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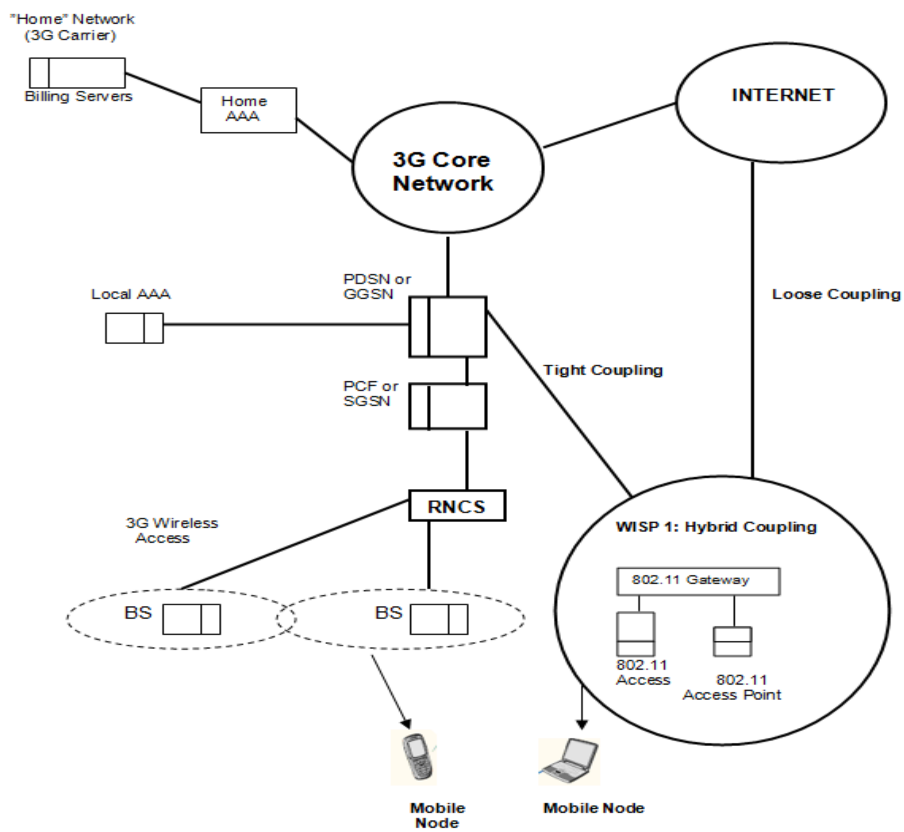
Decision algorithm and procedure for fast handover between 3G and WLAN

Master's Thesis in Computer Network Engineering

Ali Murtaza, Mansoor Ahmed



School of Information Science, Computer and Electrical Engineering
Halmstad University

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Box 823, S-301 18 Halmstad, Sweden

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Description of cover page picture: Handover between 3G and WLAN

Preface

In the research of our thesis, we learned too much about past, present and future technologies of wireless communication and networks. We learnt how they work and how these can be integrated to make fourth future generation of mobile communication for the freely movement of mobile nodes anywhere and anytime without the discontinuity of connection according to our proposed solution.

First of all, we would like to present our heart felt gratitude to ALLAH ALMIGHTY who always makes our path easy in every matter of life. We are also very thankful to Annette Böhm and Professor Tony Larson, who patiently helped us to complete this thesis work smoothly in addition to their busy schedule. Thank you for guiding us.

In addition, we would like to thank to our parents for their prayers, love and appreciation strengthened to our goals and thank for always taking our work into their consideration and remembered us during their supplication.

Ali Murtaza

Mansoor Ahmad

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Abstract

Different types of wireless network systems have been developed to offer Internet access to mobile end users. Now days a burning issue is to provide the network facility to end users on anywhere and anytime bases. Typical examples of wireless networks are 3G and WLAN (wireless local area network). An important issue is to integrate these heterogeneous networks and manage the mobile nodes while moving across heterogeneous networks with session continuity, low latency for handover between networks that are based on different technologies (vertical handover) and minimum packet loss. To achieve this, it is important to find the right point in time to perform a handover between two networks and to find a new network that, in fact, improves the connectivity over a reasonable time span. In this thesis, we propose vertical handover techniques for mobile users, based on predictive and adaptive schemes for the selection of the next network. The handover decision between the technologies takes the velocity of the mobile node, battery condition of mobile node, signal to interference ratio (SIR), application requirements and received signal strength RSS) as decision parameters. In order to reduce unnecessary handover, the concept of dwell timer is used and to reduce the handover latency, the predictive mode of Fast Mobile IPv6 (FMIPv6) and for minimum packet loss, the concept of tunnelling and buffering of packets on new access router in advance are proposed.

Contents

List of Acronyms

UMTS	Universal Mobile Telecommunication System
RSS	Received Signal Strength
BER	Bit Error Rate
MIPv6	Mobile IPv6
IETF	Internet Engineering Task Force
CoA	Care of Address
HA	Home Agent
CN	Correspondent Node
FA	Foreign Agent
MN	Mobile Node
IMT-2000	International Mobile Telecommunications-2000
3GPP	3rd Generation Partnership Project
GSM	Global System for Mobile Communications
WCDMA	Wideband Code Division Multiple Access
UTRA	UMTS Terrestrial Radio Access
WLAN	Wireless local Area Network
TCP	Transmission control protocol
VoIP	Voice over IP
MIPv6	Mobile IP version 6
RSSI	Received Signal Strength Indicator
IAPP	Inter-Access Point Protocol
3G	Third Generation
SGSN	Serving GPRS Support Node
GGSN	Gateway GPRS Support Node
PDSN	Packet Data Serving Node
AAA	Authentication, Authorization and Accounting
RAN	Radio Access Networks
AR	Access Router
PAR	Previous Access Router
NAR	New Access Router
SNR	Signal to Noise ratio
SIR	Signal to Interference Ratio
BS	Base Station
MN	Mobile Node
FA	Foreign Agent

HA	Home Agent
HoA	Home Address
FMIPv6	Fast Handovers for Mobile IP version 6
FNA	Fast Neighbouring Advertise
FBU	Fast Binding Update
FTP	File Transfer Protocol
CDMA	Collision Domain Multiple Access
QoS	Quality of Service
BLER	Blocked Error Rate
HI	Handover Initiation
HIAck	Handover Initiation Acknowledgement

1. Introduction

1.1. Application Area and Motivation

Handover among different wireless technologies is a very important and burning issue today. Every user wants connectivity to the Internet anywhere and anytime through whatever technology is available at the time. The connectivity of all these technologies is a difficult issue because every network has its own features and characteristics, such as data rate, geographical coverage area, latency, frequency and bandwidth.

The purpose of designing the first and second generation of mobile communication was to provide speech service and limited service of text messaging, and third generation emerged with the both capability. Now, the fourth future generation of mobile communication (4G) which is the integration of all wireless networks is in the way to its destination, in which a mobile node can freely move from one wireless technology to other technology. All the above three generation of mobile communication were market and technology driven while fourth generation (4G) is user driven and it will have user control services [1]. George H. Heilmeier said [2], in early nineties, "I think the bottom line is to bring information-age capabilities to everyone, capabilities that enable people and their machines to access information anywhere, anytime, in any medium or combination of media in a cost-effective and secure manner." Now, after more than ten years, his assumption is going to be true.

Next, the fourth generation of mobile communication must have the capability to support the mobile users either they belong to any wireless network. Recent mobile technologies have different characteristics in terms of bandwidth, frequency, coverage area and latency. For example, 3G, such as Universal Mobile Telecommunication System (UMTS) [3], provides a large coverage area with low bandwidth, while Wireless LAN (IEEE 802.11) provides a low coverage area with large bandwidth. So, by the combination of these two technologies, the mobile user can benefit from the best features of both technologies by roaming seamlessly and transparently between them.

1.2. Problem Studied

Handover is a process of maintaining the mobile node active while seamlessly moving across different wireless networks. Handover within a technology is called "horizontal handover", while handover between different technologies is called "vertical handover", for example, between UMTS and WLAN. However, when mobile node moves across different network/technologies, different types of issues appear, for example, why is it necessary to move in other network, what are the pros and cons of this movement and what are the parameters which decide whether it should move or not. Second issue is to decide the exact timing of layer 2 and layer 3 handover, now, how and who decides this timing of handover accurately is also a issue, so that latency of handover can be minimized. In this thesis, triggering time of layer 2 handover is very important because layer 2 handover triggering must be after the completion of layer 3 handover for low latency of handover. The third issue is reducing the packet loss which is solved by using the concept of tunneling and storing the packets in the new Access Router (AR) before the attachment of mobile node to this AR. A further issue is the ping pong effect, i.e. reducing the unnecessary handover, which can be solved by the concept of dwell timers. This thesis discusses and proposes a solution for all these problems.

In most technologies, received signal strength (RSS), bit error rate (BER), coverage area and signal to interference ratio (SIR) are used to measure the current condition of present network and other available networks. UMTS, e.g., checks the status of other neighboring base stations before triggering the process of handover, i.e. area under coverage of neighboring base station, transmitting power of neighbouring base station, how many mobile nodes it can support and how many are attached at the moment etc. WLAN handover depends on the MAC layer evaluation and physical layer measurement for determining the appropriate time for triggering the handover process [4]. The proposed solution uses the received signal strength (RSS), velocity of mobile node (MN), battery power of mobile node, and signal to interference ratio as decision parameters which are calculated dynamically.

1.3. Approach Chosen to Solve the Problem

The way which we followed in our thesis.

- First we formulated the question to be solved and identified the different problems and issues connected with the question.
- The following step was to improve our knowledge about the general area of handover and study related works and evaluated existing solutions.
- Then we develop our own algorithm.
- We continued by combing of existing solutions with our own solution.
- As a final step, we evaluate our proposal and discussed its strength and weaknesses.

1.4. Thesis Goals and Expected Results

First, we discuss the case study which define and illustrate our thesis in a best way, so a common reader can understand our thesis work; we take an example which explains our thesis for technical and non-technical people. Suppose, a user is at home and his PDA is attached with the home WLAN. The user is leaving from home for work; WLAN access is going to weaken as he moves away from home. His personal digital assistant (PDA) starts to search for a new network. Now, there are two possible scenarios. One, if the other WLAN is available, and the velocity of the mobile node is not greater than the threshold value, and the new WLAN fulfils the required SIR and QoS parameters discussed in thesis, then PDA gets attached with WLAN, otherwise with UMTS. Secondly, if WLAN is not available then mobile node attaches with UMTS.

Now, suppose the user is moving in the car or bus, the mobile node is attached with UMTS and moving with a velocity greater than threshold value. The mobile node detects many WLAN networks on the way but the velocity of mobile node is greater than threshold value then it prefers to remain in UMTS instead of again and again handover from UMTS to WLAN and vice versa to avoid ping pong effect. When reaches on work place if WLAN is available then switches into WLAN otherwise remains in UMTS.

This thesis defines auto-configuration architecture of handover between heterogeneous networks with the integration of a decision module by using the hybrid coupling interworking model as an integration of WLAN and UMTS. The vertical handover decision module is based on a predictive and adaptive scheme. This vertical handover decision is based on network conditions, such as the velocity of the mobile node, battery condition of mobile node, signal to interference ratio (SIR) and received signal strength (RSS). With the help of our proposed decision module, the mobile node decides whether it should move to the other network or not. If the conditions are satisfied, then the mobile node moves to the other technology otherwise remains into the same technology. These conditions are, for example if the battery power of mobile node is going to critical condition i.e. UMTS uses more battery power as compare to WLAN, or present technology is not providing the required SIR for the application or the received signal strength is less than the requirement of the application then mobile node decides to move other technology. This decision module chooses the best available technology for the end users according to the requirement of application. If both WLAN and UMTS are available then it prefers to WLAN because it provides more bandwidth, consumes less battery power and cheap as compare to UMTS. On the other hand, if WLAN is not available, or the velocity of mobile node is greater than the threshold value then prefers to remain in UMTS to avoid ping pong effect.
To provide a satisfactory result for the mobile node and network, an adaptive, predictive and dynamic approach is proposed for the handover decision process, such as too much handover reduces the performance of the network. The concept of dwell timer is used to reduce the effect of ping pong.

2. Handover Issues

There are many issues in handover between 3G and WLAN. First of all, the major issue is to find out the right time when the handover should take place and then initiation of handover, either handover be triggered by network or user or any one of them. So, to efficiently initiate and perform the handover, prompt reaction can be used. The second issue is to support real-time and non-real time application during the process of handover. Not all application can be handled in the same way because the requirements are different during the process of handover. VoIP and multimedia applications are more vulnerable to latency and packet loss, and a fast handover is required for them. TCP-based applications keep their connectivity with the end-points during the process of handover by creating a session between end users. The key requirements during the process of handover are to minimize the latency and packet loss. Another key issue is transparency and reliability. When the MN is moving from one network to other, the process should be transparent from the mobile user or simply we can say from the application layer. Moreover, vertical handover should be seamless, or, if a disconnection occurs, the resulting delay should be minimal and not be felt by the upper layer. In the case of failure, it should have the capability to recover the connection with minimum delay.

2.1. Handover Latency

In Mobile IP Version 6 [MIPv6], the time interval when the mobile node cannot send or receive any kind of traffic during handover is called “handover latency”. Layer 2 handover is the process of detachment from the old access router and scanning, authentication and re-association with the new access router while layer 3 handover means acquisition of a Care of Address (CoA), binding updates and making tunnels between the access routers (ARs). Handover latency can, therefore, be classified into layer 2 handover latency and layer 3 handover latency.

2.1.1. Layer 2 Handover Latency

L2 latency is the time period when the air-link with the current access router (AR) is disconnected and the mobile node is not connected to the air-link of new access router which it wants to get attached. According to this scenario, the whole process of layer 2 handover can be divided into three phases:

- Scanning
- Authentication
- Re-association

This delay of scanning, authentication and re-association is called “layer 2 delay”.

2.1.2. Layer 3 Handover Latency

L3 latency is the sum of total time of movement detection latency, Binding Update latency and the acquisition of new CoA latency. This will add up to overall latency and lot of packets can be lost.

3. Heterogeneous Network Architecture

In this part, the requirements, model, interworking issues and proposed configuration of the next generation of wireless network will be discussed.

3.1. Wireless Heterogeneous Networks

It is expected that the next generation of mobile communication will fulfil the increasing requirements of user and real-time multimedia service. It is, therefore necessary to make such criteria which fulfil the requirements of mobile node and application which is running on mobile node while moving across different heterogeneous networks, such as the requirements can be high bandwidth, minimum packet loss and low handover latency etc. Every network provides different bandwidth, coverage area and quality of services (QoS) to the end users.

3.2. Heterogeneous Network Requirements

Many challenges have to be faced in the seamless interconnection of many heterogeneous networks, such as the challenges associated with seamless handover, with heterogeneous network architecture and secure mobility between 3G and WLAN. So these requirements, which can be met by the fourth generation, are:

Seamless access: in 4G mobile node can move seamlessly and transparently from 3G to WLAN, and vice versa, without disrupting the connection.

Low Blocking Probability: the management of the handover should be in such a way that handover latency and blocking probability, i.e. the probability of disconnecting during the process of handover is near to zero.

Appropriate bandwidth utilization: With the integration of 3G and WLAN appropriate bandwidth can be utilized regarding the requirements of the application.

Secure Access: quality of service and security parameter should also be maintained while moving between the different networks.

3.3. Interworking Issues

The major issue is designing a seamless handover scheme which works in a heterogeneous network environment, because every network has its own handover policies, metrics and decision making algorithms. Some issues which affect the handover in heterogeneous networks are:

Signal Quality: the signal strength received from the base station can not be compared in different networks. In UMTS, signals are transmitted with more power because the mobile station can be far away from the base station. So both base station and mobile station have to transmit the signal with more power, whereas in WLAN, the distance between base station and mobile station is less and signals are transmitted with lower power.

Data rates: the data rate in 3G and WLAN is different. WLAN supports a higher data rate than 3G, so WLAN should be preferred if available.

Handover Decision: the handover decision between 3G and WLAN is a big task and it is not easy to manage. In decision making, the user's quality of service requirements and networks signal strength availability is kept in consideration. All these decision making parameters are measured periodically.

Coverage Discovery: WLAN provides high data rate but less coverage area whereas 3G provides a geographically wide area coverage but with less data rate.

Security: it should be given a guarantee by the security mechanism that only the corresponding parties have the knowledge of key mobile node identity and this level of security should be maintained when the user is roaming between 3G and WLAN.

4. Architectures for 802.11 and 3G Integration

There are two main ways of integration of 3G and WLAN. These ways define the degree of inter-dependence that one is willing to introduce between WLAN and 3G network. These two types of integration are tightly-coupled interworking [5] and loosely coupled interworking [6].

4.1. Tightly-Coupled interworking

The idea behind the tightly-coupled interworking is to make the WLAN network appear to the core part of the 3G network as another 3G access network. Also, WLAN would pretend that it is the part of 3G radio access networks. In tightly coupled architectures, the WLAN (802.11) gateway network element appears to the upstream 3G core as an SGSN in the UMTS. In this approach, the WLAN gateway hides all the detail of 802.11 networks from the 3G core, and all the required protocols, such as mobility management and authentication, etc. are implemented on 802.11 gateway to access the 3G radio network. On the mobile node side, a 3G protocol stack is required to be implemented on the top of 802.11 standard network cards and switch from one physical layer to the next as needed. The traffic generated by the clients in the WLAN is injected into the 3G core network by using the 3G protocol stack [5]. In this way, different networks would share the signalling, transport authentication billing infrastructures independently from the physical layer protocols on the radio interface.

There are some disadvantages of tight-coupling also, such as, in this approach 3G network directly exposes its interface into the WLAN network and operators are the same for both networks. So, in tight-coupling interworking only those WLANs can work which are integrated properly, independently working 802.11 Networks Island could not be integrated with 3G networks.

3G networks are deployed using carefully engineered network-planning tools, such as; parameters of the networks are set according to the capacity and configuration of each network element. These parameters are set after the calculation of appropriate mechanisms which are specific to the utilization of the technology over the air interface. So by directly injecting the 802.11 traffic into the 3G network, the whole set up of the 3G network has to modify such as PDSNs and GGSNs to sustain the increased load.

There are some other issues on the client device side as well with this approach, such as the implementation of 3G stack on the 802.11 network cards and using the 3G specific authentication mechanisms which are based on different modules as in [7].

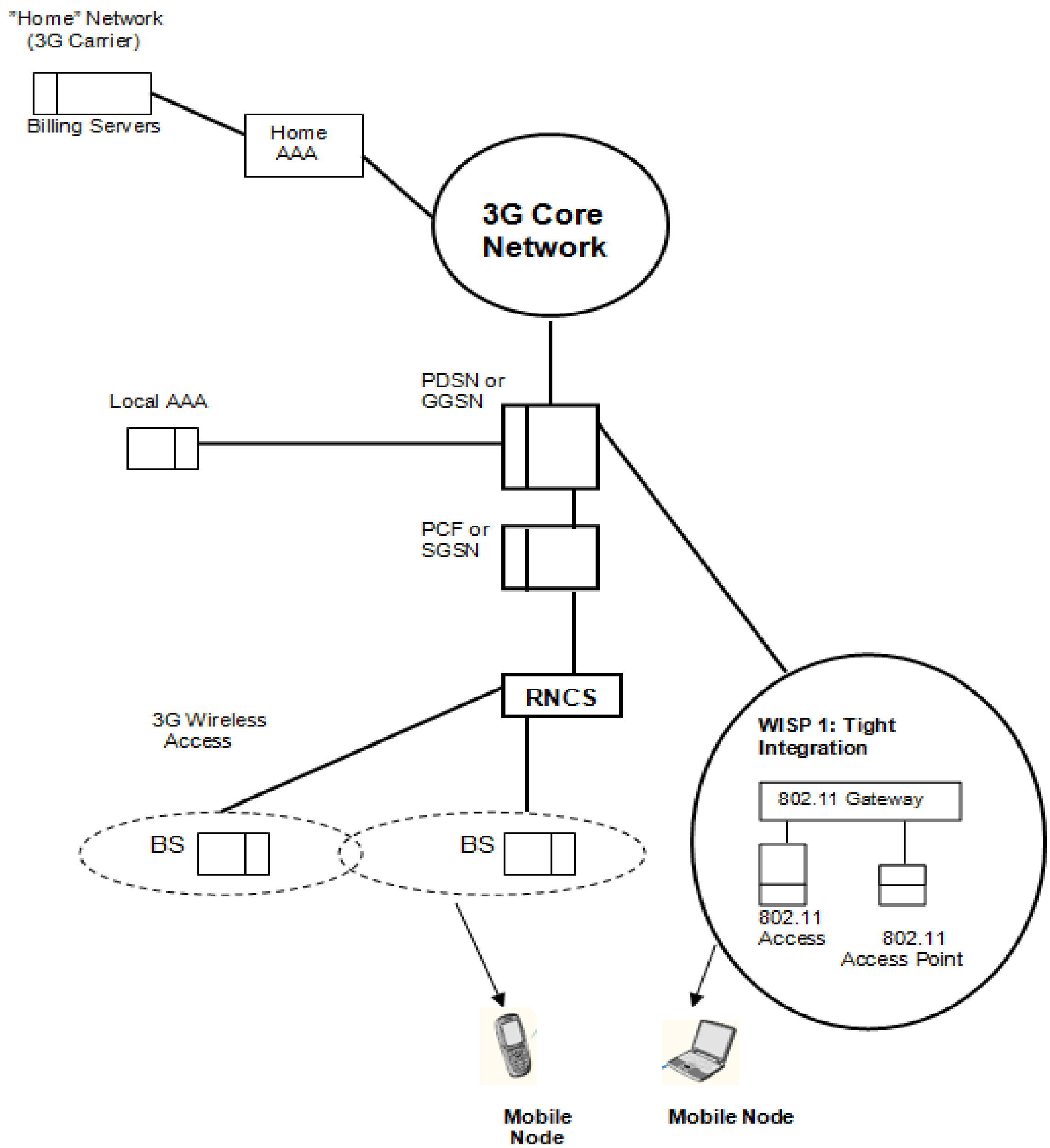


Figure 4.1.1:Tight Coupled-Internetwork

4.2. Loosely-coupled interworking

In the loosely-coupled approach, new gateways are introduced in 802.11 networks, as the figure shown below. In loose-coupling [6], WLAN gateways are not directly connected to the 3G networks elements such as GGSN, PDSN or 3G core network switches. Instead, they are connected to the Internet.

Both, mobile and local users signed in of WLAN, access the gateways services of WLAN. This approach is called “loosely-coupled interworking” because it separates the data paths in 3G and WLAN networks. In loosely-coupled interworking, high speed data traffic of 802.11 is not injected into the core networks of 3G, but the end users have the seamless access.

Different protocols and mechanisms handle the different functionality, such as billings, authentication and mobility management in 3G and WLAN networks. Seamless operation is only possible if all the functionalities interoperate. In the operation between 802.11 and UMTS, mobile IP functionality should be supported by the 802.11 gateway to handle the mobility, and AAA services, as in [23], to interwork with 3G home network AAA servers. In this way, the 3G provider would be able to collect the 802.11 accounting records and generate the unified billing statement of the usage of both the network, according to the given price scheme of both 3G and WLAN networks and, at the same time, by using the compatible AAA services gateway of WLAN obtains the per-user service policies from the home AAA servers dynamically and implement the same policies in the other network.

There are some advantages of loose coupling as well, such as independent deployment and traffic engineering between 3G and WLAN networks. Without intensive capital investment, 3G carriers can gain benefit from other providers, such as WLAN.

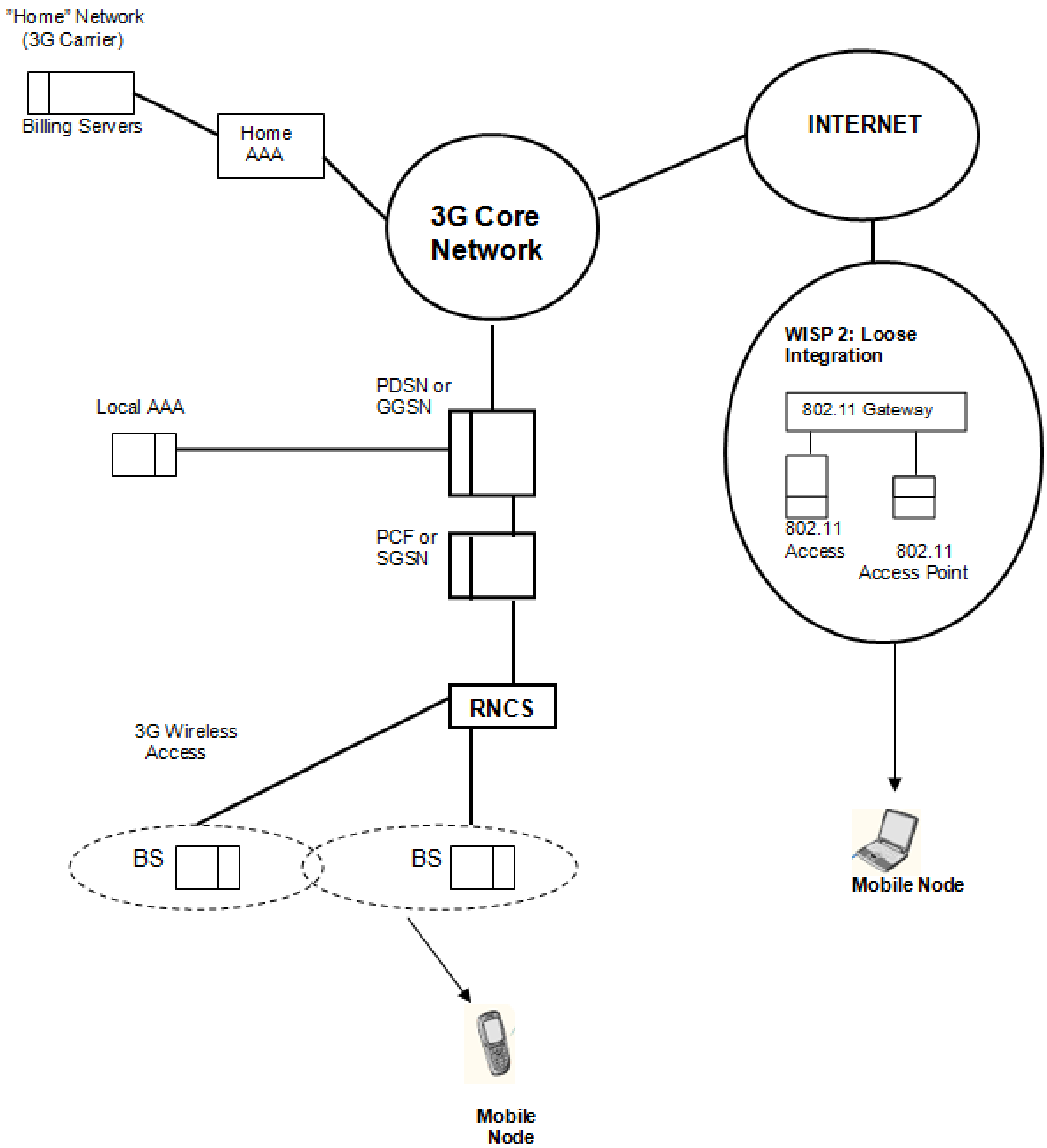


Figure 4.2.1: Loosely-Coupled Internetwork

4.3. Hybrid Interworking

A third type of interworking model, hybrid coupling, as in [8], can be formed with the combination of tight and loose coupling. In hybrid architecture of interworking, WLAN and UMTS are interconnected in such a way that data can be sent both ways, either by the way of tight coupling or loose coupling it depending on the type of data, i.e. real time application data such as, VoIP and video streaming through tightly-coupled interworking and non-real time application data such as, email through loosely-coupled architecture.

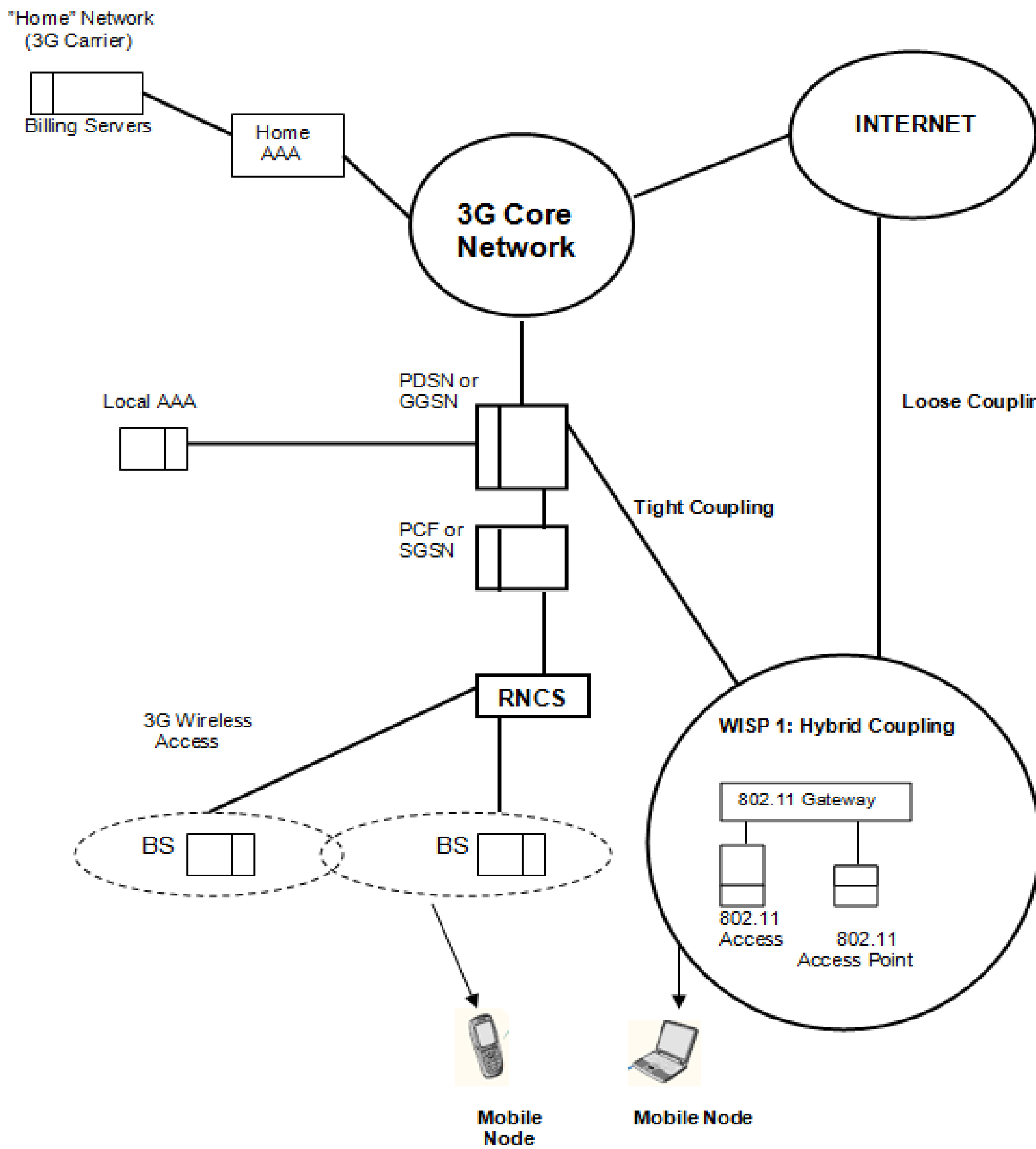
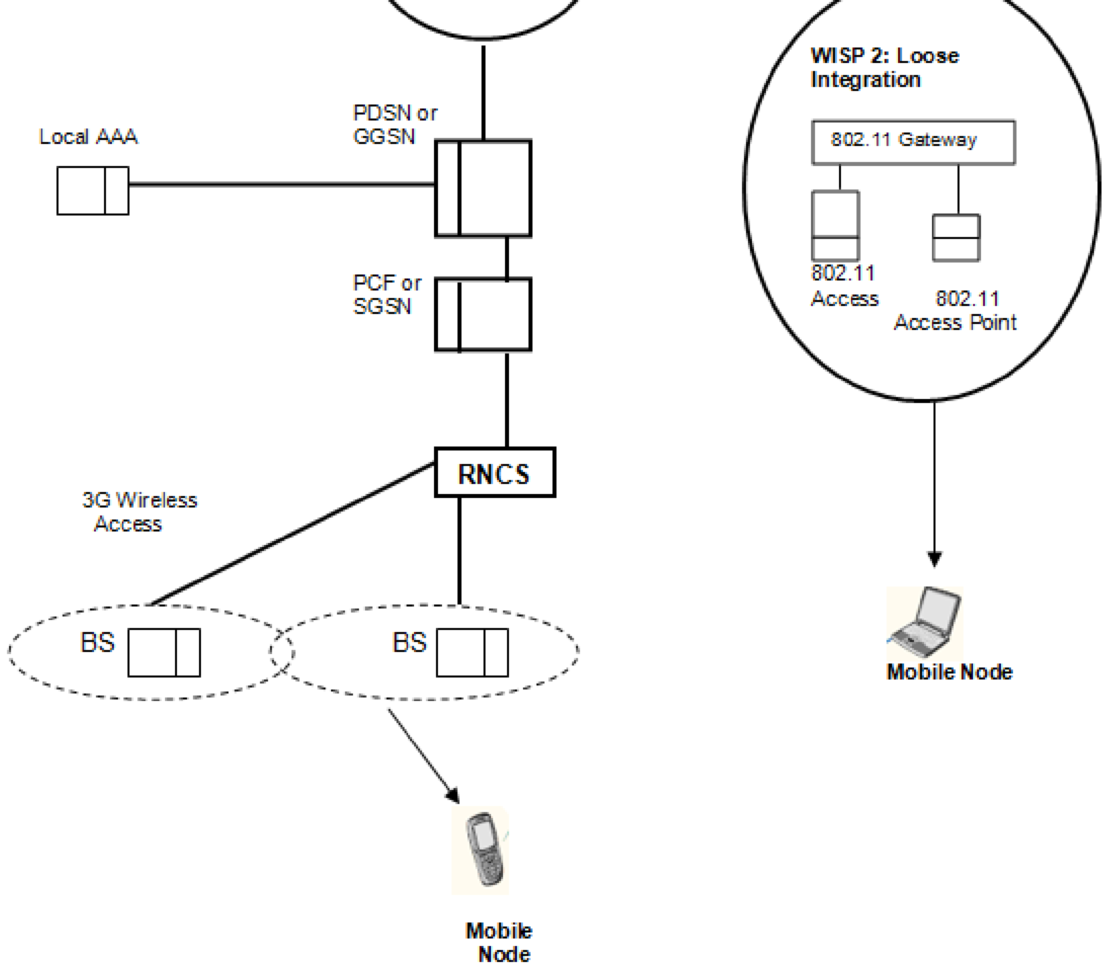


Figure 4.3.1:Hybrid Coupled-Internetwork


WISP 2: Loose Integration
802.11 Gateway
802.11 Access
802.11 Access Point
Mobile Node
Local AAA
PDSN or GGSN
PCF or SGSN
RNCS
3G Wireless Access
BS
BS
Mobile Node

5. Handover Management

Handover means that a mobile station connection is transferred from one channel to another channel of different frequency and during communication. In mobile communication systems, handover is a frequent procedure. The reason for handover is to keep the mobile station connected to the network. If the mobile station is moving away, and remains connected to the original base station, the signal may get weaker and weaker and the connection will be interrupted at last.

The handover process can be divided into three phases. Firstly, measurements of different parameters, such as received signal strength, signal to interference ratio (SIR), velocity and the battery power of mobile station, must be gathered. Secondly, a handover decision on the bases of these measurements must be made and, thirdly, of the actual handover must be executed.

In general, the best handover scheme is the one that results in minimum latency and packet loss because the performance of the network depends on the performance of the handover.

5.1. Handover Types

Different types of handover are discussed below

5.1.1. Horizontal Handover

Horizontal handover occurs when the mobile station moves from one base station to another base station within the same technology. Horizontal handover also called intra-technology handover, such as handover between the base stations of UMTS, where mobile nodes move from one base station to other base station.

5.1.2. Vertical Handover

Vertical handover means handover between different wireless technologies, such as handover between UMTS and WLAN. It is also called “inter-technologies” handover. In recent years, a lot of research has been done in this field, e.g. on 4G technology based on vertical handover.

Vertical handover can be classified into two types:

- **Upward handover**

  Moving of a mobile node from a small network cell with a high data rate to a big network cell with a low data rate is called “upward handover”. Although the small network has a high data rate, the mobile node has to move into a large network with low data rate when leaving the transmission range of the existing small network.

- **Downward handover**

  In downward handover, the mobile node moves from a large network cell with a low data rate to a small network cell which has high data rates. In downward handover, the mobile node discovers the available network, selects the one which provides the highest data rates and then decides to execute the handover. As it is a disadvantage to remain connected to the low data rate network when a high data rate network is available, handover optimizes the overall network performance.

5.1.3. Hard handover

In hard handover [10], the mobile node has to disconnect first from the current network before connecting to the new network.

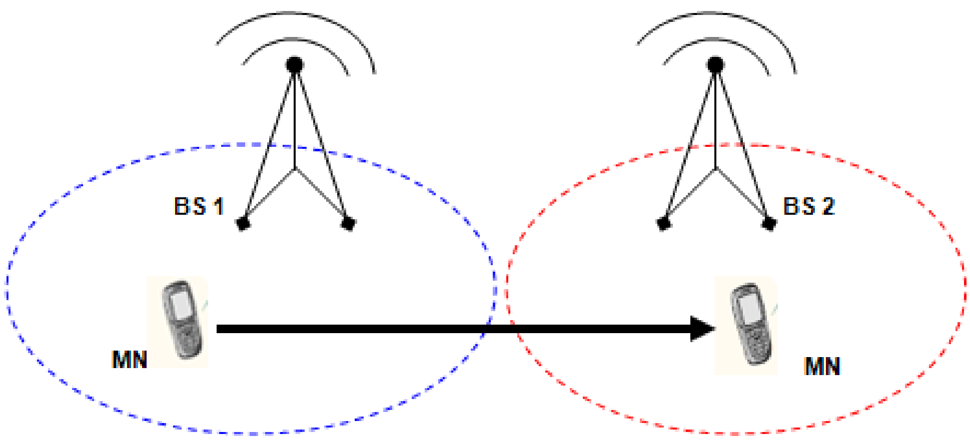


Figure 5.1.3.1: Hard Handover

5.1.4. Soft handover

In the concept of soft handover [10], the mobile node can select the new network before the disconnection of the current network. So in soft handover mobile node is connected to two networks at the same time.

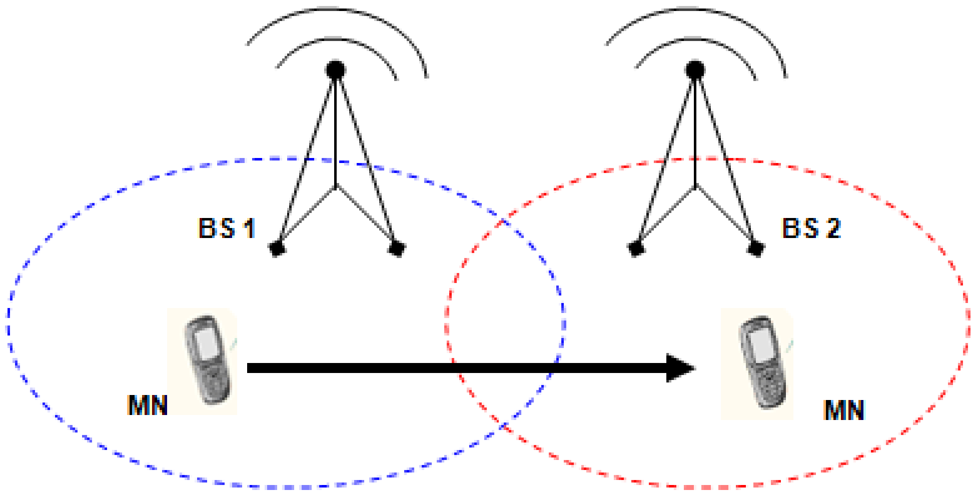


Figure 5.1.4.1: Soft Handover

5.2. Requirements of handover

In order to achieve an efficient handover in a heterogeneous network environment, compromises between different operating characteristics should be considered.

Reliability

Reliability of handover means that the quality of a call or data transfer should be good during and after handover. The factors which help to determine the quality of candidate base stations are the signal to interference ratio (SIR), bit error rate (BER), and signal to noise ratio (SNR).

Seamlessness

Handover should be seamless, which means that the handover process should be so fast that the mobile node does not experience any interruption or service degradation. This service degradation can be due to co-channel interference or reduction in signal strength and the interruption due to a hard handover approach. This problem of interruption can be reduced by soft handover, but resources are still wasted. The most important thing is that the process of handover must be transparent to the upper layers to maintain the continuity in communication.

Interference prevention

Handover should prevent interference. There can be two types of interference, intra-cell and inter-cell interference. Intra-cell interference is due to the transmission of several devices in the same cell, while inter-cell interference is due to the co-channel and adjacent channel. Co-channel interference is due to the channels which have the same frequency and adjacent channel interference is due to the neighbouring cell, both intra cell and inter cell interferences severely effect the data rate.

Necessity of Handover

The performance of handover can be improved by reducing the unnecessary handover. Frequent handovers increase the risk of denial of channel access and the probability of dropped calls. The more horizontal handovers that are performed, the higher the delay in the processing of handover requests, which will result in reduction in signal strength.

So, as long as the current base station is providing the required service quality without interference, there is no need to perform handover.

6. Technologies

This chapter gives a background on the 3G mobile network technology, WLAN and their connection setup and handover procedures.

6.1. Third Generation (3G)

3G (3rd Generation) [11] , which is also known as “International Mobile Telecommunications-2000 (IMT-2000), ITU” contains a few standards for 3G, such as UMTS, GPRS and EDGE. In the mobile environment, all of these standards provide some services, which are Voice, fax, Video calls and data through wireless. If we compare 3G with its previous generations, such as 2G and 2.5G, it is providing more data rate service with a wide range of coverage by using the best spectral efficiency and good quality of voice with multiple usage of speech at the same time, along high level security. The UMTS (Universal Mobile Telecommunication System) is specified by 3GPP (3rd Generation Partnership Project). It uses WCDMA (Wideband Code Division Multiple Access) [12] technology as the underlying air interface for transmission. It supports more efficient modulation than GSM (Global System for Mobile Communications) with maximum data transfer rate 21 Mbits/s. The network consists of three major elements, Core Network, Radio Network Subsystem (RNS) and User Equipment (UE).

In 3G network architecture UE which is usually handsets or can be desktop/laptop computers which support to UMTS interfaces for high speedy data transition, when UE tries to join a 3G network, then it first establishes connection with Node B, which works as a transceiver in one cell for communication with User’s Equipment (UE), the Node B further directly connected to backend RNC (Radio Network Controller) via Iub interface. The RNC’s responsibility is to manage the resources of radio and the function of mobility; it does also perform encryption and decryption of users’ data to protection from eavesdropping. RNC establishes the GPRS tunnel with SGSN (Serving GPRS Support Node) of core network. It is the packet switched element which performs mobility management. SGSN also manage to sessions which uses for QoS (Quality of Service) and the contexts of PDP (Packet Data Protocol). It also manages to connections of different areas which are in between SGSN and radio network controller through IuPs interface. SGSN further creates a GPRS tunnel with GGSN (Gateway GPRS Support Node). It works as a gateway between external packet switched network and UMTS packet switched network i.e. it forwards data packets of active users to SGSN.

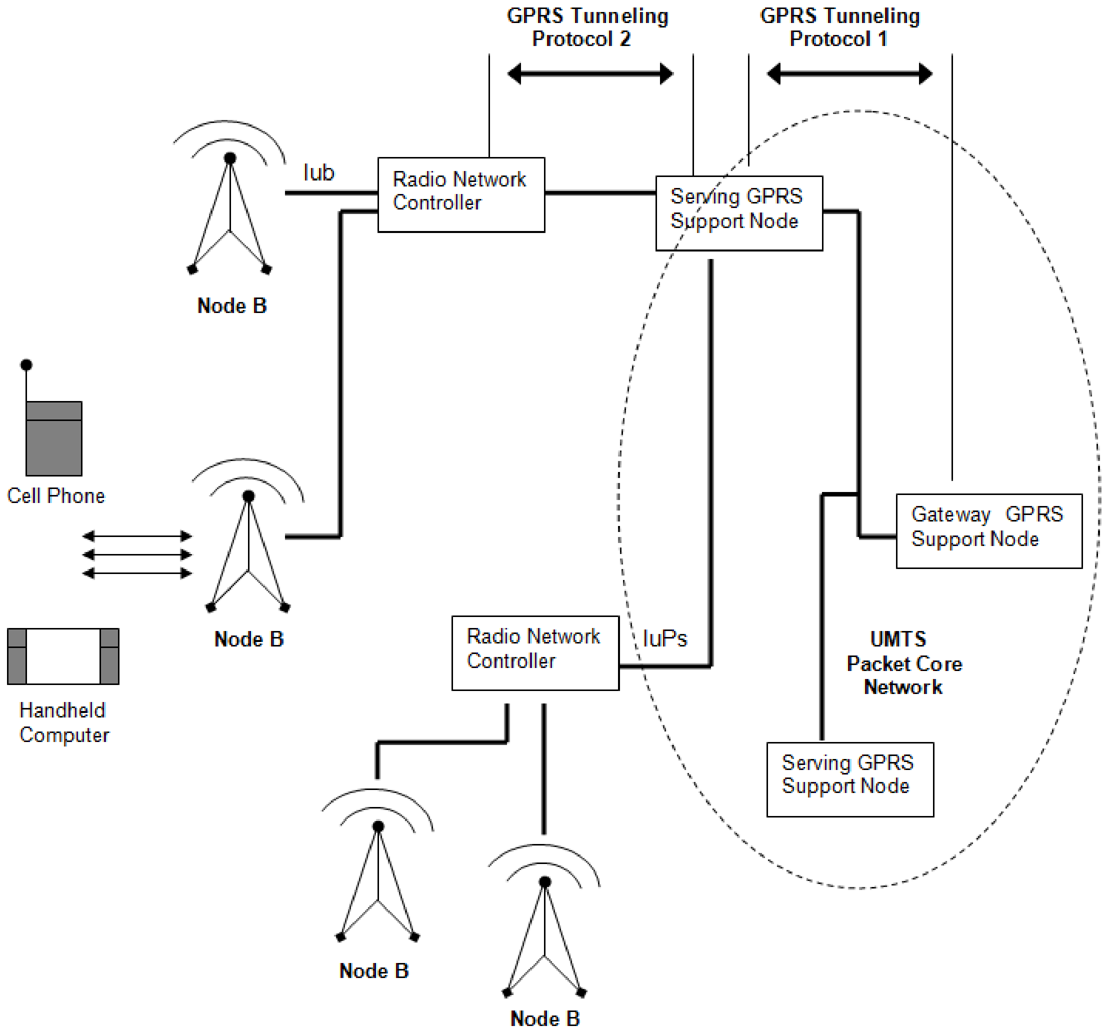


Figure 6.1.1: 3G Network Architecture

6.2. WLAN

WLAN *(wireless local area network)* in [11], is the network in which different nodes communicate with each other on the basis of radio waves. Wireless signals are broadcasted, so the nodes in range can easily share it [13]. We can say that it is an extension of current wired based networks; it provides much flexibility to users who can easily change their positions without disconnection. Normally, its data transfer rate is 1 to 54 Mbps, within a radius of 65 to 300 feet; a few latest standards are also providing 300 to 600 Mbps.

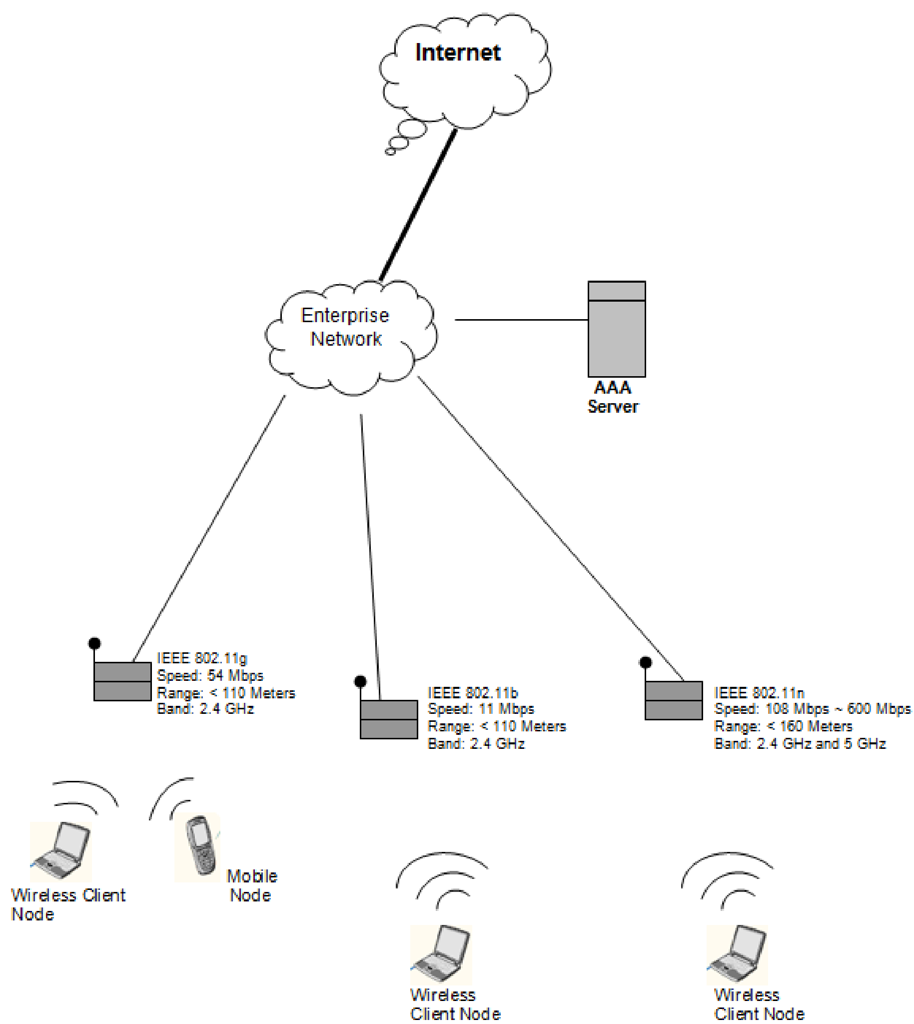


Figure 6.2.1: WLAN Architecture

In above figure 6.1.1, the enterprise wireless network consists of three AP's (access point) with three wireless client nodes and one mobile node. We have different types of IEEE standards for WLAN i.e. (IEEE 802.11g, IEEE 802.11b and IEEE 802.11n), our network is attached to AAA (Authentication Authorization Accounting). This is the term which is used for controlling the access of nodes, auditing of usage and billing for services. This combination makes an effective way for managing the network and its security. This whole WLAN is connected back to the Internet for giving access to wireless client/mobile nodes to internet.

6.3. 3G & WLAN Comparison

The comparison between 3G and WLAN is given below.

Features	**3G**	**WLAN**
Standard	WCDMA, CDMA2000	IEEE 802.11
Max Speed	7.2 Mbps	54 Mbps
Operation	Cell Phone Companies	Individuals, WISP
License	Yes	No
Converge Area	Several Km	About 300 m
Velocity Support	High Velocity	Low Velocity
Advantages	Range, Mobility	Speed, Cheap
Disadvantages	Relative slow, expensive	Short Range

7. Handover Approaches

Most handover decision algorithms are based on received signal strength identification (RSSI) [14]. It is a good method only when the handover is within the same network technology. In [15], handover decision between WLAN and UMTS based on RSS and distance parameters is defined. Besides the RSS, other factors can also affect the decision of handover, such as available bandwidth, monetary cost and many other factors also. As in [16], the handover decision is based on cost function, performance and power consumption. A QoS calculation based algorithm was proposed in [17]. In this paper, the QoS support of each network is measured by using the RSS, channel capacity and transmission rate of data. The handover is then triggered to the network, which provides better QoS. In some papers, decision algorithm mechanisms, based on the cost, signal quality and the user preference on operator and technology are described. This cost function is considered as a static because the network parameters do not change when the mobile node moves across the heterogeneous network. However there are some parameter of network which changes with the passage of time such as RSS, signal to interference ratio and bandwidth. Another approach, [18], is based on battery consumption and load balancing across available access point and base stations. This approach is focused on increasing the battery life of the mobile node, but it does not discuss other issues like packet loss, data transmission rate, bit error rate (BER) and velocity of the mobile node. In [19], the velocity of the mobile node is proposed as a decision parameter for handover and this paper tried to find the optimal threshold velocity to reduce the probability of handover dropping, call blocking and unnecessary loss of data.

7.1. Mobile IP Concept

We would like to discuss the concept of Mobile IP [20], which is one solution for providing continuous connectivity to the mobile users regardless of their physical movement, and was developed by IETF. There are three functional entities in mobile IP, namely home agent (HA), foreign agent (FA) and mobile node (MN). Every MN has two addresses, one permanent home address (HoA), which is assigned in its home network, and a temporary care-of address (CoA) which it obtained temporarily in the network which the MN will move into. The foreign agent (FA) in the visited network provides a CoA to the mobile node which can be either unique or shared. When the MN moves to a new network, it registers its CoA with its HA, which keeps the binding of the HoA with the CoA. All the packets meant for the MN are addressed to the HoA, where the HA intercepts all the received packets and tunnels them to the MN via the FA. It is not a satisfactory solution for mobile users having a large distance between the visited network and the home network (because of signalling delay) because it requires the registration of the visited network before it can start sending the packets and, due to the long distance, long handover delays and packet loss occur. Fast handovers for mobile (FMIP) and hierarchical mobile IP (HMIP) is used to overcome this problem in mobile IP.

7.2. Mobile IPv6

The solution provided by Internet Engineering Task Force (IETF) for network mobility is mobile IPv6. In MIPv6, for the management of users' movement, two addresses are used, a permanent address, and care of address (CoA), to communicate from the temporary location. Whenever the MN attaches to a foreign network, a temporary address CoA is allocated to it. This address is used to exchange agent solicitation and agent advertisement messages. The MN sends the binding update (BU) message with the new CoA to the HA. By this conversation, the HA is informed of the current foreign agent (FA) of MN. Now the HA is able to re-tunnel the packet to the MN via the new FA. The one enhanced feature in MIPv6 is route optimization, which is used to avoid the triangular routing [21]. In this way, the MN has a direct binding with CN (corresponding node) without involvement of HA. MIPv6 provides both L2 and L3 latencies because it deals with layer 2 and layer 3 sequentially. So this delay can not be compensated in real-time applications such as video conferencing, and VoIP (voice over internet protocol) is the packet switching technology in which the voice signals are transmitted in the form of packets. Many solutions have been proposed to reducing the latency of MIPv6. Fast mobile IPv6 [22] provides the concept of pre-acquisition of CoA with the help of layer 2 trigger which is discussed below. Handover steps in MIPv6 are as follows.

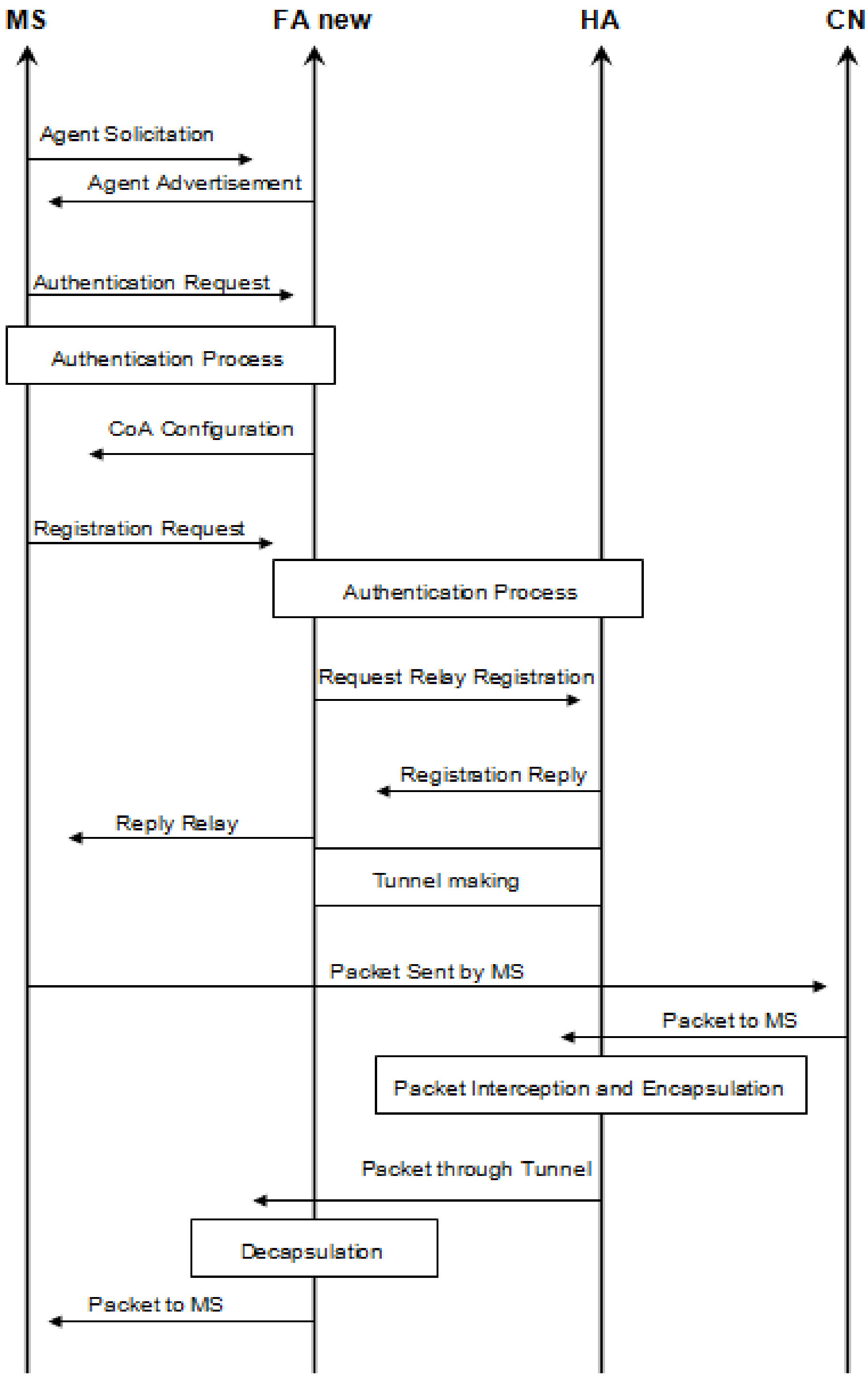


Figure 7.2.1: Mobile IPv6

7.3. Fast Mobile IPv6

The aim of FMIPv6 is to reduce the handover latency of MIPv6. In FMIPv6, when a MN finds a new access router (AR), it triggers a L2 message to its old AR with the MAC address of the new AR and asks it to set up a binding update (BU) and make the bidirectional tunnel with it. In this way, before the end of layer 2 handover, the ARs have done a BU and acquisition of CoA. One precaution is taken, namely that the MN should not use the CoA unless it receives the acknowledgement.

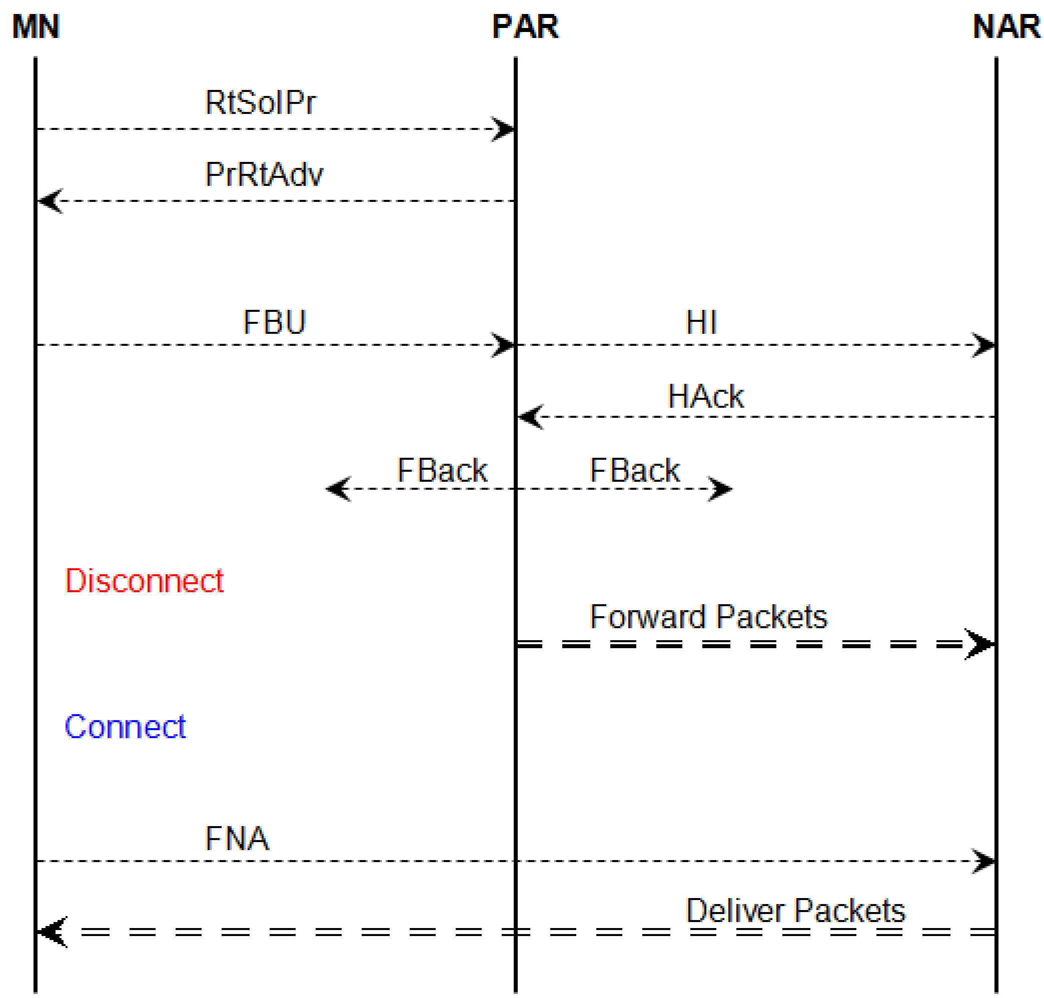


Figure 7.3.1: Predictive Mode of Fast Mobile IPv6 [18]

The messages which are sent during the initiation of trigger to L3 handover are discussed below. In this scheme, the MN sends a Router_Solicitation_For_Proxy to the previous access router (PAR) and, as a response; it sends a Proxy_Router_Adertisement which contains a new CoA of the new AR for the MN. The PAR sends a handover initiation message to get the new CoA to the new AR. The new AR replies with the handover acknowledgement which contains the CoA. The new AR registers the MN in its neighbouring cache with this CoA.

Just before moving, the MN sends a FBU (fast binding update) message to the PAR. On receiving this message, it creates a tunnel with the new AR to send the message, and sends a binding update acknowledgement. Now, the layer 3 handover is ready and it triggers a Link_Down, initiating the layer 2 handover. When the L2 process is done, the Link_Up trigger is fired to instruct the MN to send the fast neighbouring advertise (FNA) to the new AR. After the successful process of FNA by the new AR, all buffered messages are delivered to the MN which was stored during the process of handover. In this way, packet loss is near to zero. As we discussed before, both layer 2 and layer 3 handovers happen in parallel. In this case, layer 3 handover finishes before the initiation of layer2 handover; this mode of FMIPv6 is called “predictive mode” of handover.

Second mode of FMIPv6 is reactive, it happens when the layer 2 handover process is completed before the completion of layer 3 handover process. In this case, MN disconnects with the PAR after the messaging of RtSolPr and PrRtAdv so the information and timing of layer 2 handover are not available in the stack of FMIPv6 before the handover of layer 2 process then FMIPv6 act in a reactive mode. In reactive mode, MN first attaches with the new AR and then do the address configuration and FBU then PAR sends packets to MN through NAR.

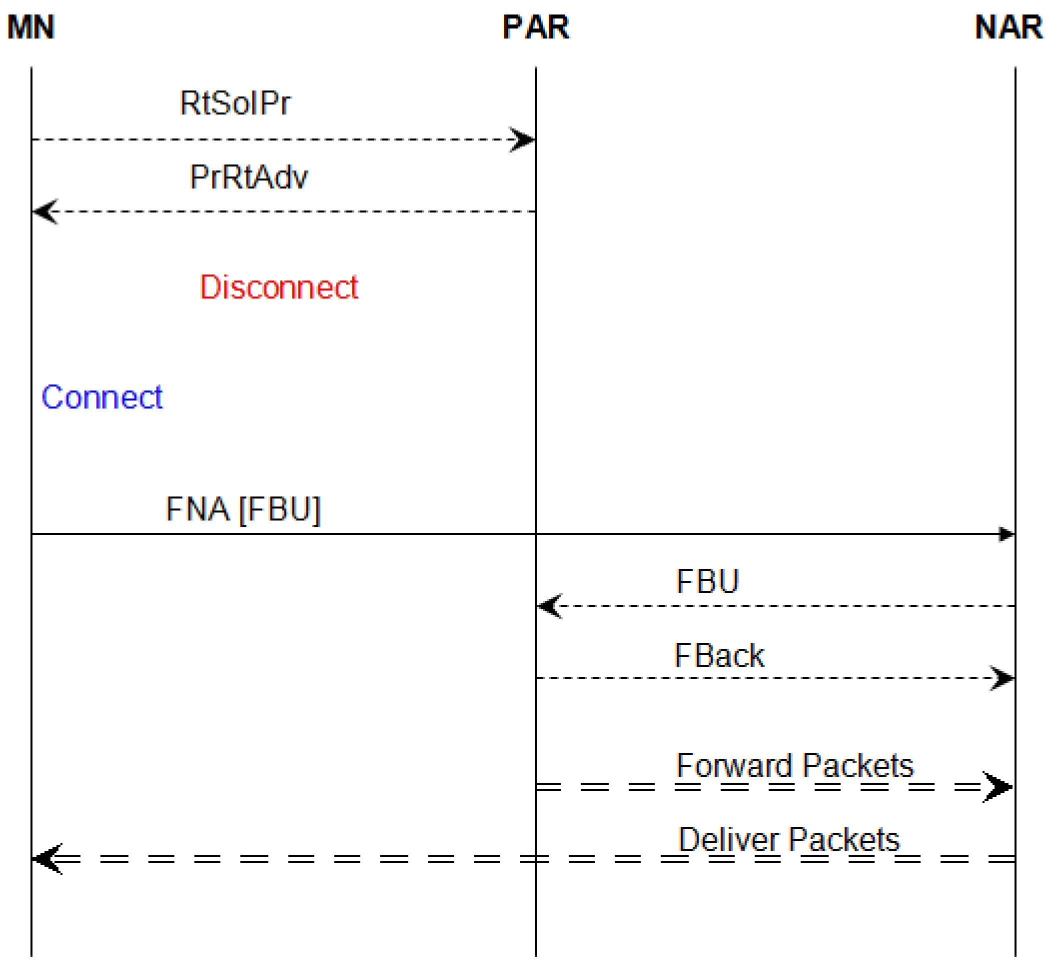


Figure 7.3.2: Reactive Mode of Fast Mobile IPv6 [18]

In proposed solution, it is bounded that layer 2 handover must trigger after the completion of layer 3 handover as discussed below in case studies of handover from WLAN to UMTS and vice versa. So, in proposed solution the mode of FMIPv6 will be predictive.

8. Proposed vertical handover procedure

To reduce the packet loss and latency during the process of handover, we propose a handover procedure based on the concept of FMIPv6.

According to the proposed procedure, a measurement process is triggered when the signal strength drops below predefined threshold values and/or if the velocity of the mobile node reaches to threshold value or if the battery reaches a critical status or the SIR of the required application is not fulfilled. On the basis of these values, the mobile node proceeds to the decision process of handover which decides when, and to which network, the MN should switch. Finally, the handover process initiates to the target network. The HA is notified about the movement of the mobile node; it gets the CoA for the mobile node from new AR and establishes the binding updates i.e. making tunnel with the new access router (AR) [21]. After the triggering of Link-down message, HA starts to send two copies of the packets, one via PAR to the MN and a second via the new AR. The packets which are sent via the new AR start to buffer on the new AR. This buffer is created temporarily, when the mobile node attaches with the new AR, mobile node synchronizes with new AR and collects the missing packets which were not received during the period of de-attachment of the mobile node from the PAR and the new attachment with the new AR. In this way, no packet is lost and latency is reduced.

Now we will discuss the steps involved in the handover from UMTS to WLAN and vice versa.

8.1. Handover from UMTS to WLAN network

As a case study, suppose mobile node is in UMTS network and when a mobile node enters in an overlap zone, the WLAN interface is activated and the decision module starts measuring different parameters of both networks. If the WLAN satisfies the conditions discussed above, for example required SIR, required velocity and battery power of mobile node, then the mobile node connects to the WLAN network after authentication and FMIPv6 binding update. Then the initiation of handover is triggered.

All steps of handover from the detection of new network to packets delivery from the new AR to mobile node are discussed below.

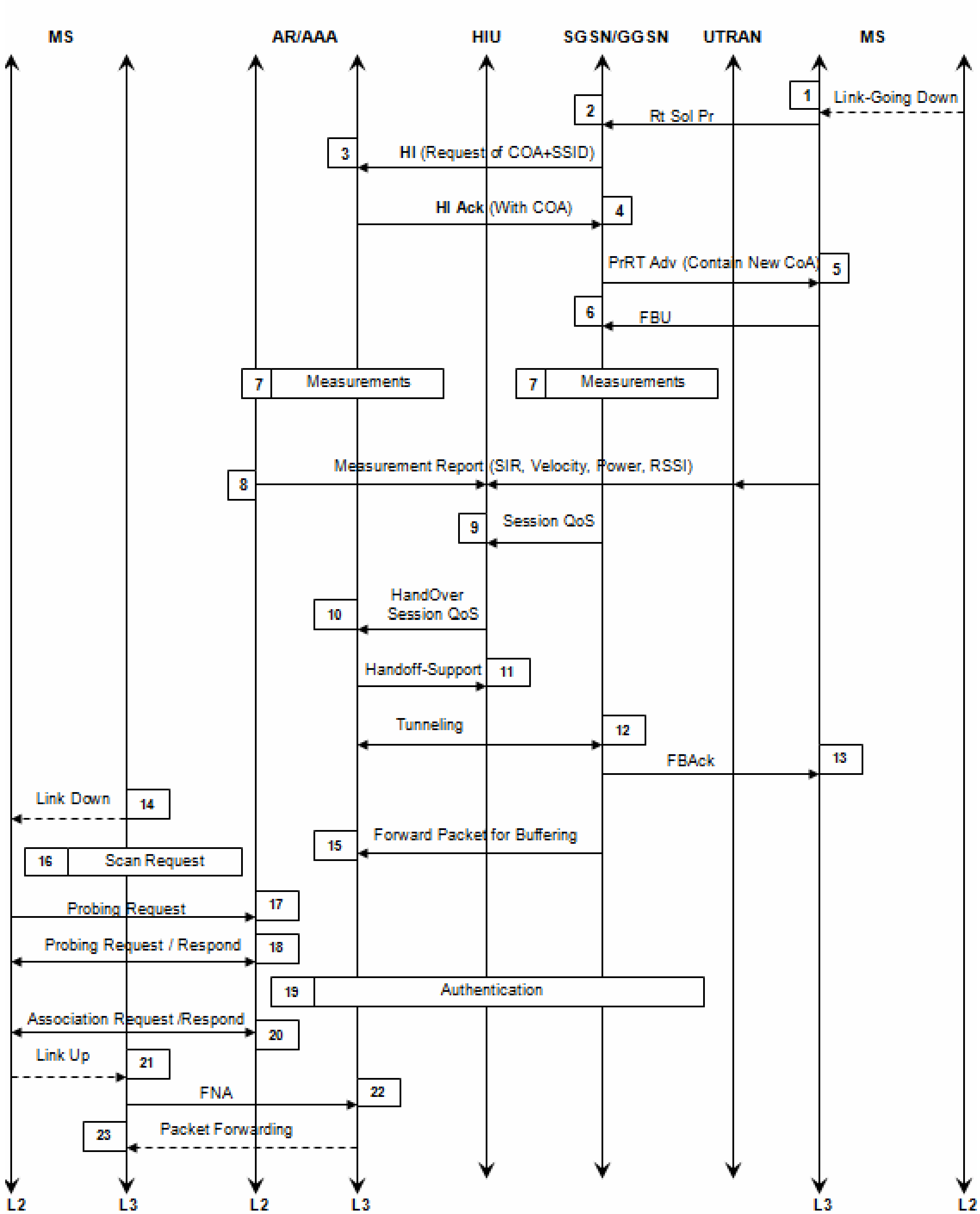


Figure 8.1.1: Handover from UMTS to WLAN Network

1. When the quality of link is going down from the threshold value, layer 2 of the mobile node triggers a Link_Going_Down message to the layer 3 with the MAC address of new access router of WLAN.

2. The mobile node sends a router solicitation for proxy (RtSolPr) message to the access router of UMTS. This message contains the MAC address of the new access router of WLAN and request for a new care of address (CoA).

3. The UMTS access router sends a handover initiation (HI) message to the WLAN access router. This message contains the SSID of the mobile node and a request for new care of address (CoA) for the mobile node.

4. In reply to the HI, the WLAN access router sends CoA.

5. In the reply to the router solicitation for proxy, the UMTS access router sends a proxy router advertisement message to the new mobile node. This message contains the new CoA which the mobile node uses when it attaches to the WLAN access router.

6. The mobile node sends a fast binding update message to the UMTS access router so that it can get binding with the WLAN access router. This binding includes making a tunnel and creating a buffer for the storage on packets for the MN etc.

7. In this step, the measurement of both network parameters will check that either which one is better for fulfils the requirements of application.

8. Both networks send the measurement report to the decision module.

9. UMTS access router sends session QoS parameters for the required application to the WLAN.

10. The decision module asks the WLAN about the required support for the application, such as bandwidth and required SIR etc.

11. The WLAN replies with the handover support which it can support.

12. The UMTS makes a tunnel with the access router of WLAN so that it can send data packet during the time of de-attachment. These packets get stored on the new access router of the WLAN.

13. After the completion of all these requirements of layer 3 handover, UMTS sends the reply of the fast binding update to the mobile node. This fast binding acknowledgment means that layer 3 handover is completed.

14. Layer 3 of mobile node triggers the Link_Down message to layer 2. This is the initiation of layer 2 handover.

15. After the initiation of L2 handover, the mobile node is disconnected with the UMTS network. In this disconnection period, all packets related to the mobile node are forwarded to the new AR of WLAN. A buffer is created on the access router of WLAN and all these packets start to store in that buffer.

16. The mobile node starts scanning the WLAN AR as it already knows the MAC address of WLAN AR and new CoA to attach with it.

17. After scanning the new AR, MN sends a probe request to AR.

18. It gets the probe response.

19. In this step authentication, authorization and accounting are done with the AAA server of UMTS.
20. After the successful completion of the above mentioned step 19, the mobile nodes get associated with the WLAN AR.

21. When the mobile node gets associated with the WLAN, it triggers a Link_Up message to the L3 daemon i.e. monitoring software which monitors the layer 3.

22. Layer 3 of the mobile node sends a fast neighbouring advertisement (FNA) to the access router of the WLAN to inform about its attachment with it.

23. When the access router of WLAN knows about the attachment of MN, it synchronizes with the MN and forwards all packets which were stored in the buffer during the time of de-attachment to the MN.

8.2. Handover from WLAN to UMTS network

As a case study, suppose mobile node is now in WLAN network and wants to move into the UMTS network. Same as discussed above, when the mobile node observes the presence of both networks, activates the UMTS interface, then it measure the parameters of both the networks for deciding that whether to initiate a handover or not. If the speed of MN is higher then the threshold value or SIR of WLAN is less then SIR of required application as discussed in the algorithm given below and UMTS fulfil the required SIR then handover decision module decides the handover from WLAN to UMTS after the authentication of mobile node. FMIPv6 set up the binding update with the UMTS, such as making tunnel and creating a buffer on UMTS AR for the storing packets and getting the CoA. then it trigger to handover initiation.

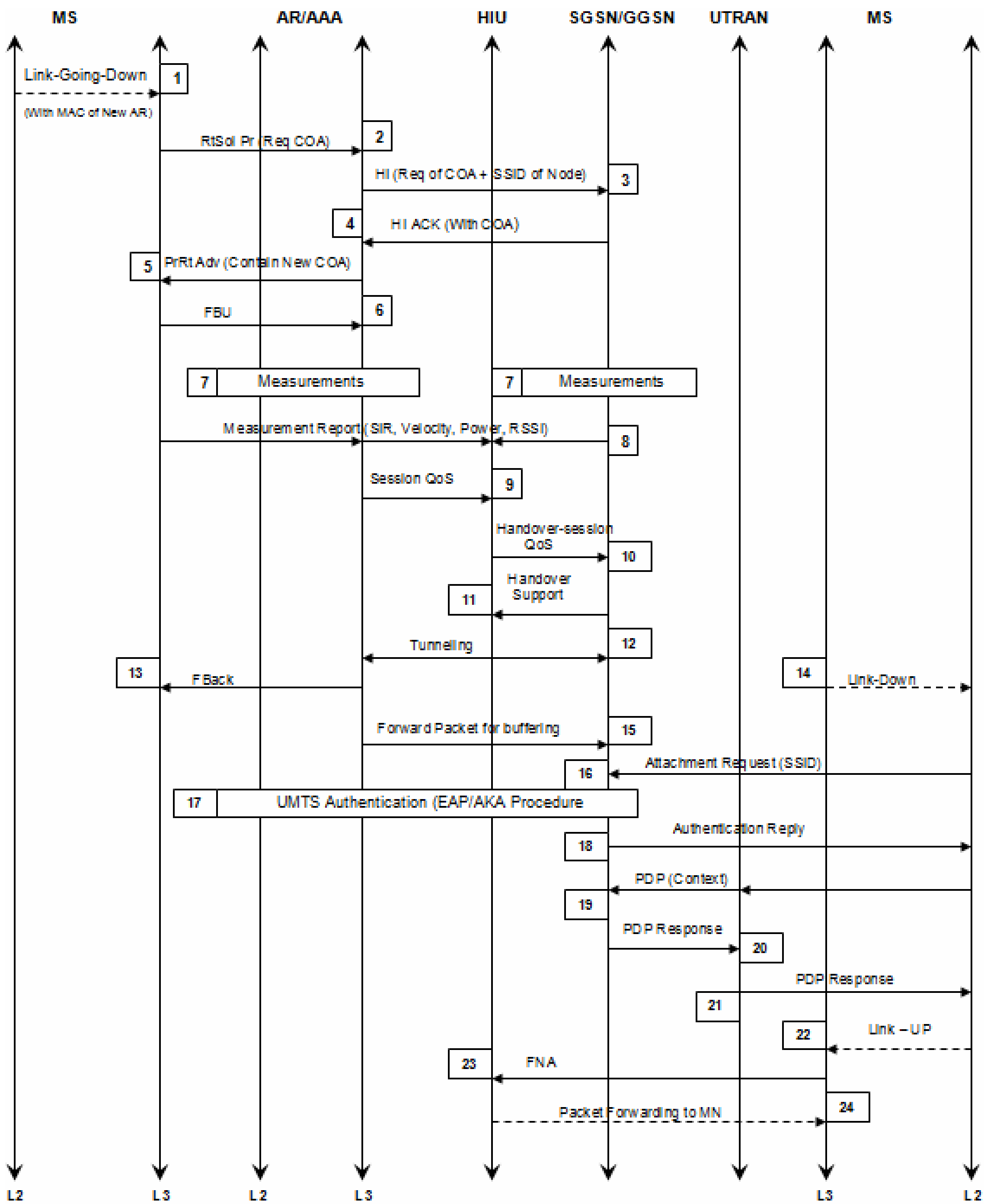


Figure 8.2.1: Handover from WLAN to UMTS Network

1. When the quality of link is going down, layer2 of mobile node triggers a Link_Going_Down message to the layer 3 with the MAC address of new access router of UMTS.
2. Mobile node sends a router solicitation for proxy (RtSolPr) to the access router of WLAN. This message contains the MAC address of the new access router of UMTS and a request for a new care of address (CoA).
3. WLAN access router sends handover initiation (HI) message to the UMTS (GGSN) access router. This message contains the SSID of mobile node and a request for new care of address (CoA) for mobile node.
4. In reply to the handover initiation, UMTS sends CoA, and registers the SSID of MN.
5. In the reply to the router solicitation for proxy, the WLAN access router sends a proxy router advertisement message to the new mobile node. This message contains the new CoA which the mobile node uses when it attaches to the UMTS.
6. Mobile node sends a fast binding update message to the WLAN access router so that it can get binding with the UMTS. This binding includes making a tunnel and creation of buffer for the storage of packets during the period of detachments etc.
7. In this step, measurement of different parameters of both networks is done for the requirements.
8. Both networks send the measurement report of different parameters, such as SIR, velocity, power and RSSI, to the decision module.
9. WLAN access router sends session QoS parameters for the required application to the decision module.
10. Decision module asks the UMTS about the required support for the application, such as bandwidth and required SIR, etc.
11. UMTS replies to the decision module with the handover support.
12. WLAN makes tunnel with UMTS so that it can send data packets during the time of de-attachment. These packets get store on the UMTS.
13. After the completion of all these requirements of handover, WLAN sends reply of fast binding update to the mobile node. This fast binding acknowledgment means that layer 3 handover is completed.
14. Layer 3 of mobile node trigger Link_Down message to layer 2. This is the initiation of L2 handover.
15. After the initiation of layer 2 handover, the mobile node is disconnected with the WLAN network. In this disconnection period, all packets related to the mobile node are forwarded to the UMTS. A buffer is created on the UMTS access router and all these packets are stored in that buffer.
16. Mobile node sends attachment request with SSID to the UMTS.
17. UMTS authenticates the mobile node with the AAA server of WLAN.
18. After authentication, UMTS sends attachment reply to mobile node.
19. After the successful attachment with the UMTS, PDP context is activated with the GGSN through the SGSN to get connection with the UMTS backbone network.

20. GGSN sends PDP context response to UTRAN if connection with the UMTS can be established.
21. PDP context is relayed by the UTRAN to the mobile node.
22. After receiving the PDP context response, layer 2 of mobile node triggers a Link_Up message to the layer 3.
23. Layer 3 of the mobile node sends a fast neighbouring advertisement (FNA) to the access router of the UMTS to inform about its attachment with it.
24. UMTS forwards the stored packets to the mobile node.

8.3. Handover Decision

A seamless handover would only be possible when it has low latency, low handover overhead, low packet loss and low probability of handover discontinuity. All these characteristics of handover depend on handover technique and a good and accurate handover decision process. The main characteristics for the handover in heterogeneous networks are discussed below.

8.3.1. Handover Characteristics

Some phases of handover are common in both horizontal and vertical handover. Such as:

- Available network domain detection
- Selecting the best network among the available
- Deciding the handover policy
- Handover execution based on decision policy

In horizontal handover, the decision of a handover mainly depends on the value of the signal strength of the received signal. If the received signal strength lies below a threshold value and the neighbour base station provides more signal strength than the previous base station, the MN will switch to the neighbour base station.

In vertical handover, only the received signal strength is not adequate as the only decision parameter. All these parameters mentioned below, collectively decide whether or not handover should take place, while all these parameters are not required in horizontal handover. Following are the proposed parameters which are taken under consideration in the decision of vertical handover:

1. **Network condition**: The purpose of handover is to provide better conditions of signal strength and high performance. Before the handover, some measurements of the target and present networks are taken to see if target network is able to provide the requirements of application for a continuous connectivity. These parameters are transmission rate, error rates and other characteristics can be measured.
2. **Application requirements**: An application running on the mobile node has its own requirements such as quality of service requirement which can affect the vertical handover. So handover decision also based on QoS as well.

3. **Bandwidth**: different applications require some specific amount of bandwidth, such as FTP or video streaming. These applications perform well when they get desired amount of bandwidth if we provide them more bandwidth then they can give us too good performance.
4. **Packet error rate**: Some applications can bear packet loss to some degree but not more than that for example voice conversation and video streaming can bear packet loss whereas FTP and email application can not.
5. **Latency**: Non-real time applications are not sensitive to latency while real-time applications need only low latency (such as in video streaming and voice conversation).
6. **Power Requirements**: Every wireless device requires some amount of battery power. If the level decreases, it is necessary to remain in low power consuming technology or handover to a technology which is using less power. WLAN uses less power compared to UMTS. If the mobile device is connected to the UMTS and battery power is going to finish and WLAN is available, the mobile device should move to WLAN for the long life.
7. **Interference**: Interface, such as co-channel or adjacent channel interference, is also a big problem. Many wireless technologies suffer from interference. Before vertical handover takes place, the network is examined regarding the co-channel or inter-channel interference which exponentially degrades the network.
8. **Velocity**: In horizontal handover, the velocity does not have the same effect just like in vertical handover. As WLAN covers a considerably smaller area than UMTS, if the mobile device is moving very fast, it is better to remain in UMTS to reduce the frequency of handover.

8.4. Handover Decision Algorithms

The handover decision algorithm has to check different parameters before initiating the process of handover. In heterogeneous technologies, handover decisions should also be based on the type of technology. If all the parameters of handover are satisfied - mean condition of current network, condition of the network in which mobile node wants to switch, user preference, battery power, velocity of mobile station and application requirement etc. - then the decision module makes the decision and initiates the process of handover. In previous research, different parameters are used for the handover decision, such as some take the decision on the received signal strength (RSS). As in most previous technologies, the decision algorithm is based on RSS, signal to interference ratio (SIR), bit error rate (BER), blocked error rate (BLER), coverage area of the current base station and the current status of the neighbouring base stations. In heterogeneous networks, some take the velocity of the mobile station as the decision parameter, such as between WLAN and CDMA system. For the best performance, a threshold value of velocity is determined to reduce the unnecessary attempts of handover.

As discussed, in previous technologies and research, handover initiation depends on specific values of parameters and handover is triggered with the pre-determined threshold values. However in our proposed handover decision algorithm, a predictive and adaptive scheme is introduced. This proposed scheme gives a best handover initiation time and selects the best available network by dynamically calculating the parameters. In previous research, the same parameters are used for both handovers from UMTS to WLAN, and vice versa. In the proposed solution, however, different parameters are used for handover from UMTS to WLAN and WLAN to UMTS because both technologies have different characteristics. In such as handover from UMTS to WLAN, battery power and RSS are taken as decision parameters to reduce the power consumption of the terminal because, in UMTS, the mobile node consumes more power sending and receiving the signal due to more distance from the base station. If these parameters are satisfied and WLAN provides the required quality of service (QoS) parameters, i.e. required bandwidth, required data rate, required signal to noise ratio (SNR), less error rate and less packet loss then MN switches from UMTS to WLAN. These QoS parameters are the same for UMTS as well, while the velocity and SIR are considered as the decision parameters when handover occur from WLAN to UMTS. If the UMTS network fulfils the required QoS parameters then mobile node switches into UMTS.

Threshold value for the battery is calculated dynamically because every network technology and every application which is running on the mobile node, consumes different battery power. The power storage capacity of all batteries is also not the same, so a code is written which calculates the battery consumption in per unit time, considering all above conditions, and then, by applying a heuristic approach, it decides the threshold value.

While threshold value of velocity is taken as a static because WLAN covers a very small area, so if velocity is greater than threshold value, it is better to switch in UMTS if it is in WLAN or, if it is in UMTS, then stay there to avoid the unnecessary handover. However velocity of MN is measured dynamically by taking some reference point in the network, which can be the access router. Velocity is measured with the reference of changes in the RSS; if the value of RSS is decreasing very sharply then it means that MN is moving far away from AR with fast velocity or the signals are getting blocked by some kind of obstacles. If the RSS value is increasing then it means that MN is moving toward AR. Velocity can also be measured with the help GPS.

Authentication and billing is done with the authentication, authorization and accounting (AAA) server. Billing can also be calculated with the help of AAA server, as in [23], when the mobile node moves from one technology to the other then first it get verifies from AAA server of previous technology. If the MN is authenticated from the AAA server of previous technology then the current network allows the MN to be attached otherwise not, now when the MN attaches to new network then its AAA will start to calculate its time of attachment with it. In this way, time of attachment with the both technologies is sum up and billing is calculated.

8.4.1. Handover decision Algorithm from WLAN to UMTS

In the upward handover, velocity and SIR are taken as the decision parameters. A threshold is defined for both metrics. If a mobile node is currently in WLAN network, it evaluates the signal to interference ratio (SIR) and mobile node velocity. If the SIR of the current network is less than threshold, and does not satisfy the requirements of the application, or if the velocity is increasing beyond a threshold, the decision module will initiate the handover process. However before the initiation of handover, the WLAN adaptor checks the QoS parameters provided by the UMTS. If the requirements are satisfied and conditions persist during the period of dwell timer, the handover process is initiated. If it has not satisfied the required QoS parameters, then WLAN starts to scan for the new access point which satisfies the required QoS parameters and resets the dwell timer.

Some key terms used in algorithms are described below.

SIR_{WLAN}: Signal to interference ratio of WLAN network
SIR_{req_app}: Threshold value of signal to interference ratio required by the application.
QoS_{WLAN}: QoS provided by WLAN network
QoS_{UMTS}: QoS provided by UMTS network
SIR_{new_AP}: SIR of the newly detected neighbouring access point
$SIR_{current\_AP}$: SIR of the current access point
VT: threshold velocity for mobile node
PT: threshold power, which determines the critical life time of mobile node battery power
RSS_{UMTS}: Received Signal Strength from UMTS network by the mobile node.
RSST: Threshold value of Received Signal Strength.
RSS_{new_AP}: Received Signal Strength of new AP
$RSS_{current\_AP}$: Received Signal Strength of current AP
RSS_{WLAN}: Received Signal Strength of WLAN which mobile node detects from the WLAN network

Algorithm 1:

Decision algorithm is when the mobile node is in WLAN network and wants to move into UMTS network.

```
Repeat
    Working in WLAN
    If [(SIR_WLAN < SIR_req_app) or (velocity > VT)] and [RSS_UMTS > RSS_T]
        If required QoS_UMTS is satisfied
            Start dwell timer
            If conditions persists till the timer expires
                Execute handover to the UMTS network
            Else
                Reset dwell timer
            End if
    Else
            Trigger passive or active WLAN network scanning
    If detection of new AP with (SIR_New_AP > SIR_Current_AP) and
            [RSS_New_AP > RSS_current_AP]
                Start dwell timer
                If conditions remain same till timer expires
                    Execute handover to the new AP in WLAN
                Else
                    Reset dwell timer
                End if
            End if
    End if
End Repeat
```

8.4.2. Handover decision Algorithm when Mobile Node is in UMTS network

In the proposed handover decision algorithm, when the mobile node is in UMTS and wants to move in WLAN, it takes the velocity and battery power of the mobile node as a decision metric. When the battery power is critical or the velocity of mobile node is lower than the pre-determined threshold, then the decision algorithm initiates the handover process if the WLAN satisfies the QoS and required SIR of the application and, if these conditions remain true till then specific time which is called the dwell time is expired. On the other hand, if these conditions are not satisfied, then the mobile node remains in the UMTS network.

Algorithm 2:

```
Repeat
    Working in UMTS
    If (Velocity < VT) or (Terminal Power < PT) and [RSS_WLAN > RSS_T]
        If (SIR_WLAN ≥ SIR_req_app) and (required QoS_WLAN is satisfied)
                Start dwell timer
                If conditions remain same till timer expires
                    Execute handover to the WLAN network
                Else
                    Reset dwell timer
                End if
            Else
            Stay in the current network
        End if
    End if
End Repeat
```

8.5. Ping Pong Effect

In proposed handover between 3G and WLAN, the concept of dwell timer is used. A dwell time is a specific time period which starts when the condition is satisfied. If the conditions remain the same till the time expires, then the handover process is triggered, otherwise we reset the dwell timer. This concept of dwell timer, introduced in [24], is used to reduce the ping pong effect. While in proposed handover scheme, the dwell timer reduces the cost of handover and ping pong effect. Reduction in the cost of handover means, minimizing the unnecessary and unbeneficial handover rate. The dwell timer value should be optimized if there is a large value, then the handover blocking rate could be more and, if short, then there could be more ping pong effect.

9. Conclusion

This thesis discusses the vertical handover in heterogeneous wireless networks environment. Three things are worth mentioning in this thesis. First, vertical handover architecture is proposed with decision module. For example, this thesis discusses the whole procedure of handover with all steps that when and how it will decide to switch from one technology to the other technology. Secondly, two decision algorithms are discussed which take the decision of handover between the technologies. These algorithms take the decision of handover on the conditions of networks, mobile node and application requirements, such as velocity of mobile node, battery condition of mobile node, required SIR of application and received signal strength (RSS). The major work of this thesis is to eliminate the layer 3 latency by completing layer 3 processes before the de-attachment from layer 2. In this way, the proposed solution only faces layer 2 latency.

Previous research also proposes many solutions; mostly solutions have latency of both layers because they first de-attach the mobile node from previous technology, then search the available technology, get the care of address, register the care of address with the home agent, buffer the packet to the previous access router and deliver it to the mobile node after attachment.

This thesis proposes a low latency and near to zero packet loss due to making the tunnel before handover where the proposed solution suggests buffering the un-received packet to the next Access Router where the mobile node is going to connect. So the proposed vertical handover solution completes the layer 3 Handover, before the triggering of layer 2 handover, with the help of FMIPv6. In this way, the proposed solution eliminates the layer 3 latency.

This thesis does not contain any evaluation of the proposed solution (analytically or through simulation). The proposed solution just discusses everything theoretically. Some problems may arise during the process of simulation or implementation, such as measuring the quality of service parameters for each specific application and measuring the threshold values for velocity and the battery of the mobile node, because the threshold value of battery depends on many things such as battery type, usage of battery per unit time in each network, the usage of battery power for specific application.

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