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Vertical Handover between WiMAX and UMTS performance analysis

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Declaration

I certify that this thesis submitted for the degree of Master, is the result of my own research, except where otherwise acknowledged, and that this study (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Hassan Issam Khalil

Date: …………….

Dedication

Praise and thanks to God for all the blessing and for the production of knowledge that, for this thesis would not be possible.

To my father Dr.Issam Khalil and my mother Dr.Amal khalil

To my wife Razan and my kid Abdallah

To my brothers and family.

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Abstract

Smart mobile communication systems are embedded with advanced computing aspects and equipped with multiple network interfaces to support different kinds of wireless technologies. However, WiMAX and UMTS technologies are heterogeneous networks and the traffic redirection between them are called a vertical handover process. Recently the IEEE 802.21 enhanced the vertical handover process and enable seamless mobility between the wireless access networks. In this research, the traffic redirection from the WiMAX to UMTS networks with the existence of the IEEE 802.21 standard. A performance comparison is done based on many application data rates and different speeds of the mobile node the effect of mobile speed on the performance is also monitored in three different scenarios. The network performance indicators are measured throughput, packet loss, delay, and handover latency. Comparing the results with the ITU-T recommended values helps us to define an acceptable threshold to insure the quality of service for different applications that run on the mobile node and the media server which is represented in our topology as a service provider. Finally, the results should be close to the reality in our scenarios as we considered the existence of the 802.21 IEEE standard which takes the received signal strength as decision maker whether to do the handover or not.

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Abbreviations

RAT	Radio Access Network
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability Microwave access
UMTS	Universal Mobile Telecommunication System
ITU-T	International Telecommunication Union
MIH	Media Independent Handover
IEEE	Institute of Electrical and Electronics Engineers
Ns2	Network Simulator 2
ABC	Always Best Connect
IETF	Direct sequence spread spectrum
1G	1st Generation
2G	2nd Generation
3G	3rd Generation
4G	4th Generation
NIST	National Institute of Standards and Technology
RSS	Received Signal Strength
OSI	Open System Interconnection
GSM	Global System for Mobile Communications
DSL	Digital Subscriber Line
VOIP	Voice over internet protocol
IPTV	Internet Protocol Television
SGSN	Serving GPRS Support Node
GGSN	Gateway GPRS Support Node
POA	Point Of Attachment
POS	Point Of Service
CBR	Constant Bit Rate
MADM	Multi Attributes Decision Making
DHCP	Dynamic Host Configuration Protocol

IETF	**Internet Engineering Task Force**
RSS	**Received Signal Strength**
AAA	**Authentication Authorization Accounting**

Chapter 1

1.1. Introduction

Internet was not designed to handle mobility. The mandatory of new functionalities and components raised to fill the gap and keep the mobility in mind and provide the Quality of Service (QoS) for the mobile users. The prevailing feature of smart wireless mobile communication systems is mobility, communicate on the go, anytime and anywhere is challenging. The revolutionized of Always Best Connected (ABC) insure that the mobile terminal must connect to best possible candidate network not only being reachable while the mobile is moving. On the other hand, the impact on performance and the service continuity of the mobile applications is a serious problem in vertical handover process [1].Because we need to guarantee real time applications and data exchange while performing the handover process from one network to another. The handover can be defined as redirection of a phone call or any traffic that run on a mobile terminal from its current cell to a new one [2]. The mobility will cause a detect in losing the connection on the mobile terminal interface which needs to make a shift to another cell in order to keep the phone call up and running[2]. Handover process can be classified according to Radio Access Technology (RAT) as Vertical or horizontal handover [3]. In vertical handover, the mobile terminal assumed the movement in heterogeneous networks while in horizontal handover which consider the mobility user are within the same network technology .The vertical and horizontal handover are also called inter-technology and intra-technology respectively. For example, a handover between 802.11 Wi-Fi access points to another is defined as horizontal handover but moving to 802.16 WiMAX site is defined as vertical handover. Horizontal handover is the traffic redirection of the same radio cells, while vertical handover is the process that enables the traffic flow to be directed between two different wireless networks such like the WiMAX and the UMTS, which have different data link layer, operation frequency, and network layer. Integration between two different heterogeneous networks is achieved by using Media independent handover (MIH) which is used to fill the gap by providing a global view of all heterogeneous candidate networks. The key evaluation metric will be calculated and the requirement of the service continuity will be considered to achieve the Quality of service (QoS) for some application and compared to the recommended values by the ITU-T.

In this thesis we implement mobility scenarios for a user that moves from WiMAX to UMTS environment. In first scenario the WiMAX is the serving point of attachment and the UMTS is the candidate network. The presence of the MIH layer which uses the event, command, and information service between the upper and lower layer to handle the packets while the mobile node is moving from the network to another. We will do a full study for the network performance indicators with different types of application bitrates and different mobile node speeds.

Network layer handover require obtaining a new IP address to allow the flow of packets which means a new connection to be stablished while the mobile moves from the source node to destination node. A cross layer concept used by the MIH designed to obtain parameters from different layers in order to process the connection migration from one network to another.

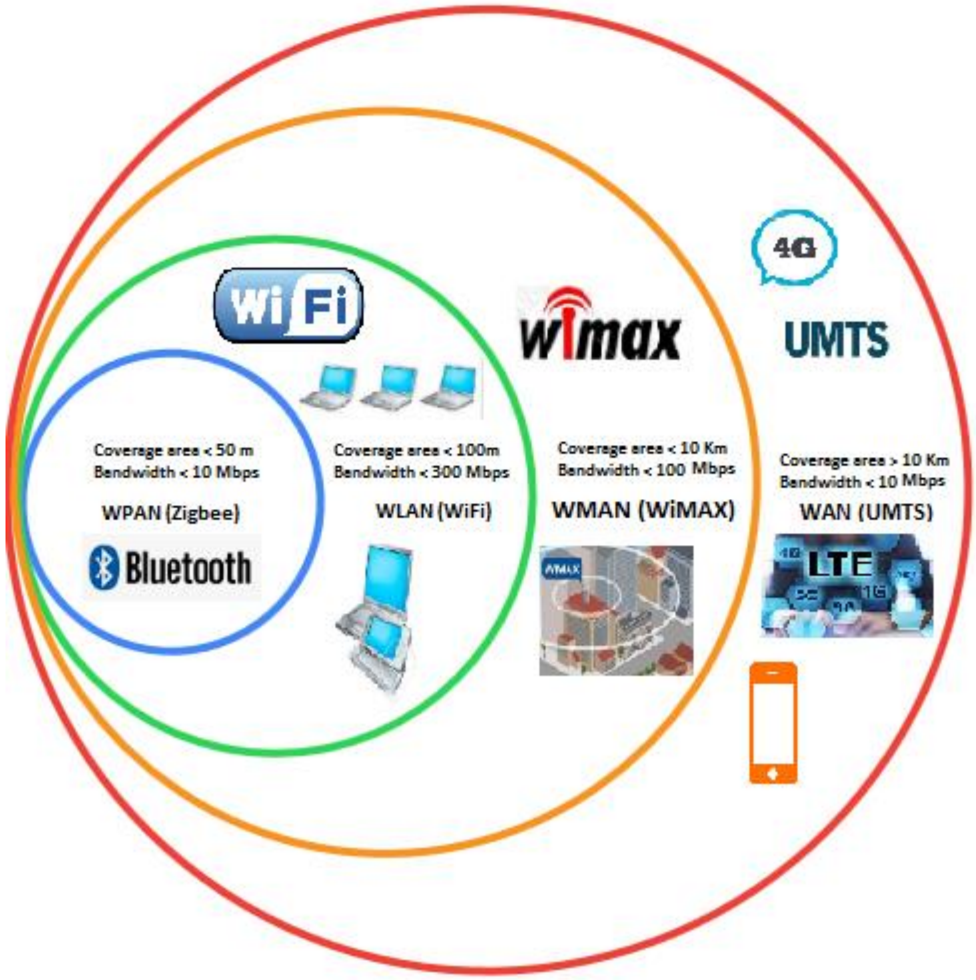

Figure 1.1: Overview of wireless network

Wireless communications have a very fast development due to increase in mobiles, and applications, it is compose of over lapping cells which form the hierarchical structure of wireless networks and limited to characteristic such like bandwidth, coverage area, capacity, and power [5][6]. To provide the services to mobile users and due to the increase in demand, the cellular networks simultaneously introduced beside the wireless networks, both technologies are restricted to a standard and have their own specifications [5]. However, the cellular networks have more restriction and limitation in cost, bandwidth, and licenses compared to unlicensed spectrum in wireless network. We can find the classification of IEEE 802 standards based on coverage and bandwidth is shown in figure 1.1 .The co-existence of multiple wireless technology standard with cellular networks will aid to enrich the users experience and achieve the QoS for the mobile applications in our new digital society world [5].

1.2. Background

Internet is the nervous of our modern life nowadays. It provides people to connect worldwide. However, not only people need to be connect but also the intelligent smart systems need to talk to each other. Cisco estimated that in 2030 the number of devices connected to internet will reach 500 billion devices [4]. And this will derive users to digital their life and will expand the demand on network devices. Therefore, network providers should guarantee the QoS for the users and insure the scalability in the network connectivity. On the other hand, there are many limitations in network that return to the standards and regulations such like allowable frequency bands, licensing, etc.

Wireless access networks can be classified in two main categories the first one is wireless network which uses the IEEE 802 family and the most popular is IEEE802.11, and IEEE 802.16 which refer to Wi-Fi and WiMAX respectively and the cellular network which work IETF group such as 1G, 2G, 3G, 4G, and 5G.Wireless networks which guarantee to solve the problem of the deployment cost and bandwidth have to overcome the problem of compatibility issues. Therefore, many standards have been developed in Wi-Fi and WiMAX which yield a lot of standards such like IEEE 802.11a/b/n …etc. In figure 1.2 we represent a simple Wi-Fi network with standard IEEE802.11n with different type of devices connect to get a different services from the internet through the WAN such like browsing and watching video, or to communicate locally between them through the local area network .

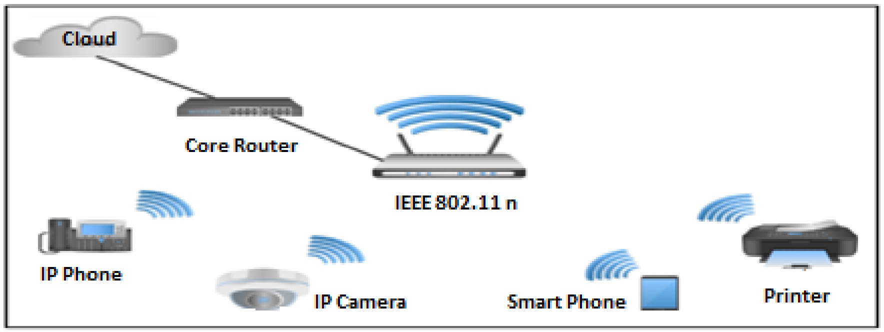

Figure 1.2: Simple Wi-Fi network

1.3. Problem Statement

The mobility of the users and the movement between different types of wireless network technology like WiMAX, Wi-Fi, and 3G cause a high degradation in the network performance indicators. Throughput, packet loss and handover delay are very important metrics to measure the quality of the service provided to the users and they are directly related to the speed of the mobile terminal, and the bandwidth of the serving point of attachment that makes the connection between the mobile node and the application server. In addition, the type of the application request by users which works on different data rates .The diversity in wireless technology standards and the lack in the compatibility between them cause a disturbance for the real time applications and cause a connection breakdown.

1.4. Research Objective

The main objective of this thesis is to perform analysis for a mobile node while it's moving from source to destination node and runs application each time with different bitrates .The network performance metric is measured during the movement from the WiMAX site to

UMTS base station which is the target network. These two networks are from different families and they have different characteristics. In this thesis, the compatibility issue between these two networks is addressed using the Media Independent Handover (IEEE 802.21) and the impact of moving from a high to low network bandwidth is studied for different speeds to observe the effect on the throughput, delay, packet loss, and handover latency in order to compare these values with the ITU-T standard.

1.5. Thesis Contributions

To meet the objective we build the scenarios using the network simulator 2 (NS 2) which consist of WiMAX (IEEE 802.16) and UMTS modules with the help of the NIST package which provide the MIH layer IEEE 802.21. A core network backbone routers and application server which provide a service for different applications bitrates run on the mobile terminal with different speeds. Analysis of the network performance indicators such as the throughput, packet loss, delay, handover time, and power on the mobile node which located in two different locations in each scenario. The preferable scenario is scenario two which have an equal distance travel in WiMAX and UMTS networks.

1.6. Organization of the Thesis

1) Introduction: Includes an overview of the thesis work and wireless technology main concepts, also we mention problem statement, thesis objective and research methods that used in order to meet these objectives.
2) Background: A brief description of the problem of the vertical handover problem and IEEE 802.16 WiMAX and UMTS network structure.
3) Literature review: We present vertical handover methods, and a set of research papers based on the vertical handover problem and discuss the different algorithms that

represented to solve the problem of the vertical handover. Also will mention how far some solution are not applicable to applied to real life scenarios.

4) Methodology: In this chapter we present the scenarios, simulation parameters, and applications properties. In addition, define the IEEE 802.21 Media Independent Handover and the NIST package add-on in NS2 plus the power boundary in WiMAX and the handover stages description.
5) Results and discussion: Based on the scenario build on NS2 between WiMAX and UMTS and the obtained result using AWK scripts. We analyse and discuss the result and investigate the effect of the speed and the application bitrate on the key performance indicators .A graphs are plots versus the speed of the mobile node.
6) Conclusion and Future Work: This chapter present some recommendations for the future work regarding the vertical handover problem and include lessons learned from our work.

Chapter 2

An overview of wireless communication network

2.1. Introduction

Open systems interconnection (OSI) is classified the wireless access networks based on the physical and MAC layer.IEEE 802 family is defined a set of wireless technology standards that we are using in our modern life today , like 802.11 and 802.16 which referred to wireless fidelity (Wi-Fi) and worldwide interoperability for microwave access (WiMAX) respectively . The growing demand for different services which use different types of protocols is a challenge and there is a need to integrate these technologies in order to optimize the mobile user experience. In this chapter we will present the main functional operations and architecture for the WiMAX technology, UMTS technology, and Media independent handover as a cross layer function. Also we will represent the handover different stages.

Table 2. 1*: **Properties for wireless technology [7]***

Parameter	WiMAX	UMTS	Wi-Fi
Data Rate Down-link	46 Mb/s	14.4 Mb/s	54 Mbps
Up-link	7 Mb/s	1.4 Mb/s	100 Mbps
Bandwidth	3.5,7,10 MHz	5 MHz	20,40 MHz
Modulation	QPSK 16 QAM 64 QAM	QPSK 16 QAM	BPSK QPSK 16 QAM 64 QAM
Multiplexing	TDM/OFDMA	TDM/CDMA	CSMA
Duplexing	TDD	FDD	TDD
Frequency	2.3,2.5,3.5 GHz	800,900,1800,1900 MHz	2.4,5 GHz
Channel Bandwidth	3.5,7,14,20 MHz	5 MHz	20 MHz

2.2. Heterogeneous and Homogeneous Network

Heterogeneous networks can be defined as a collection of 802 wireless standard families (Wi-Fi, WiMAX, etc.) and mobile cellular networks (2G, 3G, Etc.) also called inter-technology systems. The integration and the connection between these technologies are defined as vertical handover so different technologies can be able to provide seamless connectivity to mobile users while moving between these networks.

Homogenous networks are defined as collection of the same radio access technologies (RAT's) or networks from the same 802 wireless family also called intra-technology systems. The connection between these networks are defined as horizontal handover which means move the connection from one access point or one cell to another.

On the left side of figure 2.1, a laptop moves from source to destination node labelled X and Y respectively. The laptop moves in heterogeneous networks including UMTS, Wi-Fi, and WiMAX networks. On the right side of figure 2.1 it moves from X to Y while connecting to WiMAX network only which present the meaning of homogeneous network.

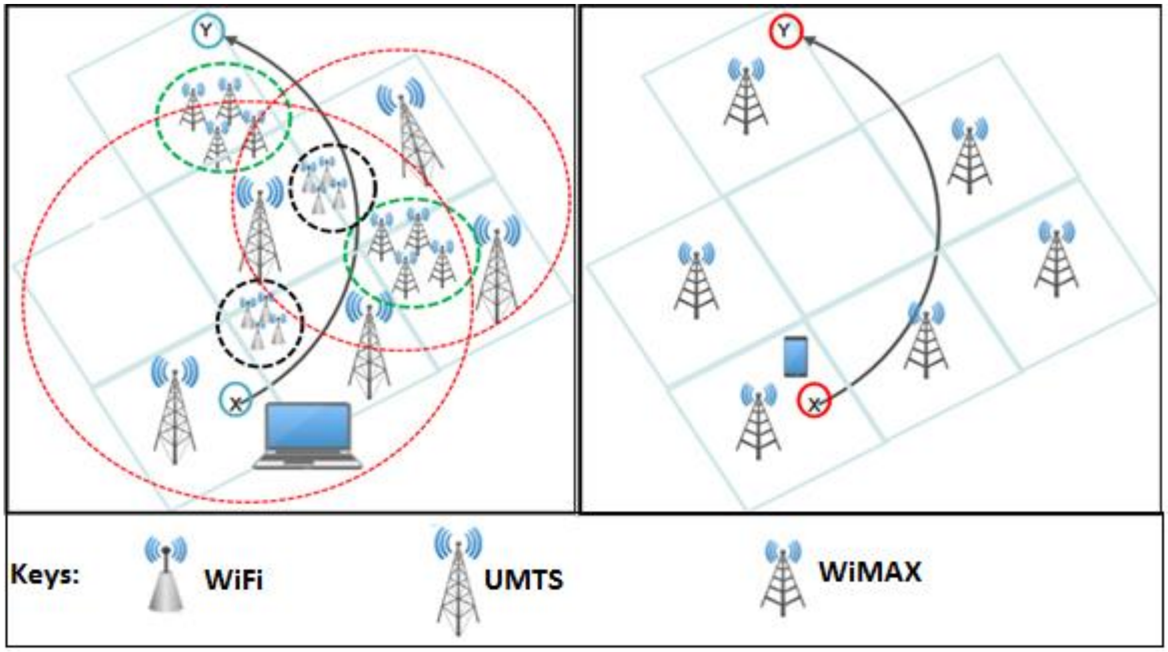

Figure 2.1: Heterogeneous Networks and Homogeneous Networks

2.3. IEEE 802.16 Standard

Worldwide Interoperability for Microwave Access (WiMAX) is a wireless network technology handle the transition of data over long distance using wireless communication techniques. WiMAX operates similar to Wi-Fi, they are two broadband technology. However, the characteristics of the WiMAX signals have a specific property in modulation used and in frequency that allows to deliver data with faster speeds, larger scale, and cheaper deployment [8]. Many of WiMAX networks deployed to replace the digital subscriber line (DSL) , and cellular wireless networks like (GSM) ,because of low cost and the ease of deployment compared to wire technology, and high capabilities in many multimedia applications especially in VOIP and IPTV [9]. The main components for the WiMAX architecture are shown in figure 2.2 which consist of:-

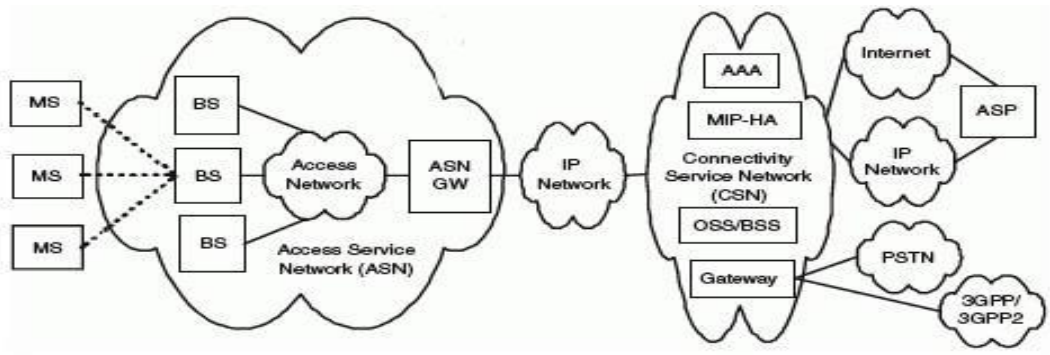

Figure 2.2: WiMAX Network [10]

1) Mobile Subscriber Station (MS): The end user equipment or the mobile terminal.

2) Base Station (BS): Electronic device with tower and includes cells with a large coverage area is known as base station located at the edge [10].

3) Access Service Network (ASN): Is consist of base station which serve a mobile terminal in a specific region and connect it to ASNGW. It may contains more than one base station and ASNGW.Also it is consist of the DHCP server which provide IP address to MS.

4) Access Service Network Gateway (ASNGW): Works as layer 2 traffic aggregation point and provide additional functionality such like location management, and Quality of Service (QoS).

5) Connectivity Service Network (CSN): Is a key element which provides the ip connectivity to subscriber and may contain AAA server which provide the authentication authorization and accounting to the WiMAX client.

6) Mobile Internet Protocol Home Agent (MIP-HA): Locate in the CSN and it store the address of the home mobile agents, act as an anchor point for mobile subscriber and it provides end to end mobile ip solution [10].

Finally, as we mentioned previously there are many advantages of using WiMAX which have high capability and flexibility compared with other network technologies in mobility support .In figure 2.3 [11] which presents the WiMAX mobility in compare with other wireless technologies. We notice that Wi-Fi bandwidth is the highest but the mobility is low because the coverage area of the Wi-Fi is not high. In contrast to the WiMAX which have a high coverage area and acceptable bandwidth. Also in UMTS we notice that the mobility is high but the bandwidth is low as shown in table 2.1.

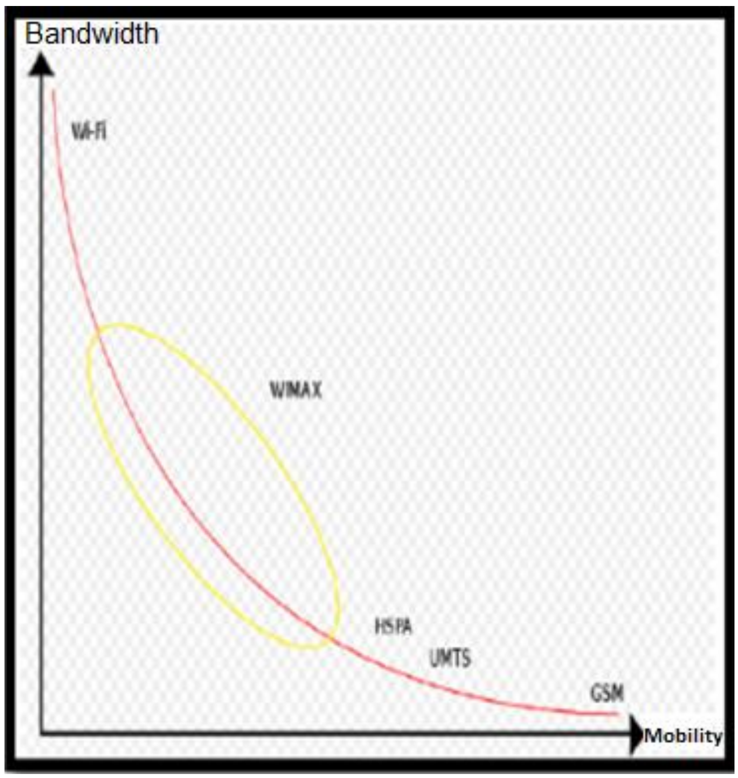

Figure 2.3: Wireless technology and Mobility [11]

2.4. Universal Mobile Telecommunications System (UMTS)

Not like the GSM network which designed for voice and simple text only. The UMTS was developed and designed to deliver different type of services such as data, multimedia and voice. Therefore, the evolution of the UMTS network become to offer new multimedia services like video, email, and SMS. In addition, It creates new opportunities for multiple network service providers to gain revenue [12]. The architecture of the UMTS network is shown in figure 2.4 which consists of four main components solve the problem of power, cost, and data compression.

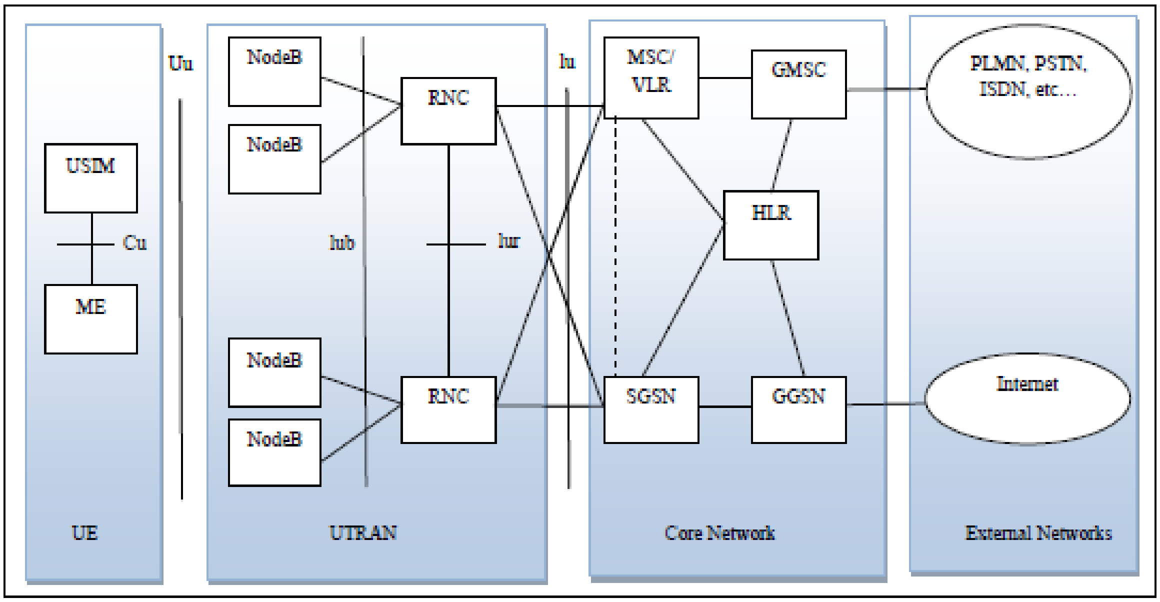

Figure 2.4: UMTS Architecture [13]

- User Equipment: It describes the end user device which stablish a connection to the UMTS network to use it service.
- RNC: It is a key element that represented by a physical connection between the base station and the mobile terminal.
- UTRAN: A collective of Radio Network Controllers (RNC's) and Radio network Subsystems (RNS) which are represented by the UMTS radio access network and it controls the connection between the mobile terminal and core network.
- Core network: - It consists of Serving GPRS Support Node (SGSN) which is connected to the RNC and performs security and access control functions and track the location of the mobile terminal. Another important component is the Gateway GPRS Support

Node (GGSN) which performs the operation of the IP routing for the packets in the network with the association of the SGSN to enhance the security and the network protections functions.

- Home Location Register (HLR): A database system which consist of a home user's service profile and information about allowed services.
- Mobile Switching Center / Visitor Location Register (MSC/VLR): MSC is used to manage the circuit switch transactions and the VLR stores the service profile for the visiting users [13].
- Global Mobile-Station Switching Center (GMSC): A switch that all the incoming and the outgoing connections to the circuit switching networks go through it [13].
- External Network: Are packet and circuit switching networks.

2.5. IEEE 802.21 Standard

Media Independent Handover (MIH): Shown in figure 2.5 defines extensible mechanism that optimize the handoff process between IEEE 802 families and other radio access network (RAN) such like the UMTS.The figure 2.5 also shows the lower layer represent the physical and MAC layer and the upper layer represent the layers from the network till application layer which also includes mobility and location management protocols such as session initiation protocol (SIP) and mobility management protocol (MIP) [13]. A mobile node which have multiple network interfaces such like WiMAX, Wi-Fi, and UMTS. The MIH isolate the lower and the upper layer in the protocol stack which make it independent of any technology. The power of IEEE802.21 insure that the change between the point of attachment and the candidate point of attachment is not noticeable by the user and doesn't affect the service continuity of the applications.

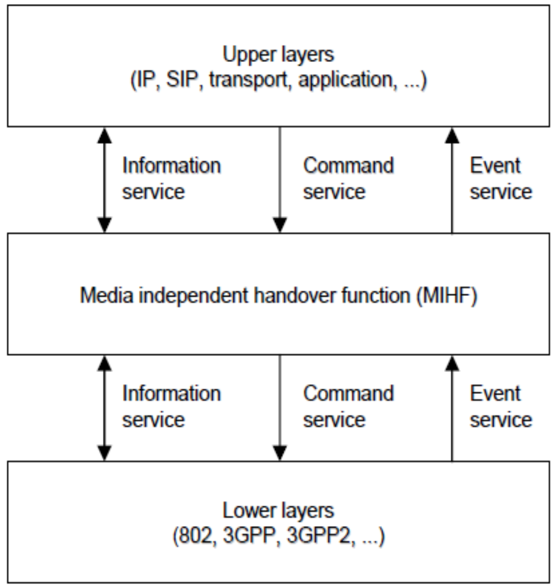

Figure 2.5: MIHF in the Protocol stack

2.5.1 Media Independent Handover Function (MIHF)

Media independent handover function represent a logical layer between layer 2 and layer 3 which refers to MAC and network layer respectively in the OSI traditional model [14]. It handle the mobility management of the mobile node and control the handover process by passing the necessary information between the two layers .MIHF should be implemented in the mobile node and in the network devices that provide the connectivity[15]. It uses different types of command to do this function MIH event, command, and information service.

1) MIH event service (MIES): It has two kinds of events one is link events which known as a triggering service based on event such as new link, link is going down, and link down events and it traverses from the lower layer to upper layer. Other is MIH events which are initiated by MIHF and responsible for handover preparation and initiation processes [16].
2) MIH Command Service (MICS): Is a set of commands which control the handover

and the switch links operation and responsible for the handover decision process.

3) MIH Information Service (MIIS): it collects useful information about the available networks in geographical area, location of point of attachment, roaming partners cost, and security.

2.5.2 Communication Model

The MIHF which defined previously is implemented in the mobile node and in the Point of Attachment (POA) that provide the connectivity. Therefore, the same layer on the mobile node (MIHF) now is communicating directly with the access network that provide the service which became the Point of Service (PoS) that provides the information for the mobile terminal in weather to do a handover or not [17].In figure 2.6 we define three types of communication that are used by the IEEE802.21 and named Service access point (SAP).The first one an technology independent located between the MIHF and the upper layer MIH user called MIH-SAP. The second one a technology dependent located between MIHF and the link layer and it is assures the communication between upper and lower layer. The third one an MIH-NET_SAP and it is used to communicate with MIH layer implemented in remote device [17].

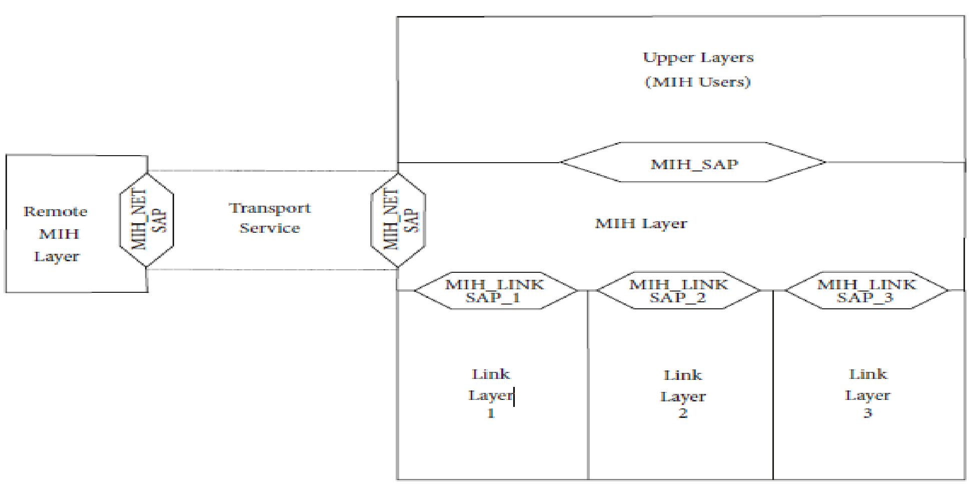

Figure 2.6: Protocol stack [17]

2.6 Handover Stages

Vertical Handover process is divided by three stages starting from handover initiation process to handover decision then handover execution. In the preparation stage the RSS signal starts to decrease until reaching a threshold value. In handover decision phase many parameters and a comprehensive information are collected in the previous stage and a selective candidate network is chosen .In handover execution the connection is established and the packets flow through the network. In figure 2.7 that classify the vertical handover stages into:-

1) Handover initiation process: - Known as system discovery phase, collect all information needed to initiate the handover. It uses the mobile interfaces to gathering information such like availability, cost, and coverage area. [18].
2) Handover decision process: - Known as network selection phase, choose the best candidate available network based on predefined algorithm and the information which collected in the previous stage will be used to take the decision whether to make handover or not .This stage is considered the core of the handover process. [18].
3) Handover execution process: - Actual traffic redirection process based on the decision made in the previous stage is take place to candidate wireless link and a new connection is established and insures seamless handover with low latency.

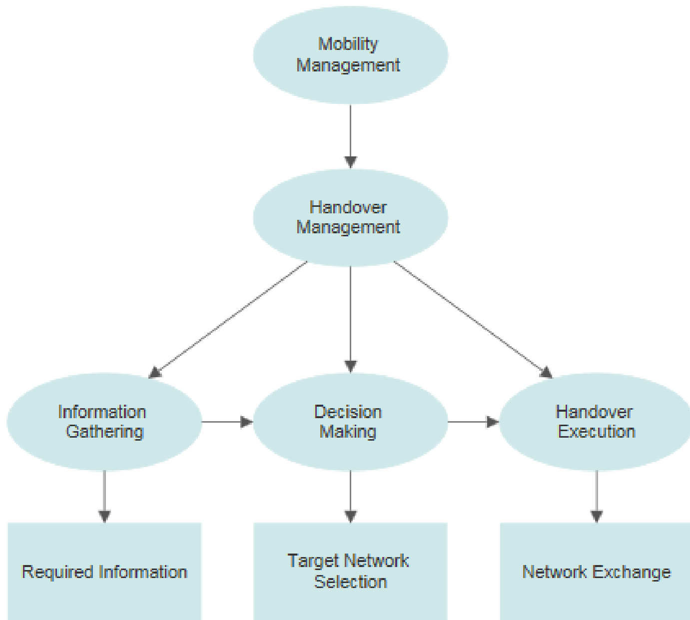

Figure 2.7: Handover Stages

2.7 Summary

In this chapter we presented the wireless technology properties, the WiMAX and UMTS architecture and the components that are consist of , also we present the IEEE 802.21 standard include the Media Independent Handover Function (MIHF), which have a triggering service for the three stages in the handover process.

Chapter 3

Literature Review

3.1 Introduction

In this section we present some papers that analyze and introduce the handover problem, which studied the handover on the field of WiMAX, Wi-Fi and UMTS networks. The articles classified from many perspective such as enhance the selection and decision phase of vertical handover based on existed and modified algorithms. In addition, the simulation tools used in the implemented scenarios. In figure 3.1 which represent the network selection methods based on different criteria/attributes and decision process which include the algorithm for the selection.

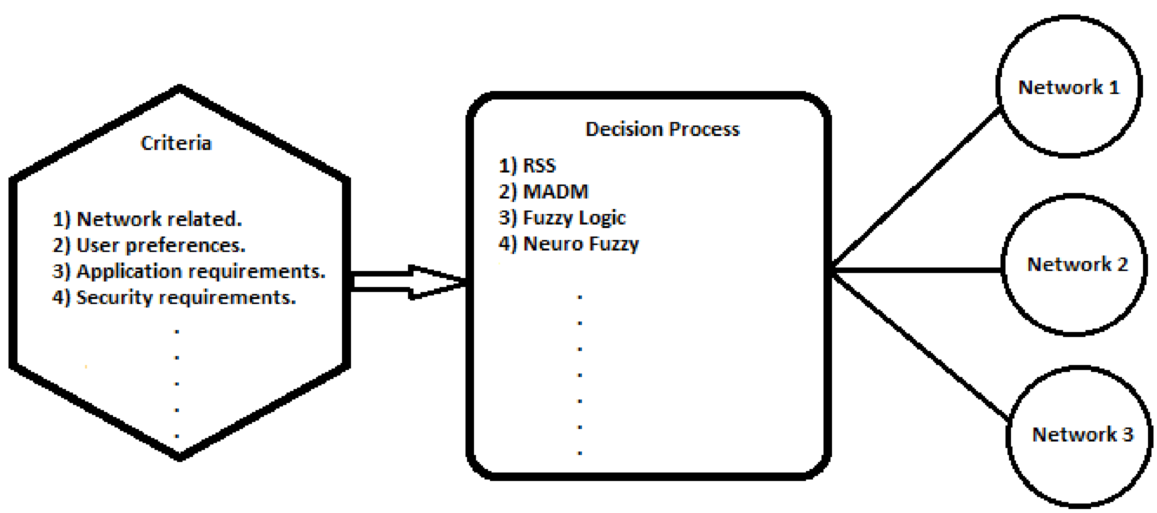

Figure 3.1: Handover Selection Methods

Handover decision as mentioned previously is the most important phase in the handover process .According to our literature review we will present the most important decision algorithms below and network selection techniques which used in the vertical handover decision phase.

3.2 Network Selection Methods

3.2.1 Multi Attributes Decision Making (MADM)

Widely used approach and it works based on a generating a decision matrix of alternatives and attributes. Which represent the available networks at the row and the criteria at the column. It uses many ranks and weights methods the most widely used is:-

- Simple Additive Weights (SAW): Ranking method, the overall score for each candidate (POA) is the sum for all the normalized network attributes multiplied by the weight values [19][27][28][38][40]. Eq. (3.1).

$$Rsaw = \sum_{j=1}^{M} n_{ij} \cdot w_j \qquad \text{Eq. (3.1)}$$

Where N= n.of candidate networks, M= n.of attributes, w_j =Weights vector, and

n_{ij}=Normalized value for each attribute j of network i.

- Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS): It works on a normalized matrix contains N alternative and M criteria based on Eq. (3.3) [39][40].

$$v_{ij} = w_j . n_{ij} \qquad \text{Eq. (3.3)}$$

Then determine the positive and negative ideal based on eq (3.4) and Eq. (3.5) [39][40].

$$Pi = \{v_1^+, v_2^+, \ldots\}, v_j^+ = \max_i(v_{ij}) \qquad \text{Eq. (3.4)}$$

$$Ni = \{v_1^-, v_2^-, \ldots\}, v_j^- = \min_i(v_{ij}) \qquad \text{Eq. (3.5)}$$

For each alternative calculate the distance from the ideal solution based on Eq. (3.6) and Eq. (3.7) [39][40].

$$d_i^+ = \sqrt{\sum_{j=1}^{M}(v_i^+ - v_{ij})^2} \qquad \text{Eq. (3.6)}$$

$$d_i^- = \sqrt{\sum_{j=1}^{M}(v_i^- - v_{ij})^2} \qquad \text{Eq. (3.7)}$$

Then select the relative closeness to ideal based on eq. (3.8) [39][40].

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-} \qquad \text{Eq. (3.8)}$$

- Analytical Hierarchy Process (AHP): It decomposes the selection process into sub problems defines objectives or goal, attributes, alternatives. Scale the importance from 1 to 9 where 1 is equal importance and 9 is extreme importance. Construct normalized pairwise comparison matrix based on Eq. (3.9) and Eq. (3.10) [38].

v_{ij} =1 where i=j and v_{ij}=1/ v_{ij} for $v_{ij} \neq 0$ Eq. (3.9)

$a_{ij} = \frac{v_{ij}}{\sum_{i=1}^{n} v_{ij}}$ Where a_{ij} is normalized vector [38] Eq. (3.10)

Assign a weight for each based on Eq (3.11)

$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{n}$ and $\sum_{j=1}^{n} w_i = 1$ Where n=n.of criteria Eq. (3.11)

Calculate the coherence ratio (CR) based on Eq (3.12)

$CR = CI/RI$;RI: Random index Eq. (3.12)

$and\ CI = \left(\frac{\lambda_{max} - n}{n-1}\right)$ Eq. (3.13)

And $\lambda_{max} = \frac{\sum_{j=1}^{n} b_i}{n}$ $such\ b_i = \frac{\sum_{j=1}^{n} w_i X a_{ij}}{w_i}$ Eq. (3.14)

- Multiplicative Exponent Weighting (MEW): Ranking method, very similar to SAW. But instead of addition it use the multiplication to get the score for each attribute is raised to the power of its weights based on Eq. (3.15) [28][40].

$$S_{mew} = \prod_{j=1}^{M} (n_{ij} \wedge w_j) \qquad \text{Eq. (3.15)}$$

- Gray Relation Method (GRA): Build a gray relation between candidate networks and rank them in order to select the highest rank. Using a Gray Relation Coefficient (GRC) to describe the similarity between the networks with comparison to the ideal network, then the selection for the most similar candidate network based on Eq.(3.16)

$$GRC\text{i} = \frac{1}{\sum_{i=1}^{N} |v_{ij} - V_j^*| + 1} \quad \text{; Where V* is the ideal solution for jth criterion} \qquad \text{Eq. (3.16)}$$

S.Bhosale and R.Daruwala combined AHP method with SAW in [38] the AHP is used to weight the mobile node and the network related criteria then SAW applied for ranking the performance of the candidate's networks in order to do the selection process. MATLAB and the ns-2 simulators with a network containing Wi-Fi, WiMAX, and UMTS. The level one sub problem is to choose the best candidate network, second level is the parameters or the input which are the mobile node speed, bandwidth, load, delay, jitter, error rate, and the cost of the network. Third level consist of the candidates networks which mentioned above. The result obtained when the mobile node is nearby three available networks, and the network traffic load equal to 40 % the best network to be selected when the mobile node speed between 0 to 22 Km/h and running a streaming video the preferred network is Wi-Fi and when the mobile moves in a high speed the preferred network is the WiMAX. The UMTS network is the preferred one when running a low bit rate applications.

M. Drissi and M.Oumsis worked based on the SAW, TOPSIS, and MEW in [40]. The AHP was used in weighting, the input/attributes to the three methods are throughput, delay, jitter, and bit error rate, and no consideration for the mobile terminal speed because it is constant.Ns-3 is the simulator with a network containing Wi-Fi and WiMAX. The result showed the delay and the packet loss only for different class of service such like background, streaming, conversational, and interactive class which refers to file transfer protocol (FTP) application, video, voice, and web browsing respectively [41]. Regarding the delay TOPSIS is recommended when using and SAW for streaming class, and both of them having the same delay when running conversational class. MEW has the lowest delay when using with interactive class of service [40]. Packet loss ratio is the lowest when using TOPSIS in conversational and streaming class. For interactive and background class it is recommended to use SAW and MEW respectively [40].

3.2.2 Fuzzy Logic and Neural Network

Work based on If-then rules converting the actual values to a fuzzy set depending on member ship function. It usually combined with MADM method in order to get a dynamic decision algorithm.

E.Zakaria,A.Awamry,A.Taman,and A.Zekry worked based on Adaptive neuro fuzzy inference system which connect the Neural Networks and the fuzzy logic together with artificial intelligence in [26] .The paper present a vertical handover scenario between three networks WiMAX , UMTS , and WIFI . The system is constructed from three Adaptive Neuro Fuzzy Inference System (ANFIS) one for each network shown in figure 3.2. The input for the system is RSS, speed of mobile, bandwidth, load, jitter, bit error rate, and delay. These parameters are considered in the handover decision phase the available networks are ranked from 1 to 7.

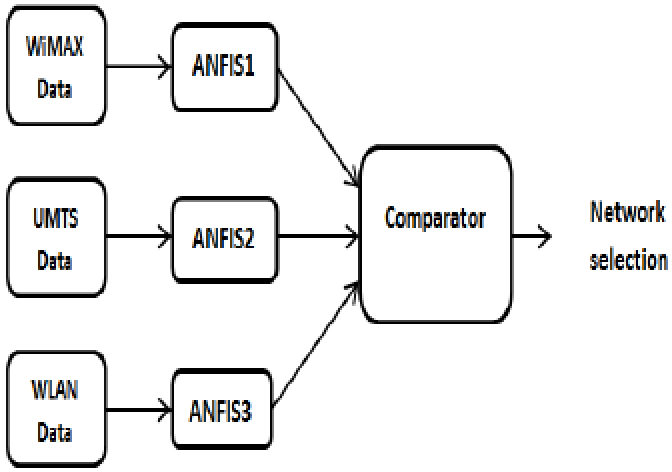

Figure 3.2: Proposed model in [26]

The result measured comparing the relative index versus the mobile node speed for the same input parameters of the ANFIS and the TOPSIS algorithm we can observe that the UMTS and WiMAX networks is the preferred to be selected when the mobile node speed is increased and that refers to the fact of high mobility support . The ANFIS presented have a very low handover decision time in compare to other techniques like TOPSIS , SAW , and PWM which conclude that this algorithms are need a lot of time in calculating matrix and algebraic work . However, the decision time phase is not the only an indicator for the total handover latency which includes the time in initiation and execution phase.

3.2.3 Mixed Approaches

S.V.Surwase and S.S.Sambare performance study is done in [19]. This paper which use a combined algorithm of called (FR-HMM) a score based system which consist of two inputs the first one is the running application bitrate on the mobile node which considered as a first input, the handover initiation process start after comparing the RSS with predefined threshold. Then collect four parameters for the candidate's network which are RSS, bandwidth, data rate, and coverage area and used it as a second input to a score based system then the mobile will do a handover to the network which have the higher score and not congested network.

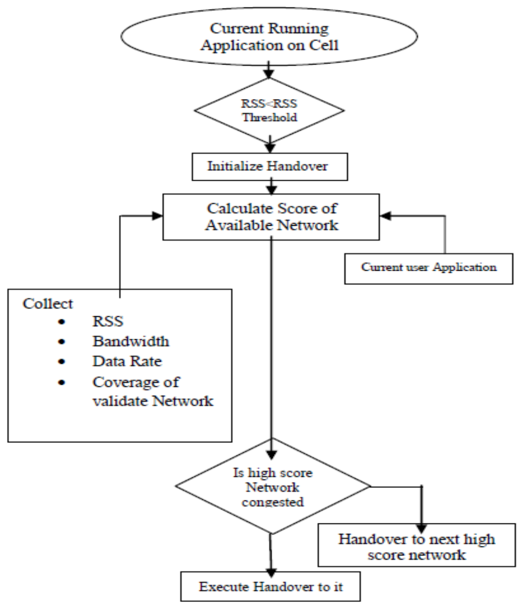

Figure 3.3: Proposed model in [19]

The second part is the HMM prediction model executes on the base station and the access point in order to determine the next base station that the mobile will do a handover and connect to it. The mobile is moving in a certain direction and currently connected to base station which called the home base station which have to predict the possible base station based on the mobile node direction.

The home base station send request to the predicted base stations which needs to calculate the Gain function and send back the reply to the home base station based on the network parameters Gi=f(L,P,RSS) which refers to network load, consumed power ,and the RSS . The gain value used by the predicted base stations is used SAW method for ranking then the home base station select the network with minimum gain value.

The paper result for the handover delay is showing that the handover time is not decreased in case the candidate point of attachment is the UMTS network .The handover time is measured around 134 ms.

I.Chattate,M.Khalili and J.Bakkoury used the Always Suitable Connection theory (ASC) to choose the best candidate network in [20] .The paper improved the decision phase in the vertical handover process by using E-MGRA method which used Modified Gray Relation Analysis (MGRA) for ranking and Fuzzy Analytics Hierarchy Process (FAHP) to determines weights. Analytic hierarchy process scale the importance from 1 to 9 where 1 is equally important and 9 is extremely important and determine the weights for each class of service. Grey relational method to classify the available networks in the destination and the level of similarity among all the attributes. The input is throughput, data rate, jitter, delay, and packet loss. The result compared between AHP and FAHP showing that the throughput is raised using FAHP, and the total handover is reduced to 2%.

M.W.Akram and P.Vanajakshi studied the impact of the speed and data rate of the application is investigated in mobility scenario based on Wi-Fi and WiMAX network in [21]. A video used as an application running on a mobile node and it uses the IEEE 802.21 standard to do the handover traffic standard is done and a network performance indicators are measured .The result shows increasing the mobile node speed will cause a degradation in the network performance metrics .No other data rate is used in the simulation to show the importance of the application bitrate on the performance.

S.Goudarzi,W.Hassan,M.Anisi,and A.Soleymani In [22,23, 28] Three papers classified different decision algorithms in the vertical handover from different perspective such like single layer such like application layer, network layer and link layer and cross layer based concept such like the MIH that we work on this study in order to get better QoS for the running application [21]. In [23] present the three handover phases and parameters such like

RSS, bandwidth, cost, user preferences, and security. In addition the paper present different selection techniques suck like MADM and combined algorithms [23]. In [28] present a network selection process includes criteria's, and decision process .Neither scenario based nor performance study in the three papers.

S.Maaloul, M.Afif and S.Tabbane implemented a three scenario cases between WiMAX and Wi-Fi in [24]. The location of the Wi-Fi access point is vary from scenario to another to study the effect of the received signal strength on the application QoS. The paper show the importance of the handover decision phase and a selection method based on perceived QoS was presented.

A.Khiat, J.Bakkoury, M.Khalili, and A.Bahnasse represented a scalable and both horizontal and vertical handover in Wi-Fi and WiMAX scenario based on VOIP application in [29] . It show that when increasing number of mobile node and the end to end delay is slightly increased. However it is increased dramatically if the base station number is increased because of new registration time to new base station. In addition, the WiMAX ranked a highest throughput and Wi-Fi gives minimum delay [29].

F.Laassiri, M.Moughit, and N.Idboufker presented the vertical handover WiMAX and Wi-Fi in [30] . Used the Omnet as a simulation tool to enhance the performance a proposed algorithm implemented SDN using the Open Flow protocol and it compute the mean of Received Signal Strength arrived to mobile terminal to choose the best candidate available network. The Simulation is based on VOIP application only.

H.Khalil and M.Hamarsheh presented a performance study in [35]. Using the MIH layer between Wi-Fi and UMTS network using different bitrate application. The effect of the speed on the key performance indicator showed that increasing the speed of the mobile terminal will decrease the throughput and increase the packet loss it give an unacceptable values for mobile node running in speed more than 40 Km/h . Moreover, in this paper the author used a Wi-Fi technology which is very limited in coverage area and didn't support mobility. Not like the WiMAX which support mobility for the mobile users and have both a wide coverage area and a high bandwidth.

A.Jain and S.Tokekar the researchers used the same methodology in this thesis in [37] by implementing vertical handover scenarios using NIST package in NS-2. The study measured the effect of mobile node speed on the performance metrics such as throughput for three types of applications when the mobile node moves between Wi-Fi and UMTS. From the results, it is clear that Wi-Fi is not suitable for high mobile node speeds that were tested because of its low coverage area (around 100 meters) which highly affected the results in [37]. Moreover, it is not realistic to measure the throughput of video application running on mobile node while it is moving with speeds more than 20 Km/h in Wi-Fi network that has coverage of 50 to 100 meters because for sure it is not beneficial to handover to such networks in such condition due to very short time connectivity. However, the results are consistent with the results in this thesis in terms of the effect of mobile speed on the throughput of the application when the coverage of the hosting network is degrading. Although WiMAX that is used in this thesis has more coverage than Wi-Fi, more realistic mobile node speeds were tested that is suitable for vertical handover to take place. We also tested the scenario that the mobile node has no other option than connecting to UMTS when the signal strength of WiMAX becomes very low which is more realistic than determining specific speeds for vertical handover such as in [37] because the handover decision is taken based on signal strength of the hosting network and not based on the mobile node speed.

Therefore, we make sure in our thesis that the mobile node will handover to UMTS while leaving WiMAX regardless of its speed and based on received signal strength of WiMAX.

3.3 Knowledge Gap

From our literature review which revised the handover process over different technology including Wi-Fi, WiMAX and UMTS. We notice a variant algorithm to implement the vertical and horizontal handover with different mobility scenarios for the mobile terminal. The researchers classified their work based on the handover process where it is vertical or horizontal, the standards used in the scenario, the algorithm implemented in the handover decision phase, and the research methodology used. Different algorithm and several parameters where implemented in the literature to enhance the vertical handover process. Below is a list of algorithms and techniques which used in the vertical handover decision phase.

1) RSS based algorithm: Is the most usable algorithm for handover and it is classified as a network related parameter where the mobile continuously measures the received signal strength of the current point of attachment and our mobiles nowadays is working based on this method where the signal strength is more powerful the mobile will connect.
2) Terminal preferences: Such like location, speed, interference and the power of the battery these values are collected in order to lead the mobile node to connect to one of the other candidate's network.
3) Cost function algorithm: Such like monetary cost, security and bandwidth these parameters are help to identify the network selection in the handover decision phase.
4) Application requirement: Such like the Quality of Service (QoS) for the running

application.

3.4 Summary

Table 3. 1: ***Papers Summary***

Paper	Input/output	Application Type	Network	Algorithm	Comments
[19]	Output: Handover time, packet delivery ratio, throughput, energy. Input 1: Application bitrate Input 2: RSS, bandwidth, data rate, and coverage area. Input 3: network load, consumed power and RSS.	3 application CBR	WiMAX Wi-Fi GSM LTE UMTS	Fuzzy rules HMM SAW	Handover time is not decreased when the candidate point of attachment is the UMTS.However the packet delivery ratio and throughput gives acceptable values in the three applications. The implemented scenario and the mobile node path is not cleared.
[20]	Output: Number of handover executed, throughput, data rate, jitter, delay, and packet loss. Input: Throughput, data rate, jitter, delay, and packet loss.	conversational ,streaming ,interactive background	LTE HSPA WLAN WiMAX	E-MGRA AHP FAHP,GRA	AHP and FAHP weight the criteria for all class of service .The Throughput is high when using the FAHP method for all classes except the streaming class which have the highest packet loss ratio. The number of handover executed is reduced when using the FAHP and E-MGRA in comparison of using AHP/E-MGRA.
[40]	Output:Packetloss,Delay Input: Bit error rate, jitter, delay, and Throughput.	conversational ,streaming ,interactive background	WLAN WiMAX	TOPSIS SAW MEW AHP	MADM have almost similar outputs regarding the end to end delay and enhanced the total packet loss ratio for the application tested. Using MEW in high bitrate application will cause a packet loss and end to end delay more than TOPSIS and SAW.
[38]	Output : Selected network Input: mobile node speed, bandwidth, load, delay, jitter, error rate, and the cost of the network	conversational ,streaming ,interactive background	WLAN WiMAX UMTS	AHP SAW	For mobile speed less than 30 km/h the preferred network is the Wi-Fi and after 30 Km/h the preferred network is the WiMAX for the streaming class and for background class the UMTS is the preferred network for speeds less than 30 Km/h and WiMAX for higher speeds.
[26]	Output: Selected network, decision time. Input: RSS, speed of mobile, bandwidth, load, jitter, bit error rate, delay.	Not mentioned	WLAN WiMAX UMTS	ANFIS	The result show that using high data rate application with high mobility speed for the mobile the preferable network is the WiMAX because it support mobility and choose the UMTS network when the application bitrate is low. The ANFIS reduce the handover Time with comparison to other MADM methods.
[37]	Output: Data transferred Input:RSS	3 application CBR	UMTS WLAN	MIH / Nist package	The paper shows three different bitrate applications the total data transferred is increased by moving from the UMTS to Wi-Fi in comparison to let the mobile moves in the UMTS only. No other parameters are measured

[21]	Output: Throughput, delay, packetloss,handover time Input:RSS	CBR	WiMAX Wi-Fi	MIH / Nist package	The paper shows performance analysis study with single application only and shows that when increasing the mobile node speed throughput will decrease.
[27]	Output: Selected network Input: Throughput, delay, jitter, and packet loss.	Voip,Streamin g,and Browsing	UMTS WiMAX WLAN	AHP SAW	The paper used the AHP for weighting and SAW for ranking the networks, the result obtained that when using high bit rate application the preferred network is WiMAX and Wi-Fi.

The common things between these algorithm is trying to enhance the handover decision phase using different methods including ranking methods such like (SAW , TOPSIS , WPM) which considered as analytical approach and may suffers from inconsistence ranked values and needs a lot of calculations and may result in wrong network selection. The fuzzy logic , artificial intelligence , neural network , and custom algorithms usage to clearly define the handoff decision parameters and help in the candidate network selection process and these methods must combined with another algorithm such like MADM and this will increase the complexity to solve the selection problem [28] .However, the most widely used algorithm which in fact close to real world scenarios where implemented using the received signal strength algorithm which we worked on because the different algorithm mentioned above are lacked to support real time application and need time to execute to take the decision of the handover and this will cause in wastage of network resources and extra time in the handover delay parameters which may cause a breakdown for the connection plus the complexity in implementation. Moreover, our mobiles today is supportive for the received signal strength already and it is considered a dynamic parameter and the most important as mentioned above when a user is moving in a high mobility heterogeneous environments .as we will see from the result it will give acceptable values in different performance metrics compared to the ITU-T standarazition.

Also the researchers used different application to implement the different scenarios including OPNET, QualNet, NS2, and Matlab. In this thesis we will use the network simulator 2 (NS2) which have the highest rank in comparison to other used software which represented in table 3.1 below [42] [43] .Also because of the implementation of the NIST package which provide a vertical handover service between the WiMAX network and UMTS.

Table 3. 2***: Simulators Table [43]***

Simulator	License Type	Interface	Used In
Network Simulator 2 (NS 2)	Open source	C++/OTCL	[19][21][24][25][38]
Network Simulator 3 (NS 3)	Open source	C++/Python	[40]
OPNET Modular	Commercial	C/C++	[29]
OMNET++	Open source	C++/NED	[30]
MATLAB	Commercial	C	[20][26][38]
Qualnet	Commercial	C++	-

Chapter 4

Methodology

4.1 Simulation Environment

Network simulator, which is called as NS2 is a powerful tool in analyzing and simulating different complex networks and implement dynamic algorithms is support for a large set of networks, protocols, and modules. Event-driven simulation tool allow the user to build the network topology easily and with high flexibility [31]. However, the lack of the Graphical User Interface (GUI) is one of the limitation in the Network simulator 2 which make it harder to simulate complex networks. Input files in the Ns2 is with extension of TCL which used to build the scenario and input arguments and they are executable files to generate trace files which is usually used to get the result using third party tool or AWK scripts[32].

Our simulation is based on network simulation tools NS2.29 [32] and the scenarios built using the TCL file then awk script is executed on the trace file in order to get the results. Our work evaluates the network based on network performance keys in each scenario from WiMAX to UMTS.

4.2 IEEE 802.21 Implementation in NS2

National institute of standard and telecommunication (NIST) implemented an add-on module that uses the Media independent handover (MIH) defined in the IEEE 802.21 standard, which include signaling framework and different triggers mentioned above. This module is used by most of the researches in the field of vertical handover process, and that returns to the fact that the NIST is part of IEEE standards and IETF [31].As we mentioned earlier, the module extend the MAC layer and includes the MIH events triggering services

[34].

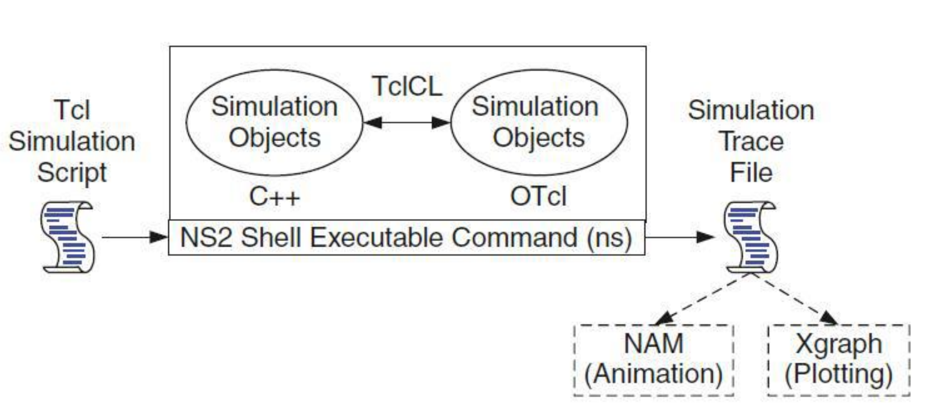

Figure 4.1: The structure of the Ns2 simulation [30]

4.3 Power Boundary Implementation

Based on the definition of the MIH and NIST .Ns2 define the power of the signals that arrives to the mobile node interface. In figure 4.2 they are classified in three categories the first one defines the minimum power without errors, the second one is used to sense if there is a signal, the third one is used to generate the Link Going Down (LGD) and they are named respectively Rx_Threshold, CS_Threshold, and LGD_Factor*Rx_Threshold [34].

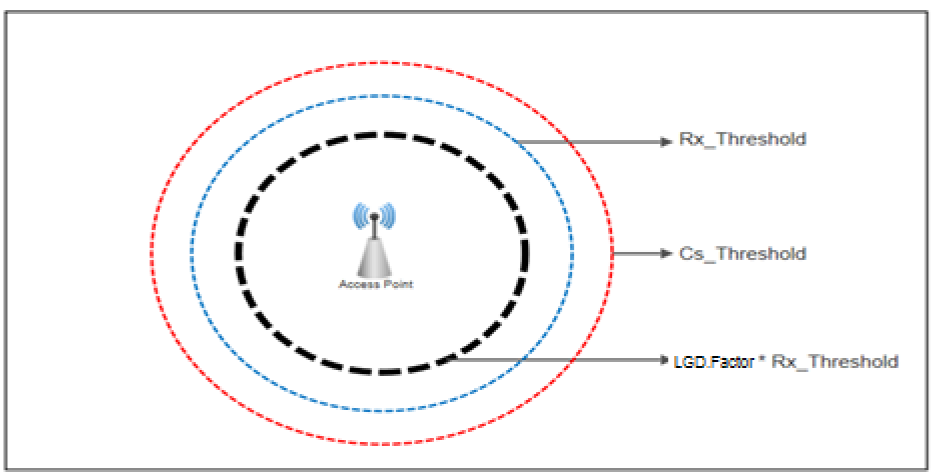

Figure 4.2: Power Boundary

4.3.1 Received Signal Strength Based Algorithm

The mobile terminal in all scenarios moves from WiMAX to UMTS the mobile will move far away from WiMAX base station or access point which means that the received signal strength that received on the mobile interface will decrease accordingly. As we clearly define the power boundaries previously, the MIH module will execute a Link Going Down (LGD) once the power of the signal received to the mobile interface is between the LGD.Factor*Rx_Threshold and Rx_Threshold. And the switch for the links is taking place once the probability is equal to approximately 80 %. After this the mobile node is connected to candidate Point of Attachment (PoA) and the packets start to receive in the UMTS interface. Figure 4.3 describe the algorithm that we worked on briefly.

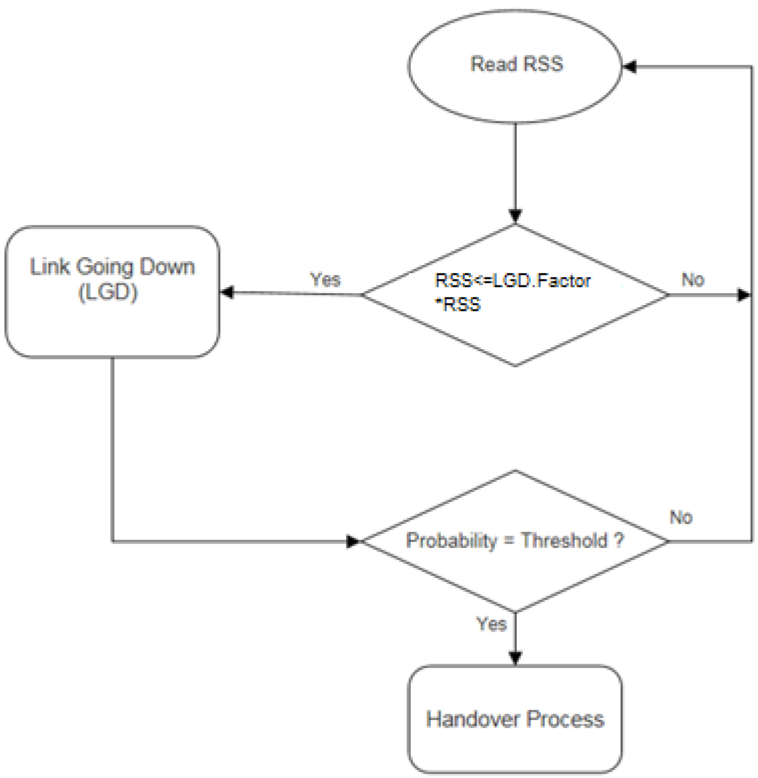

Figure 4.3: RSS algorithm

4.4 Simulation Scenarios

The mobile will move from the source to destination node from node A to node B labelled in figure 4.4. In this thesis we study the effect of the mobile terminal speed versus the application bitrate while measuring the different key performance metric in each speed, and application bitrate. The simulation parameters are shown in the table 4.1 which present the position of the mobile terminal, WiMAX, and UMTS networks. The mobile node moves from WiMAX network to UMTS network while running one application each time. We ran five different applications with different bitrate shown in table 4.2. The speed of the mobile node is constant in each scenario from the beginning to the end with no acceleration, and we ran six different speed 5, 10, 15, 20, 25, and 30 Km/h in the scenario 1 and scenario 2, and three high speeds 80, 150, and 160 Km/h in scenario 3. The application bitrate are described in table 4.2 which present the application bitrate that we work on including type of the traffic is constant bit rate (CBR) to and packet size 1200 which refer to udp packet size except in VoIP which refer to a standard VoIP characteristics based on the ITU-T standardization [32]

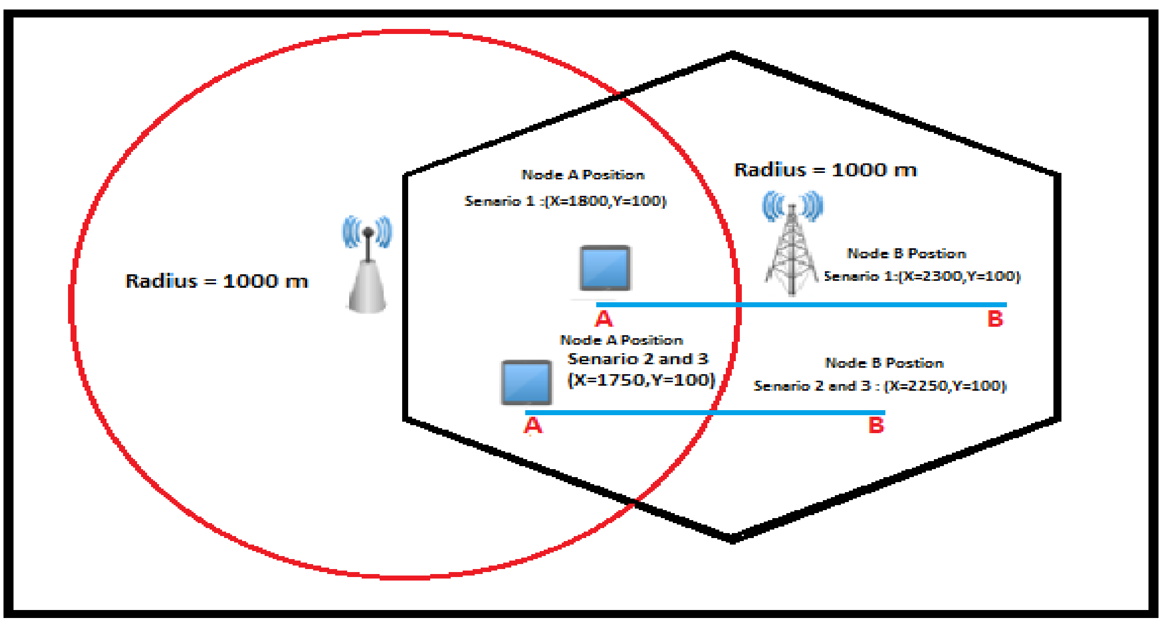

Figure 4.4: Scenario WiMAX-UMTS network

Table 4. 1: Simulation Parameters

Coordination Parameters	
Topology size for all scenarios	3000x3000 Meter
WiMAX site Coordination for all scenarios (X, Y)	1000,100
UMTS Base Station Coordination Scenario one and Two (X, Y)	1500,1500
UMTS Base Station Coordination Scenario Three (X, Y)	1500,100
Mobile Node Coordination Scenario one (X, Y)	Start (1800,100) Finish (2300,100)
Mobile Node Coordination Scenario Two and three (X, Y)	Start (1750,100) Finish (2250,100)
Mobile Speeds	
Mobile Speed Scenario One and Two	5,10,15,20,25,30 Km/h
Mobile Speed Scenario Three	80,150,160 Km/h
UMTS Parameters	
UMTS coverage area	1000 Meter
UMTS Bandwidth	384 Kbps
TTI	2 ms
WiMAX Parameters	
WiMAX coverage area	1000 Meter
WiMAX Receiving Threshold (RX)	7.59375e-11 W
LGD Factor * RX Threshold	1.1 * 7.59375e-11 = 8.353125e-11 W
Threshold (%)	80
Power Transmit	15 W
WiMAX Bandwidth	Up to 10 Mbps
Simulation Time	500 Second

Table 4.2: Application properties

Data Rate (Kbps)	Traffic Type	Packet size(byte)	Interval (s)
64 kbps (VoIP)	Cbr	160 X 1	0.02
128 kbps	Cbr	160 X 2	0.02
960 kbps	Cbr	1200 X 1	0.01
2880 kbps	Cbr	1200 X 3	0.01
3840 kbps (Video)	Cbr	1200 X 4	0.01

4.5 Summary

In this chapter we represented the power boundary defined in Network Simulator 2 (NS2) for the WiMAX and the Received Signal Strength (RSS) algorithm. The simulation scenarios including the speeds and the mobile positions. In addition, the simulation parameters plus the applications properties that we worked on in this thesis.

Chapter 5

Results and Discussion

5.1 Introduction

Based on different network key performance indicators we monitor the effect of the speed and application bitrate and how they affect the performance and the QoS of the application. Measure Throughput, Delay, Handover Delay, throughput normalization, packet loss, packet received, and power. Based on the application bitrate found in table 4.2.

5.2 Scenario One

5.2.1Throughput

Throughput can be defined as total size of packets that arrived in the interval of time (Bits/Second). We measure the throughput in both networks WiMAX and UMTS versus the mobile speed [31].

$$Throughput = \frac{size\ of\ the\ packets\ recieved}{time.lastpacketwas\ sent - time.firstpcketwas\ sent} \qquad \text{Eq. (5.1) [31]}$$

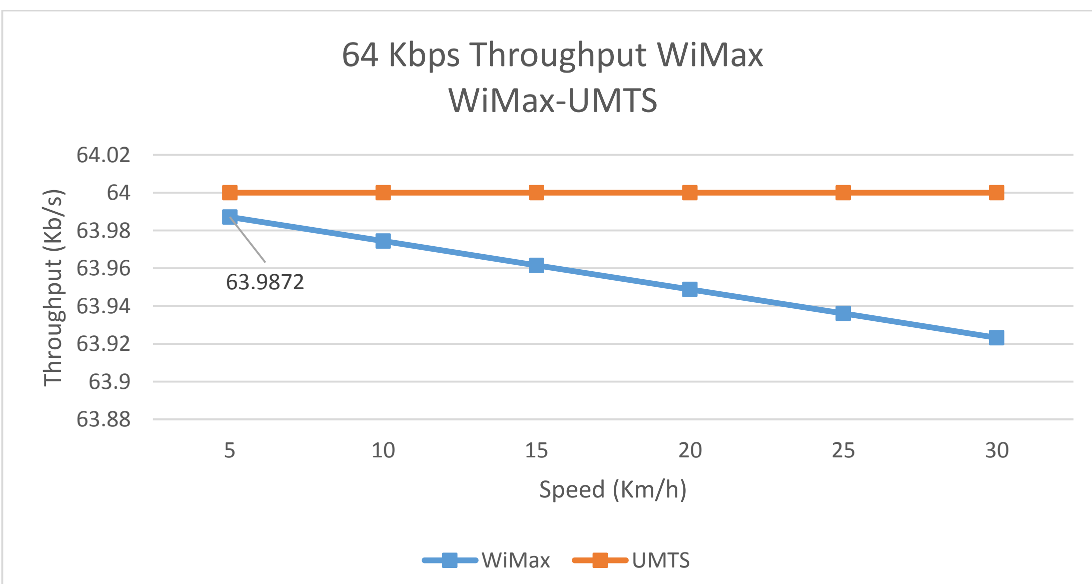

Figure 5.1: 64 kbps WiMAX to UMTS

From Fig 5.1 show the throughput versus the mobile speed while running an application with 64 kbps and we measure the throughput based on equation 5.1 that the throughput measured on the WiMAX interface when the mobile speed is (5 km/h) and (30 km/h) is equal to 64 kbps and 63.92 respectively.

Therefore, a degradation in the throughput while the mobile speed increase. Also we notice that in the UMTS the throughput is constant and that refers to the strong power signal that arrived to the mobile node from the UMTS network which act as a candidate Point Of Attachment (PoA) and the application low bitrate usage which is 64 kbps and the maximum of the UMTS is 384 kbps which conclude that using low application bitrate in the UMTS is recommended in contrast to performance and as declared previously in figure 2.3 the UMTS gives high mobility and the application with a low bitrate will not affected by the speed.

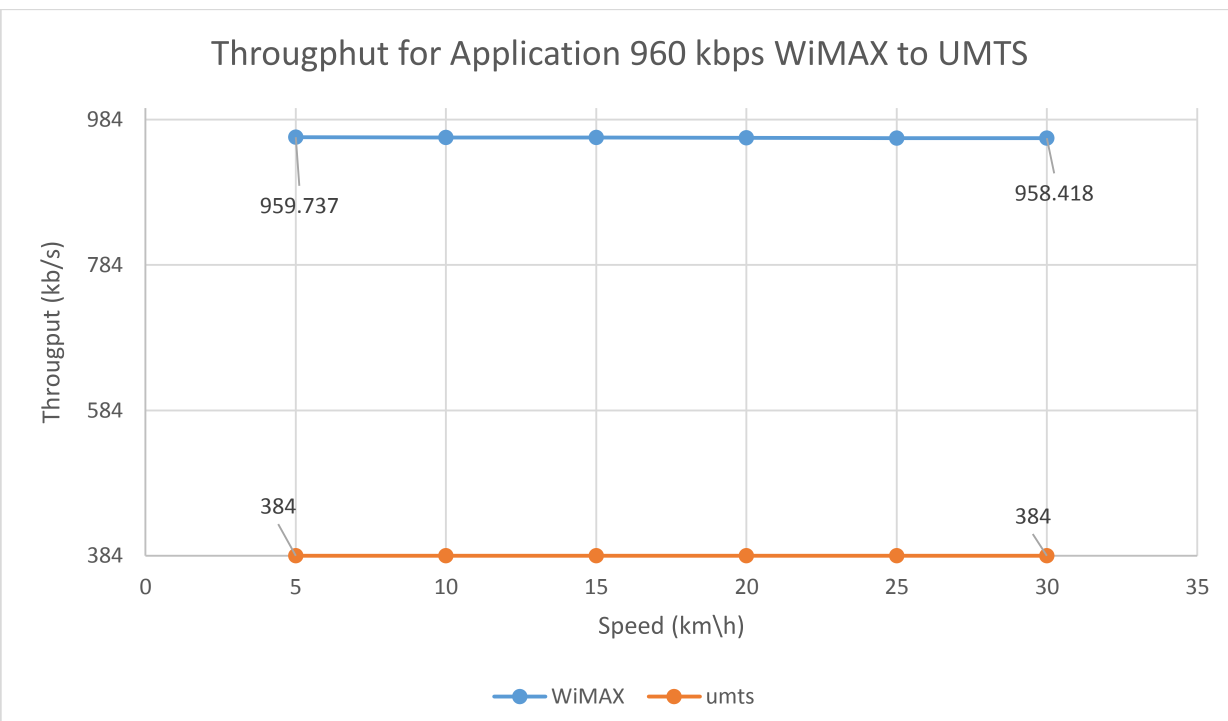

Figure 5.2: 960 kbps WiMAX to UMTS

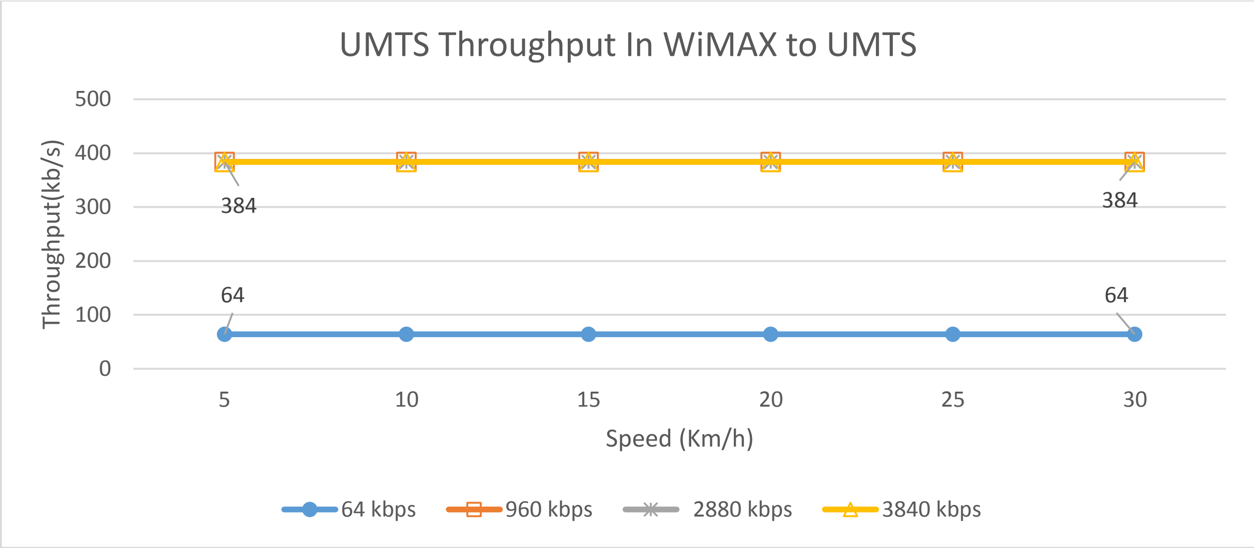

Figure 5.3: Throughput different applications WiMAX to UMTS

From figure 5.2 and 5.3 we notice that when we run application with medium data rate like 960 kbps in WiMAX network and move the mobile node toward UMTS network we found in speed 5 km/h the average throughput on the mobile node is reach to 959.737 kbps and in speed 30 km/h it reaches 958.418 kpbs which conclude that using application with higher data rate more than the 348 will be effected more when we increase the application data rate not only the speed of the mobile node.

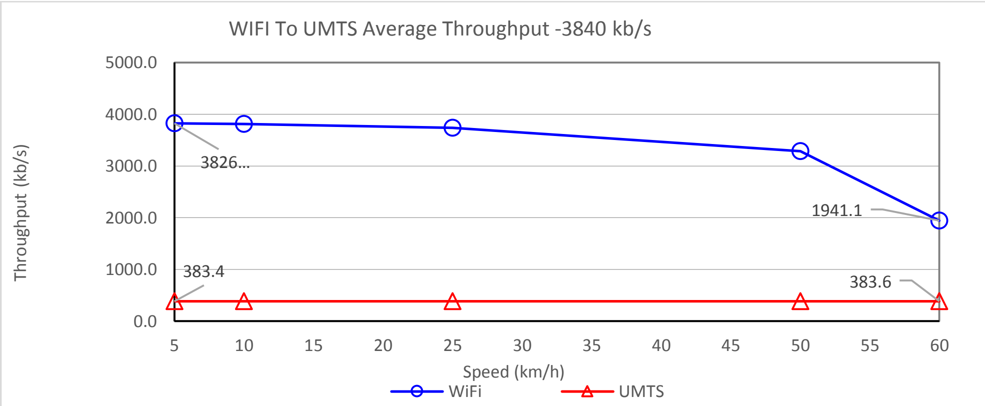

Figure 5.4: Throughput 3840 kbps Wi-Fi to UMTS [35]

From Figure 5.4 which shows the throughput for application with CBR traffic 3840 kbps running on mobile node moves from Wi-Fi network with 11Mbps bandwidth to UMTS network which is limited to 384 kpbs. We can found the same behavior as in WiMAX which work on 10 Mbps bandwidth to UMTS scenario. The throughput in the Wi-Fi network while moving the mobile node in speed 5 km/h reaches 3826.3 kbps and increasing the speed 60 km/h the throughput degrades to 1941.1 kbps

5.2.1 Normalized Throughput

Normalized Throughput: It equals to the throughput divided by the application bitrate [35].

$$Normailized\ Throughput = \frac{Throughput}{Bitrate} \qquad \text{Eq. (5.2) [35]}$$

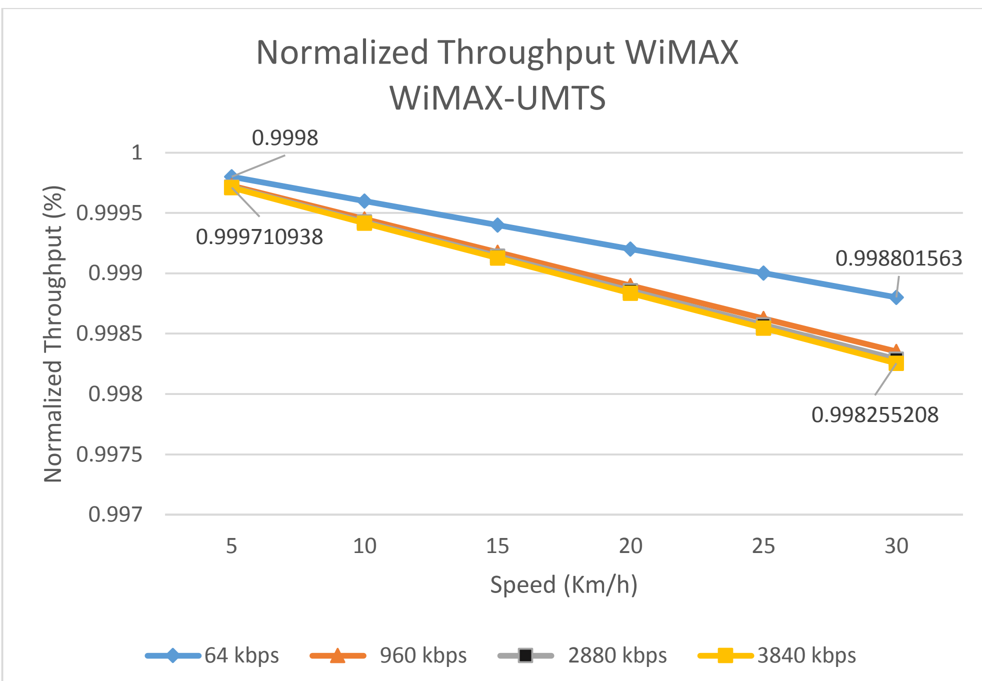

Figure 5.5: Normalized throughput different applications WiMAX to UMTS

From the previous section that we measured the throughput for different mobile application with different bitrate .We measure the degradation in throughput by calculating the normalized throughput to show the effect of the speed and application bitrate and we conclude that increasing the speed of the mobile and the usage of higher data rate application will cause a degradation on throughput from 0.99875 % to 0.99835 % in WiMAX to UMTS scenario. Fig 5.5 show the normalized throughput for different application running with different data rate and different speed. And we notice that increasing the speed and the application bitrate will affect the throughput and will decrease while increasing one of them. Moreover, when the mobile node is moving in high speed it moves far away from the WiMAX site and which cause the power of received signal strength to be degraded and the total time spent in the network decrease and also the received packets arrived to the interface decrease so the throughput will decrease accordingly.   What will happen if we use a higher data rate than 960 kpbs and increase the speed more than 30 km/s? What is the degradation in the throughput will reach if we use Wi-Fi technology with very limited coverage area 50-100m instead of using WiMAX?

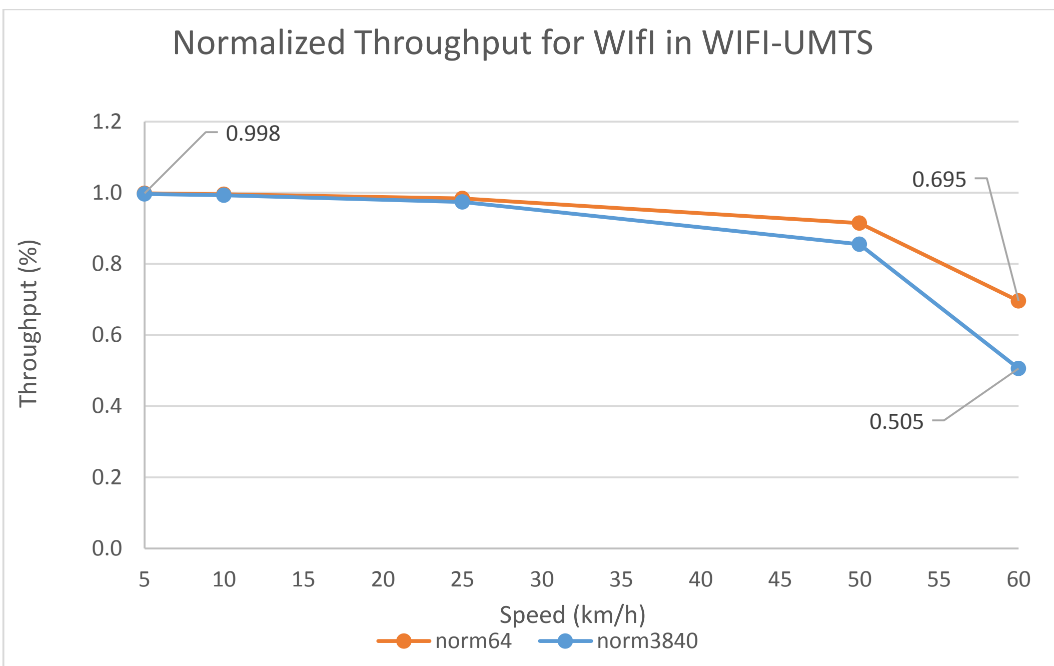

Figure 5.6: Normalized throughput different applications Wi-Fi to UMTS [35]

Figure 5.6 which refer to the Wi-Fi to UMTS scenario running application with 64 kbps and

3840 kbps with different speed start from 5km/h to 60 km/h the normalized throughput for the 64 kbps is degraded from (99.8%) to (96.5%) and when running application of 3840 kbps is degraded from (99.8%) to (50.5%) and this degradation is referred to the weakness of mobility support in the Wi-Fi network. In both scenarios WiMAX to UMTS and Wi-Fi to UMTS we notice the limitation of the bandwidth in the UMTS network. However, the UMTS has a high coverage area and it supports high speed mobility for the mobile. On the other hand, running high bitrate applications will cause a high degradation on throughput so running application higher than 384 kbps will cause the bandwidth to be fully occupied. From Fig.5.6 which represent the UMTS throughput we found that the throughput for all the applications is around the maximum throughput in UMTS 384 kbps except the VoIP application because it is a low data rate application.

5.2.2 Data Received

Data received defined as the number of packets that arrived to destination successfully. We measure the data received for both networks for WiMAX and UMTS network versus the mobile speed.

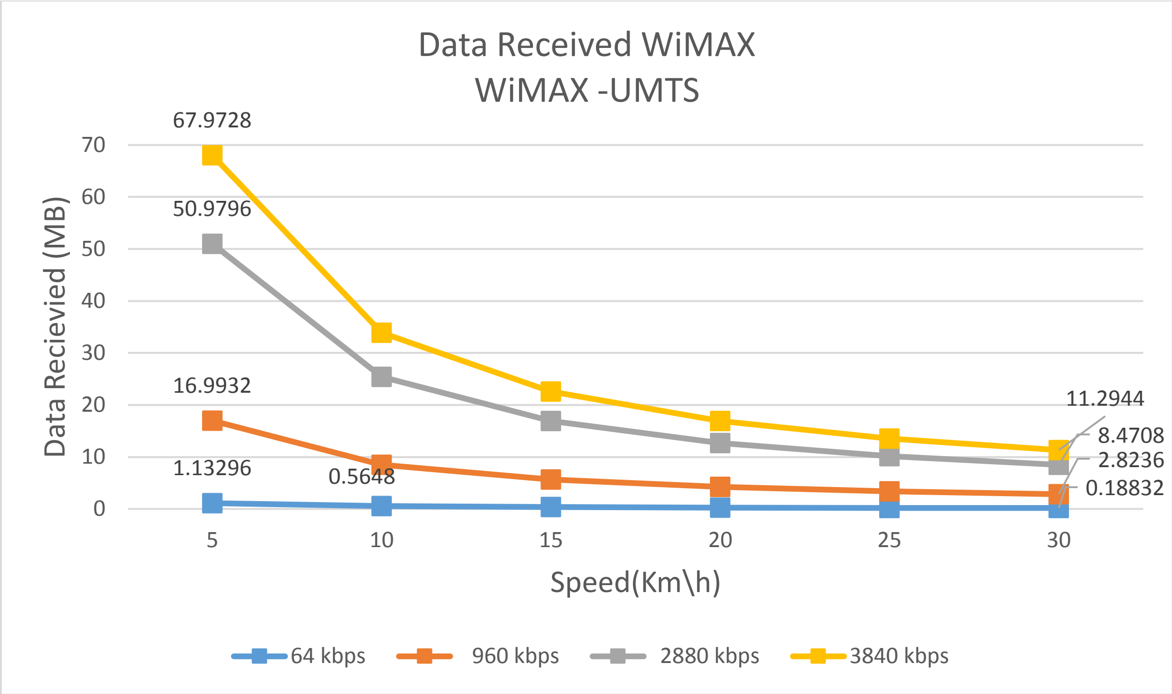

Figure 5.7: Data Received in WiMAX to UTMTS

From Figure.5.7 We notice that the total received packets is decreased while the mobile node is increase. And from definition above when running application with 64 kbps and 3840 kbps we find that the total received data is 1.13 MB and 11.29 MB. While increasing the mobile speed to 30 km/s the total received packet is decreased to 0.18 MB and 11.29 MB and that conclude that both the throughput and the normalized throughput will be affected and this will cause a decreased in both of them as showed in the Figure.5.4. Moreover, we study the packet loss ratio in the next section in order to show what is the effect of increasing the application bit rate and speed on the Qos for the application.

5.2.3 Packet Loss Ratio

Packet Loss Ratio: Is a number that indicates how many packet are not delivered successfully to destination [44].

$$PLR = \frac{packet.sent - packet.recieved}{packet\ sent} X100 \qquad \text{Eq. (5.4) [44]}$$

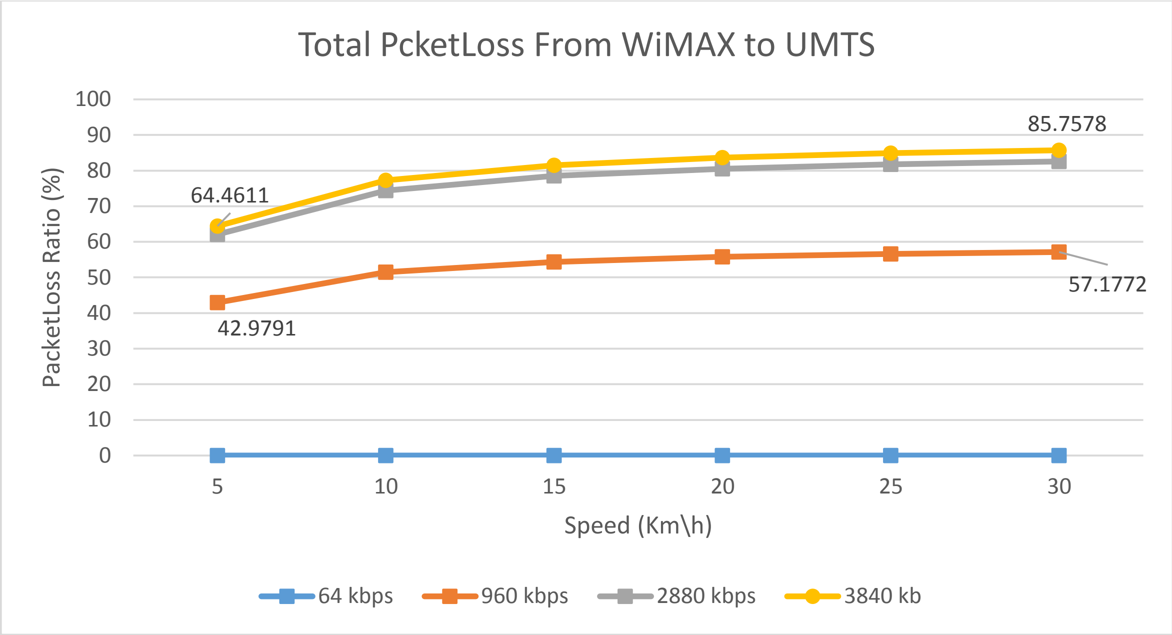

Figure 5.8: Packet Loss Ratio on WiMAX interface for different applications WiMAX to UMTS

From figure 5.8. We measure the total packet loss ratio and we notice that when increasing both the mobile node speed and the application bitrate the Packet loss ratio is also increase accordingly. Moreover, when the speed is 5 km/h and the application bitrate is 960 kbps and 2880 kbps a the packet loss ratio is around 42.9 % and 64.4 % . and when increasing the speed to 30 km/h the packet loss ratio increases to 51% and 84% respectively. which means that only 57 % of the packets are arrived successfully when the mobile node is running in 30 km/h and with application bitrate 960 kbps and that decrease the throughput and the normalized throughput . Also as we mentioned previously that the WiMAX is supporting the high mobility speed for the user and high application data rate will increase the number of the send packets but the most of the packet lost in the high application data rate is returned to the fact of the limitation of the UMTS network which is limited to 384 kbps. Moreover, when moving the mobile with low speed allow the user to spent more time in the WiMAX network which allow the WiMAX interface to receive more packets and increase the throughput.

5.2.4 Delay

Delay is the time needed for the packet to arrive from source to destination. We measure the Delay for both networks from WiMAX and UMTS versus the mobile speed [31].

$$Avg.Delay = \frac{Time.packet\ was\ recieved - Time.packet\ was\ sent}{n.of\ packets} \qquad \text{Eq. (5.5) [31]}$$

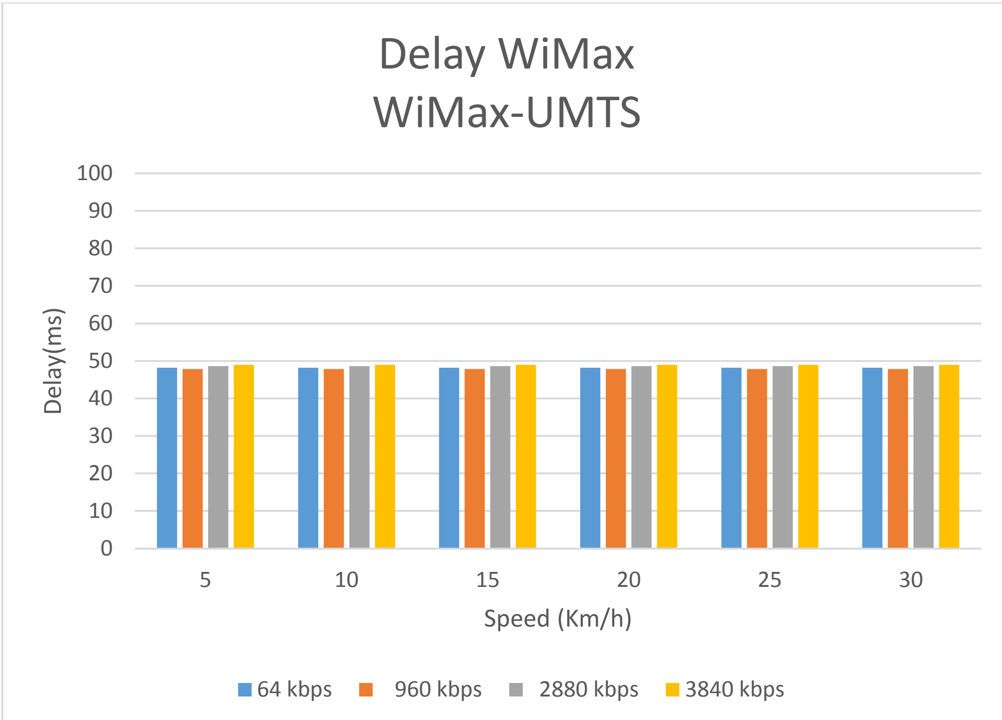

Figure 5.9: Delay on WiMAX interface for different applications WiMAX to UMTS

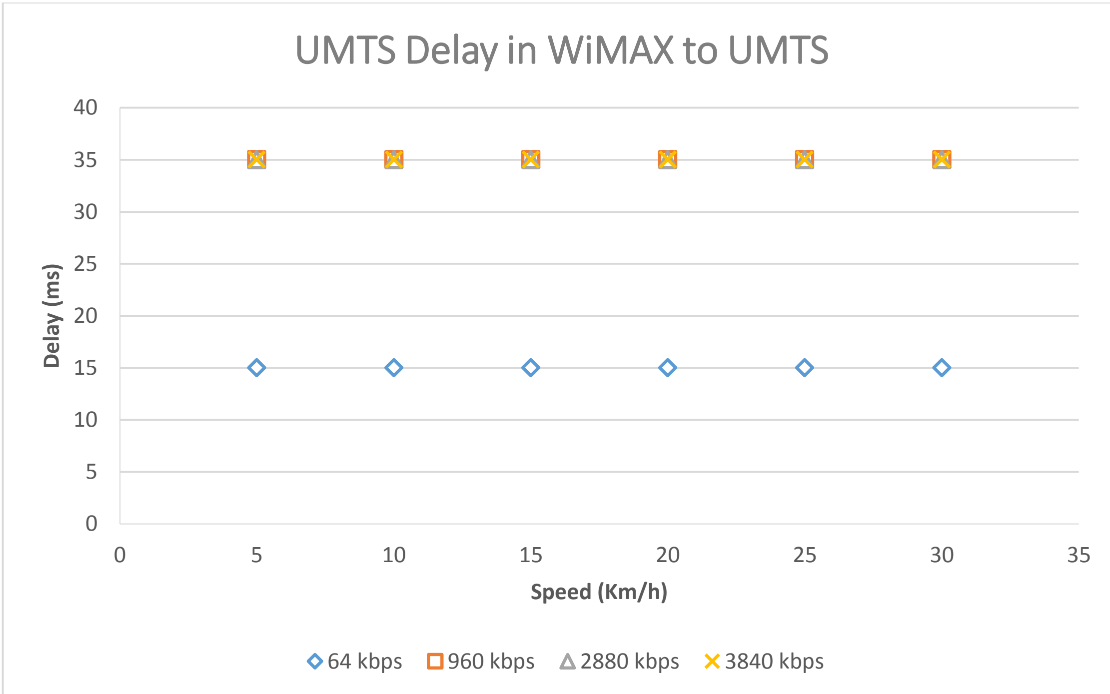

Figure 5.10: Delay on UMTS interface for different applications WiMAX to UMTS

From figure5.9 and 5.10. We notice that increasing the application bitrate will slightly increase the delay. These values of the delay is almost constant and it is between 47 ms and 50 ms in WiMAX network for all the mobile speed. Also as we mentioned above that the packets arrived from the application server connected to the network using cables and it have a link delay reaching it is gateway. In addition, the results of delay compared to the ITU-T and it gave acceptable values for the application QoS in VoIP application. For As mentioned above we measured the delay on the WiMAX interface which represent the time spent for the packet leaving the source till arrived to the mobile node interface, while running different speeds and application bitrate.

5.2.5 Handover Delay

Handover latency is the time difference between last packet received on the point of attachment and the first packet arrived to candidate point of attachment.

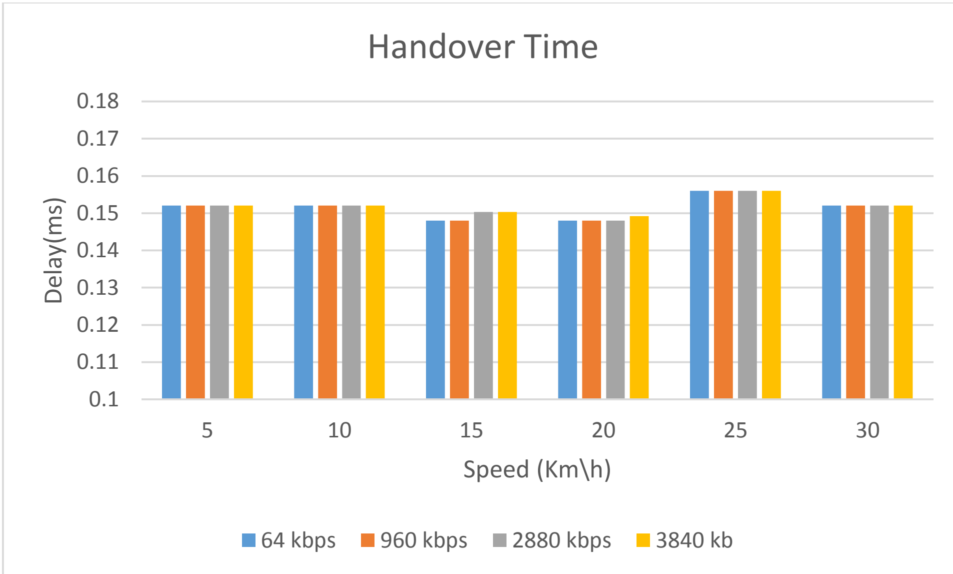

Figure 5.11: Handover Delay on for different applications WiMAX to UMTS

From fig.5.11 like the end to end delay the handover latency doesn't infected by the speed of the mobile terminal, However, it is slightly increased when increasing the bitrate of application. As mentioned in the definition above we measured the time required for the packets to be directed from one interface to another which called also the Handover time.

5.2.6 Power Threshold

In figure5.12 it shows the power signal versus the mobile node speed and the threshold value after reaching this threshold switch for the connected links occurred and the packets start to the received on the mobile UMTS interface.

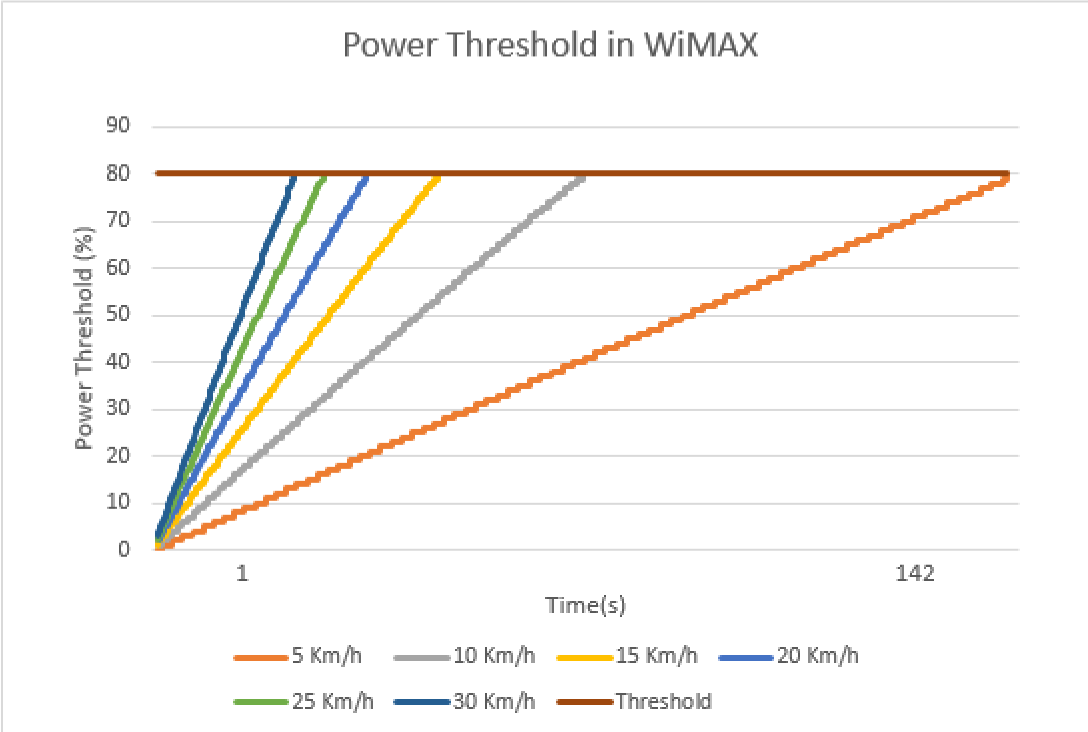

Figure 5.12: RSS on WiMAX interface for different applications WiMAX to UMTS

As mentioned in the previous chapters our work is based on the received signal strength which implemented in the IEEE 802.21 standard and it is considered the most usable algorithm in the handover study. Link Going Down triggers is executed and probability value based on the current received signal strength which implemented in the handover module to avoid the service disconnection and prevent the mobile node to reach the CS_threshold value. When the probability reaches 80% a new connection to candidate point of attachment is established which is in our scenario is the UMTS. From Fig 5.12 which represent the power of the received signal strength in the WiMAX interface. We notice that increasing the mobile node speed will behave in reaching the boarders of the WiMAX network faster and the switch to the UMTS network which will directly affected the throughput and the total received packets when running high data rate applications.

5.3 Scenario Two

In this scenario we will change the coordination of the mobile terminal to cross equal distance from source to destination node to take the advantage of the WiMAX network because as mentioned above the main cause of the degradation in network performance indicators is the limitation in the UMTS network and the speed of the mobile node specially when using application more than 384 kbps.

5.3.1 Throughput Equal Distance

The throughput is increased as expected because the mobile node is moving in the WiMAX environment which have a high bandwidth and spent more time in the coverage area before reaching the threshold of the network.

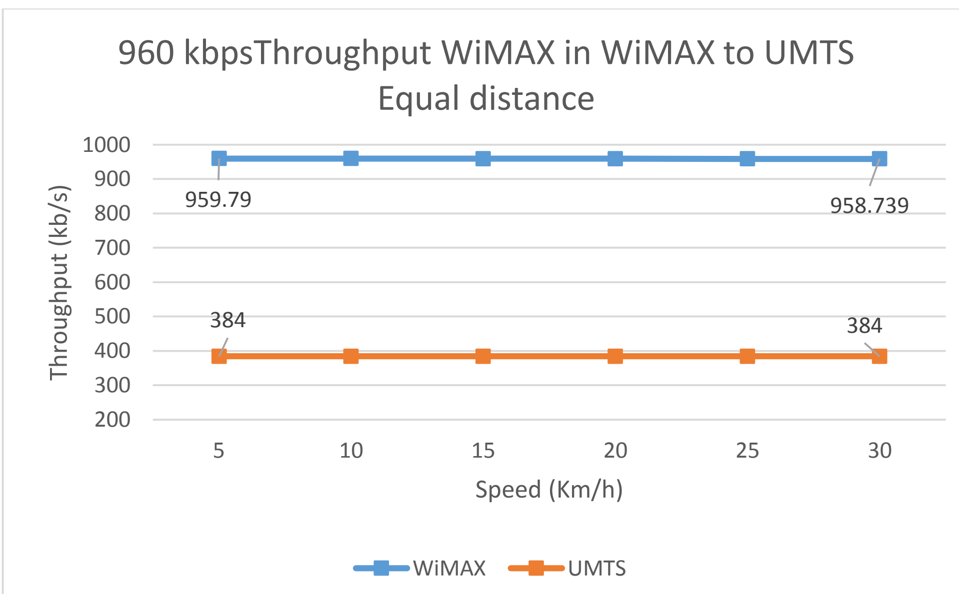

Figure 5.13: 960 kbps Throughput WiMAX to UMTS Equal Distance

From figure 5.13 we found that the throughput is increased slightly in the WiMAX network in 5 km/h it equal to 959.79 kbps and in 30 km/h it equal 958.739 kpbs compared to figure 5.2 which present the throughput for the same application in scenario one the throughput equal to 959.737 kbps and 958.418 kbps for the same speeds.

5.3.2 Data Received Equal Distance

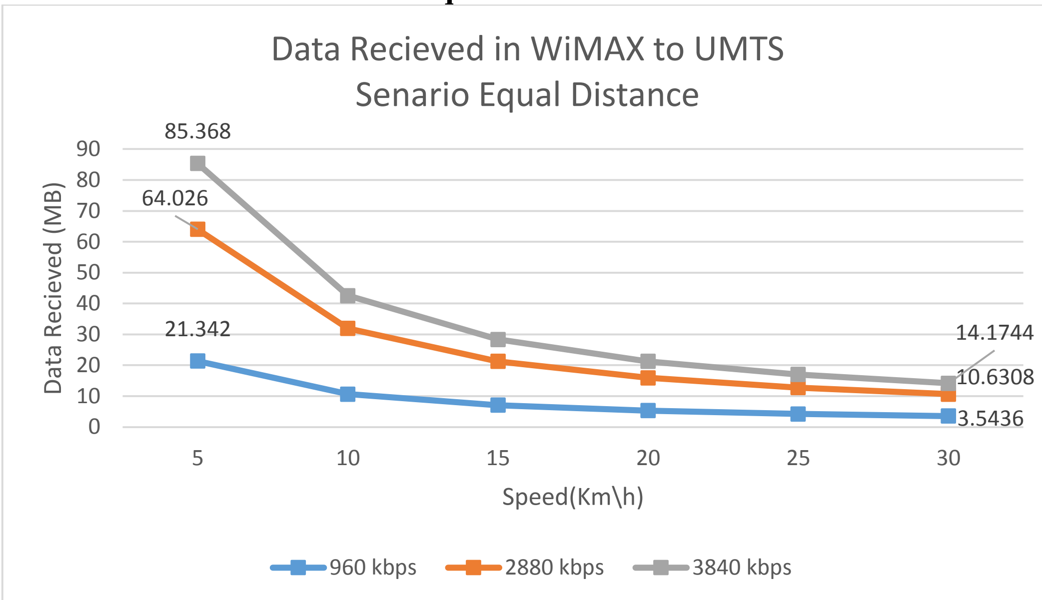

Figure 5.14: Packet Received WiMAX to UMTS Equal Distance

From Figure 5.14 we found the packet received is also increased for the applications. In speed 5 km/h for application 2880 kbps it reached 64.02 MB and in 30 km/h it reach 10.63 MB compared to the packet received in scenario one from Figure 5.7 which equal to 50.97 MB and 8.47 MB for the same speeds.

5.3.3 Packet Loss Ratio Equal Distance

The total packet loss ratio in scenario two is decreased for all the applications when the mobile node is initially connected to WiMAX the loss in packets is almost zero in both scenarios and that return to the fact that the degradation in the packet loss ratio in scenario one is caused by the UMTS network which is limited in bandwidth.

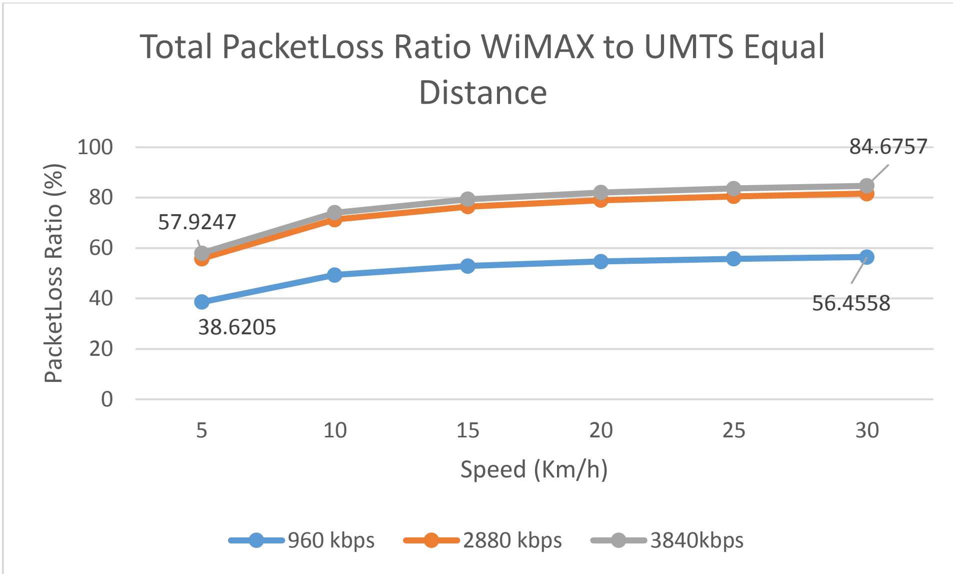

Figure 5.15: Packet Loss WiMAX to UMTS Equal Distance

From Figure 5.15 which represent the total packet loss during the mobile travel from source to destination and we notice that the ratio is decreased around 4 % in the 960 kbps application in speed 5 km/h with comparison to the previous scenario.

5.3.4 Delay Equal Distance

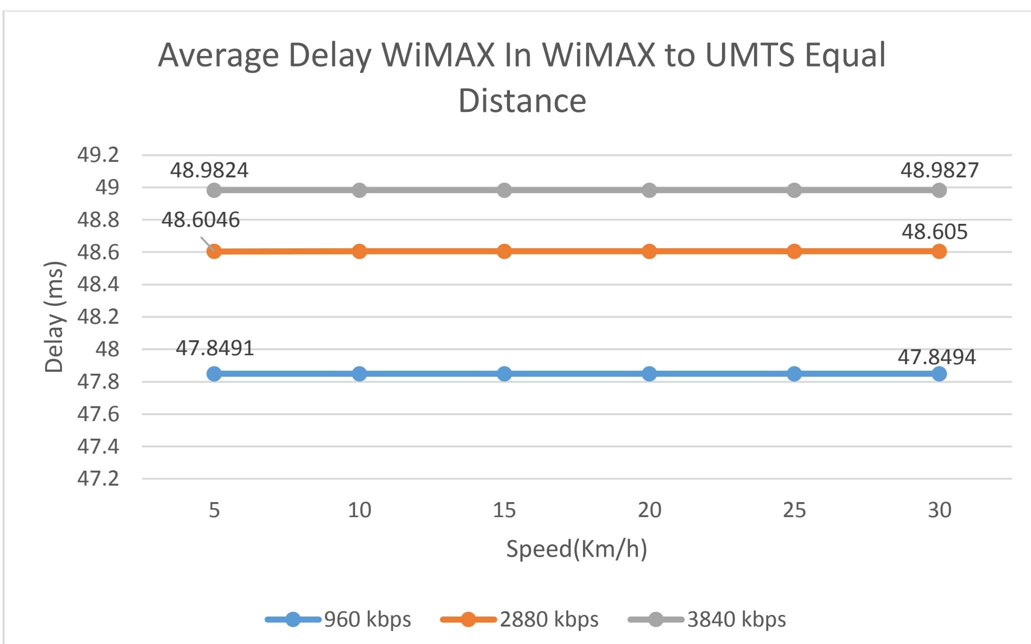

Figure 5.16: WiMAX Average Delay WiMAX to UMTS Equal Distance

As mentioned previously the delay is not affect by the speed and it is slightly increased by the application bitrate. In scenario two the average end to end delay in WiMAX which presented in Figure 5.16 it is slightly increased for all the application bitrate.

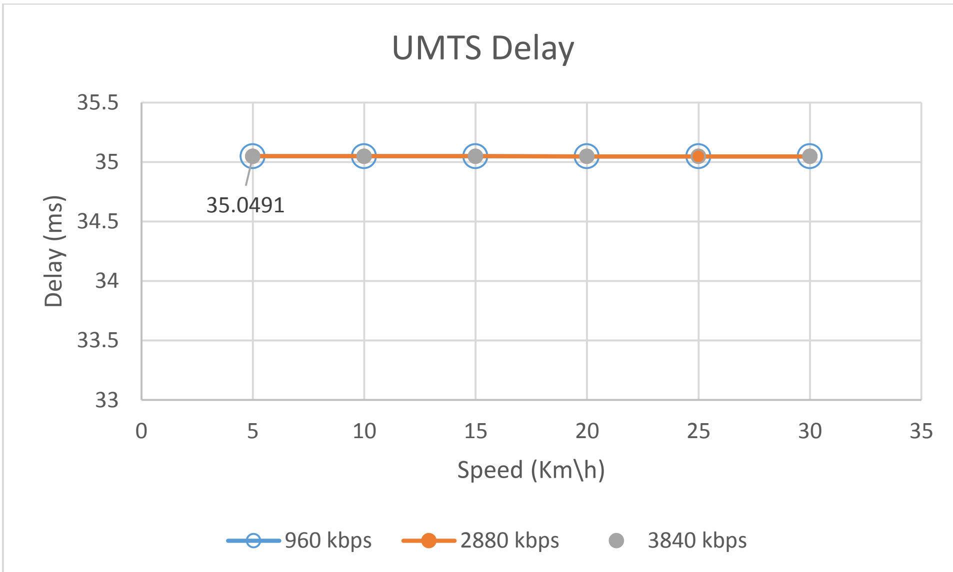

Figure 5.17: UMTS Average Delay WiMAX to UMTS Equal Distance

The UMTS average end to end delay is the same for the three applications and in two scenario it gives around 35 ms in the UMTS and 48 ms in the WiMAX network.

5.3.5 Handover Delay Equal Distance

In handover delay there is no changes it gives the same number since the handover delay is not infected by the speed of the mobile terminal nor the position of it because from the definition of handover delay it is the time needed to switch the link between the WiMAX and the UMTS it give values from 150 ms to 160 ms.

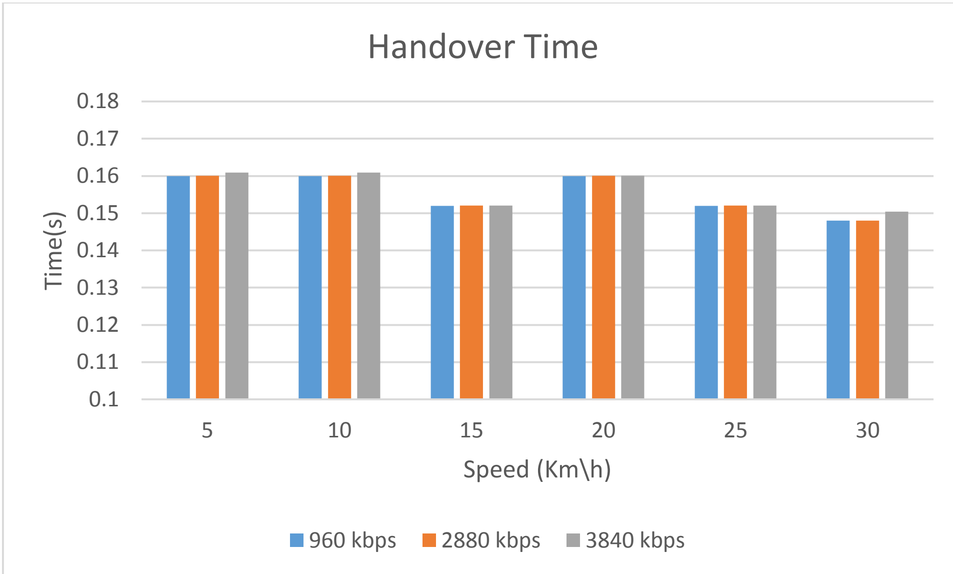

Figure 5.18: Handover Delay WiMAX to UMTS Equal Distance

5.4 Scenario Three

In this scenario we will use a high speed mobility and we will move the UMTS base station to point at (1500, 100).

5.4.1 Throughput High Speed

From Fig 5.19 which represent the throughput for application of 128 kbps when moving the mobile node in high speed .when the speed is equal to 80 Km\h and 160 Km\h the throughput is equal to 127.675 kbps and 127.353 kbps in WiMAX and that refer to the speed of the mobile terminal.

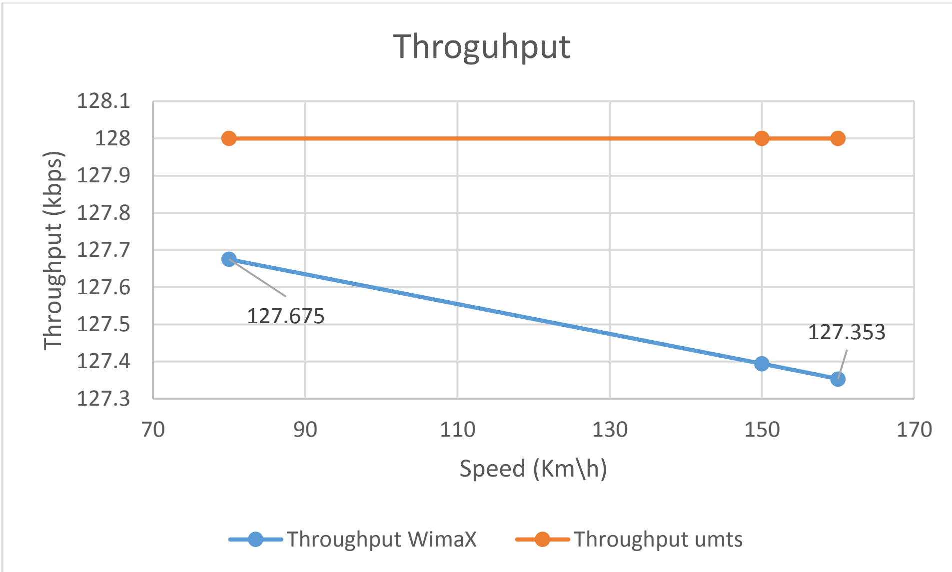

Figure 5.19: Throughput WiMAX to UMTS High Speed

From Fig 5.20 which represent the throughput for application of 960 kbps when the speed is equal to 80 Km\h and 160 Km\h the throughput is equal to 956.661 kbps and 953.702 kbps in WiMAX which means that it degraded and the effect of the speed start to appear clearly after 150 Km/h and that's refers to the strong power signal and high mobility support in the WiMAX technology.

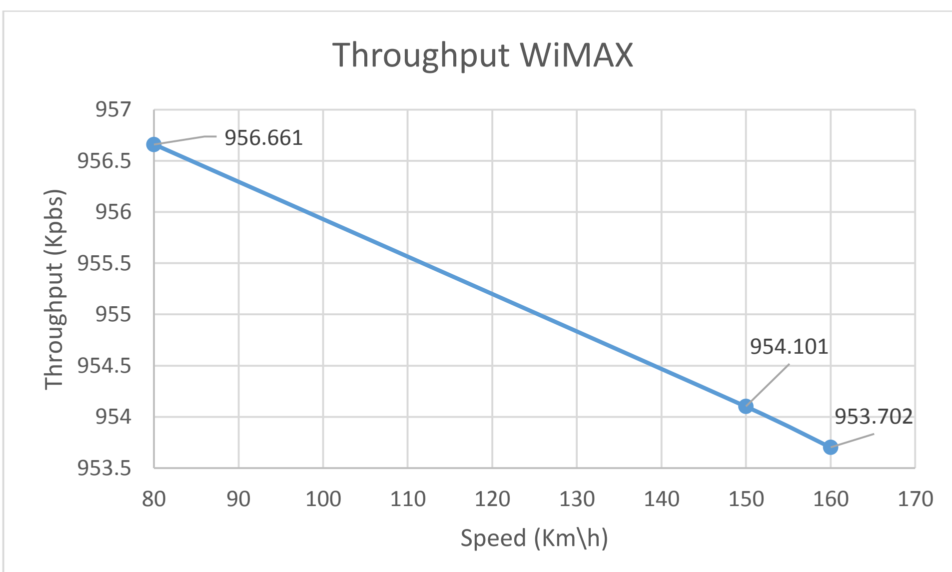

Figure 5.20: Throughput 960 kbps application WiMAX to UMTS High Speed

5.10.2 Data Received High Speed

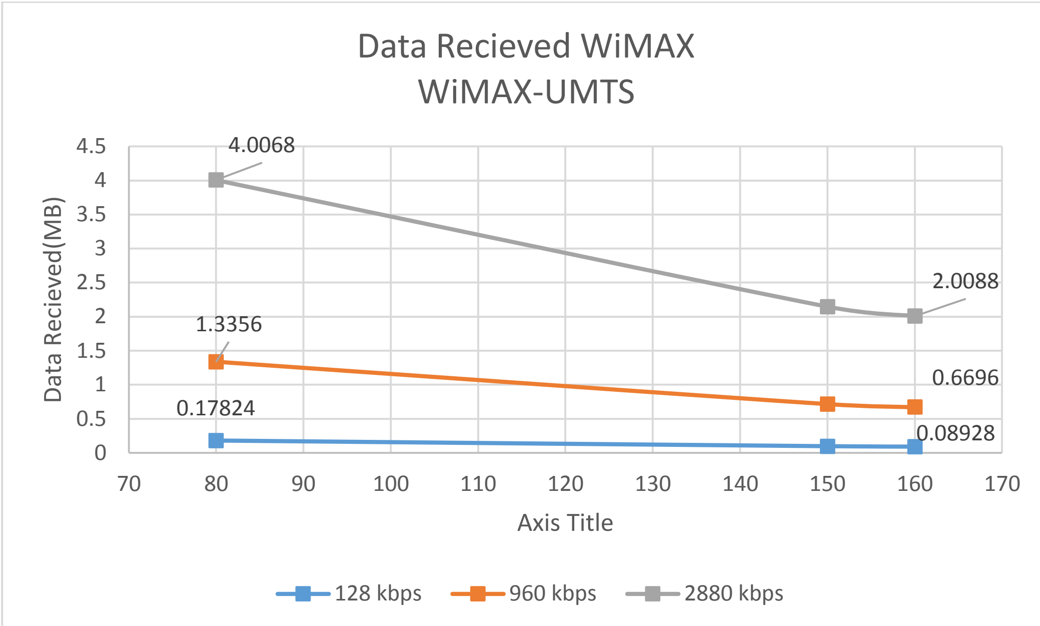

Figure 5.21: Data Received WiMAX to UMTS High Speed

From Figure 5.21 which represent packet received on the WiMAX interface is decrease when the mobile node speed increased.

5.10.3 Total Packet Lost High Speed

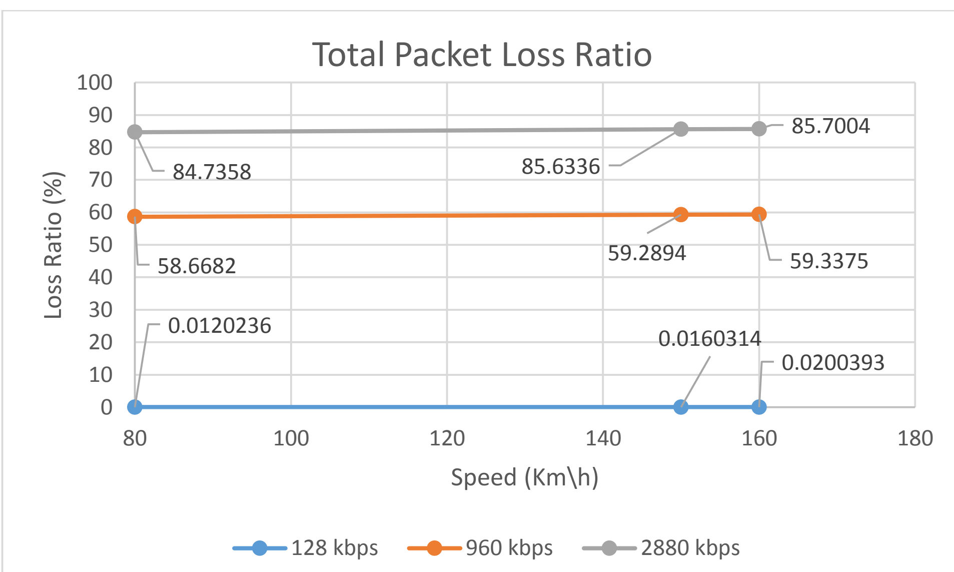

Figure 5.22: Packet Loss Ratio WiMAX to UMTS High Speed

Total packet loss ratio is increased by increasing the speed for all the applications. For example when the application is 960 kbps the total loss ratio is 38.6205 % while moving in speed 5 Km\h but it increased to 59.3375 % when moves the mobile in 150 Km\h and most of the loss is happened during the movement in the UMTS network which is limited in bandwidth. In addition, the application of 128 kbps the total packet loss ratio is less than 1% , and that refers to the high mobility support in both of the WiMAX and UMTS network.

5.10.4 Delay High Speed

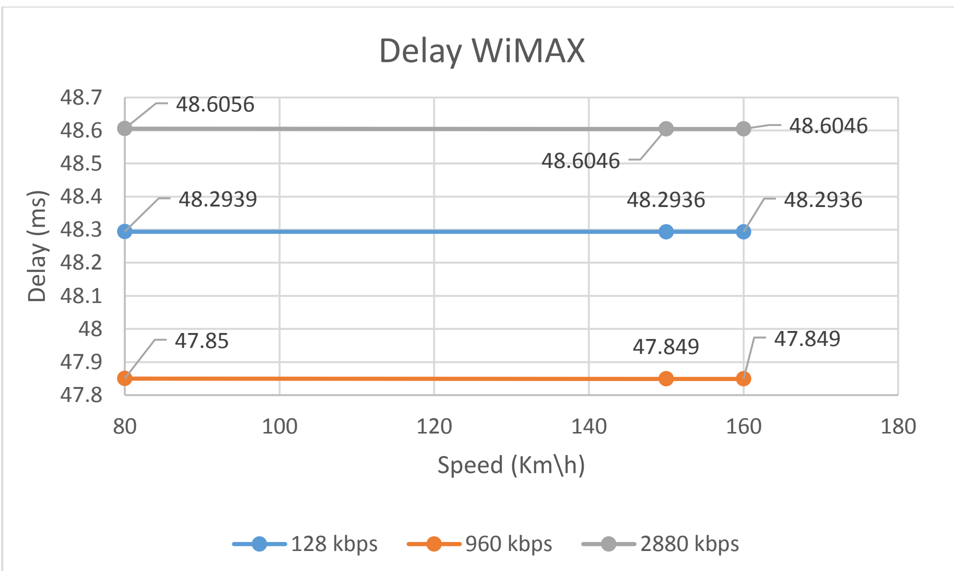

Figure 5.23: Delay WiMAX WiMAX to UMTS High Speed

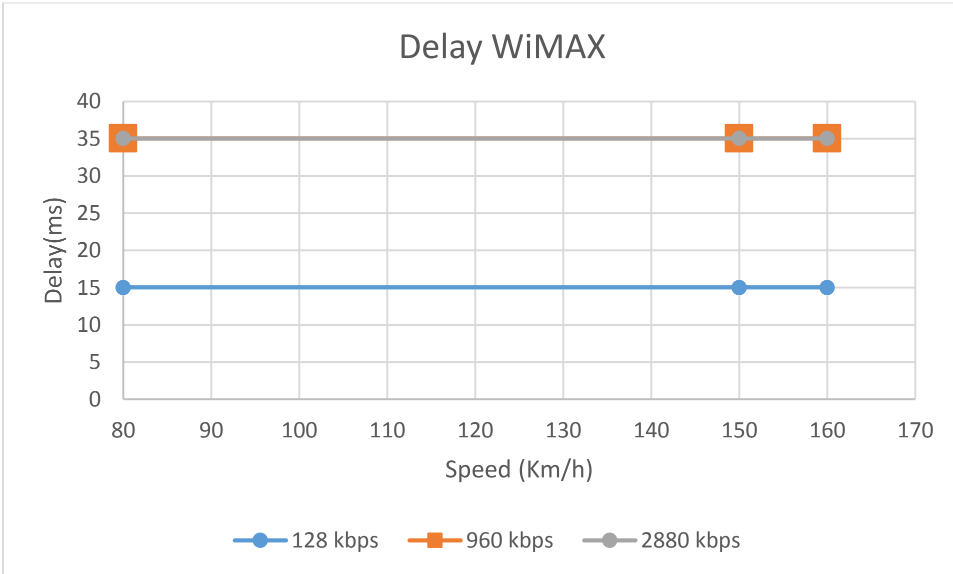

Figure 5.24: Delay UMTS in WiMAX to UMTS High Speed

Delay is not affected by speed of mobile and it gives the same values as previous for application bitrate that are higher and lower than 384 kbps.

5.10.5 Handover Delay High Speed

Figure 5.25: Handover time WiMAX UMTS

The handover time is not affected by the speed from figure 5.25 represent the handover time it is measured between 148 to 160 ms same as previous in scenario one and two.

5.5 Result Summary

Based on the obtained result and with comparison to other paper work we indicate from our simulation in the WiMAX to UMTS in the table below we conclude the effect of the speed and data rate on the different performance metrics.

Table 5.* 1*: Result Summary Table

Network Performance Indicator	**WiMAX to UMTS scenarios comments**
Throughput and normalized throughput	The throughput and normalized throughput are affected by the mobile speed and the application bitrate. When increasing the speed, the throughput is decreased. The main cause of this degradation is referred to the limitation of the mobility support for the technology used and the movement to the UMTS network which is very limited in bandwidth. The result compared with other work like [21] In Fig .7and it gives the same behaviour.
Packet Received	The total received packets is increased while increasing the application bit rate. And decrease while moving the mobile node in high speed. Compared with [21] In Fig.8. And [37] in Fig 3.
Packet Loss Ratio	The packet loss ratio is affected by the mobile node speed and it increased also when using a high data rate application.
End to End Delay	Delay is not affected by the speed but also increasing the mobile application bit rate will slightly increase the delay. When using the VOIP application 64 kbps which refers to the coded G.114 our result give an acceptable value for the delay because it gives 48.2 ms in WiMAX plus the delay in the UMTS 15 ms plus the handover delay 140 ms so total delay is 48.2+15+140=238.2 ms at the handover moment and the allowable according to ITU-T is 300 ms [33] and [29] Table 6 and Fig.5.

Handover Delay	The handover delay is not affected by speed but increasing the application bit rate will slightly increase the handover delay. The result compared to the handover latency provided in [25] and gives approximately the same value when the number of nodes is 1 but the paper used a very high speed scenario starting from 40 km/h.it shows that the handover delay is increased by both the number of nodes and the speed plus the increasing the application bitrate.
RSS Power	Moving the mobile node with low speed which allowed the mobile to spend more time in WiMAX network which have a wide bandwidth will allow to increase the performance such like throughput and packet received.

Chapter 6

Conclusion and Future Work

This chapter will go through the works done to fulfill the objective explained at the beginning of the thesis, conclusions, and point out future directions based on the present study.

6.1 Conclusions

Dealing with QoS requirements and providing the best configuration to maximize the performance characteristics of such systems is a challenging task due to the diversity Of technologies and standards [36]. One of the main issues in determining the system performance in wireless systems is mobility [36]. From our literature review in chapter 3 we notice that when the researchers consider the input parameters for the different algorithm including (MADM, fuzzy logic, etc.) it is very important to include the speed of the mobile terminal and the application bitrate as an input to any algorithm and also the papers which consider these two parameters are having more accurate result than the others. Moreover, speed of the mobile terminal and the application bitrate are directly related to the QoS for the application and should be considered in the handover decision phase parameters. Therefore, many researches had already done in the compatibility problem between different networks technologies and still there is a gap between network providers and network players and a perfect solution for the vertical handover problem is the most challenging because of user's and applications needs.

In this thesis we study the network performance indicators in term of mobility and the application data rate. From the result that obtained we found that some network performance indicators mainly throughput, and packet loss are affected by the mobile node speed which is directly related to the QoS. On the other hand, delay and handover delay are slightly effected by the application data rate.

6.2 Future Work and Research Recommendation

The vertical handover is a very hot topic in communication and still there is a need for research in this area. From the literature review discussed in chapter 3, we found that the descion phase is the most important and it is the vital core of the vertical handover process many algorithms were developed in order to fill the requirements of the user and applications and they are try to enhance the network performance indicators such like handover delay, throughput, and packet loss ratio which affect the quality of service for the applications.

Furthermore, some researchers study the vertical handover from different perspective using combined algorithms depends on many input parameters which need a lot of processing such like normalizing, and weighting calculations and may cause influences in ranking the candidate networks and increase the complexity in the handover decision phase in order to take the decision to which network should the mobile connect. Moreover, to support the high mobility and the real time applications the handover time should be the minimum and from the definition it is very important to add the handover initiation and handover execution time plus the handover decision time to clearly define the period which needed for the mobile node to switch the links and insure the packet flow to the candidate point of attachment.

Moreover, include more than two technologies such like Wi-Fi, WiMAX and UMTS in the same scenario which increase the topology complexity .On the other hand, the mobile node in our implemented scenario has no other option connect to UMTS. In addition, the topology of the network and the speed of the mobile is very important factor to be considered, it is not realistic to measure the throughput of a video or high data rate application running on mobile with very high speed like 100 Km/h in a Wi-Fi network with very limited coverage area from

50 to 100 meter. Choosing the WiMAX which support a very high mobility users and have a high coverage area better than the Wi-Fi which is limited in coverage The IEEE802.21 standards which implemented between the data link and the network layer solve the problem of handoff delay, computational cost, reduce handover fails, and satisfied the efficiency. However, the standard lacks from any security and authentication and it is very important to address such issue.

In our future work we will consider the handover in the 4G and 5G since they are widely used today and they are having a high bandwidth between 50-100 Mbit/s in comparison to the UMTS bandwidth which is very limited. In addition, the mobility which supposed to reach the 250-300 Km/h without affecting the application QoS using the 4G because this technology is designed to handle high mobility speeds. Moreover, it is very efficient to combine the RSS algorithm which we worked on in this thesis with one of the MADM algorithm in order to improve the handover delay. On the other hand, the overall network performance metric should enhance especially the throughput and the packet loss ratio when using high bitrate applications.

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ملخص

هذه الدراسة تبحث عملية التسليم العامودي بين الشبكات اللاسلكية المختلفة من عدة نواحي كسرعة و التغطية و الطاقات المتفاوته و التصميم الفيزيائي و الترددات اللتي تعمل عليها.فهنالك صعوبة في التواصل في ما بينها.فقام الباحث بدراسة خصائص هذه الشبكات وكيفية عملها .و

فما قدمه الباحث من عمل في هذا الجانب هو استخدام تقنية (IEEE802.21),

و الذي توفر هذه الخدمة و عليه تم العمل على بناء سيناريوا في برنامج (NS2)بين شبكة الجيل الثالث و شبكة WiMAX وتم فحص هذه الخدمة من خلال تشغيل عدة برامج ذات سعات مختلفة على هاتف نقال يقوم بلاتصال بشبكة WiMAX و يبدأ بتحرك بتجاه شبكة الجيل الثالث وتحصل عملية التسليم العامودي دون انقطاع للخدمة .

تبدأ عملية التحرك للجهاز المحمول وتنتهي في سرعات ثابته دون اي تغير و في كل مرة نعمل على تشغيل برنامج مختلف عن الاخر و تتم عملية فحص جميع معايير الجودة مثل نسبة فقدان الحزم و نسبة التاخير في وصول و. تم الحصول على النتائج المرادة و تبين بأن هنالك فرق في الكفائه و المعايير التي تم قياسها باختلاف السرعات و باختلاف حجم الخدمة المراد تشغيلها بحيث كل ما زادت السرعة و حجم الخدمة تأثر بشكل سلبي على الخدمة عند وصولها الى المستخدم . ويعود ذلك التأثير الى المحدودية في خدمة الشبكات اللاسلكية و ايضا في قدرتها على تلبية متطلبات المستخدم. و تم عمل مقارنة بين النتائج اللتي تم الحصول عليها مع معايير عالمية مقدمة من قبل ITU-T .واتضح انها ضمن المعايير المعمول بها.

قدم الباحث بعض التوصيات و النصائح للعمل في مجال التسليم العامودي ومن اهمها اخذ درجة الامان في البحوثات القادمة و الاخذ في المحدوديات في اختيار التكنولوجيا اللاسلكية.