</td>
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<tr>
<td>CN</td>
<td>Core Network</td>
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<td>MIP</td>
<td>Mobile IP</td>
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<tr>
<td>AMI</td>
<td>Application Mobility Interface</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>BU</td>
<td>Binding Update</td>
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<tr>
<td>RTT</td>
<td>Round Trip Time</td>
</tr>
<tr>
<td>MAP</td>
<td>Mobile Anchor Point</td>
</tr>
<tr>
<td>MN</td>
<td>Mobile Node</td>
</tr>
<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>RTP</td>
<td>Real Time Protocol</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>SDP</td>
<td>Session Description Protocol</td>
</tr>
<tr>
<td>CLD</td>
<td>Cross Layer Design</td>
</tr>
<tr>
<td>DHCP</td>
<td>Dynamic Host Control Protocol</td>
</tr>
<tr>
<td>CDMA</td>
<td>Coded division Multiple Access</td>
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</table>
List of Contents

1 Introduction
   1.1 Introduction.......................................................................................10
   1.2 Related works.....................................................................................11
   1.3 Motivation..........................................................................................12
   1.4 Objectives..........................................................................................12
   1.5 Outline................................................................................................13

2 Backgrounds
   2.1 Overview..........................................................................................14
   2.2 Handover Management.........................................................................14
      2.2.1 Horizontal Mobility.................................................................14
      2.2.2 Vertical Mobility........................................................................16
   2.3 Mobility across Heterogeneous Networks.........................................18
   2.4 Mobility Management.........................................................................19
   2.5 Mobility Issues in 4G.......................................................................20

3 VOIP mobility
   3.1 Overview..........................................................................................24
   3.2 Requirements for VOIP services......................................................24
   3.3 VOIP over heterogeneous network...............................................25
   3.4 VOIP mobility Problems and Solution...........................................27
      3.4.1 VOIP Over GPRS.................................................................27
      3.4.2 VOIP Over WLAN.............................................................28
   3.5 Mobility management for VOIP services........................................28
      3.5.1 Handover Support.................................................................29

4 Mobility Mechanisms
   4.1 Overview..........................................................................................30
   4.2 Cross layer Design...........................................................................31
   4.3 Cross layer mobility support.........................................................31
      4.3.1 Cross Layer Interaction.........................................................32
   4.4 Cross layer Architecture..............................................................33
   4.5 Experimental Results......................................................................36
5 Simulations

5.1 Scenario Description ................................................................. 41
5.2 Experiment Setup and Results ..................................................... 43
6 Conclusions and Future Works ......................................................... 47
APPENDIX ......................................................................................... 48
References ......................................................................................... 57
List of Figures

Figure 2.1 Horizontal Mobility ................................................................. 15
Figure 2.2 Vertical Mobility ................................................................. 17
Figure 3.2 VOIP in Heterogeneous Networks ............................................. 26
Figure 4.1 Present and Future Protocol Stack of Internet .......................... 30
Figure 4.2 Cross Layer Co-ordination Plane .............................................. 33
Figure 4.3 Mobility plane ................................................................. 35
Figure 4.4 Neighbor Graph Caching ....................................................... 37
Figure 4.6 Cross Layer Mobility Support ............................................... 38
Figure 5.1 Handoff Scenario for conference call ..................................... 41
Figure 5.2 Handover result for different handover techniques ..................... 43
Figure 5.3 performance of Different Handover Techniques ....................... 46
List of Tables

Table 1 Feature changed in horizontal/vertical handover....................................17
Table 2 Capabilities in Vertical/Horizontal handover.........................................17
Table 3 Performance for the up handoff over different networks.........................39
Table 4 Average packet loss in WLAN- UMTS ..................................................40
Chapter 1

Introduction

1.1 Introduction

In present world, telecommunication operator feels the pressure to provide the best service to their customers. So, the implementation of heterogeneous networks is thus very much realistic to them. As a consequence of its heterogeneity, heterogeneous network requires mobility implementation. In these heterogeneous networks, Internet Protocol version 6 (IPV6) will be played a vital role for multimedia traffic as well as data traffic. IPV6 already includes basic mobility support. So in order to provide mobility support we required efficient handover mechanism. With the increasing number of users scalability is another issue which is to be focused on.

In recent years, internet access through Wire Local Area Network (WLAN) becomes popular due to its mobility at the same time getting the internet connection. The integration of wireless network together with the mobile communication systems such as 2G or 3G provides the golden opportunity to mobile operator. In today’s world, users can access anytime, anywhere and always being best connected while enjoying a great variety of application [1].

In wireless system mobility actually means that changing of access AP’s to the wireless network while keeping the ongoing session intact. Traditionally in circuit switch based network is network controlled. Network requires measurement to the mobile station and the corresponding network element is the decision maker in contrast The IETF standardized body, which is standardizing all the mobility extensions to the IP protocol, consider the mobility procedure mostly host oriented. But the fact is mobility problem and the solution regarding mobility is not yet fully solved. Thus it is clear that control should reside in the network but IETF supported protocols are not yet ready to get involved in IP base network Controlled mobility across heterogeneous networks access.
The goal of using heterogeneous network in Voice over Internet Protocol (VOIP) session is an interesting opportunity, for example in a moving car or train it provides high speed connection when they are available. It is also useful in a smaller area where distribution of Access Points (AP) cannot achieve full coverage.

1.2 Related works
In 2G network, mobile users enjoyed the benefit of mobility while they are moving. During 2G networks a new architecture as well as associated functionalities introduced the concept of handover. In early stages of mobile networks mobility management was rather a simple operation. The concept of mobility management is enhanced increasing both flexibility and complexity covering a large variety of scenarios. The fact is providing IP connectivity to users on the move becoming the major challenges both research as well as from business point of view. To overcome these challenges 3GPP standardization body proposes protocols to support IP based services in the internetworking technologies supporting IP such as WLANs [2]. These facilities provide a great flexibility to the users to enjoy a large variety of multimedia applications while keeping the ongoing session intact. In such environment mobility management get quit complex and the requirements of real time application such as VOIP also get complex.

The 3GPP is currently developing standards in order to support seamless mobility over 3g and 4G Wireless Local Area Networks (WLANs) based on the protocol s of the IEEE 802.11 and other networks [3]. Recently 3GPP also defined the IMS to support VOIP, streaming and video conferencing [4]. IMS provide real time services among the end users connected both on the internet and cellular networks. By adopting these techniques mobile systems should be able to offer real time services across heterogeneous technologies in seamless way. However, mobility support raises some issues not only handoff management but also to the quality of services (QoS) [5]. In this thesis paper we will mainly focus on handover issues.
1.3 Motivation
In future it will be a heterogeneous wireless networking world with support of any service and at any time delivered in an optimized way. Over the last few years the demand for multimedia services such as VOIP, video conferencing, IP telephony etc increases tremendously to the evolution of the wireless based all-IP networking. That’s why a research effort for the internetworking heterogeneous technologies is required for delivered these services. The QoS of multimedia services such as VOIP will greatly depend on the impact of handover hence traffic redirection in a seamless and secure manner. Furthermore it should be keep in mind that cross layer architectural solution will also be the important issue to deliver multimedia services over heterogeneous network in a cost effective manner.

To achieve seamless service mobility to the end users in an optimized way, we required mobility management and cross layer techniques to facilitate effective co-operation among heterogeneous wireless networks [6]. That’s why our goal of this thesis work to study the cross layer architecture and the relation between cross layer architecture and mobility management and hence how they effect on VOIP mobility.

1.4 Objectives
The main objectives of this thesis are

1. Identifying the problems that can occur during mobility across heterogeneous networks.
2. How do these factors affect the mobility across heterogeneous network?
3. Find out the requirements for VOIP services?
4. Identifying the problems that can occur for VOIP across heterogeneous network?
5. How do these factors affect the VOIP mobility across heterogeneous network?
6. Find out the suitable mobility mechanism for better performances of VOIP across heterogeneous network and homogeneous wireless networks.
1.5 Outline
This thesis report consists of six chapters. Chapter 1 gives an introduction of the mobility management and cross layer techniques and presents the related work, motivation and objective of this thesis.

Chapter 2 describes the mobility management in heterogeneous network as well as mobility management within the same network and the problems regarding the mobility management.

Chapter 3 dedicated to requirements for VOIP services and VOIP over heterogeneous network, problems regarding VOIP mobility and contemporary solution and finally we discussed mobility management for VOIP services.

Chapter 4 which illustrates cross layer architectural phenomena and cross layer mobility which describes the relation between cross layer architecture and the mobility issue, hence their effect on VOIP mobility over heterogeneous network.

Chapter 5 dedicated to the simulation results. In this chapter we present the result for different parameters which have significant impact on VOIP mobility over homogeneous wireless networks.

Finally chapter 6 concludes this thesis work. This chapter presents several recommendations that should be taken into consideration about VOIP mobility and the future work which is about signaling and security issues for VOIP mobility management.
Chapter 2
Background

2.1 Overview
Future generation wireless system will be integrated wireless system where mobility support will be one of the main features in wireless technology. Mobility management is an element of the IP routing protocol, would be more useful for both customer and operators.

Third generation system have been designed to support internet facilities to the end user. It is becoming more vulnerable to handle mobility at network layer as mobile networks currently do. An incorporated solution whereby MM is an essential part of the IP routing protocol, will be more helpful for both the operator and end users [7].

2.2 Handover Management
According to handover management the characteristics that makes a big difference amid straight handover and straight down handover as follows

a. Horizontal Handoff
   Handoff within the same access networks; actually it referred to as the intra-handover.

b. Vertical Handoff
   Handoff across heterogeneous networks, actually it referred to as the inter-handover.

It is specially noted that horizontal and vertical handoff has different requirements and techniques to allow handover.

2.2.1 Horizontal mobility
The principle concern of horizontal handover is to maintain ongoing service by changing the IP address due to the mobility of MN. Maintaining ongoing session is done by hiding the change of IP address or dynamically updated the IP address.
Following figure 2.1 depicts horizontal mobility

To hide the IP address changing during the movement of MN, MIP keeps two types of IP address, one permanent IP address which is known as home address might be used under transport layer.

The majority of the proposed handover techniques might be included in horizontal or homogeneous handover because they focus on maintain ongoing session and only the IP address is changed.
2.2.2 Vertical mobility

It is happened when a MN travel across heterogeneous access networks. Apart from horizontal handover, it requires changing of the access technology and IP address, it is happened because the MN moves dissimilar access network which utilizes different access technology. For this, the principle concern for vertical handover is to maintain ongoing session even though the change of IP addresses and interface of the network, QoS etc. Figure 2.2 shows the concept of vertical mobility.

![Figure 2.2 Vertical Mobility](image)

It is worth noted that handover techniques for horizontal handover could not be used in vertical handover [8] [9]. Horizontal handoff can solve the trouble of the change IP address; they could not maintain ongoing session while network interfaces or QoS characteristics are changed.

<table>
<thead>
<tr>
<th>Table 1: Feature that distorted in horizontal/vertical handover</th>
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<tbody>
<tr>
<td>Horizontal</td>
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16
To allow vertical handover, the modifying of Mobile IP is needed [10]. The major capabilities of vertical handover as compared to horizontal can be given as follows:

1. dissimilar access medium
2. Numerous network interfaces
3. Numerous IP address
4. Numerous QoS parameters
5. Numerous network connections

Table 2: Capabilities in straight down and straight handover

<table>
<thead>
<tr>
<th></th>
<th>straight Handover</th>
<th>straight down handover</th>
</tr>
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<tbody>
<tr>
<td>Access technology</td>
<td>solitary technology</td>
<td>Mixed Technology</td>
</tr>
<tr>
<td>Network Interface</td>
<td>Distinct</td>
<td>many</td>
</tr>
<tr>
<td>Truly used IP address at a time</td>
<td>Distinct</td>
<td>many</td>
</tr>
<tr>
<td>QoS parameter</td>
<td>distinct value</td>
<td>many values</td>
</tr>
<tr>
<td>Network connection</td>
<td>distinct connection</td>
<td>many Connections</td>
</tr>
</tbody>
</table>
Mobility management for horizontal handover has many restrictions because of having the MN has only distinct network interface, distinct IP address, distinct IP address and distinct network connection at a time. In horizontal, break before make is that a MN can create a new network connection before disconnecting the aged connection.

In vertical handover, we have many IP address, many network interfaces, and many network connections we can develop a mechanism based on make before break. It is a process that a MN can create a new network connection before disjoining the old connection. So handover latency time could be decreased or eliminating permanently. Also, soft handover could be available in vertical handover.

2.3 Mobility across heterogeneous networks

Mobility management can be happened in different layers:

- **Link layer**: Mobility in link layer is specific for each wireless access network. For UMTS, it supports handoffs from one cell to another, whereas in WLANs, it allows roaming between access points belonging to the same subnet.

- **Network layer**: Mobility has been proposed as an extension of the IP protocol [11]. Mobility at this layer provides a uniform mobility management that makes handoffs and network changes invisible to upper layers.

- **Transport layer**: Mobility in this layer uses an extension to transport protocols, as in the case of mobile SCTP [12]. The drawback of this mobility approach is that mobility is restricted to applications using a specific transport protocol. The performance is also usually worse than in the network case.

- **Application layer**: It is actually application specific. For real time application such as VOIP an interesting opportunity is to introduce mobility management in the SIP protocol [13][14], so that it becomes part of the signaling protocol with no extra cost.

**Advantages**: It does not require any extra hardware so it is cost effective.

We know that SIP is capable of handling session, terminal, personal and service mobility. The main remedies are performance and lack of mobility support for non SIP based applications. When wireless links are in errors the disruption time in SIP horizontal handoffs increases much more with respect to
the MIPv6 [14]. Recent result [15] shows that for vertical handoff provide a value of 1.5-2 s for SIP based WLAN-UMTS handoff delay when the Frame Error rate (FER) is between.01 and .1 on the UMTS link. The reason is due to the transmission of handoff signaling messages on the error-prone UMTS.

There are several advantages we can get from network layer mobility:
- Better performance with respect to solutions implemented at upper layers of protocol stack.
- A transparent mobility management to any application or higher level protocol. Network application just use one source address which is known as home address and are unaware of access network changes.

It has some disadvantages. Such as
- It requires hardware.
- It is expensive.

When a mobile node moves through other networks, the HA keeps track of the current binding of the mobile node. During handover mobile node sends a message booth to the HA and to any node with which it is communicating, usually it is a Corresponding node (CN). This mechanism known as horizontal handoff if the migration is between homogeneous networks. For mobility in heterogeneous network we can use the same procedure except we need to use more than one network interface. Here change of active address is called vertical handover since it takes place in the presence of a hierarchy of overlaid networks with different features.

2.4 Mobility management

According to layer concept of mobility management, mobility can be divided in 2 ways

Horizontal Mobility: Mobility within the same layer. In fact it refers mobility within the same access technology.

Vertical Mobility: Mobility among different layers. In fact it refers mobility across heterogeneous networks.

One of the main requirements for MM in the next generation networks is to provide support across different access technologies.
In recent years performance of IPv6 has been studied [19] [20]. Vertical handover may be implemented by MIP but analysis is required. Horizontal handoff require because off the connectivity problem in contrast vertical handover happens because off convenience rather than connectivity.

Efficiency of vertical handover depends on movement diction and capability of detecting that the current access network is going to become unusable before it actually does. Original IPv6 is not well suited for this task. It needs some modification which is described in following section.

The Mobility Manager (MM) can be used to provide mobility support to any kind of application for example VOIP application. In legacy applications, the MM delivers event notifications to an application mobility interface (AMI) in charge of completing adaptation at the session layer and issuing adaptation commands for the legacy application.

2.5 Mobility issues in 4G

Mobility is the core issue in the aspect of 4G. The following issues can be regarded mobility management in 4G:

1. Firstly we have to consider best choice of access technology or how to be best connected. If a user is offered connectivity from more than one technology at any one time, one has to consider how the terminal and overlay network choose the radio access technology suitable for services the user is accessing.

Though there are several network technologies are available we have to choose the good one. For example, WLAN is best suited for high data rate indoor coverage whereas GPRS and UMTS are best for nation wide coverage and can be regarded as wide area networks which provide higher degree of mobility. So users have to choose the best radio access technology from the available one. An algorithm is needed for both determine which network to connect as well as when to perform a handover between the networks. Another important thing is to the network selection strategy should take into consideration the type of application being run by the user at the time of handover.
2. Secondly, the design of mobility enabled IP networking architecture which contains the functionality to deal with mobility between access technologies which includes fast, seamless vertical handovers, QoS, security and accounting.

Real time applications such as VOIP in the future will be required seamless handovers for smooth operation. MIPv6 is not optimized to take advantage of specific mechanisms that may be deployed in different administrative domains.

To enhance the MIPv6, ‘micro- mobility’ protocols such as Hawaii [15], Cellular IP [16], Hierarchical MIPv6 [17] have been developed for seamless handovers that result in minimum handover delay, minimal packet loss and minimum loss of communication state.

Thirdly adaptation of multimedia transmission across 4G networks. There is no controversy over the claim that 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 frame work for multimedia transmission must be adaptive.

Users in UMTS compete for scarce and expensive bandwidth. Changeable bit rate utilities provide a path to ensure service provisioning at lower costs. Wireless networks has dynamics that renders it is difficult to provide a guaranteed network service. So the multimedia services are must be adaptive.

Large variation in QoS leads to significant variation in multimedia quality. May be sometimes result will not be acceptable to the users.
IPv6 Mobility

Characteristics in IPv6 mobility management

1. A large number of addresses (128 bit)
2. Provide high quality support for the real time audio and video transmission, short connections in P2P applications, web applications etc.
3. No header checksum is used at each relay, faster packet delivery, reduced processing cost.
4. Fast handoff when mobile nodes travel from one to another subnet.

There are some main areas that have to be improved prior to used as the core networking protocol in 4 G networks [18].

- Paging support
  
  To preserve connectivity with the backbone communications, the MN needs to create location updates each time it changes its point of attachment. Massive signaling caused by regular action leads to a major wastage of the mobile node’s battery power. So it is not appropriate to depend completely on location updates and it is require defining some sort of flexible paging support in the intra-domain mobility management.

- Scalability

  IPv6 support nodes to move within the internet topology while maintaining connections between mobile and CN. For this, a MN sends biding updates (BU) to its HA and all CN s it communicates with every time it moves. Authenticating BU requires about 1.5 round trip times between the MN and CN. Additionally one round trip time (RTT) is needed to update the HA, this can be done while updating CNs. These RTT delays will disrupt active connections every time a handoff to new radio technologies performed. So this delay needed to be eliminated. Additionally a mobile anchor point (MAP) has been suggested, that can be located any where in hierarchical routers. It is used to limit the signaling outside the local domain.
• Heterogeneous Networks

Reasons for network switching can be happened because of
a. When the signal of current network becoming weak
b. While MN detects a better network which is capable to provide better applications
   than current one.

To choice the suitable network MN compare the following things
• Signal strength
• Network bandwidth
• Certain policies

Suppose a user is streaming a video, he may use WLAN and when, he is listening to
highly compressed audio, he might switch GPRS.

Another critical issue that has to be solved is that informing the HA when MN has
moved. In this case, MN does a location update to it’s HA, which then sends
datagram to MN’s a new location.
Chapter 3
VOIP Mobility

3.1 Overview
In recent past years VOIP over wired networks has get vast attention as the bandwidth of the internet accesses of a custom user is increasingly continuously. The rapid growth of mobile environment induces an effort for integrating mobile communication with VOIP. But the problem is integration of VOIP with mobile environment. Because it is not easy as wired networks. A lot of task to be done in order to get a sufficient quality of such environment.

Majority of internet application uses TCP/IP whereas VOIP uses UDP/IP/RTP. We know that TCP is a reliable protocol connection oriented and UDP provides unreliable and connectionless delivery service using IP. RTP is a protocol which is used for real time transmission such as VOIP, video conferencing.

There are several call signaling protocols like H.323 or SIP call using SIP [21]. SIP is a control protocol which can set up and terminate a session. SDP is used to define details of the call. There is a urgency to code after completing VOIP call establishment, analog data has to be converted into digital and it has to be compressed as well.

The challenge for VOIP service is to ensure real time communication between the two end points based on the internet. The critical requirement for this service is
- Low latency
- No jitter
- Reduced packet loss

3.2 Requirements for VOIP services
VOIP mobility has several requirements such as
- It is delay sensitive. Acceptable VOIP delay must be within 150-200 ms. But the fact wireless access networks has large packet delay. An RTT in WLAN of 20-50 ms is expected, but present cellular technologies have values of up to 150-200 ms. But the fact of reducing VOIP call delay is not a easy task [22].

• Synchronization of VOIP application must be speech play out with a limited amount of buffering time. A delay in the network may loss the synchronization.

• Packet loss may also increase the delay in VOIP applications. This is happened when packed is arrived too late to be played back.

• When mobile node moving to another network that offers low bit rate, a VOIP application may suffer from packet loss and service degradation. Suppose a 64 kbps codec for human voice can be used in WLAN but it is not acceptable in UMTS because UMTS has maximum rate in up link is 64 kbps. So the task depends on the application to detect bit rate and to adapt the behavior when changing the networks. This can be solved by next generation networks, video conferencing may suffer from the same problem in mobility situation. So, the adaptation is an important application for this application.

• Service interruption due to handover must be under .1-.2 s for seamless communication. Packet loss is acceptable but that must be as low as possible and handover frequency also be low. Ping-pong effect between to networks must be avoided.

To achieve this goal we need a cross layer mechanism because traditional single layer of the network stack cannot solve this problem. The cross layer approach can solve these problems in the following way

• Application layer - Delay and synchronization
• Session layer – Bandwidth requirements
• Network layer - Vertical handover optimization.

3.3 VOIP over heterogeneous networks

• VOIP for next generation wireless communication requires mobility with quality service. The mobile node can suffer from disruption of ongoing VOIP session caused by handovers. This disruption time known as handover delay and can heavily dissatisfied the users. For this reason this delay time must be reduced to satisfy customer satisfaction level. In this paper we focus on layer 2 mobility for
heterogeneous network. Assured host node mobility with QoS is one of the main challenges in upcoming heterogeneous network. The demand for VOIP services is increasing day by day and is being extended to networks. So it is the challenge for operator to provide a good level of quality in the voice session. Mobility is an important issue for the strong need to have continuous network connectivity. Mobility can be modeled as changing the nodes point of attachment to the network. Providing mobility at the layer 2 is therefore naturally modeled as changing the routing of packets to the destination mobile node, so that they arrive at the new point of attachment.

During the handover process in MIP, mobile node could not be received IP packets on its new point of attachment until the handoff terminates. This may hamper the ongoing VOIP session and dissatisfies the users. VOIP in mobile system require low handoff delay which is less than 400ms to achieve seamless handovers.

Figure 3.2 shows VOIP in heterogeneous network
3.4 VOIP mobility problems and solutions

In the following sections we will discuss about VOIP mobility problems and solutions over various technologies.

3.4.1 VOIP over GPRS

Different problems can be arisen when we using VOIP over GPRS because of the GPRS characteristics. The features like low bandwidth, high latency, packet loss are the main concerns. Voices are suffered from delay if any of the above feature get slow. There are two fundamental problems related to VOIP over GPRS. The first thing is quality of the communication and the second one is IP address allocation among the mobile users.

Different approaches are discussed in the following

- **UDP – Lite**
  
  This was designed for the following reasons
  
  1. low error rate
  2. low latency
  3. high bandwidth

  We need to consider following features for GPRS connection
  
  - low bandwidth
  - High error rate
  - High latency

  For real time voice transfer delay time is small while majority of the decoding algorithm can handle also damaged data. We can reduce the delay time by reducing the reliability. This solution is an appropriate solution for VOIP.

  One of the major disadvantages of this protocol is that it should be allowed by both parties. It has its own protocol identifier.

- **SIP compression**
  
  We have to ensure that receiver received the whole packet after successful connection. GPRS reliability means great answering time. Another important thing is
SIP protocol is textual, so a great amount of data is required to be transmitted through radio connection.

- **RTP header compression**
  Compressing the RTP header is a key issue. The feature of the cellular networks has to be taken consideration as well.

**3.4.2 VOIP over WLAN**

Construction of micro mobility is easy to make than macro mobility system. It is assumed that in near feature the expansion of such system is expected. There is a need for cooperation between the different providers in handling information about AAA. Although macro mobility can be handled technically.

- **Mobility with MIP**
  By using MIP the changing of access points is solved in such a way that connection remains but there is still several problems when using it in VOIP environment. The packets are send through the HA in one direction that causes longer path and delay and the second thing is in tunneling mechanism.

- **Mobility with SIP**
  SIP has the capability of handling offline roaming which means user can choose accessible location and device. One of the major drawback for the SIP based mobility when CoA is requested.

**3.5 Mobility management for VOIP services**

Mobility management can be divided into two functions

- **Location management** – it is concerned with maintaining locality of the mobile node.
- **Handover management** – It deals with the connections as the mobile node moves across the different access points.

Followings are the major requirements for the IP based mobility

- **Hierarchical architecture** – to localize scope of location updates
- **Fast handover support** – packet redirection with minimum delay
• Paging - It is to minimize network signaling and save battery power
• Compatibility – compatible with QoS

Since this paper is only deal with the mobility issue hence handover management is more important issue. We will discuss it in the following section.

3.5.1 Handover support

Handover in IP-based mobility management involve redirecting the IP packet flow to the mobile nodes current point of attachment. The goal is

• Low handover latency
• Low packet loss

The hand over mechanism is going to be discussed are concerned with hard handover. So this mechanism involves both in link layer and IP layer establishment. Handover time can be defined as the time between receptions of the last packet through the old access point till reception of the first packet through the new access point.

There are several handover mechanism exist to eliminate the L3 delay, thus reducing handover time to the layer 2 delay.

Generally handover can be divided as proactive and reactive.

• Proactive – it employs link layer triggers to assist the MN in determining that a handover is obvious and establish packet flow to the target AP before handover.
• Reactive – It is simply follow the base mobile IP movement detection methods.
Chapter 4

Mobility mechanism

4.1 Overview

The traditional protocol stack is composed of the protocol modules TCP over IP over data link layer. Sometimes UDP is used instead of TCP. The upcoming communication systems in the 4G networks are forcing the traditional protocol structure into incorporate QoS and mobility. QoS demands to deploy real time communication over IP based networks. Micro mobility has the benefit of the terminal user to roam between adjacent wireless access points over the homogeneous networks using IP based solution. Moreover there is huge demand from the users to support mobility across heterogeneous networks. The upcoming networks are assumed to be multi interfaced network such as UMTS, blue tooth, Zig bee, WLAN. Even though each technology has its own bandwidth, cost and coverage. The 4G has the concept of always best connected which requires the terminal to select the best access method available. So mobility across IP layer becomes important. Figure 4.1 shows the present and future protocol stack of internet.

![Current and Future Protocol Stack of Internet](image)

(a) Present     (b) Future

Figure 4.1 Present and future protocol stack of internet
4.2 Cross layer design

**Definition**
To fully optimize wireless broadband networks, both the challenges from the physical medium and the QoS demands from the applications have to be taken into considerations. Rate, power and coding at the physical layer can be adapted to meet the requirements of the applications given the current channel and network conditions. Knowledge has to be shared between layers to obtain the highest possible adaptability [24].

Even though cross layer design in wireless cellular networks has been given a lot of concentration in the last decades there are also some criticism exist for this approach.

- A modular design has proved it self over the times. It provides necessary information to the engineers and researcher to fully understand the system. The traditional OSI reference model for example in which the internet and its success is loosely based on. A modular design can also fast the development with the
- Guarantee that the whole system will co-operate each other but this is not true for a cross layer design (CLD).
- CLD makes relation between processes and layers. These relations may be intentional or unintentional.
- CLD systems will need to be adapted to every application and this will increase cost and time greatly.
- If the layered system is broken the possibility to review and redesign parts of the system is lost.

4.3 Cross layer mobility support

In 4G, wireless mobile broadband access network is proposed and distinguish against 3G architecture. The following are the reasons why cross layer design in 3G network is difficult.

- Various layered protocol follow a strict layered design.

Different technologies do not have enough real time information about sudden channel condition which is required for any scheduler making decisions.
• Due to huge delay among the other network components, so information sharing among them can not be done in efficient way.
• Ability of the transceiver and the controller can be limited by the isolation between the layers.

4.3.1 Cross layer interaction (with MM architecture)
• Between network layer and the application layer
The main task of the class is co-operation between the layers without disturbing the transport layer. There is a relation exist between the terminal mobility and high level mobility. Thus the two layers should perform in a co-operative way.

In mobile node - handover scenario, an integrated approach may be improved the management efficiency. Suppose in MIP-SIP integration running in the two layers at the same time, decreased overheads over the air could be expected by using the internal cross layer signaling between the two protocols. For example to create a new IP address for handover both SIP and MIP would turn to a network service. MIP is used to deal with network layer matter, so we can configure MIP to communicate With DHCP. SIP has some difficulties to detect the new IP address. So an active notification is required to solve this problem and the CLASS is the best choice [25].

• Interaction between the physical /link layers and the network layer
The notifications of link layer handover and system related information to the network layer can accelerate the layer3 handover in case of MIP over WLAN. This technique can be applicable to the other access networks. Moreover handover technique in layer 2 could also benefit the layer 3. For example CDMA layer 2 soft handoff could lead to seamless handover.

• Interaction between physical/link/network layer and transport/application layer
Multi layer MM can also help to adaptation of applications such as mobility and heterogeneous network. Notification of information from of the start and end of handover are generated from link and network layer and are sending to the transport layer.
These messages are uses for transport layer mobility. So during the handover process TCP may terminate the connection.

4.4 Cross layer architecture

To show the advantages of cross layer approach a coordination plane is introduced. It is cross section view stack of protocols where interlayer algorithm can be applied and it is intend to solve many problems. Here we showed four co-ordination planes as shown in figure 4.2 along with traditional internet protocol stack and future protocol stack.

![Cross layer coordination plane diagram](image)

Figure 4.2 Cross layer coordination plane

These planes can be defined as
1. Security plane
   In order to erase the multi-layer encryption this plane is used.
2. QoS Plane
   It is used to distribute the quality of service requirements and restrictions along the protocols and co-operate their effort.
3. Mobility plane
This is the major plane which our topic belongs to. It is deals with mobility problems, MIP and layer 2 solution as well as mobility across heterogeneous networks.

4. Wireless link adaptation plane
This plane deals with bit error rate, bit rate and problems related to wireless link layer.

According to our thesis topics we focus only on mobility issue, so we discuss here only about mobility plane.

- Mobility
There are a lot of problems arise when we start to talk about mobility in IP networks. Basically internet was not designed with mobility in mind. For this reason IP networks are unable to handle mobility well. In traditional TCP where a mobile node is moving from one AP to another, the following happens to TCP connection
  - Old link of AP begins to lose its power, the bit error rate increases gradually and TCP begins to drop packets.
  - In later times, the old link is lost and the mobile node tries to reconnect to a new AP which has strong signal power than old one.
  - At last the new connection is established and TCP connection restarts.

In above process, there is a time when TCP packets are dropped, some of the things that are happened can be explained in the following way
  - The size of the congestion window drops to a minimum level during the handover process but at a slower rate to return its original value when the new link is established.
  - TCP has a round trip time value which is used to calculate the retransmission value. During the inter- technology handover process, it is better to discard the old round trip time value so that more accurate value is probed.

A possible solution can be described in the following figure 4.3
The central layer which is for MIP designed to protect from upper layers from the operational details of mobility support. Suppose it automatically changes the CoA for the HA in the destination field of the received packets and changes HA for the CoA in the source field of the outgoing packets so that upper layers can continue to work in the presence of mobility.

It is unfortunate that protecting the upper layers from handover process is actually not effective. Now we want to describe about following handover process.
- **Horizontal handover**
  As discussed earlier it is happened when mobile nodes moves from one AP to another within the similar access networks and it is expected to be short duration. During the handover process TCP connections is terminated and resettle after getting connection with the new AP and the congestion window value is assumed to be similar.

- **Vertical handover**
  This occurs when mobile nodes moves for one AP to another which is consisting of different technologies. For this we have to be careful because the new AP does not contain the similar technology of the old one. So it is better to slow down the start stage, quickly get the new link and discard the old RTT value in order to obtain the new one.

For any of these scenarios link layer must inform to the MIP layer before and after the handovers take place.

We can perform the fast handover by implementing make fore break scenario, this is an old link have to be disconnected only when a new connection is available with strong signal power from the old one.

We describe some solution regarding mobility in the following way

- To get the fast RTT value we can use the handover notification and terminate the TCP connection during handover.

- According to vertical handover TCP we do not update its RTT value which makes the RTT value suboptimal for the new link. The solution is use handover notification, terminates TCP connection and forced RTT to be recalculated.

- During handover, some QoS required to have their reservation updated which can be solved by sending end handover notification.

### 4.5 Experimental Results

In this thesis paper we want to present two types VOIP mobility schemes. These are

1. VOIP mobility in homogeneous wireless networks
2. VOIP in heterogeneous wireless networks
   - VOIP mobility in homogeneous wireless networks
Seamless handover in wireless networks for VOIP applications is one of the critical issues because of handover latency. Neighbor graph cache (NGC) [26] mechanism to reduce scanning latency while a mobile node wants to make a link layer handover. We briefly describe this procedure in the following ways.

**Neighbor graph cache**

It is a kind of algorithm used to collect nearby APs to construct a subset of channels for scanning. To decrease the scanning delay we have to reduce the values of Min and MaxChannelTime or N (total amount of channel according to spectrum released by a country). We can also increase these values by optimization but N is fixed in each country. One more thing is the channels which are occupied by APs are not same in all Basic Service areas (BSAs) or extended service areas (ESAs). This mechanism uses not only topological information but also cache BSSIDs, SSIDs and channels of APs. This mechanism can also be showed in the following flow charts.

![Figure 4.4 Neighbor Graph Caching](image-url)
According to [26] we showed a flow chart as shown in figure 4.4. The simulation result will be shown in next chapter.

- **VOIP in heterogeneous wireless networks**

The efficiency of this scheme depends on movement detection and precisely on the capability of detecting that the current access network is going to inaccessible before it actually does. According to [22] figure 4.6 describes the cross layer approach proposed to support handover decisions. The MM is a user level application in charge of

- Observing connection parameters through appropriate system calls
- Performing handover with correct timing using MIPv6 operation.
- Sending information about connectivity updates and network parameters to any application residing on the mobile system that notifies its interest in these evens through an API.

MM scope is limited in network layer. In IEE802.21 link layer trigger is used to improve the handover management at the layer 2. The MM can be used to provide mobility support to any kind of application for example VOIP application. According to [22] MM shows considerable improvements for handover from higher priority interfaces with packet loss. The handover delay at network layer is reduced to .2 ms from 2s.

![Figure 4.6 Cross layer mobility support](image-url)
Experimental results

The main task is to focus on handover performance in network layer. According to [22] both up and down handoff are performed. The experimental setup is performed by using two laptops with Linux 2.4 and the MIPL 1.0 MIPv6 implementation. Due to UMTS does not support MIPv6, it restored to an IPv6 in IPv4 tunnel from the mobile node to IPv6 AP. The maximum router advertisement (RA) interval was set to 100 ms on LAN and WLANs and 200 ms on UMTS networks. The minimum interval for RA is set 50 ms.

In the WLAN-LAN environment experiment handover is performing by unplugging the Ethernet cable for the mobile node whereas in WLAN-UMTS handover is performed by moving away the mobile node until it loss the signal from AP. Packet loss and handover delay are comparable on the VOIP ends. It is important to note that packet loss is not proportional to the handover delay because in WLAN-UMTS scenario with MM there is an also a delay when no packet loss occurs. Table 3 shows the result for homogeneous networks.

The results show MM achieves better handover performance. After performing 15 experiments with VOIP conversation of about 180 s with four handoff each at different hours of day results are reported in the following Table 4.

Table 3 performance for the up handoff over different networks

<table>
<thead>
<tr>
<th></th>
<th>WLAN-UMTS(MN)</th>
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<tbody>
<tr>
<td></td>
<td>Delay(ms)</td>
<td>Loss</td>
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<td>L3 trigger (25</td>
<td>351</td>
<td>5</td>
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<tr>
<td>packets)</td>
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<tr>
<td>L3 trigger (50</td>
<td>426</td>
<td>14.3</td>
<td>340</td>
<td>13.7</td>
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<tr>
<td>packets)</td>
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<tr>
<td>MM (25 packets)</td>
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<tr>
<td>MM (50 packets)</td>
<td>167</td>
<td>0</td>
<td>234</td>
<td>4.7</td>
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Table 4 Average packet loss in WLAN-UMTS (mobility)

<table>
<thead>
<tr>
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<th>Average packet loss(%)</th>
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<tr>
<td>L3 triggering (25 packets)</td>
<td>13.95+9.5% 0r 13.95-9.5%</td>
</tr>
<tr>
<td>L3 triggering(50 packets)</td>
<td>13.56+4.96% or 13.56-4.96%</td>
</tr>
<tr>
<td>MM(25packets)</td>
<td>4.52+1.31% or 4.52-1.31%</td>
</tr>
<tr>
<td>MM(50 packets)</td>
<td>2.38+1.43% or 2.38-1.43%</td>
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</table>

We can conclude with these results is that efficient heterogeneous mobility is smart management of wireless links rather that reduce the handover delay.
Chapter 5
Simulation

Here OPNET modeler version14.0 is used to analyze and simulate 3 handoff schemes at layer 2, which are active, passive and neighbor graph cache for VOIP mobility in wireless homogeneous networks. We will describe the configuration of these scenarios in the following section.

5.1 Scenario Description

These networks have 2 WLAN APs 12 and 13. AP 12 will operate on channel 1 with maximum data rates 54 Mbps and access point 2 operates on channel 6 with the same data rates. A voice client (vc101) moves from AP 1 to AP2 and performs a handover. These 3 scenarios are shown in figure 5.1. We can configure the voice client to use one of the 3 implemented mechanisms under Attributes/wireless LAN/ wireless parameters/Extended parameters/ scanning parameters. There we can also set different handover depending variables. We can either configure the APs to forward packets in case of a handover. A detailed description of configuration is given in Appendix.

Figure 5.1(a) Passive Handoff scenario for conference call
Figure 5.1(b) Active Handoff scenario for conference call

Figure 5.1 (c) Neighbor cache Handoff scenario for conference call
5.2 Experiment setup and results

Here we used contributed model [26] as shown in figure 5.1 as the fundamental concept to implement our simulation. The simulation scenario can be seen as some of students have a conference call with their teacher, while vc101 moves from access point 1 to access point 2 and vc102 travel from access point 2 to access point 3 and the others are waiting.

Results of the handoff time experiment can be shown in figure 5.2(a,b,c). Now we consider the first figure 5(a), when vc101 have handoff time nearly about 37 seconds which is passive handoff technique.
Figure 2(b) Handover result for Active handoff scheme

Figure 5.2(c) Hand off result for neighbor cache technique
The number of received packets also decreased with this scheme. Packets received by others for example vc102 and 105 are also affected. That is it will interfere the quality of whole wireless network.

It can be seen that results of figure 5.2(b) is better than 5.2(a). The reason behind that is saving time of scanning of others APs but the problem of others voice client is still be affected. From 5.2(c) we can see that there is no coherence observed during handover. So from the results we can conclude that in multiple users’ environment by using conventional handoff scheme will affect the other users as a result of packet loss and disconnection. Figure 5.2 (c) is the better choice in VOIP communication.

In figure 5.3 we compare node vc100 in different handover techniques while sending and receiving voice data. We can see from the graph that neighbor graph cache gets the better quality than others. Another important issue for voice communication is jitter. As shown in figure 5.4, voice jitter for neighbor graph cache is negligible comparing to others.

(a) Data received
Figure 5.3 Performances of different handover techniques.

Figure 5.4 Voice jitter for different handover techniques
Chapter 6
Conclusion and Future Works

In this paper we study VOIP mobility in wireless networks both the homogeneous and heterogeneous wireless networks. In homogeneous section, the source of handoff latency form the analysis and discussion can be easily understood. The neighbor graph cache method can keep the data of AP information during the establishing neighbors. Getting back the data the AP can use it for the next handoff process. Since mobile node is not necessary to scanning procedure again hence handoff delay can be decreased significantly and the required QoS for VOIP is achieved. We can see from the Figure 5.2 that we cannot achieve the required QoS for VOIP services with conventional handover techniques.

In heterogeneous environment, a VOIP application required the ability to adapt to changes of the network features. It is not enough to devise methods for low latency handoffs since management of wireless links and adaptation to delay, jitter of networks In use has much impact on the VOIP applications than the handoff delay. That’s why a good technique is required such as cross layer concept. Cross-layer approach depends on the mobility manager on a mobile device to provide information about handover events. This solution is effective for audio stream play out and buffer management. Other advantages are it does not require to change the existing infrastructure and it greatly depends on protocols.

In this thesis paper we study only on mobility issue others issues such as signaling and security are also related to VOIP in heterogeneous networks. So in future this work can be extended with focusing on these issues.
Appendix: Simulation steps

Opening OPNET modeler 14.0

Making new project
Choosing campus network

Defining X and Y plane
Adding WLAN_adv module in the project

Duplicating another 2 scenario namely Handover-Active major and Neighbor_Major
Profile configuration

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Application configuration
AP configuration
Workstation configuration
Voice server configuration

Choosing individual statistics
After this we collect the graph that is shown in chapter 5.
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