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Optimization WIMAX performance by minimize the handover effect

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Thème

Optimization WIMAX performance by minimize the handover effect

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ABSTRACT

WiMAX (Worldwide Interoperability for Microwave Access) utilize advanced technologies, such as Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple-Input and Multiple-Output (MIMO). WiMAX is based on IP (Internet Protocol) with provision of data over long distance and high-speed data transmission capability which can accomplish quick Internet access and at suitable Quality of Service (QoS) at high mobility. Handover is a significant factor to evaluate the performance for WiMAX network and it occurs when a Mobile Station (MS) moves between Base Stations (BSs). WiMAX requires support and capacity for high mobility to avoid the loss of quality of service. The goal of faster mobility can be achieved, but the problem, WiMAX network needs the support of an effective handover mechanism to ensure continuous and without any interruption in data transfer. This research focusses to reduce the handover problem in mobile WiMAX (IEEE 802.16e).

In order to reduce the problem above, we worked to find and identify the factors which directly effect on the handover process by used OPNET Modeler simulator (V14.5). After detailed simulation and analysis, it has been found out that 10 factors could be used to improve handover delay in WiMAX and these factors which directly effect on the handover delay in WiMAX. The following parameters that are directly linked to the handover are identified are as follows:

1) Distance between BS

2) Comparison between MIMO and SISO

3) VOIP codecs

4) Scanning threshold

5) Scan iteration

6) Interleaving Interval

7) Start frame

8) Ranging Backoff Start

9) Neighbour Advertisement Interval

10) Mobile IP registration lifetime request

The simulation experiments on individual factors has identified that these factors result in a minimum handover delay at specific values which are called best performing values. When these best performing values of the 10 factors were applied to single WiMAX experiment, the improvement was identified, which showed that there have been better handover delay results and a minimum data dropped and the throughput was drastically improved.

The future work would be to develop the handover system to reduce more handover delay and to be tested to support high speed mobility.

Résumé

WiMAX (interopérabilité mondiale pour l'accès par micro-ondes) utilise des technologies de pointe, telles que l'accès multiple par répartition orthogonale de la fréquence (OFDMA) et l'accès multiple à sorties multiples (MIMO). WiMAX est basé sur IP (Internet Protocol) avec la fourniture de données sur de longues distances et une capacité de transmission de données à haut débit permettant un accès rapide à Internet avec une qualité de service (QoS) adaptée à une mobilité élevée. Le transfert intercellulaire (Handover) est un facteur important pour évaluer les performances du réseau WiMAX mobile. Il survient lorsqu'une station mobile (MS) se déplace entre des stations de base (BS). WiMAX nécessite un support et une capacité de mobilité élevée pour éviter la perte de qualité de service. L'objectif d'une mobilité plus rapide peut être atteint, mais le problème, le réseau WiMAX a besoin de la mise en place d'un mécanisme efficace de transfert pour garantir une transmission continue et sans interruption du transfert de données. Cette recherche vise à réduire le problème de transfert intercellulaire dans le WiMAX mobile (IEEE 802.16e).

Afin de réduire le problème ci-dessus, nous avons travaillé à la recherche et à l'identification des facteurs qui affectent directement) sur le processus de transfert intercellulaire (Handover) à l'aide du simulateur OPNET Modeler utilisé (V14.5). Après une simulation et une analyse détaillée, il a été découvert que 10 facteurs pourraient être utilisés pour améliorer le délai de transfert dans WiMAX et ces facteurs ont une incidence directe sur le délai de transfert dans WiMAX. Les paramètres suivants, directement liés au transfert intercellulaire, sont les suivants (en anglais) :

1) Distance between BS
2) Comparison between MIMO and SISO
3) VOIP codecs
4) Scanning threshold
5) Scan iteration
6) Interleaving Interval
7) Start frame

8) Ranging Backoff Start

9) Neighbour Advertisement Interval

10) Mobile IP registration lifetime request

Les expériences de simulation sur des facteurs individuels ont montré que ces facteurs entraînaient un délai de transfert minimal à des valeurs spécifiques, appelées valeurs les plus performantes. Lorsque les valeurs les plus performantes des 10 facteurs ont été appliquées à une seule expérience WiMAX, l'amélioration a été identifiée, ce qui a montré que les résultats de délai de transfert étaient meilleurs, que le nombre de données perdues était minimal et que le débit était considérablement amélioré.

Les travaux futurs consiste à développer le système de transfert intercellulaire pour réduire plus le délai de transfer et à tester la compatibilité avec la mobilité à grande vitesse.

الملخص

تستخدم WiMAX تقنيات متقدمة ، مثل OFDMA و MIMO. يعتمد WiMAX على IP (بروتوكول الإنترنت) مع توفير بيانات على مسافة بعيدة وإمكانية نقل البيانات عالية السرعة والتي يمكن أن تحقق وصولاً سريعًا للإنترنت وفي جودة خدمة مناسبة (QoS) في تنقلية عالية. يُعد التسليم (Handover) أمرًا مهمًا لتقييم أداء شبكة WiMAX ويحدث عندما تتحرك محطة متنقلة (MS) بين المحطات الأساسية (BS). يتطلب ال WiMAX الدعم والقدرة على للتنقل العالي لتجنب فقدان جودة الخدمة. يمكن تحقيق هدف التنقل بشكل سريع ، لكن المشكلة شبكة WiMAX تحتاج إلى دعم آلية تسليم فعالة لضمان الاستمرار ودون أي انقطاع في نقل البيانات. يركز هذا البحث على تقليل مشكلة التسليم في WiMAX المحمول (IEEE 802.16e).

للحد من المشكلة أعلاه ، عملنا على إيجاد وتحديد العوامل التي تؤثر بشكل مباشر على عملية التسليم باستخدام محاكي OPNET Modeler (V14.5). بعد المحاكاة التفصيلية والتحليل ، تبين أنه يمكن استخدام 10 عوامل لتحسين تأخير التسليم في WiMAX وهذه العوامل التي تؤثر بشكل مباشر على تأخير التسليم في WiMAX. المعلمات التالية مرتبطة مباشرة بالتسليم هي كما يلي (بالإنجليزية) :

1) Distance between BS

2) Comparison between MIMO and SISO

3) VOIP codecs

4) Scanning threshold

5) Scan iteration

6) Interleaving Interval

7) Start frame

8) Ranging Backoff Start

9) Neighbour Advertisement Interval

10) Mobile IP registration lifetime request

لقد حددت تجارب المحاكاة الفردية على العوامل أن هذه العوامل تؤدي إلى تأخر التسليم في قيم محددة تسمى القيم الأفضل أداءً. عندما تم تطبيق هذه القيم الأفضل أداءًا لعوامل 10 على تجربة WiMAX واحدة ، تم تحديد التحسين ، مما أظهر أن هناك نتائج أفضل لتأخير التسليم وانخفض فقد البيانات وتم تحسين الإنتاجية بشكل كبير.

سيكون العمل في المستقبل هو تطوير نظام التسليم لتخفيض المزيد من تأخير التسليم واختباره لدعم التنقل عالي السرعة.

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I am also thankful for the support of my family. Especially my mother and father for their generous support they provided me throughout my entire life and particularly through the process of pursuing the master degree.

Dedication

I am dedicating this thesis to my brothers Ilyes, Amine, Rami and all my friends have supported me throughout the process. I will always appreciate all they have done.

I also dedicate to the all classmates and to my professors at MOUHAMED KHIDER University.

LIST OF ABBREVIATIONS

3G	Third Generation
4G	Fourth Generation
AAS	Adaptive Antenna System
ACP	Automatic Cell Planning
AMC	Adaptive Modulation and Coding
BS	Base Station
BTS	Base transceiver station
CDMA	Code Division Multiple Access
CS	Convergence sublayer
CPS	Common part sublayer
DCD	Downlink Channel Descriptor
DL	Downlink
DSL	Digital Subscriber Line
EVDO	Evolution-Data Optimized
FBSS	Fast Base Station Switching
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
GSM	Global System for Mobile Communications
HO	Handover
HHO	Hard Handover
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
LOS	Line-of-Sight
LTE	Long Term Evolution (4G)
MAC	Media Access Control
MAN	Metropolitan Area Network
MDHO	Macro Diversity Handover
MIMO	Multiple in and multiple out
MOS	Mean Opinion Score

LIST OF ABBREVIATIONS

MS	Mobile Station
NLOS	Non-Line-of-Sight
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OSI	Open System Interconnection
PHY	Physical layer
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SNR	Signal to Noise Ratio
TDD	Time Division Duplex
TDMA	Time-Division-Multiple-Access
UCD	Uplink Channel Descriptor
UL	Uplink
UMTS	Universal Mobile Telecommunications System
VoIP	Voice over Internet Protocol
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity

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GENERALE INTRODUCTION

At the present time, in an era of mobile phones, Laptops, tablets, and electronic gadget there is often a necessity to set up a network to enable communication among these devices. Wireless communication is the origin of the active research, the development and growth of it has increased in human lives with the birth of the mobile telephony system.

A cellular network is one of the types of wireless networks, that uses the wireless communication links to interconnect wireless host like mobile phones. This type of network is called infrastructure-based network, because it needs infrastructure to operate. The base station (BS) is the main part of this wireless network infrastructure, and it is responsible for communicating with the wireless hosts, coordinates simultaneous transmission and reception by many hosts under its control and forwarding packets of data between these hosts.

WIMAX stands for worldwide interoperability for microwave access by the WiMAX Forum. It is based on IEEE 802.16 standard, officially known as Wireless- MAN, it aims to provide wireless data coverage over a metropolitan area like a city. The forum describes WiMAX as a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. WiMAX standard supports both fixed and mobile broadband data services. WiMAX is provided high-speed Internet access in a coverage range several kilometers in radius. In theory, WiMAX provides for speeds around 70 Mbps with a range of 50 kilometers. The WiMAX standard has the advantage of allowing wireless connections between a base transceiver station (BTS) and thousands of subscribers without requiring that they be in a direct line of sight (LOS) with that station. This technology is called NLOS for non-line-of-sight

Mobile WiMAX was the first mobile broadband wireless-access solution based on the IEEE 802.16e standard that enabled convergence of mobile and fixed broadband networks through a common wide-area radio access technology and flexible network architecture. The mobile WiMAX air interface is using orthogonal frequency division multiple access (OFDMA) as the preferred multiple access method in the downlink (DL) and uplink (UL) for improved multipath performance.

The important challenge in cellular network is Handover (also called handoff) of an mobile station (MS), where the MS currently has an ongoing communication session from the current cell to the next cell. The importance of performing handover seamlessly, is to avoid call drop and throughput degradation. Performing handover seamlessly, efficiently, reliably and fast is still an important area of existing research and the current project includes our work on this problem which is minimization of effect of handover in the WiMAX network.

The object of this research to create the most efficient WiMAX Network by reducing Handover delay to a minimum by changing some of WiMAX Network parameters that have an effect on the Handover and by identifying the factors which will reduce the handover delay, ensure the better WiMAX Mobility, highest Quality of service (QoS) and Signal throughput. The main question now is how to reduce the handover delay in WiMAX?

As this question we need of deeper understanding of how WiMAX works and to understand the handover in detail and its types and also identify factors or parameters which have direct effect in handover and identify when these factors give a minimum handover delay which would help us to standardize these factors in order to get the best mobility in WiMAX.

The project presented in this research has been organized into three different chapters. A brief summary of the contents of the three chapters is as follows:

• **Chapter 1:** This chapter provides a general discussion about the WiMAX technology. It includes a discussion some important features and its network architecture. A discussion is provided on the different WiMAX Types and standards and we explained characteristics and main technologies of WiMAX.

• **Chapter 2:** This chapter provides a discussion of the Mobility management in WiMAX Mobile. A discussion is provided on the different types of handover techniques supported by it and an overview of handover procedures in WiMAX and of Mobile IP protocols.

• **Chapter 3:** This chapter provides a detailed analysis of simulation experiments results on WiMAX mobile standards IEEE 802.16e. In this study, there is a total of 2 main experiments with a number of sub-experiments. The aim is in this research is to study the handover effect and reduce this effect in WiMAX network, ensuring minimum handover delay and maximum mobility.

Finally, there is general conclusion that summarizes our research work including future work.

CHAPTER 1:

WIMAX TECHNICAL OVERVIEW

1 Introduction

WiMAX, the Worldwide Interoperability for Microwave Access is a new technology dealing with provision of data over long distance using wireless communication method in many different ways. Based on IEEE 802.16 WiMAX is claimed as an alternative broadband rather than cable and DSL [1]. WiMAX provide high-speed Internet access in a coverage range several kilometers in radius. In theory, WiMAX can achieve speeds around 70 Mbps with a range of 50 kilometers. The WiMAX standard has the advantage of allowing a high capacity of users [2]. This chapter establishes a detailed presentation of WIMAX by exploring the various technologies used in this network.

2 Introduction to WIMAX

2.1 What is WiMAX?

WiMAX that stands for World Interoperability for Microwave Access, is a standard based on IEEE 802.16 broadband wireless access metropolitan area technology, and it is an air-interface standard for microwave and millimeter-wave band. WiMAX also known as IEEE Wireless MAN (Metropolitan Area Network), can provide an effective interoperability broadband wireless access method under the MAN of a point to multipoint multi-vendor environment[1].

The Institution of Electrical and Electronics Engineers (IEEE) established a group in 1998 (termed 802.16) to look at the wide area broadband wireless access issues and to recommend air interfaces and modulation techniques. The group gave its first recommendation in June 2001 specifying the 802.16 standard[2].WiMAX is a metropolitan area network service that typically uses one or more base stations that can each provide service to users within a range of 50 kilometers for distributing broadband wireless data over wide geographic areas [3].It is also an alternative to traditional wired networks, such as Digital Subscriber Line (DSL) and cable-modem. There are two modes defined in WiMAX networks: point-to-multiple-points (PMP) mode and mesh model[4].

WiMAX provides fixed, nomadic, portable and, soon, mobile wireless broadband connectivity without the need for direct line-of-sight with a base station. WiMAX has already begun making important inroads through real-world deployments. Small niche players, creating commercial hot spots for example, have proven out the technology as large players are beginning to position WiMAX in their wireless platforms[5].

The goal of WiMAX is to provide high-speed Internet access in a coverage range several kilometers in radius. In theory, WiMAX provides for speeds around 70 Mbps with a range of 50 kilometers. The WiMAX standard has the advantage of allowing wireless connections between a base transceiver station (BTS) and thousands of subscribers without requiring that they be in a direct line of sight (LOS) with that station. This technology is called NLOS for non-line-of-sight. In reality, WiMAX can only bypass small obstructions like trees or a house and cannot cross hills or large buildings. When obstructions are present, actual throughput might be under 20 Mbps[6].

2.2 Early 802.16 Standards

2.2.1 Introduction to the IEEE 802 Standard

IEEE 802 refers to a family of IEEE standards dealing with local area networks and metropolitan area networks. More specifically, the IEEE 802 standards are restricted to networks carrying variable-size packets. (By contrast, in cell-based networks data is transmitted in short, uniformly sized units called cells[6]. The IEEE 802 Standards Committee (also known as IEEE 802) has been in operation since March 1980. The objective of this group has been to develop LAN and MAN standards and protocols that are mapped to the lower layers (i.e., physical and data link layers) of the seven-layer Open System Interconnection (OSI) reference model[7](13).

2.2.2 IEEEE 802.16 Standards

The IEEE 802 committee set up 802.16 working group in 1999 to specifically develop broadband wireless access standard. IEEE 802.16 is responsible for developing standards for the wireless interface of broadband wireless access and its associated functions (Refer to figure 1.1). IEEE 802.16 protocol standard consists of two-layer structure, which defines a physical layer and a MAC layer. MAC layer includes 3 parts: service specific convergence sublayer (CS), MAC common part sublayer (CPS) and privacy sublayer. However, encryption protocol sublayer is optional. IEEE 802.16 physical layer defines two duplex modes: Time Division Duplex (TDD) and Frequency Division Duplex (FDD), and these two methods both use burst data transfer format. This transmission mechanism support adaptive burst business data. Transmission parameters (modulation, coding, transmit power, etc.) can be dynamically adjusted, but requires the MAC layer to help the process[1].

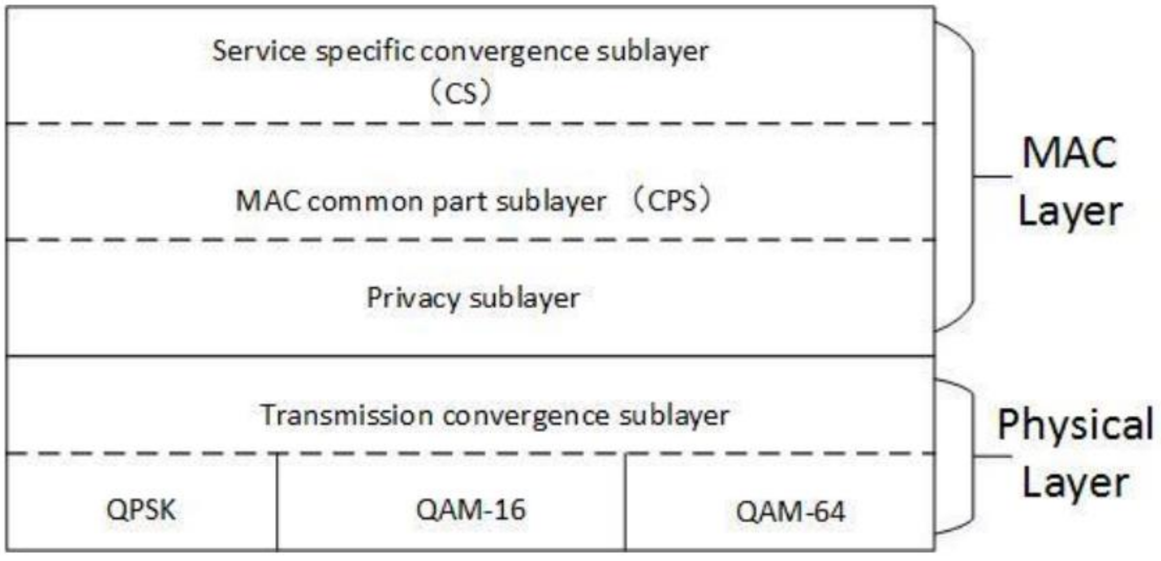


Figure 1. 1 802.16 protocol stack structure [1]

The table 1.1 on the next page provides some useful information on the evolution of the IEEE 802.16 standards.

Standard	Description	Release Date
IEEE std 802.16	Defines wireless metropolitan area networks (WMANs) on frequency bands higher than 10 GHz.	September 2001
IEEE std 802.16c	Amendment to IEEE Std 802.16, Air Interface for Fixed Broadband Wireless Access Systems – Amendment 1: Detailed System Profiles for 10–66 GHz	January 2003
IEEE std 802.16a	Amendment to IEEE Std 802.16, Air Interface for Fixed Broadband Wireless Access Systems – Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2–11 GHz	April 2003
IEEE std 802.16d	Amendment to IEEE Std 802.16, Air Interface for Fixed Broadband Wireless Access Systems – Amendment 1: Detailed System Profiles for 10–66 GHz	August 2003
IEEE std 802.16f	Amendment to IEEE Std 802.16, Air Interface for Fixed Broadband Wireless Access Systems – Management Information Base	December 2005
IEEE std 802.16e	Amendment to IEEE Std 802.16, Air Interface for Fixed Broadband Wireless Access Systems – Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands	February 2006
IEEE Std 802.16-2009	IEEE Standard for Local and Metropolitan Area Networks – Part 16: Air Interface for Broadband Wireless Access Systems Revision of IEEE Std 802.16-2004, developed by Maintenance Task Group under the project draft title “P802.16Rev2.” This work resulted in the second revision of IEEE Std 802.16, following IEEE Std 802.16-2001 and IEEE Std 802.16-2004. It consolidates and obsoletes IEEE Standards 802.16-2004, 802.16e-2005 and 802.16-2004/Cor1-2005, 802.16f-2005	May 2009
IEEE std 802.16m	Project to amend IEEE Std 802.16-2009, Air Interface for Fixed and Mobile Broadband Wireless Access Systems – Advanced Air Interface	March 2011

Table 1. 1 IEEE 802.16 Standards [7]

2.3 Types of WiMAX

The revisions of the IEEE 802.16 standard fall into two categories:

- Fixed WiMAX, also called IEEE 802.16-2004.This standard is the formal one being used for current fixed and nomadic Line Of Sight(LOS) and Non Line Of Sight(NLOS) WiMAX (IEEE 802.16) implementations and is based on and backwardly compatible with 802.16 and 802.16a. The WiMAX Forum profiles supporting IEEE 802.16 2004 are in the 3.5 GHz and 5.8 GHz frequency bands. Vendors are currently creating indoor and outdoor customer subscriber stations equipment and laptop PCMCIA cards to support this specification. This standard will be used for cell creation in non-mobile scenarios and LOS distance links[8].
- Mobile WiMAX, also called IEEE 802.16e, allows mobile client machines to be connected to the Internet. Mobile WiMAX opens the doors to mobile phone use over IP, and even high-speed mobile services[6]. Mobile WiMAX has evolved from fixed wireless access and inherits its features for optimized broadband data services. EV-DO and HSPA, 3G CDMA standards, have been originally conceived for mobile voice services and inherit both advantages and limitations of legacy 3G systems. Consequently, mobile WiMAX faces the challenge to support mobility whereas 3G systems faces the challenge to support higher data rates[9].

In the table 1.2 we compare between fixed and mobile WIMAX network.

Features	**Fixed WIMAX**	**Mobile WIMAX**
Network architecture	Fixed, Nomadic, Portable	Fixed, Nomadic, Portable, Mobile
PHY Technology	OFDM 256	OFDMA 128, 512, 1024, 2048
Duplexing format	TDD, FDD, HD-FDD	TDD, FDD, HD-FDD
Modulation	64QAM, 16QAM, QPSK and BPSK	64QAM, 16QAM, QPSK and BPSK
Channel size	1.25-20 MHz	1,25-14 MHz
Spectrum profiles	2.5 GHz, 3.5 GHz and 5.8 GHz	2.3 GHz, 2.5 GHz, other TBD
QoS Features	Best effort, non real time polling service, real time polling service, unsolicited grant service	Same as fixed WIMAX plus Extended real-time polling service

Table 1. 2 Comparison of fixed and mobile WIMAX network[9].

2.4 ADVANTAGES WiMAX

- **Standard for all usage models (fixed to mobile):** By leveraging the same technology networks, WiMAX technology will become the most cost-effective solution for carriers to deploy for any usage model including fixed, portable, nomadic and mobile.
- **Wider coverage:** The technology behind WiMAX is optimized to provide excellent non-line-of-sight (NLoS) coverage. NLoS advantages are coverage of wider areas, better predictability of coverage and lower cost as it means fewer base stations and backhaul, simple RF planning, shorter towers and faster CPE install times.
- **Higher capacity:** WiMAX technology utilizes Orthogonal Frequency-Division Multiplexing (OFDM) over EDGE, GPRS, HSPA to deliver higher bandwidth efficiency and therefore higher data throughput, with more than one Mbps downstream and higher data rates. Adaptive modulation also increases link reliability for carrier-

class operation and the possibility to keep higher order modulation at wider distance extend full capacity over longer distances.

- **Lower cost:** A standards based platform for WiMAX technology drives down costs delivering volume economics to WIMAX equipment.
- **Quality of Service (QoS):** The fundamental premise of the IEEE 802.16 MAC architecture is QoS. It defines Service Flows which can map to MPLS flow labels that enable end-to-end IP based QoS. Additionally, subchannelization and MAP-based signaling schemes provide a flexible mechanism for optimal scheduling of space, frequency and time resources over the air interface on a frame-by-frame basis.
- **Scalability:** Despite an increasingly globalized economy, spectrum resources for wireless broadband worldwide are still quite disparate in its allocations. Mobile WiMAX technology therefore, is designed to be able to scale to work in different channelizations from 1.25 to 20 MHz to comply with varied worldwide requirements as efforts proceed to achieve spectrum harmonization in the longer term. This also allows diverse economies to realize the multi-faceted benefits of the Mobile WiMAX technology for their specific geographic needs such as providing affordable internet access in rural settings versus enhancing the capacity of mobile broadband access in metro and suburban areas.
- **Security:** The features provided for Mobile WiMAX security aspects are best in class with EAP-based authentication, AES-CCM-based authenticated encryption, and CMAC and HMAC based control message protection schemes. Support for a diverse set of user credentials exists including; SIM/USIM cards, Smart Cards, Digital Certificates, and Username/Password schemes based on the relevant EAP methods for the credential type.
- **Providing a wireless alternative to cable:** and digital subscriber line (DSL) for "last mile" broadband access.
- **Providing data**: telecommunications (VoIP) and IPTV services (triple play).
- **Providing a source of Internet connectivity:** as part of a business continuity plan[10].

3 CHARACTERISTICS OF WIMAX

3.1 Physical Layer

The Frequency range of WiMAX is in the ranges from 2 to 66 GHz while channel bandwidth has the possibility of being adjusted within the range from 1.5-20 MHz, which provides the opportunity to fully utilize frequency spectrum in distributed channel bandwidth. WiMAX signals are scattered as macro cells, which had maximum coverage up to 50km. While channel bandwidth of 20 MHz will provide and support sharing data transmission rate up to 70Mbit/s where the maximum coverage in this situation will be 3-5 km. The system capacity can be expanded using multi-Sector technology and provide support for more than 60 business users and while thousands of home user having E1/T1 at the same time. The adoption of latest new technologies within WiMAX to ensure NLOS and LOS transmission. These technologies such as OFDM diversity when receiving or transmitting and adaptive modulation and these technologies have improved the efficiency of wireless transmissions in the cities. There are two kinds of wireless duplex multiple access, which is supported on a physical layer such as TDD/DMTA and FDD/TDMA, to ensure WiMAX is able to adopt telecom requirements in different regions. The physical layer also supports single carrier (SC), OFDM (256 points), and OFDMA (2048 points) and they are selected flexibly as needed. There might be changes in physical layer due to transmission channel performance. The physical layer parameters of modulation mode can be changed in order to provide better transmission quality[11].

3.2 MAC LAYER

WiMAX MAC layer has three sub-layers which are Service Specific Convergence Sub-layer (CS), Common Part Sub-layer (CPS) and Privacy Sub-layer (PS)[12].

- **Service Specific Convergence Sub-layer (CS)**

  The primary function CS is defined as that it is used to convert and map the data received from the external network by SAP to MAC SDU and later on transmit it to the SAP of MAC layer. The various external protocols are provided with a multiple CS specification by this protocol.

- **Common Part Sub-layer (CPS)**

  The core of MAC layer is CPS, which is providing the main function of system access, bandwidth allocation, connection establishment and connection maintenance. CPS receives data from multiple CS layers via MAC SAP, which classifies them into particular MAC connections and in the meantime, QoS controls are implemented to ensure data is transmitted and sent to the physical layer.

- **Privacy Sub-layer (PS)**

  PS provides basic function of authentication, key exchange and encryption/decryption processing.

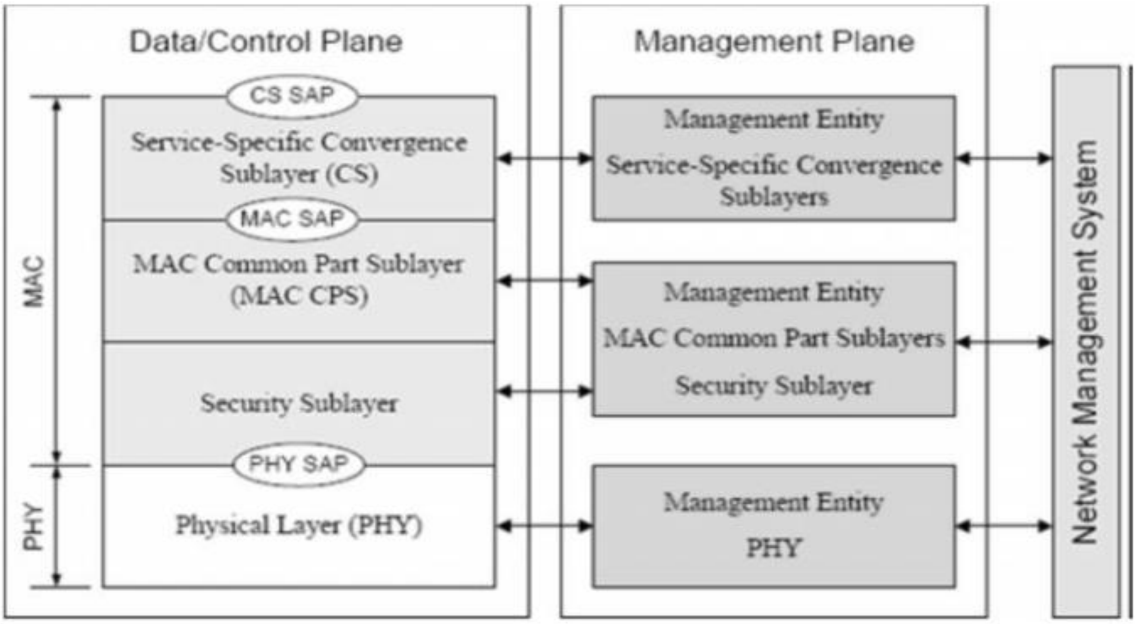


Figure 1. 2 MAC Layer and PHY Layer of WiMAX [11]

4 MAIN TECHNOLOGIES OF WIMAX

4.1 WIMAX Mechanism

WiMAX is capable of working in different frequency ranges but according to the IEEE 802.16, the frequency band is 10–66 GHz. A typical architecture of WiMAX includes a base station built on top of a high rise building and communicates on point-to-multi-point basis with subscriber stations which can be a business organization or a home. The base station is connected through customer premise equipment with the customer. This connection could be an LOS or an NLOS.

- **Line of sight (LOS):** In LOS connection, signal travels in a straight line which is free of obstacles, which means, a direct connection exists between a transmitter and a receiver. LOS requires its most of the Fresnel zone to be free from obstacles, but if the signal path is blocked by any means, the strength of the signal decreases signify cantly resulting in poor connectivity. There must be a direct link between a WiMAX base station and the receiver in LOS environment as shown in Figure 1.3. The following are the features of LOS connections[13]:
  - Uses higher frequency between 10 and 66 GHz
  - Huge coverage area
  - Higher throughput

- Less interference
- Threat only comes from atmosphere and the characteristic of the frequency
- Requires most of its first Fresnel zone to be free of obstacles

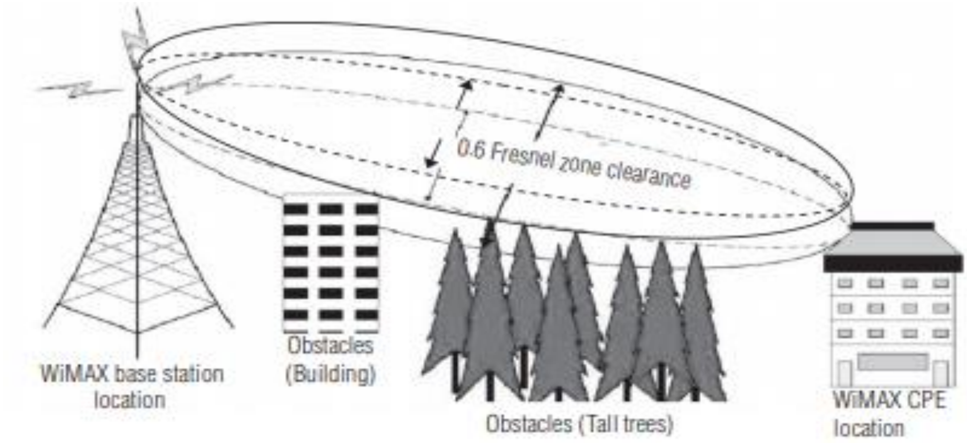


Figure 1. 3 WiMAX in LOS condition

- **Non-line of sight (NLOS):** In NLOS connection, signal experiences obstacles in its path and reaches to the receiver through several reflections, refractions, diffractions, absorptions, and scattering. These signals arrive at the receiver in different times with different attenuation and strength which makes it hard to detect the actual signal. WiMAX shows good performance in NLOS condition as it is based on orthogonal frequency division multiplexing (OFDM), which can handle delays caused in NLOS perfectly. WiMAX offers other following benefits which work well in NLOS condition[13]:
    - Frequency-selective fading can be overcome by applying adaptive equalization.
    - Adaptive modulation and coding (AMC), AAS, and multiple-input multiple-output (MIMO) techniques help WiMAX to work efficiently in NLOS condition.
    - Sub-channelization permits to transmit appropriate power on sub-channels.
    - Based on the required data rate and channel condition, AMC provides the accurate modulation and code dynamically. • AAS directs WiMAX BS to a subscriber station.

- MIMO helps to improve the signal strength and throughput in both stations.
- In NLOS condition, the speed is high, but the coverage area would be lower than that of LOS condition. WiMAX in NLOS condition is shown in Figure 1.4.

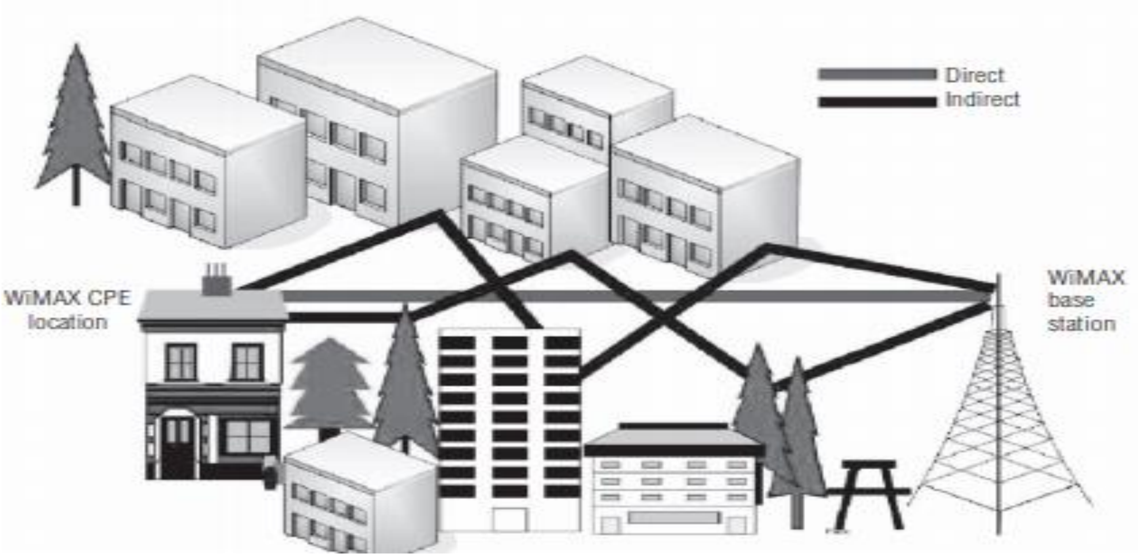


Figure 1. 4 WiMAX in NLOS condition[13]

4.2 MIMO

Single antenna has long been perceived as the natural way of building a wireless communication system, but recent studies unveiled that the use of multiple antennas can significantly enhance the reliability and/or increase the capacity substantially. The reliability originates from the beamforming and spatial diversity effects, while the high data rate originates from the spatial multiplexing effect of the multiple antenna system. Multiantenna technologies may be categorized into adaptive antenna system (AAS) and multi-input multi-output (MIMO) technologies: AAS technology is intended to take advantage of the beamforming (BF) effect, and the MIMO technology is intended to take advantage of space diversity (SD) or spatial multiplexing (SM)[14].

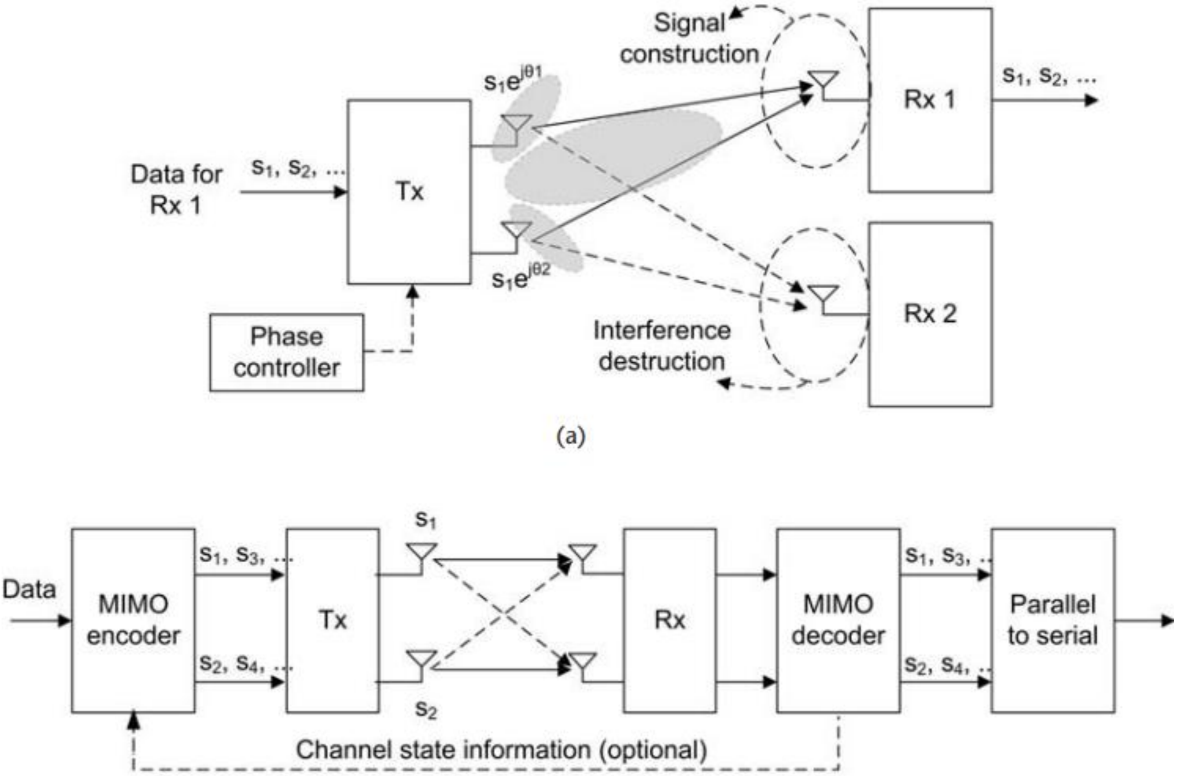


Figure 1. 5 Illustration of AAS and MIMO operations: (a) AAS, and (b) MIMO. [14]

One of the strong features of WiMAX is the support of smart antenna technologies and multiple antennas which help to increase the throughput which can be attained in a given transmission environment[2]. MIMO (multiple input and multiple outputs) systems were invented at the time when was really needed. MIMO uses space-time coding (STC) its element array and that benefits in spectrum efficiency within the specific bandwidth and which makes MIMO one of the main technology for WiMAX, LTE, 802.11n and all other superior wireless technologies, usually called wireless communication systems for the future[15].

MIMO is the type of technology which uses multiple transmitting and receiving antennas and which is improved for each user according to QoS. When the comparison is done between MIMO technology and traditional single element system, MIMO provides a better amortization rate of the frequency spectrum, due to which it provides better data transmission with higher speed under limited bandwidth. Especially in systems such as WiMAX 802.16e system, uses MIMO and OFDMA to ensure and better coverage and doubles the WiMAX system capacity and including the cost of network establishment and maintenance are reduced and due to development in the field of mobile WiMAX has greatly improved[16].

4.3 OFDM

OFDM is a digital encoding and modulation technology. It has been used successfully in wireline access applications, such as Digital Subscriber Line (DSL) modems and cable modems as well as WiFi. Products from WiMAX Forum member companies are using OFDM-based 802.16 systems to overcome the challenges of NLoS propagation. OFDM achieves high data rate and efficiency by using multiple overlapping carrier signals instead of just one. All future technologies for 4G will be based upon OFDM technology[17].OFDM is a multicarrier transport technology for high data rate communication system. The OFDM concept is based on spreading the high speed data to be transmitted over a large number of low rate carriers. The carriers are orthogonal to each other and frequency spacing between them are created by using the Fast Fourier transform (FFT)[9]. the Fast Fourier transform enables 52 channels to overlap without losing their individual characteristics. This allows the channels to be processed at the receiver end more effectively. OFDM is known for its resistance to forms of interference and degradation and is widely used in Wireless applications.

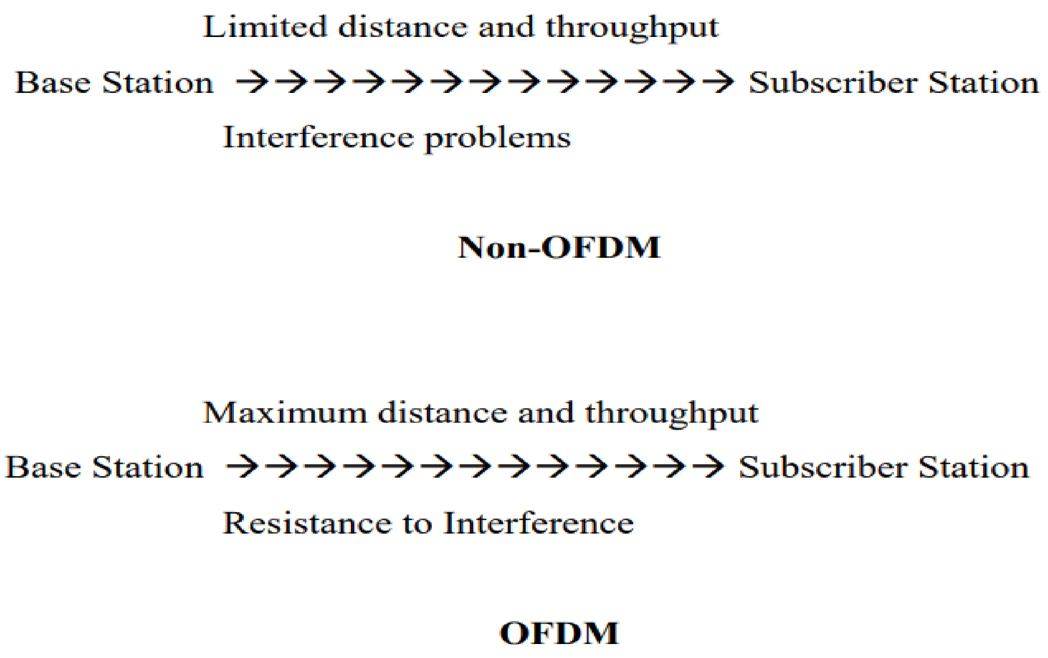


Figure 1. 6 : Significance of OFDM: A focused beam delivering maximum bandwidth over maximum distance with minimum interference [18]

OFDM is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers—often called subcarriers, or tones. The subcarrier makes non-flat channels with different frequency options and every subchannel is relatively flat and narrowband transmission is completed on subchannels with signal less than the corresponding bandwidth of the channel. Multicarrier modulation schemes eliminate or minimize intersymbol interference (ISI) by making the symbol time large enough so that the channel-induced delays—delay spread being a good measure of this in wireless channels— are an insignificant (typically, <10 percent) fraction of the symbol duration [19].

Orthogonal frequencies are formed by placing the peak of one sinc pulse on to the zeros of the adjacent sinc functions. This gives no interference component mixing from one orthogonal frequency centered at peak of a sinc function in to other frequency. This closely packed structure gives rise to improved spectral efficiency. This organization of the peak of one sinc on to the zero of other to form orthogonal frequencies is shown in the Figure 1.7 [20].

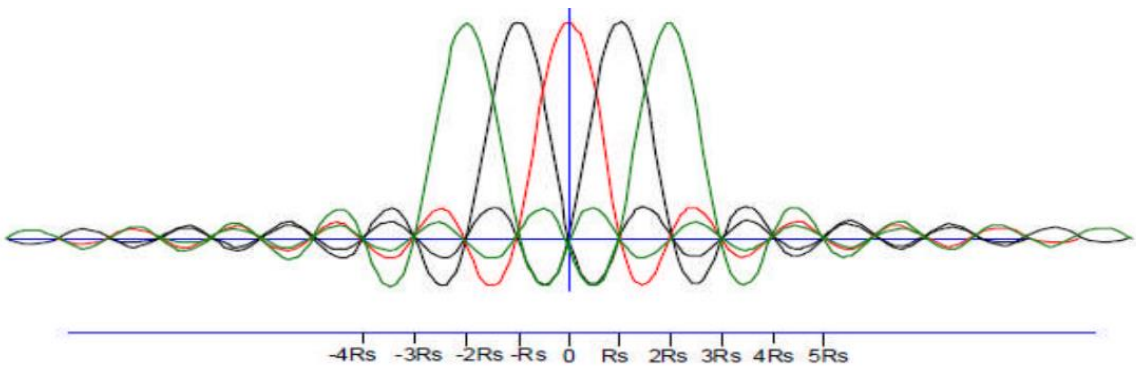


Figure 1. 7 Orthogonal Frequency Division Modulation (OFDM) Tutorial[20]

OFDM originates from Frequency Division Multiplexing (FDM). In FDM, separation of signal at the receiver is achieved by placing the channels sufficiently far apart so that the signal spectra does not overlap. Of course, the resulting spectral efficiency is very low as compared with OFDM, where a comparison is depicted in Fig 1.8.

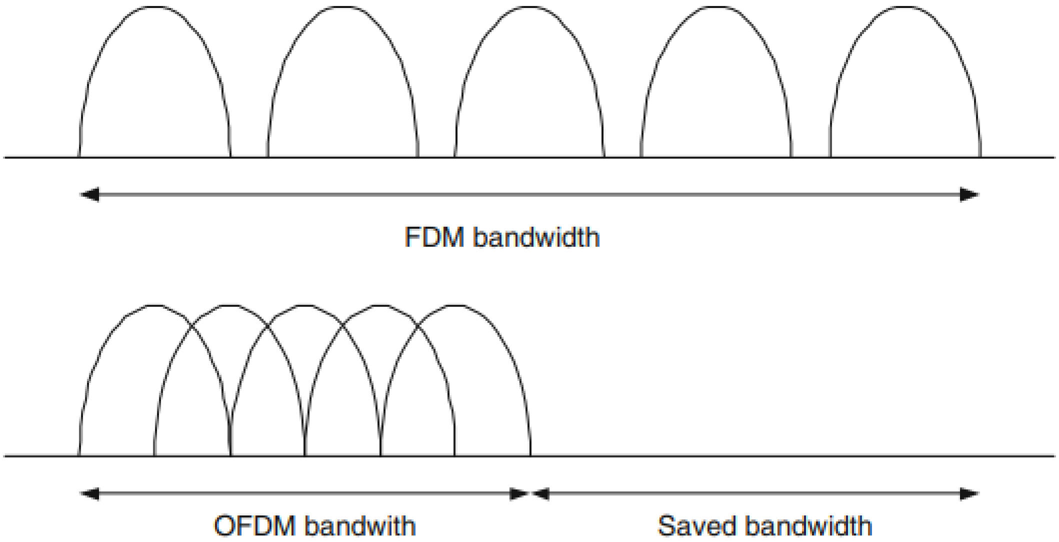


Figure 1. 8 Comparison of OFDM and FDM [9]

4.3.1 OFDM System implementation

At the transmitter side, an OFDM system treats the source symbols as though they are in the frequency-domain. These symbols are feed to an IFFT block which brings the signal into the time-domain. If the N numbers of subcarriers are chosen for the system, the basic functions for the IFFT are N orthogonal sinusoids of distinct frequency and IFFT receive N symbols at a time. Each of N complex valued input symbols determines both the amplitude and phase of the sinusoid for that subcarrier. The output of the IFFT is the summation of all N sinusoids and makes up a single OFDM symbol. The length of the OFDM symbol is NT where T is the IFFT input symbol period. In this way, IFFT block provides a simple way to modulate data onto N orthogonal subcarriers.

At the receiver side, The FFT block performs the reverse process on the received signal and bring it back to frequency-domain. The block diagram in Figure 1.9 depicts the switch between frequency-domain and time domain in an OFDM system[13].

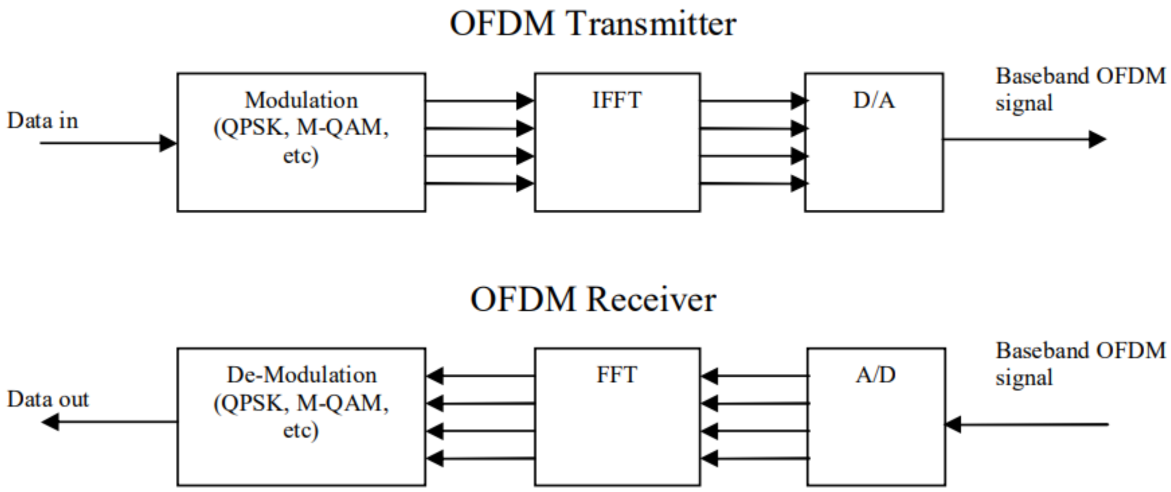


Figure 1. 9 Basic OFDM transmitter and receiver[13]

4.3.2 Advantages of OFDM

CDMA is old technology which is being replaced by OFDM in a new generation of core technology in wireless communication network systems and the main reason of this changes the features and advantages of OFDM and these are[19]:

- **Higher frequency spectrum efficiency**

  It approaches the Nyquist limit theoretically with sub-carriers, which partly overlap the FFT processing. It effectively ensures the avoids the interference between the users using OFDM- based which establishes the orthogonality of different users in a particular area capacity.

- **Good expandability of bandwidth**

  OFDM system can provide good expandability of bandwidth due to its ability to include many sub-carrier where OFDM system based on quantity of subcarriers used. Due to this feature its ability to realize bandwidth from few to hundreds of KHz to as large as hundreds of MHz. It can provide service of mobile broadband communication from 5MHz to maximum 20MHz above the support of OFDM system to bigger bandwidths.

- **Anti-multipath-fading**

  Broadband transmission is transformed by OFDM into narrowband transmission on different sub-carriers and sub-carriers in the channel can be accepted as a horizontal fading channel which reduces the complexity of the received equalizer. In other words, the multipath equalization sharply increases complexity of the single carrier as there is increase of bandwidth for which broader bandwidth is hard to support

- **Frequency spectrum resource for flexible allocation**

  The OFDM system use and select a suitable sub-carriers establishes a dynamic Frequency allocation where number resources, and it's also fully uses the frequency diversity which provides optimum system performance for multiuser diversity.

- **Realization of MIMO**

  OFDM each channel subcarriers are accepted as a horizontal fading channel where additional complexity is created by the MIMO system and which is controlled in lower level and with the quantity of antenna presents a linear increase. Where the complexity of each single carrier within the MIMO system is in direct relation to the power of the product by multiplying the quantity if quantity of multi-paths and antennae which negatively affects the implementation of MIMO [21]

4.3.3 Disadvantages

In spite of various advantages there are various disadvantaged of OFDM systems.

- High sensitivity to Doppler shift
- Sensitive to frequency synchronization problems
- High peak-to-average-power ratio (PAPR)
- Intercarrier Interference (ICI) between the subcarriers
- Requires a more linear power amplifier[22].

4.4 OFDMA

Orthogonal Frequency Division Multiple Access (OFDMA) is enhanced OFDM and used in Mobile WiMAX technology and the IEEE 802.16e-2005 standard, and it is the foundation for the next-generations of mobile broadband to come. It is a multi-user version of Orthogonal Frequency-Division Multiplexing (OFDM). The difference between the two technologies is that OFDMA assigns subsets of sub-carriers to individual users allowing simultaneous low data rate transmission from several users[17].

OFDMA is a multi-user version of the popular OFDM digital modulation scheme. Multiple Access is achieved by assigning subsets of sub-carriers to individual users. This allows simultaneous low data transmission rate from several users. OFDMA is fast growing in several applications which are the heart of next generation of wireless communication[23]. The bandwidth resources are allocated as per user on demand, which ensures system resources easily optimized. It is ensured that there is no interference between users to achieve idea synchronization as different users occupy nonoverlapped subcarriers [4].

In the downlink, a subchannel can be provided for different groups of receivers; in the upstream direction (uplink), an issuer assigns one or more subchannels, and several transmitters can transmit simultaneously. Subcarriers forming a single subchannel, but do not need to be adjacent[24].

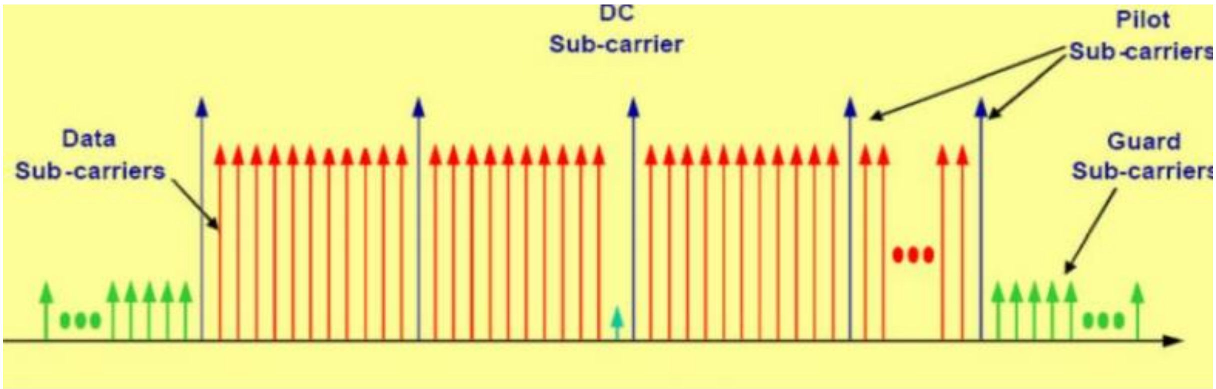


Figure 1. 10 Frequency description of the OFDMA [24]

In figure 1.11 shows illustrates an overview of the Physical Layer (PHY) for WiMAX base-station with scalable OFDMA based on IEEE 802.16e-2005 [23].

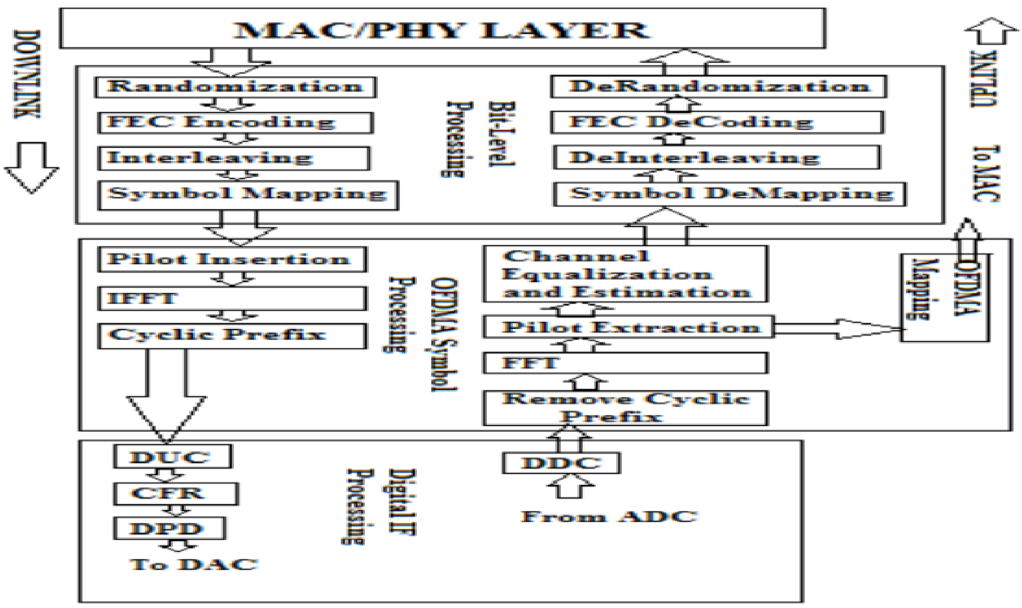


Figure 1. 11 Overview of IEEE 802.16e-2005 Scalable OFDMA Physical Layer for WiMAX Base-stations

Existing FDMA was inefficient in using spectrum, since overlapping in spectrum bands was not allowed. OFDMA resolved this problem by securing orthogonality among the constituent subcarriers. OFDMA divides the given frequency band into multiple subcarriers, each of which is equally spaced, and modulates the user data on the subcarriers. Orthogonality implies that a subcarrier is not affected by another subcarrier, which is guaranteed because all the other subcarriers take value 0 when any of the subcarriers takes the peak value[14]. (9)52

In OFDMA first the available spectrum is divided into number of orthogonal subcarriers with the spacing of Δf between them (Δf =15 KHz and 10.94 KHz for LTE and WiMAX respectively) . Then fixed numbers of subcarriers are grouped together to form a Resource Block (12 and 18 subcarriers in LTE and WiMAX respectively). The RB is then defined in time for numbers of OFDM symbols in time (5–14 symbols) depending on the system configuration. RBs are then grouped in the frame 10ms in case of LTE and 5ms in case of WiMAX. Base station who is the main controller of the RB assigns one or many units of it to an active user for data transmission. The physical representation of the OFDMA subcarrier and time allocation for different users can be graphically represented as in the Figure 1.12[20].

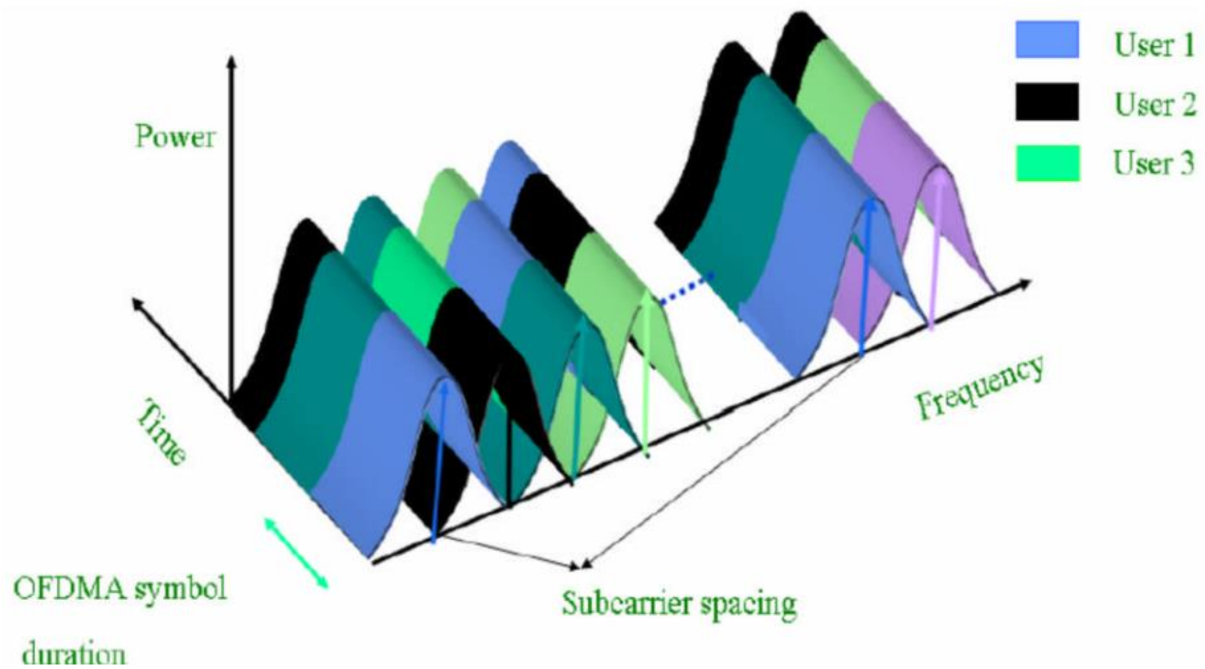


Figure 1. 12 Time and frequency resource allocation to users in OFDMA[23]

4.5 Adaptive Modulation

WiMAX system supports adaptive modulation to regulate the Signal Modulation Scheme (SMC) depending on the Signal to Noise Ratio (SNR) state of the radio link. When the radio link is soaring in quality, the peak modulation scheme is used, offering the system additional capacity. During a signal fade, the WiMAX system can move to a lower modulation scheme to keep the connection quality and link permanence. This element allows the system to overcome time-selective fading. The key element of adaptive modulation is that it enhances the range that a higher modulation scheme can be used over, because the system can bend to the actual fading circumstances, as opposed to having a fixed scheme that is planned for the worst case situations[5].

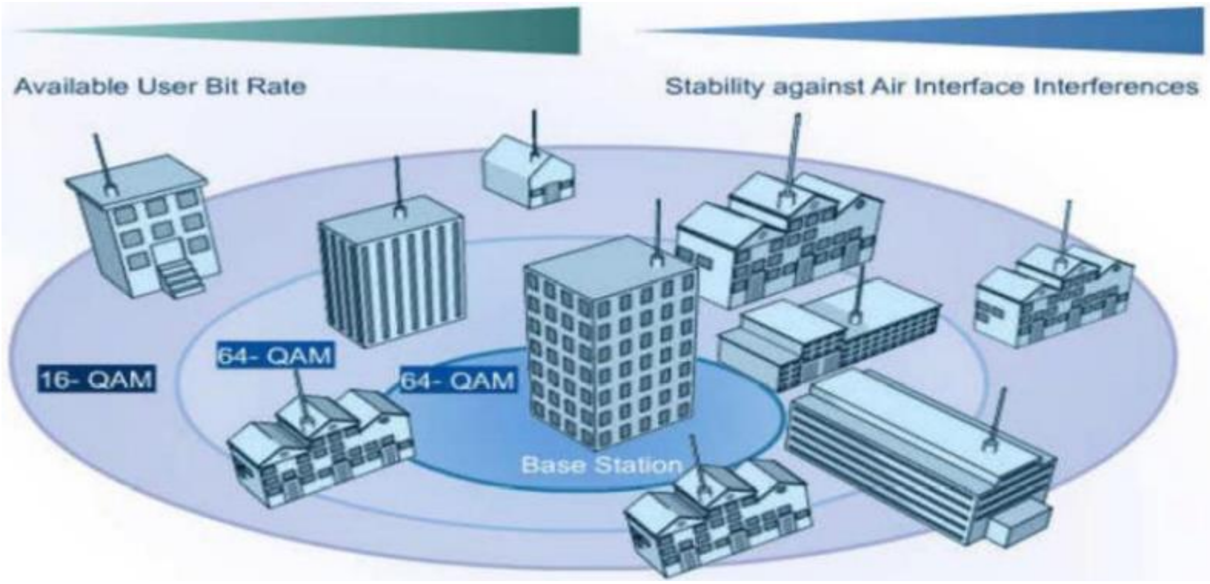


Figure 1. 13 Adaptive Physical Layer

4.6 Duplexing techniques

Duplexing is the process used to create bidirectional channels for the transmission of data in uplink and downlink, knowing that the multiplexing used is of the type TDM (time division multiplexing). The 802.16 2004 standard supports 2 duplexing techniques [24]:

4.6.1 TDD (Time Division Duplexing):

Time division duplex (TDD) refers to duplex communication links where uplink is separated from downlink by the allocation of different time slots in the same frequency band. It is a transmission scheme that allows asymmetric flow for uplink and downlink data transmission. Users are allocated time slots for uplink and downlink transmission[25].

Instead TDD systems use the same channel for UL and DL transmission separating them in the time domain. Each channel consists of one DL and one UL sub-frame as illustrated in Figure 1.14. TDD systems use guard intervals between the transition from DL to UL and from UL to DL. These guard intervals are called Transmit/receive Transition Gap (TTG) and Receive/transmit Transition Gap (RTG).

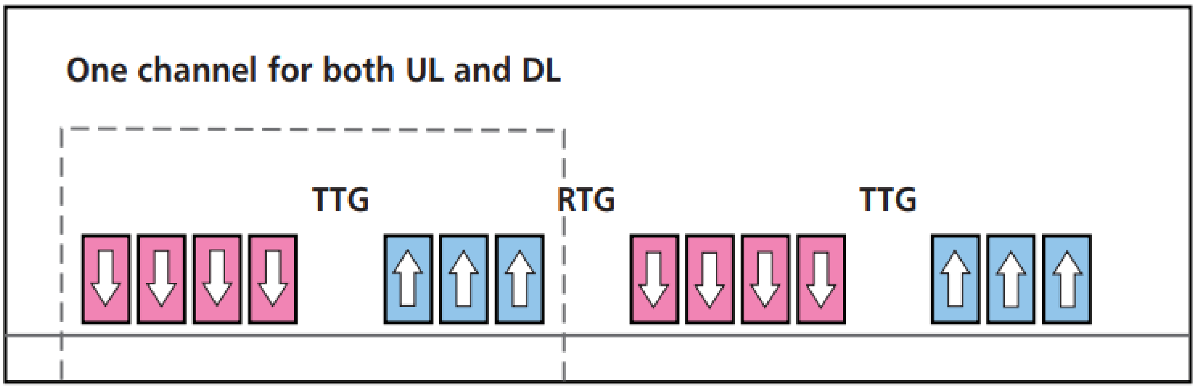


Figure 1. 14 TDD structure [26]

4.6.2 FDD (Frequency Division Duplexing):

Frequency division duplex (FDD) is a technique where separate frequency bands are used at the transmitter and receiver side. Because the FDD technique uses different frequency bands for send and receive operations, the sending and receiving data signals don't interfere with each other. This makes FDD a better choice than Time Division Duplex (TDD) for symmetric traffic such as voice applications in broadband wireless networks[25].

In FDD systems UL and DL transmissions are allocated separate frequency bands. The UL and DL channels are grouped into contiguous blocks of paired channels as shown in Figure 1. The paired UL and DL channels are typically separated by 100MHz. Thanks to the guard band between UL and DL, the interference of one FDD system with another is minimized.

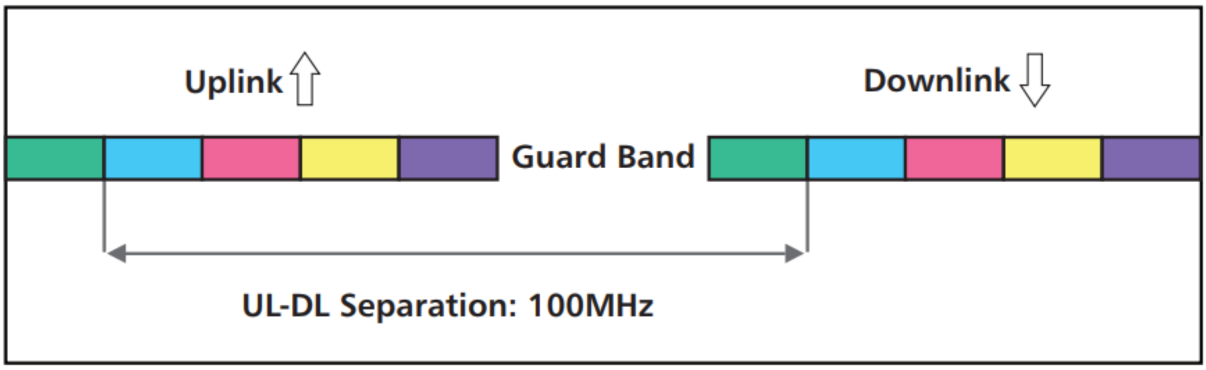


Figure 1. 15 Spectrum allocation in FDD systems [26]

5 WiMAX Core

Mobile WiMAX network architecture is based on the WiMAX Forum's Network Working Group (NWG) specification. The main components of WiMAX network architecture are shown in Figure 1.16. The components are[6]:

- Subscriber Station, SS / Mobile Station, MS: The Subscriber station, SS may often be referred to as the Customer Premises Equipment, CPE. These take a variety of forms and these may be termed "indoor CPE" or "outdoor CPE" - the terminology is self-explanatory. The outdoor CPE has the advantage that it provides better performance as a result of the better position of the antenna, whereas the indoor CPE can be installed by the user. Mobile Stations may also be used. These are often in the form of a dongle for a laptop, etc.

- Base Station, BS: The base-station forms an essential element of the WiMAX network. It is responsible for providing the air interface to the subscriber and mobile stations. It provides additional functionality in terms of micro-mobility management functions, such as handoff triggering and tunnel establishment, radio resource management, QoS policy enforcement, traffic classification, DHCP (Dynamic Host Control Protocol) proxy, key management, session management, and multicast group management.

- ASN Gateway, ASN-GW: The ASN gateway within the WiMAX network architecture typically acts as a layer 2 traffic aggregation point within the overall ASN. The ASN-GW may also provide additional functions that include: intra-ASN location management and paging, radio resource management and admission control, caching of subscriber profiles and encryption keys.

  The ASN-GW may also include the AAA client functionality (see below), establishment and management of mobility tunnel with base stations, QoS and policy enforcement, foreign agent functionality for mobile IP, and routing to the selected CSN.

- Home Agent, HA: The Home Agent within the WiMAX network is located within the CSN. With Mobile-IP forming a key element within WiMAX technology, the Home Agent works in conjunction with a "Foreign Agent", such as the ASN Gateway, to provide an efficient end-to-end Mobile IP solution. The Home Agent serves as an anchor point for subscribers, providing secure roaming with QOS capabilities.

- Authentication, Authorization and Accounting Server, AAA: As with any communications or wireless system requiring subscription services, an Authentication, Authorization and Accounting server is used. This is included within the CSN.

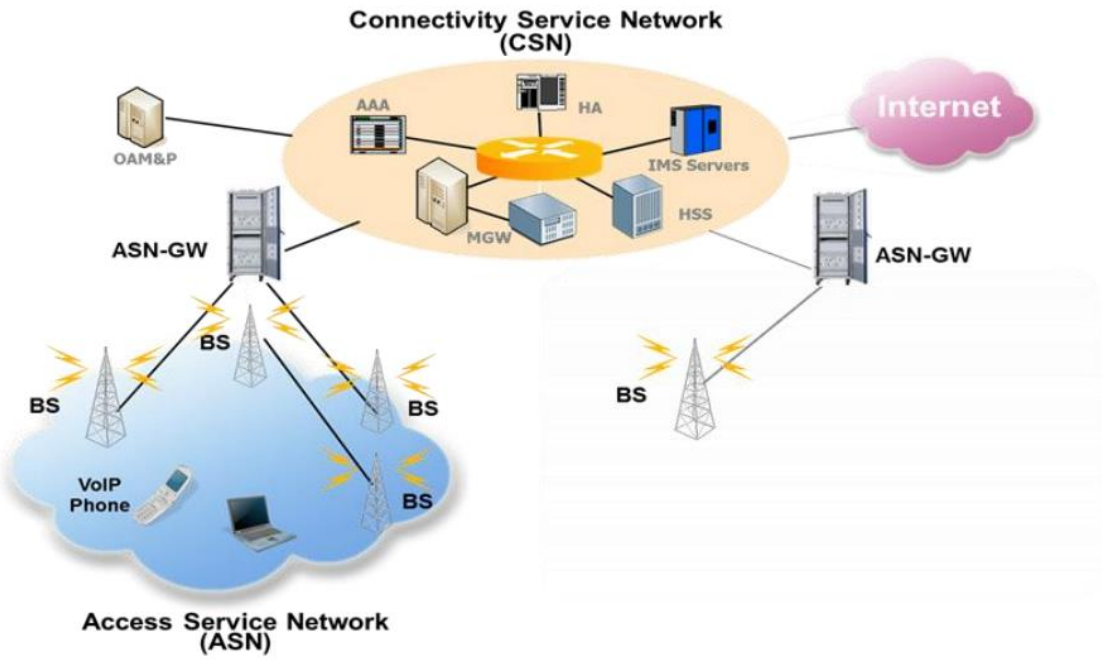


Figure 1. 16 WiMAX Network Architecture[6]

6 Quality of service

The term QoS refers to the averages of instantly regulating the routing of packets in networks. According to the needs of the users, the packages can transit more or less quickly in each network section depending on the load of links or network equipment. In case of saturation, some packages may be lost. Therefore, the QoS concept consists in how best to manage the packets and by which means[6]. Communication on the IP network is perceived less reliable in contrast to the circuit-switched public telephone network, as it does not provide a network-based mechanism to ensure that data packets are not lost and are delivered in sequential order. It is a best-effort network without fundamental Quality of Service (QoS) guarantees. A sequence of packets sent from a source to a destination is called a stream. The qualitative needs of a stream can be characterized by four parameters: the Bandwidth, the delay time , the variation of Jitter and the Packet loss[27].

Therefore, VoIP implementations may face problems with end to end delay, packet loss and jitter.

- Jitter is variations in delay of packet delivery and maximum acceptable value is 40ms.
- End to end delay is the time taken for a packet to be transmitted across a network from source to destination which should be less than 125ms.

- Packet loss is description of error condition on packets data that droop when too much traffic or poor network and 5% is the maximum suitable standard[6].

Any connection in WiMAX is accompanied by a service flow. A service flow is a bidirectional flow of data packets that guarantees a certain quality of service (QoS). Each service flow consists of a set of QoS parameter values. WiMAX supports four types of service flow: Unsolicited Grant Service (UGS), Real Time Polling Service (rtPS), Non Real Time Polling Service (nrtPS), and Best Effort Service (BES). The quality of service is guaranteed according to the Service Level Agreement (SLA) established between the provider and the user. The service flows are described as follows:

- **Unsolicited Grant Service (UGS):** This service is designed to support services depending on jitter delay or latency such as VoIP (Voice over IP). It offers a strict guarantee of speed and latency. It has as equivalent the CBR (Constant Bit Rate), service offered in ATM.
- **real time Polling Service (rtPS):** A service that supports data packets of varying sizes. These are usually multimedia streams like MPEG video. It offers guarantees for the bit rate, but gives a great tolerance for latency. Its ATM equivalent is the RT-VBR (Real Time Variable Bit Rate).
- **non real time Polling Service (nrtPS):** This service only guarantees the flow, it is intended for applications that do not depend on the latency time (like for example the emails). It is the service that supports very burst profiles. varied. In ATM, it is called NRT-VBR (Non RT-VBR).
- **Best Effort Service (BES):** This service does not give any guarantee but offers all possibilities for any application. It is mainly intended for applications like web access. In ATM, we speak of UBR[28].

7 WiMAX Simulation Tools

The best features of WiMAX are the accurate calculation and optimization of the Radio Frequency and Capacity, Network planning. To achieve this you have to choose the best simulation tool which works on the WiMAX system. Some of the most well-known and widely used simulation and planning tools are: OPNET tool, Planet EV, EDX (SignalPro), Provision Communication, Radio Mobile (Freeware), Atoll, CelPlan, ICS Telecom, Asset 3G/WiMAX, Winprop, Volcano Siradel, NS-2 (Freeware), NS-3 (Freeware), Qualnet NCTuns Network Simulator and Emulator[3].

8 WiMAX Applications and Services

The maturing of the WiMAX technology has made possible a number of new applications beyond data communications. The bandwidth and range makes WiMAX suitable for the following applications[17].

- Mobile broadband connectivity across cities and countries through a wide variety of devices.
- Fixed wireless broadband
- Wireless alternative to cable and digital subscriber line (DSL) for broadband access
- Data, telecommunications (VoIP) and IPTV services
- Internet connectivity
- Smart Grid and metering
- Smart Cities
- Public Safety
- Aviation
- Oil & Gas

There is a vast number of real time services and applications that are already provided on WiMAX networks. This means that service providers are not forced to develop special applications specifically for WiMAX. Few of such applications, which already exist on wired networks are classified under service classes and listed in Table 1.4.

Type of service class	Application	Required bandwidth
Interactive gaming	Interactive gaming	50–85 kbps
VoIP, video conference	VoIP Video phone	4–64 kbps 32–384 kbps
Streaming media	Music/speech Video clips Movies streaming	5–128 kbps 20–384 kbps > 2 Mbps
Media content download (store and forward)	Bulk data, movie download Peer-to-peer	> 1 Mbps > 500 kbps

Table 1. 3 WiMAX service classes and applications [27]

9 Security Functions

Unlike Wi-Fi, WiMAX systems were designed at the outset with robust security in mind. The standard includes state-of-the-art methods for ensuring user data privacy and preventing unauthorized access, with additional protocol optimization for mobility. Security is handled by a privacy sublayer within the WiMAX MAC. The key aspects of WiMAX security are as follow.

- **Support for privacy:** User data is encrypted using cryptographic schemes of proven robustness to provide privacy. Both AES (Advanced Encryption Standard) and 3DES (Triple Data Encryption Standard) are supported. Most system implementations will likely use AES, as it is the new encryption standard approved as compliant with Federal Information Processing Standard (FIPS) and is easier to implement.10 The 128-bit or 256-bit key used for deriving the cipher is generated during the authentication phase and is periodically refreshed for additional protection.
- **Device/user authentication**: WiMAX provides a flexible means for authenticating subscriber stations and users to prevent unauthorized use. The authentication framework is based on the Internet Engineering Task Force (IETF) EAP, which supports a variety of credentials, such as username/password, digital certificates, and smart cards. WiMAX terminal devices come with built-in X.509 digital certificates that contain their public key and MAC address. WiMAX operators can use the certificates for device authentication and use a username/password or smart card authentication on top of it for user authentication.
- **Flexible key-management protocol:** The Privacy and Key Management Protocol Version 2 (PKMv2) is used for securely transferring keying material from the base station to the mobile station, periodically reauthorizing and refreshing the keys.
- **PKM is a client-server protocol:** The MS acts as the client; the BS, the server. PKM uses X.509 digital certificates and RSA (RivestShamer-Adleman) public-key encryption algorithms to securely perform key exchanges between the BS and the MS.
- **Protection of control messages:** The integrity of over-the-air control messages is protected by using message digest schemes, such as AES-based CMAC or MD5-based HMAC.
- **Support for fast handover:** To support fast handovers, WiMAX allows the MS to use preauthentication with a particular target BS to facilitate accelerated reentry. A three-way handshake scheme is supported to optimize the reauthentication mechanisms for supporting fast handovers, while simultaneously preventing any man-in-the-middle attacks. [19](4)54

10 Conclusion

In this chapter, we introduced different IEEE 802.16 of WiMAX standard technologies. Fixed WiMAX (IEEE 802.16) is a digital wireless metro network access technology that has many advantages such as long-distance accessibility, high speed, low cost and variety of use and also offers good QoS level for fixed subscriber stations. The mobile version of WiMAX (IEEE 802.16e), is a promising technology that offers good QoS for mobile devices that move at a maximum speed of 120 km / h. The range, as well as the bit rates offered by this technology depend on the user environment (rural or urban area ...).

CHAPTER 2:

MOBILITY MANAGEMENT IN MOBILE WiMAX

1 INTRODUCTION

With the convergence of the Internet and wireless mobile communications and with the rapid growth in the number of mobile subscribers, mobility management emerges as one of the most important and challenging problems for wireless mobile communication over the Internet. Mobility management enables the serving networks to locate a mobile subscriber's point of attachment for delivering data packets (i.e. location management) and maintain a mobile subscriber's connection as it continues to change its point of attachment (i.e. handover management) [29]. In this chapter we have focusing on the handover management in WiMAX network.

2 Introduction to Mobile WiMAX Network

WiMAX continues the developments on different stages to support the mobility. it supports subscriber stations (SCs) moving at vehicular speeds, thereby Specification it introduced a system for combined fixed and mobile broadband Wireless Access (BWA), the mobility services also known as mobile WiMAX. System used 4G (Fourth generation) system to solve the problems of 3G (Three generation) systems. 4G designed to give new services like high-quality voice to high-definition video to high –data-rate wireless channels. Video conferencing contains the transfer of audio and video between two users point to point (PTP) or among multiple users multiple users to multiple users (MTM). The video is encoded as a series of video frames, with frame rates ranging from 8 frames per second (fps) for low-bandwidth, video with low quality, to 30 fps or higher for video with high-quality. The video is compressed by using lossy compression codes like MPEG-4 or H.264 to save bandwidth. VoIP voice over IP may deliver voice communications and multimedia sessions over Internet Protocol (IP). This process includes fragmentation defragmentation of voice, isolation of jam signals and then compression the voice signal with the use of compression/decompression (coding/ encoding) algorithms. The communication basic role in WiMAX network consists of one Base Station (BS) and one or more Subscribers Station (SS)[29].

3 Mobile WiMAX Network Configuration

Based on IEEE 802.16 and IEEE 802.16e specifications, the NWG of the WiMAX Forum defines functionalities and protocols for network entities in a WiMAX network and reference points between these entities. These network entities are logical components and may be integrated together on a physical network node. The reference point is a conceptual interface between network entities and is associated with a set of protocols. While logical entities collocate on a network node, reference points between entities may be implicit. Figure 2.1 illustrates the system architecture of a Mobile WiMAX network[30].

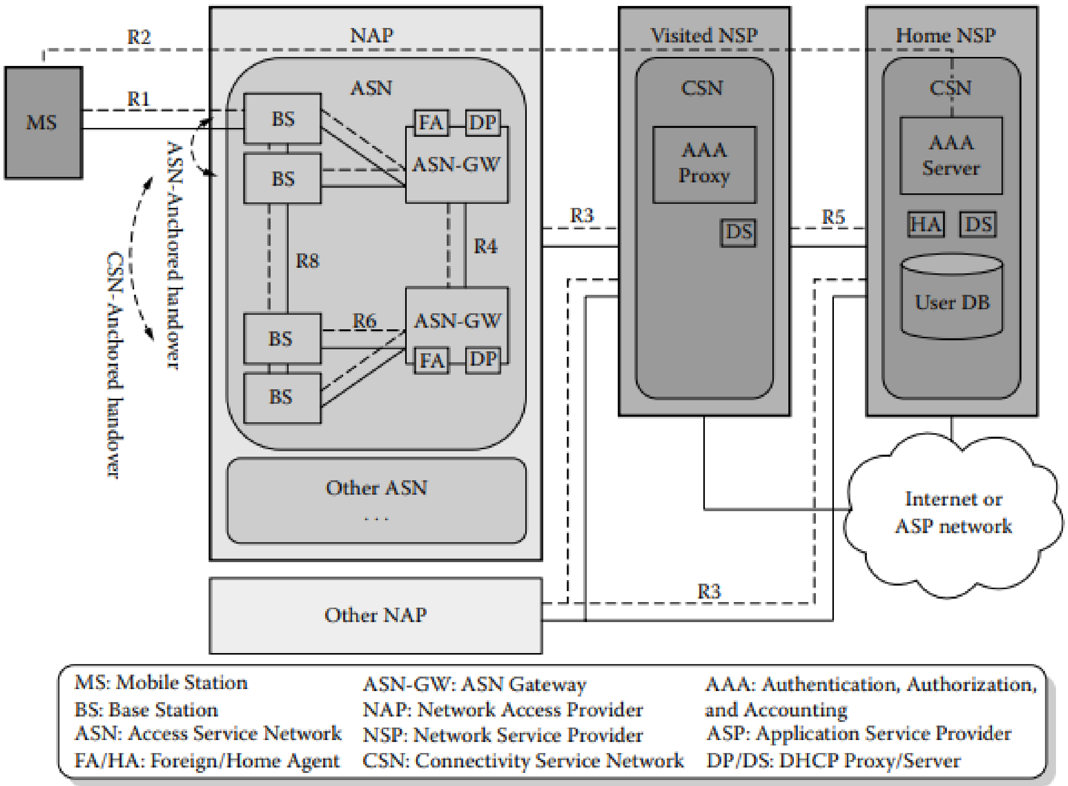


Figure 2. 1 System architecture of a mobile WiMAX network[31].

A Mobile WiMAX network consists of three major components: mobile stations (MSs), network access providers (NAPs), and network service providers (NSPs). The R1 reference point is the interface between the MSs and BSs, and it implements control and data protocols conforming to IEEE 802.16 and IEEE 802.16e standards. Moreover, an MS further needs to establish the R2 logical connection with its home authentication, authorization, and accounting (AAA) server for authentication and authorization purposes. A NAP that establishes, operates, and maintains WiMAX networks is an operator for access networks. A NAP may own several ASNs that are deployed in different geographical locations. An ASN is an access network infrastructure to which an MS attaches, and it consists of a number of base stations (BSs) that are controlled by one or more ASN-gateways (ASN-GWs). An ASN-GW is a gateway between an ASN and a CSN for a NSP. It serves as a relay node to tunnel MS packets between ASNs and specific CSNs that MS associate with. An ASN plays an important role to process MS packets from and to CSNs, handles mobility management functions such as ASN-anchored handover and mobile Internet protocol (IP) foreign agent (FA), implements security functions such as an authenticator and key distributions, and manages radio resources of the BSs in an ASN. The R4, R6, R7, and R8 reference points are defined in an ASN. The R4 is an interface between ASN-GWs and it is mainly used for transferring control plane messages for mobility management and forwarding data packets between ASN-GWs during handover. The R6 reference point defines control and data plane protocols between BSs and an ASN-GW. The R8 is an interface for transferring control plane packets and, optionally, data packets between BSs. The R8 facilitates fast and seamless handover between BSs. The ASNs of an NAP further connect to an NSP which owns WiMAX service contracts with end customers. An NSP operates a CSN, which manages subscribers' information such as service policies, AAA records, etc[31].

There are multiple levels of mobility in WiMAX, they are namely IEEE 802.16 air interface mobility, access service network gateway (ASN-GW) re-anchoring mobility, and connectivity service network (CSN) mobility, as shown in Figure 2.2. The IEEE 802.16 air interface mobility covers functions to complete the migration of MAC and PHY layers from one serving BS to a target BS. As long as the serving BS and target BS are served by the same ASN-GW, the handover can be completed through MAC state migration and packet forwarding from the serving BS to the target BS. ASN-GW re-anchoring happens when the MS is transferred to a target BS belonging to a different ASN-GW. This is IP based and it involves a mobile IP registration with the home agent in the core network[30].

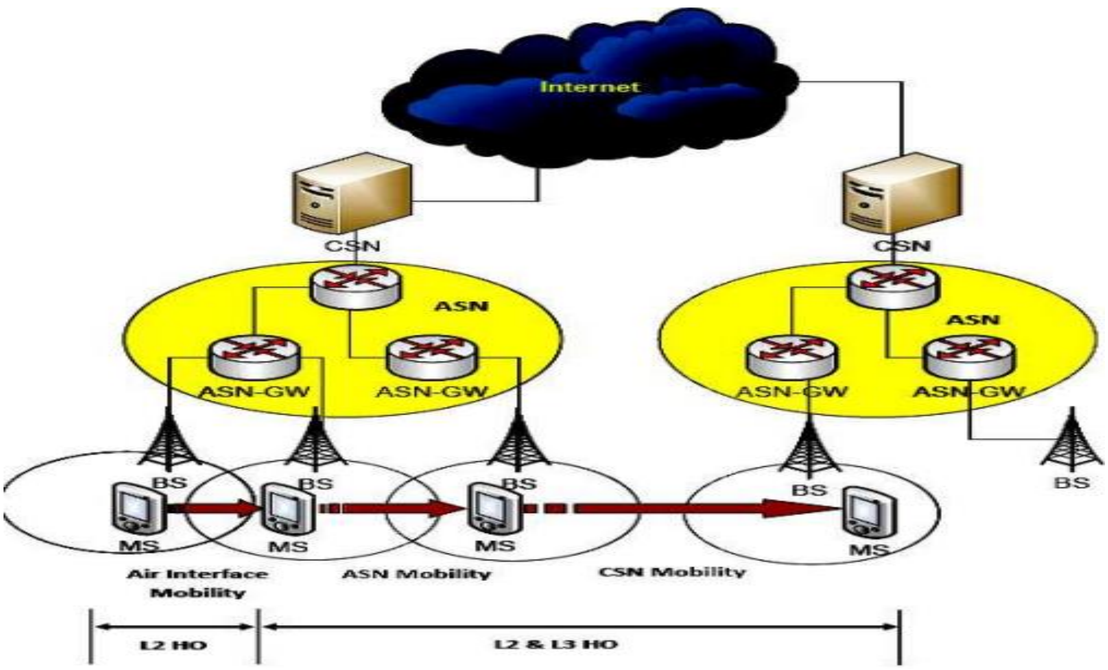


Figure 2. 2 Mobility levels in WiMAX network

4 Power Management

Mobile WiMAX supports two modes for power efficient operation: Sleep Mode and Idle Mode.

Sleep Mode is a state in which the MS conducts pre-negotiated periods of absence from the Serving Base Station air interface. These periods are characterized by the unavailability of the MS, as observed from the Serving Base Station, to DL or UL traffic. Sleep Mode is intended to minimize MS power usage and minimize the usage of the Serving Base Station air interface resources. The Sleep Mode also provides flexibility for the MS to scan other base stations to collect information to assist handoff during the Sleep Mode.

Idle Mode provides a mechanism for the MS to become periodically available for DL broadcast traffic messaging without registration at a specific base station as the MS traverses an air link environment populated by multiple base stations. Idle Mode benefits the MS by removing the requirement for handoff and other normal operations and benefits the network and base station by eliminating air interface and network handoff traffic from essentially inactive MSs while still providing a simple and timely method (paging) for alerting the MS about pending DL traffic[32].

5 Handover

Handover can be explained as it’s a process which helps and ensures a stable connection to the mobile station (MS) while it's on the move from an area of the one base station (BS) to another base station. While the BS which provides connection to MS is called to serve base station, which is updated when Mobile Station is Moving from the area of one BS to another BS. The new base station BS will provide services to MS when the handover is completed and that new BS is called target BS. Blow Sections will provide information and overview available in a different version of WiMAX standards with the support of full mobility.

Handover refers to the mechanism by which an ongoing session is transferred from one BS to another. Therefore, a handover decision mechanism is indispensable function of a cellular network. The decision for handover could be based on several parameters: signal strength, signal to interference ratio, distance to the base station, velocity, load, etc. The performance of the handover mechanism is extremely important in mobile cellular networks, in maintaining the desired quality of service (QoS)[33].

For instance, figure 2.3 illustrates a typical signal strength reading as mobile station traverses to another cell. A handover decision may be triggered either when the target signal strength is higher than serving signal strength or when serving signal strength falls below a threshold. One can see that former may induce handover early but sustain better quality connection; however, the latter induces robust but poor-quality connection since wireless channel introduces random large-scale variation in the received signal strength and handover decision mechanism based on measurements of signal strength induces the "ping-pong" effect, frequent handovers due to false triggers. Frequent handovers influence the QoS, increase the signaling overhead on the network, and degrade throughput in data communications[14].

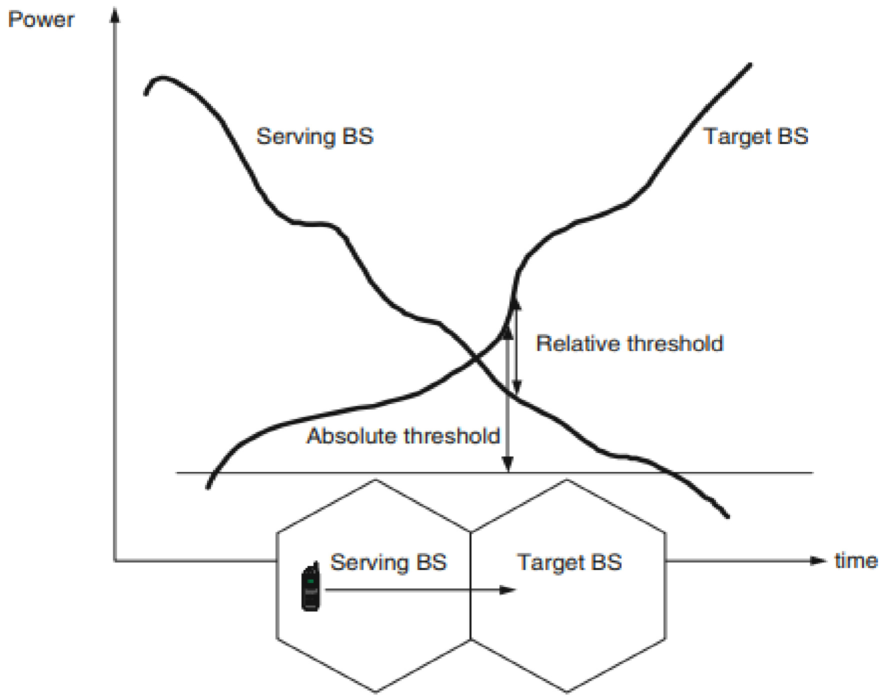


Figure 2. 3 HO decision [14]

5.1 Types of Handover in Mobile WiMAX

As mentioned earlier, handover is a mechanism to maintain uninterrupted user communication session during a user's movement from one location to another. Handover mechanism handles MS switching from one BS to another. Mobile WiMAX supports three types of handovers: Hard handover (HHO), fast base-station switching (FBSS) handover and macro-diversity handover (MDHO). Of these, the HHO is mandatory, while FBSS and MDHO are two optional modes(MDHO and FBSS are known as soft handover)[30].

5.1.1 HARD HANDOVER

During the hard handover, a MS communicates with just one BS in each time. All connections with a serving BS are broken before new connections to a target BS is established. It means that there is a very short time interval when the MS is not connected to any BS. Handover is executed after an observed channel parameter (e.g. signal strength) from a neighboring BS exceeds the same parameters from the serving BS. This situation is shown in Figure 2.4.

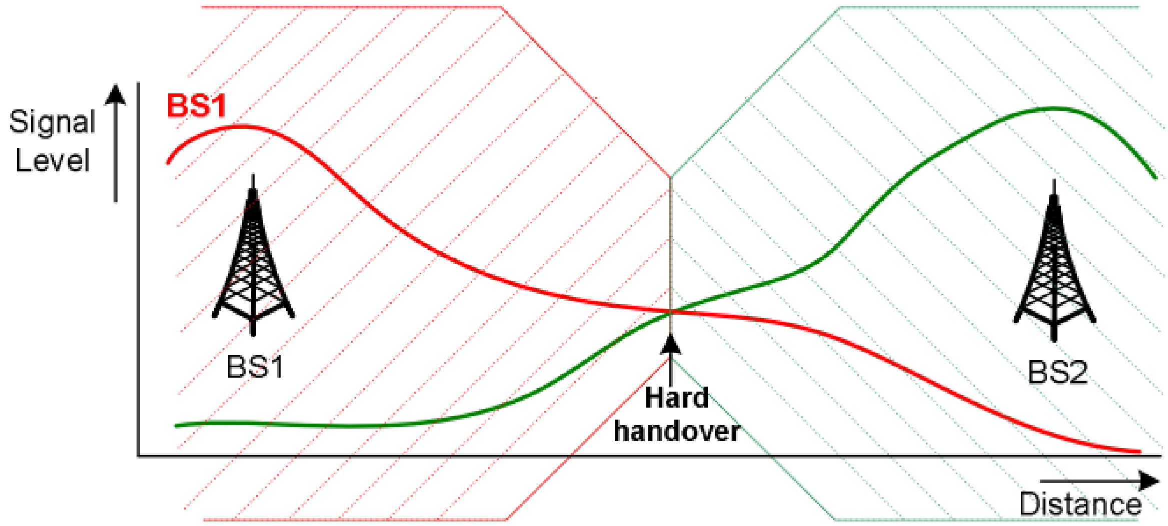


Figure 2. 4 Hard handover

This type of handover is less complex and fairly simple. However it causes higher delay of packet[34].

5.1.2 MACRO DIVERSITY HANDOVER

When the MDHO is supported by a MS as well as by BSs, a diversity set (in some publications, usually focused on UMTS or LTE (Long Term Evolution), noted as active set) is maintained by the MS and BSs. The diversity set is a list of BSs, which are involved in the handover procedure. The diversity set is maintained by the MS and by the BSs. It is updated via MAC (Medium Access Control) management messages. A transmission of these messages is usually based on a CINR (Carrier to Noise plus Interface Ratio) level of BSs and it depends on two thresholds defined for addition and deletion of a BS from the diversity set: Add Threshold and Delete Threshold. Threshold values are broadcasted in DCD (Downlink Channel

Descriptor) message. The diversity set is defined for each MS in the network. The MS continuously monitors all BSs in the diversity set and selects an anchor BS. The anchor BS is one of the BSs from diversity set. The MS is synchronized, authorized and registered to the anchor BS. Furthermore, the MS performs ranging and monitors a downlink channel of anchor BS for control information. The MS communicates simultaneously (including user traffic) with the anchor BS and with all active BSs in the diversity set (see Figure 2.5)[34].

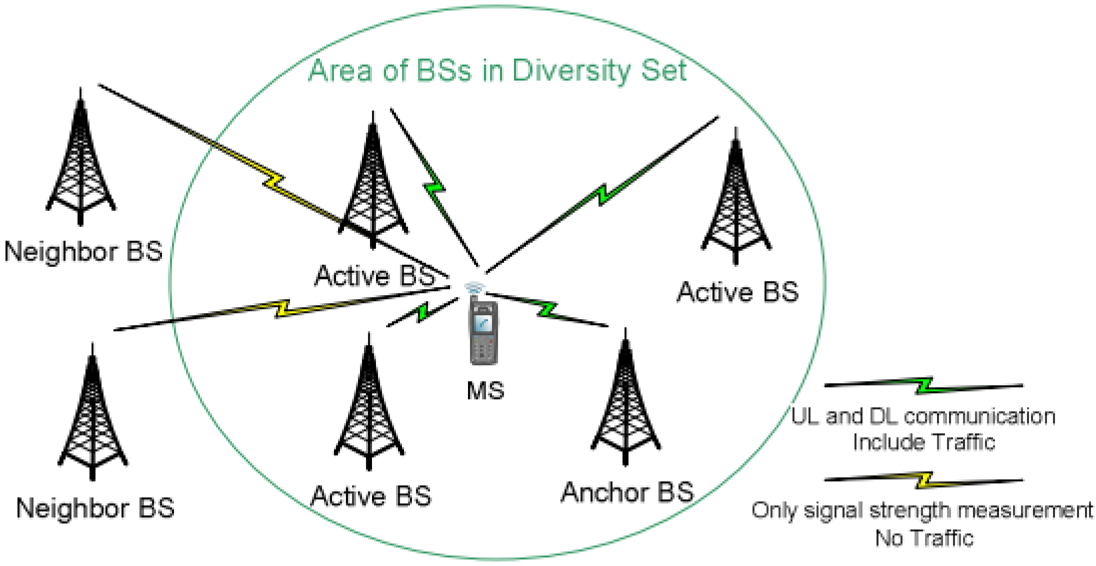


Figure 2. 5 Macro Diversity Handover

In downlink direction, two or more BSs transmit data to the MS such that diversity combining can be performed by the MS. In uplink direction, the MS transmission is received by multiple BSs. Consequently, a selection diversity of received information is performed. The BS, noted as neighbor BS, can receive communication among the MS and other BSs, however signal level received by the MS from this BS is not sufficient to add the neighbor BS to the diversity set[34].

5.1.3 FAST BASE STATION SWITCHING

In FBSS, the diversity set is maintained by a MS and by BSs exactly as in the case of MDHO. Opposite to the MDHO, the MS communicates only with anchor BS for all types of uplink and downlink traffic including management messages (see Figure 2.6). When the MS is connected to just one BS, thus the diversity set contains only this one BS that must be termed the anchor BS. The anchor BS can be changed on frame to frame basis depending on a BS selection scheme. This means that every frame can be sent via different BS in the diversity set.

The anchor BS updating procedure is based on the same principle as the diversity set update[34].

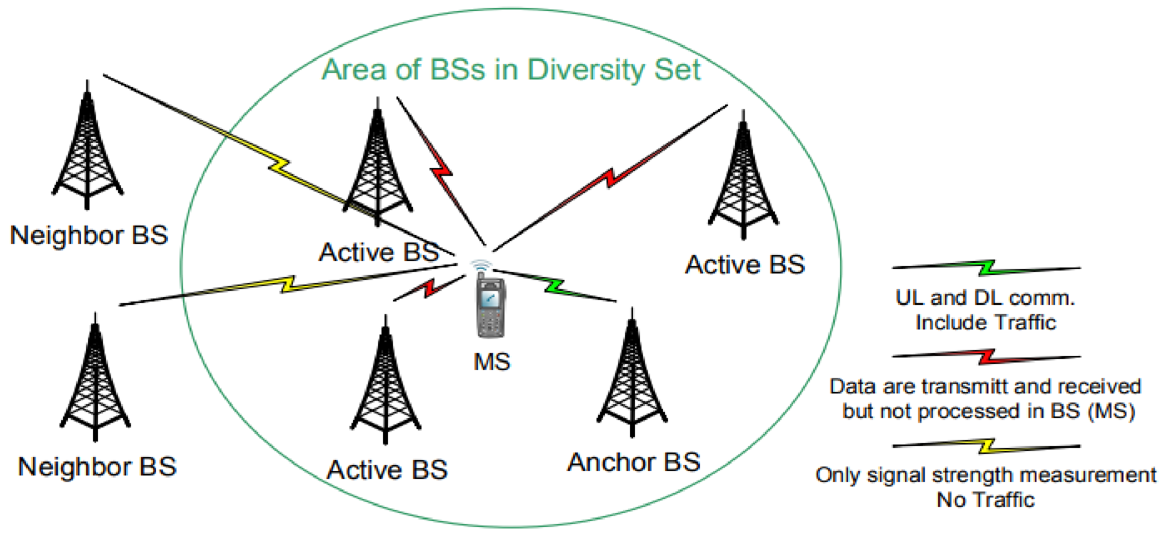


Figure 2. 6 Fast Base Station Switching

5.1.4 Characteristics of hard handover vs. soft handover

Although hard HO (HHO) is more bandwidth-efficient than soft HO, it causes longer delay and greater loss of packets. Thus, optimization of HHO mechanism becomes one important research areas for mobile WiMAX. The objective of this optimization is to reduce HO latency to make it suitable for real-time applications. Soft HO such as MDHO or FBSS normally is more complex and adds significantly to the hardware costs in IEEE 802.16e. Although the mandatory handover technique in WiMAX is HHO, the study of spectral efficiency of downlink traffic in multi-hop relay system (802.16e) as simulated. A summary of the characteristics of various handover types is listed in Table 2.1[30].

	Hard Handover (HHO)	**Soft Handover (SHO)**
Complexity	Less	High
Disruption time	High	Less
Packet loss	High	Less
Network resources	Use less resources	Use more resources
Additional hardware	Not required	required
Extra radio link	Not required	MS consume extra radio link

Table 2. 1 Characteristics of hard handover vs. soft handover

5.2 WiMAX handover procedures

The handover procedure can be separated into several phases: network topology advertisement, cell reselection via scanning, handover decision and initiation, and network re-entry including synchronization and ranging with a TBS as shown in Fig 2.7[35].

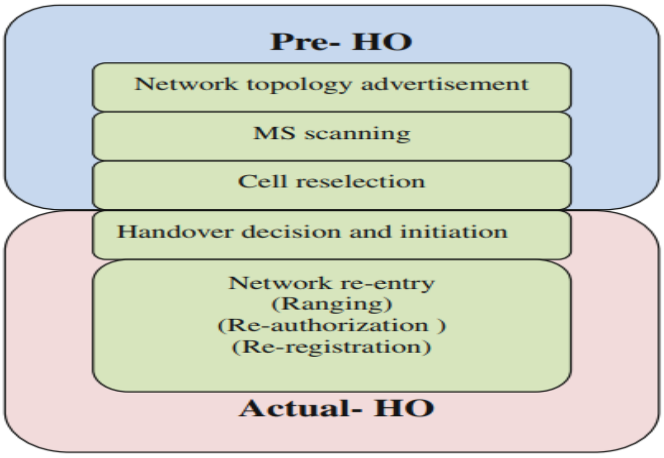


Figure 2. 7 Handover procedure in mobile WiMAX system

5.2.1 Network Topology Advertisement

A BS broadcasts information about the network topology using the MOB_NBR-ADV (neighbor Advertisement) MAC management message. This message provides channel information about neighboring BSs normally provided by each BS's own DCD/UCD message transmissions. The MOB_NBR-ADV does not contain all the information of neighboring BSs, UCD and DCD. The standard indicates that a BS may obtain that information over the backbone and that availability of this information facilitates MS synchronization with neighboring BS by removing the need to monitor transmission from the neighboring (handover target) BS for DCD/UCD broadcasts. The BSs will keep mapping tables of neighbor BS MAC addresses and neighbor BS indexes transmitted through the MOB_NBR-ADV message, for each configuration change count, which has the same function as for the DCD message[36].

5.2.2 MS scanning procedure

Based on the information provided by the MOB_NBR-ADV, the MS becomes aware of the neighbouring BSs and triggers the scanning and synchronization phase. Indeed, to handoff, the MS needs to seek available BSs and check if they are suitable as possible target BSs. Therefore, the MS sends MOB_SCN-REQ message to the serving BS indicating a group of neighbouring BSs for which a group of scanning intervals is requested. The MOB_SCN-REQ message includes the requested scanning interval duration, the duration of the interleaving interval, and the requested number of scanning iterations. In the example illustrated in Figure 2.8, these parameters correspond to P frames, N frames, and T iterations, respectively. Note that the scanning phase could be triggered by the serving BS. If it is the case, the serving BS shall send to the MS a MOB_SCNRSP message indicating a list of recommended neighbouring BSs.

Upon reception of the MOB_SCN-REQ message, the serving BS responds with a MOB_SCN-RSP message. In this message, the serving BS either grants a scanning interval at least as long as the one requested by the MS (which is the case in our example of Figure 2.8) or rejects the request.

After receiving the MOB_SCN-RSP message granting the request, the MS may scan beginning at Start frame one or more BSs during the time allocated by the serving BS. Each time a neighbouring BS is detected through scanning, the MS may attempt to synchronize with its downlink transmissions and estimate the quality of the PHY channel to evaluate its suitability as a potential target BS in the future. The serving BS may ask (by setting the report mode field to 0b10 in the MOB_SCN-RSP) the MS to report the scanning results by transmitting a MOB_SCN-REP[3].

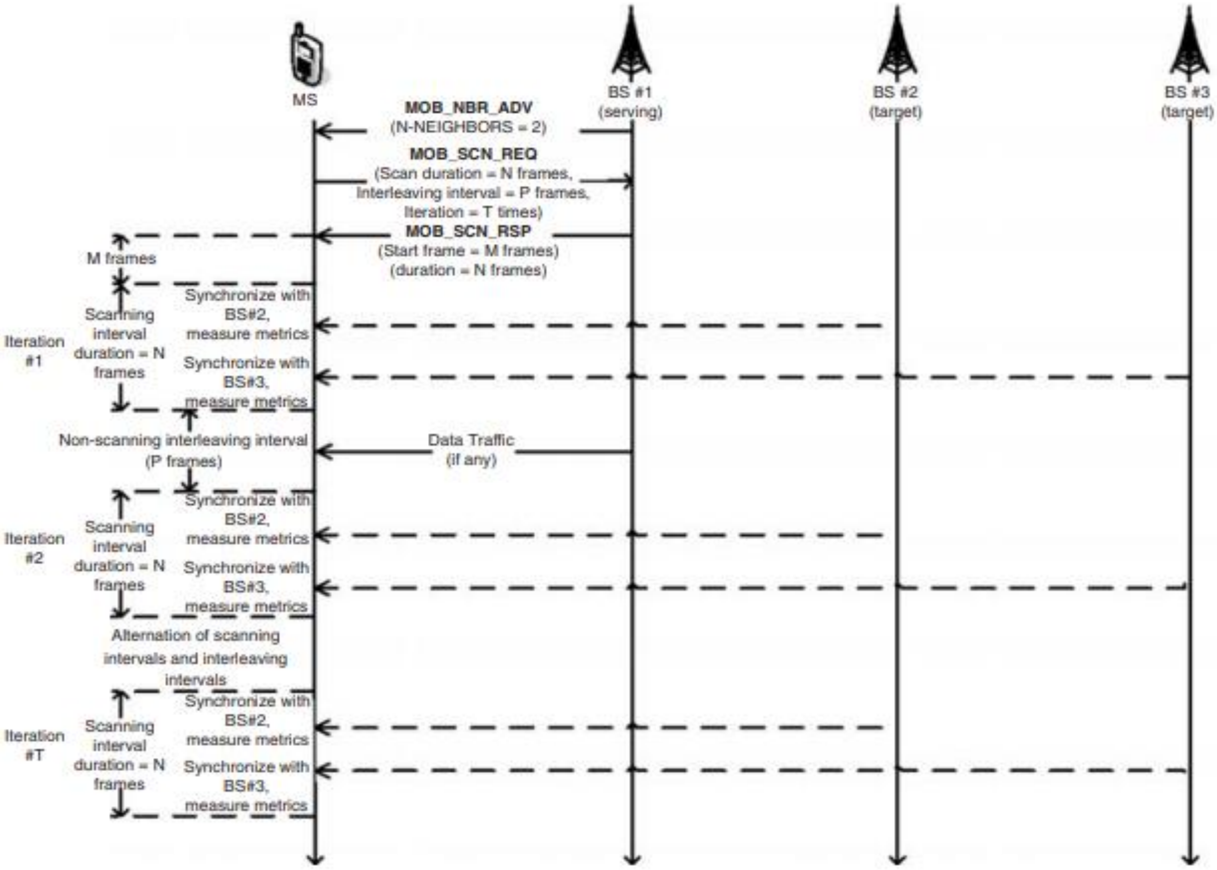


Figure 2. 8 Example of neighbour BS advertisement and scanning (without association) by MS request

During the scanning interval, the serving BS may buffer incoming data addressed to the MS and then transmit that data during any interleaving interval after the MS has exited the scanning mode. Depending on the value of the scanning type field indicated in the MOB_SCN-REQ, the MS may request either scanning only or scanning with association. The association procedure is an optional ranging phase that may be performed during the scanning interval. It enables the MS to acquire and record ranging parameters by adjusting the time offset, the frequency and the power level – to be used to choose a potential target BS. The standard IEEE 802.16e defines three levels of association[3]:

- Association Level 0 – scan/association without coordination: the target BS has no knowledge of the scanning MS and only provides contention-based ranging allocations (Figure 2.9).
- Association Level 1 – association with coordination: the serving BS coordinates the association between the MS and the requested neighbouring BSs. Each neighbor (NBR) BS provides a ranging region for association at a predefined “rendezvous time” (corresponding to a relative frame number). It also reserves a unique initial ranging code and a ranging slot within the allocated region. The NBR BS may assign the same code or ranging slot to more than one BS but not both, so that no potential collision may occur between transmissions of different MSs.
- Association Level 2 – network-assisted association reporting: the procedure is similar to level 1 except that the MS does not need to wait for RNG-RSP from the NBR BS. The ranging response is sent by the NBR BS to the serving BS over the backbone, which then forwards it to the MS.

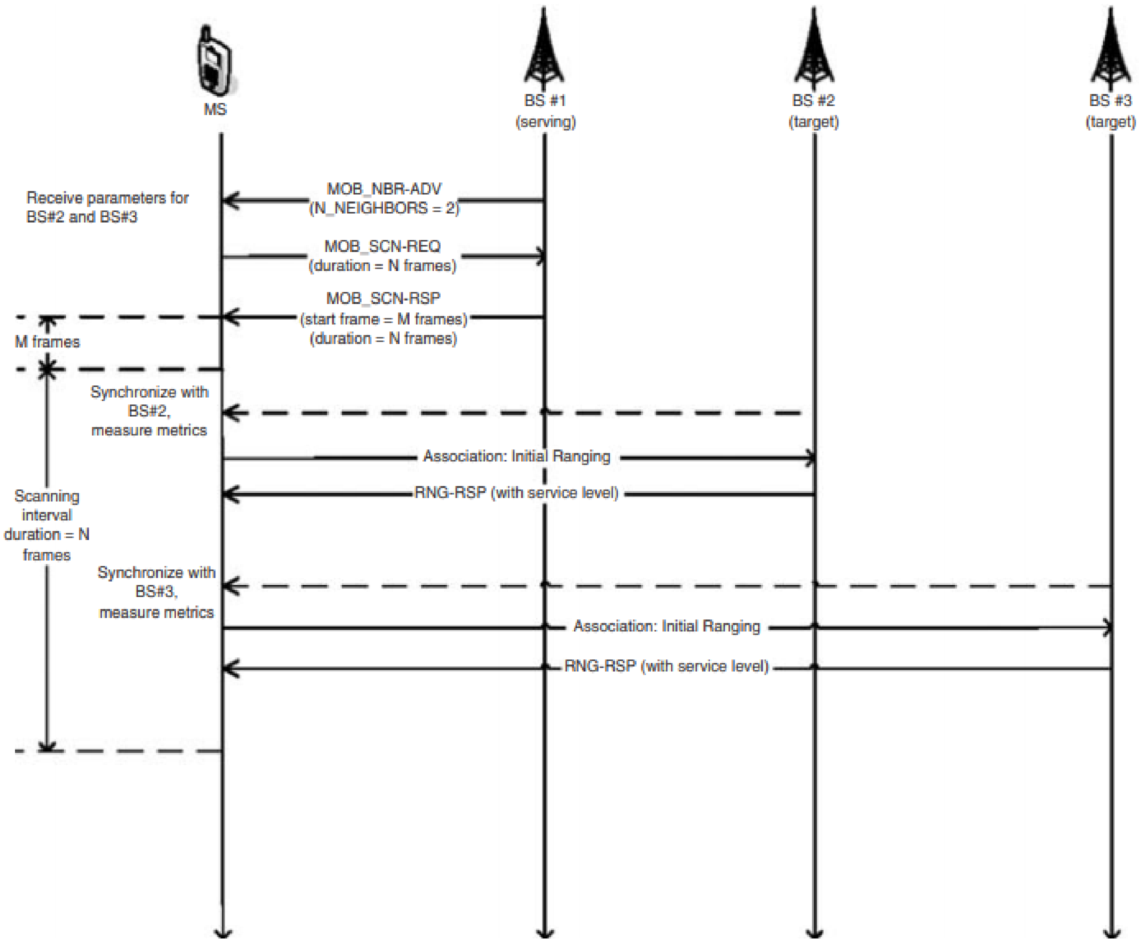


Figure 2. 9 Example of neighbour BS advertisement and scanning (with non-coordinated association) by MS request[3].

5.2.3 cell reselection

Cell reselection refers to the process of an MS scanning and/or association with one or more BS in order to determine their suitability, along with other performance considerations, as a handover target. The MS may use neighbour BS information acquired from a decoded MOB_NBR-ADV message or may make a request to schedule scanning intervals or sleep intervals to scan, and possibly range, the neighbour BS for the purpose of evaluating the MS interest in the handover to a potential target BS.223

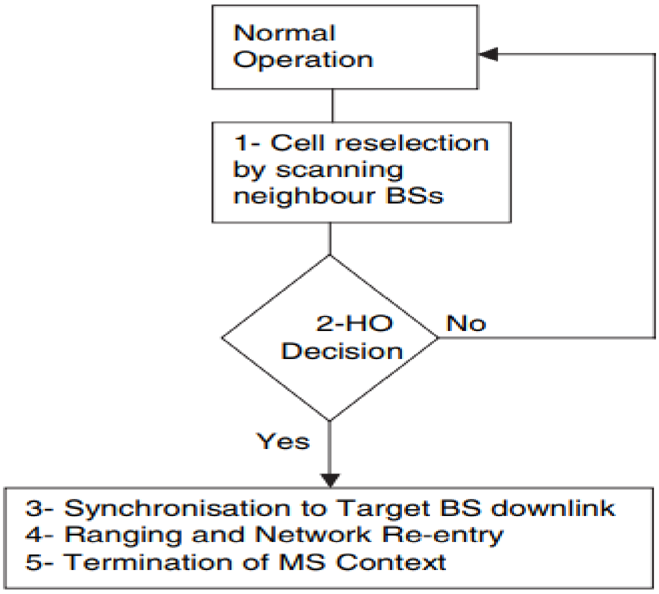


Figure 2. 10 Illustration of handover process stages[36]

5.2.4 handover decision and initiation

The HO trigger decision and initiation can be originated by both the MS and the BS using a MS HO Request message (MOB_MSHO-REQ) or a BS HO Request message (MOB_BSHO-REQ) respectively. Here we use the HO started by the MS as an example as illustrated in Figure 2.11. The MS makes a decision about which BS(s) is (are) its target(s). A HO begins with when the MS sends a MOB_MSHO-REQ message to its serving BS indicating one or more possible target BSs. The serving BS may obtain directly from potential target BSs the expected MS performance at the target BSs through the exchange of HO indication and response messages. After receiving a response from a target BS (MOB_BSHORSP), the MS notifies the serving BS about its decision to perform a HO by means of a HO Indication (MOB_HO-IND) message. The MS can also ask the serving BS to negotiate with the target BS the allocation of a ranging opportunity. If necessary, the MS may start ranging after HO initiation[37].

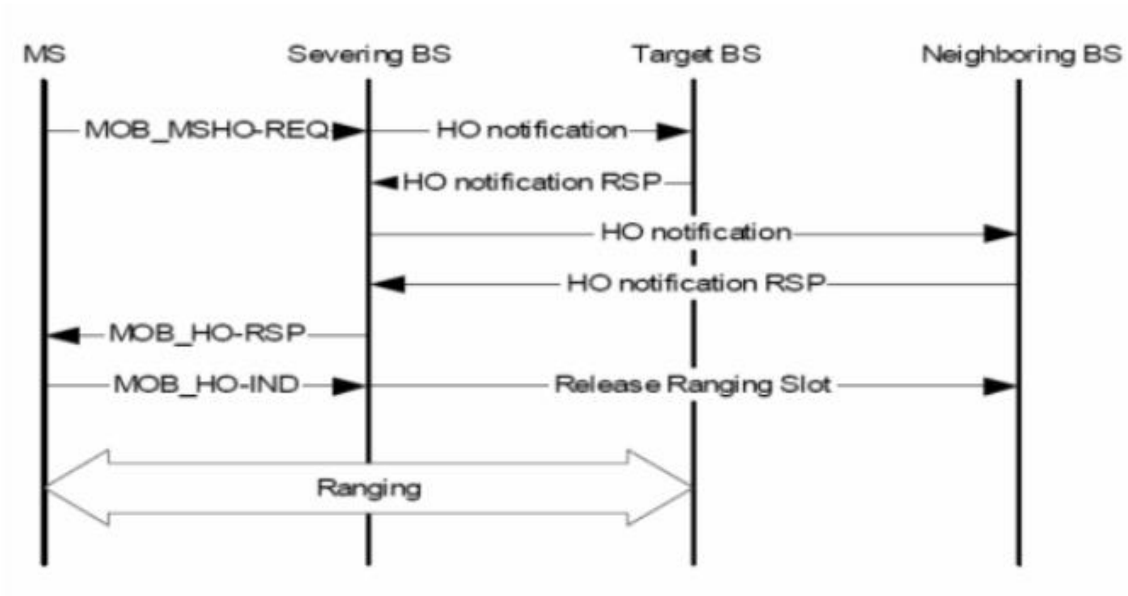


Figure 2. 11 Handover Decision and Initiation[37]

For the initialization of a HO procedure in MDHO and FBSS two thresholds are defined: Add Threshold (T_Add) and Delete Threshold (T_Delete) (see Figure 2.12). While the former threshold defines absolute signal level for adding of the BS into the diversity set, the latter threshold defines absolute level of the signal for removing of the BS from the diversity set. When one of these thresholds is met by the neighboring BS, the HO procedure can start[38].

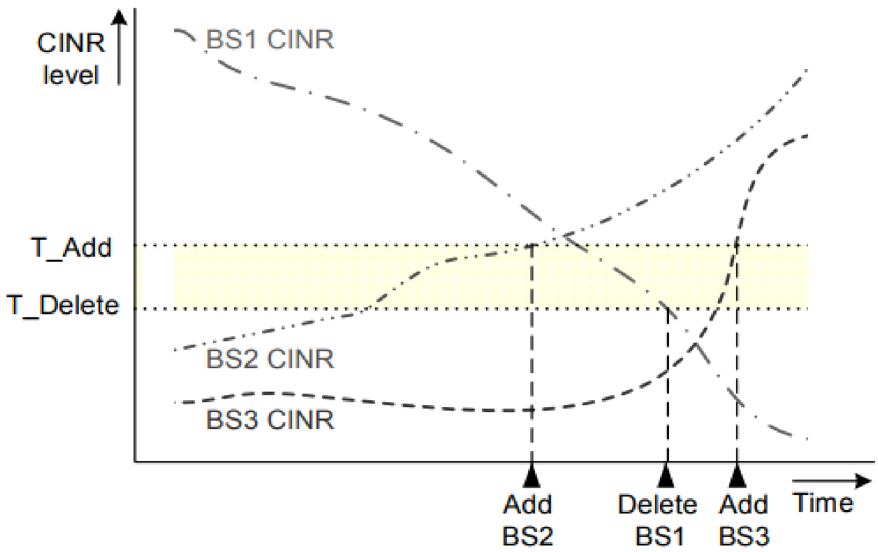


Figure 2. 12 Principle of HO initialization in MDHO and FBSS. Black arrows present the time instance of initialization of HO.

In case of HO, "Hysteresis margin" is used by the MS to include a neighbor BS to a list of possible target BSs. The neighbor BS is included in the list of possible target BSs if its CINR is larger than the sum of the CINR of the current serving BS and the hysteresis margin. The HO is initialized based on the comparison of signal level of the current serving BS and the possible target BS (see Figure 2.13).

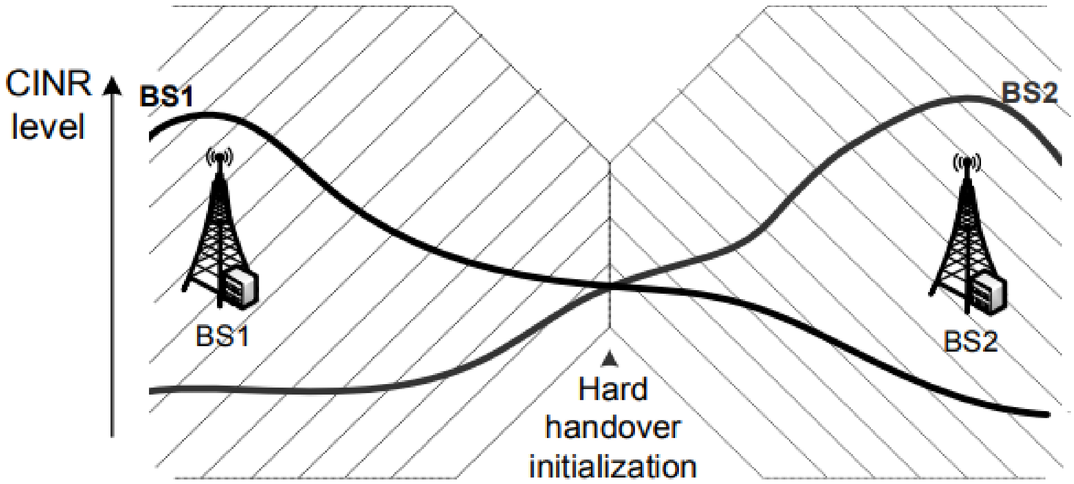


Figure 2. 13 Principle of hard HO initialization. The HO is initialized when the signal level from BS2 cross the signal level of BS2[38].

5.2.5 network re-entry

After the TBS is chosen and the MS sent the MOB_HO-IND message to the SBS, the network re-entry process begins as illustrated in Figure 2.14. The network re-entry process includes ranging, re-authorization and re-registration. The MS needs to synchronize with downlink transmission and obtain downlink and uplink transmission parameters with TBS. Then the MS starts exchanging Ranging Request message (RNG-REQ) and Ranging Response message (RNG-RSP) to complete the initial ranging process. This may be done contention-based or non-contention based. If RNG_REG contains the serving BSID, the target BS may obtain MS information from the serving BS through backbone network.

After the channel parameters have been adjusted, the MS can communicate with target BS to negotiate channel capability, perform authorization and conduct registration. The target BS requests MS authorization information from the Authorization server (AS) via backbone network. Then the new BS registration is performed with REG-REQ/RSP message. Processes including capabilities negotiation, MS authorization, key change, and registration can be abbreviated based on the association level.

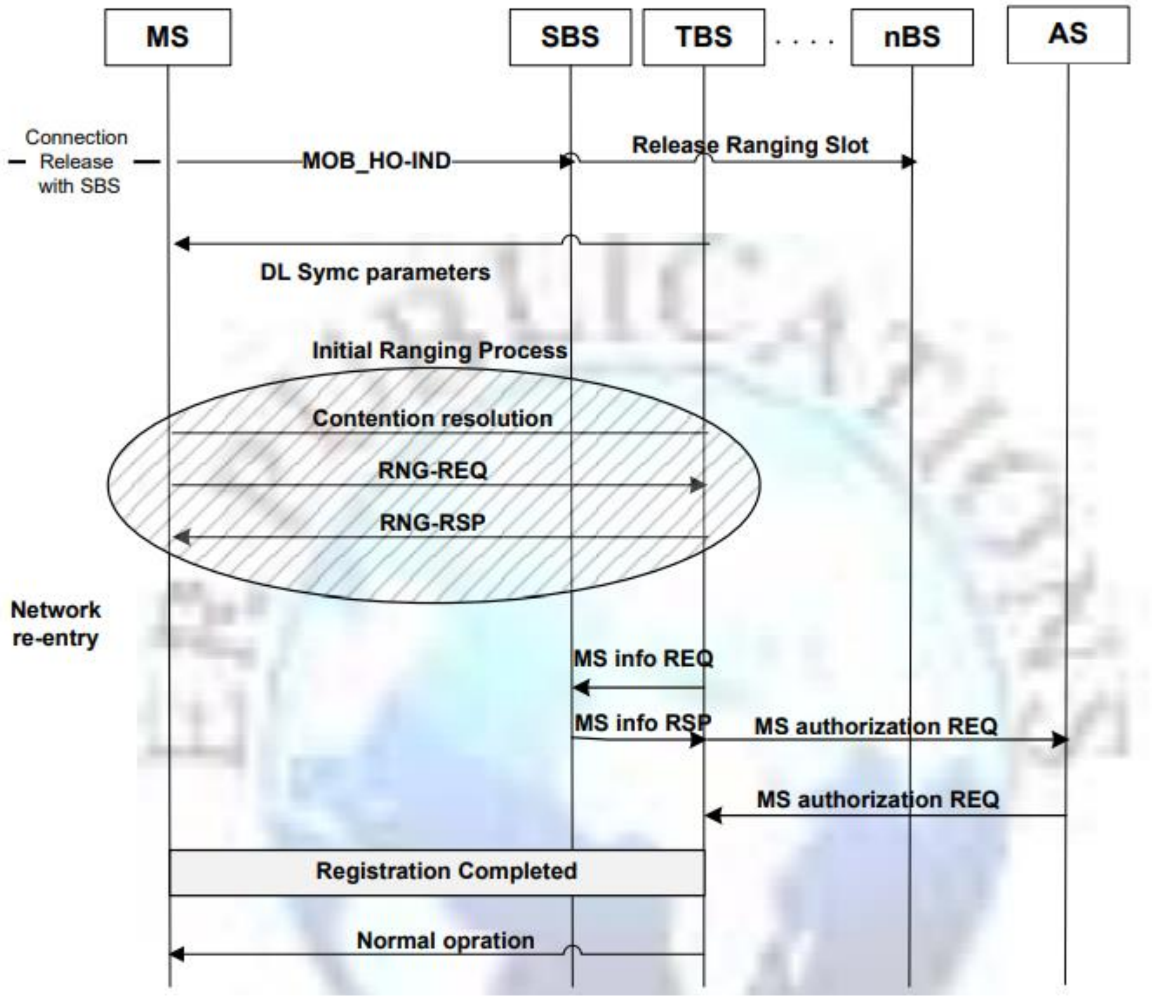


Figure 2. 14 Handover network re-entry [30]

5.3 Handover and Latency

The handover interruption time, also known as handover latency or handover delay[3]. Handover is a mechanism to maintain uninterrupted user communication session during a user's movement from one location to another. When the Mobile Station (MS) moves to another cell and performs handover, the service packets for the MS will be delayed and the service might be disrupted for some time[39]. Handover delay is a key metric for evaluating and comparing various handover schemes as it has a direct impact on perceived application performance[3] .For non real-time service such as e-mail or file transfer, Latency time is not an issues. However, the delay sensitive applications, such as video streaming service, should be delivered within the delay of 20 to

25ms. If the transmission delay of real-time packets is longer than the play out delay, those packets will be discarded and packet lossprobability is increased[39].

5.4 variables involved in the Handover

The set of variables involved in the HO strategy are listed on Table 2.2. Some of them are handover design parameters to be defined by the handover algorithm designer. Others are dynamic information obtained from RSSI measurements or location information sources. Other variables are related to MS data profile and the data application being supported.

Configuration parameters	Range
Frame size Neighbour Advertisement Interval	2 ms to 20 ms
Ranging parameters : Backoff Window Size Ranging Backoff Start Ranging Backoff End T3 = Timeout value for receiving a valid Ranging code Ncs = Contention Area Number of retries to send contention ranging requests (T33)	 0–15 0–15 0 – 200ms > 2 ∗ 6 > 16
Scanning parameters : Scan Duration (N) frames Interleaving Interval (P) frames Scan Iterations (T) frames Start Frame (M) T44 Scan request retransmission timer	 0–255 frames 0–255 frames 0–255 frames 0–15 frames 0–100 ms

Table 2. 2 Variables involved in a HO handover strategy. Range values for the variables involved based on IEEE802.16e [3]

6 Macro-Mobility protocols in WiMAX

Network level mobility is also known as Macro Mobility. It's about managing a mobile user's move between two different domains (see Figure 2.5). This move will require an update of the database: "Location Directory" and an update of the current IP address of the mobile station. In this case, the mobile station performs an intercell handover between two cells managed by different gateways. For example, in the case of IEEE 802.16e, the mobile passes between two cells covered by two base stations each managed by a different ASN-GW. In this case, the mobile station must update its current IP address to fit with the new network that manages the second cell.

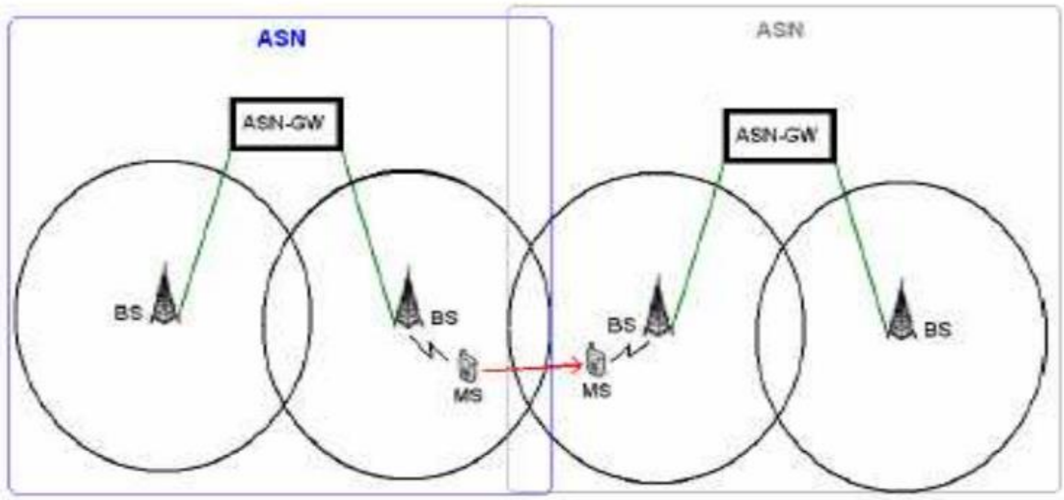


Figure 2. 15 Inter-ASN Handover (Macro-Mobility) [40]

6.1 OVERVIEW OF MOBILE IP

Mobile IP, as proposed by the Internet Engineering Task Force (IETF) in RFC 2002 and subsequent RFCs, provides an efficient, scalable mechanism for node mobility within the Internet. Nodes may move and change their point of attachment to the Internet without changing their IP address. This allows them to maintain transport and higher-layer connections while moving. Node mobility is realized without the need to propagate host specific routes throughout the Internet routing fabric. The mobile node uses two IP addresses: a fixed home address and a care-of address that changes at each new point of attachment.

Mobile IP is intended to solve node mobility issues over the IP layer. It is just as suitable for mobility across homogeneous media as it is for mobility across heterogeneous media. Mobile IP facilitates node movement from one Ethernet segment to another as well as handling node movement from an Ethernet segment to a wireless local area network (LAN)[41].

The IETF solution for enabling the IP mobility is to use two IP addresses, a permanent address – the home address – assigned to the IP node and acting as the endpoint identifier, and a temporary address – the care-of address (CoA) – giving the current location of the node. The approach here is to maintain the same IP address −the so-called home address− wherever the terminal is located, so that it will always have a unique identifier. In this situation, it becomes the responsibility of the Mobile IP protocol (MIP) to track the location of the mobile terminal in a meaningful way (topologically significant) in order to deliver any packet to it wherever it moves. The mobility functions needed by the mobile node (MN) are administered at the network level (IP layer) by two mobility functions implemented in IP routers: the Home Agent function (HA) in the home network and (eventually) the Foreign Agent function (FA) in a foreign network[42].

6.1.1 Mobile IPv4 (MIPv4)

Mobile IPv4 is designed to provide a way to support Mobile Node mobility. A MN periodically receives the agent advertisement messages from Foreign Agents (FAs) when it moves into a foreign network. In these messages, care-of addresses (CoAs) of FAs are included. If the MN finds out that received FA CoAs are different from the former one, MN is aware that it is inside new foreign networks. So, it sends a new FA CoA in a registration request message to his Home Agent (HA) to update its FA CoA record. Afterwards, all packets sent by Correspond Node (CN) to the MN are intercepted by the HA in the home network. Then these packets are forwarded by the HA to MN’s new FA through a tunnel. The tunneled packets are de-tunnelled and forwarded to the MN by the new FA. In this way, the IP connectivity is maintained and ongoing communication sessions are not disrupted [43].

6.1.2 Mobile IPv4 Architectural Entities

Mobile IP introduces the following functional entities[43] :

- **Mobile Node**

  A host or router that changes its point of attachment from one network or subnetwork to another. A mobile node may change its location without changing its IP address; it may continue to communicate with other Internet nodes at any location using its (constant) IP address, assuming link-layer connectivity to a point of attachment is available.

- **Home Agent**

  A router on a mobile node's home network which tunnels datagrams for delivery to the mobile node when it is away from home, and maintains current location information for the mobile node.

- **Foreign Agent**

  A router on a mobile node's visited network which provides routing services to the mobile node while registered. The foreign agent detunnels and delivers datagrams to the mobile node that were tunneled by the mobile node's home agent. For datagrams sent by a mobile node, the foreign agent may serve as a default router for registered mobile nodes.

In mobile IPv4, mobility agents periodically broadcast advertisements messages. Active MNs listen to these advertisements to detect a movement to another network then try to acquire a new CoA from this new network. After acquiring a new CoA, the MN must register it with its HA (also called location update). Computers that want to communicate with a MN send packets to the MN's home address. When a MN roaming outside its home network receives a data packet, the HA intercepts and tunnels it to the MN's current location (i.e. CoA). Although this mobility management scheme is simple and scalable, it has some deficiencies. Indeed, all packets destined to a MN must pass through the home agent as shown in Figure 2.16 (arrow 1) but the MN replies directly to the Correspondent Node (CN) without passing via the HA (arrow 2)[44].

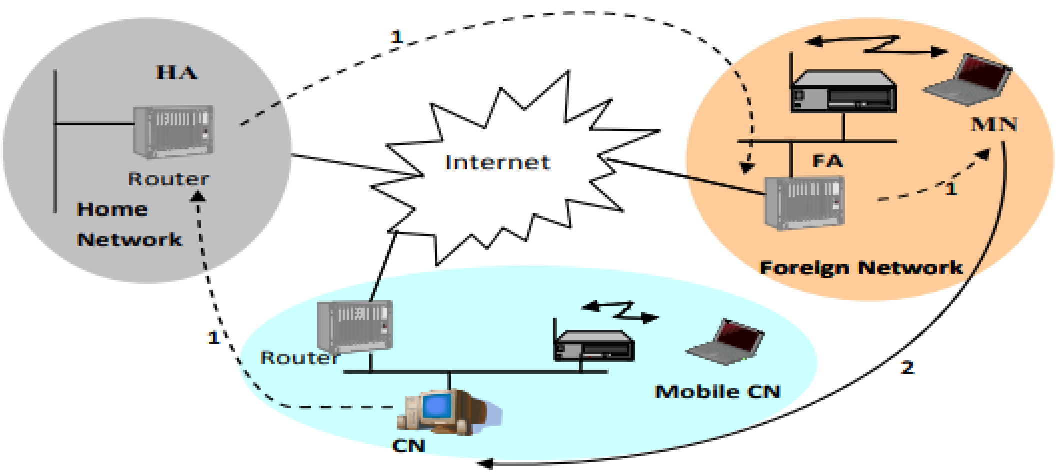


Figure 2. 16 Mobile IPv4 Architecture.

6.1.3 Operation of Mobile IPv4

The following steps provide a rough outline of operation of the mobile IP protocol[41]:

- Mobility agents (i.e., foreign agents and home agents) advertise their presence via agent advertisement messages. A mobile node may optionally solicit an agent advertisement message from any locally attached mobility agents through an agent solicitation message.
- A mobile node receives these agent advertisements and determines whether it is on its home network or a foreign network.
- When the mobile node detects that it is located on its home network, it operates without mobility services. If returning to its home network from being registered elsewhere, the mobile node deregisters with its home agent through exchange of a registration request and registration reply message with it.
- When a mobile node detects that it has moved to a foreign network, it obtains a careof address on the foreign network. The care-of address can either be determined from a foreign agent's advertisements (a foreign agent care-of address), or by some external assignment mechanism such as the dynamic configuration protocol (DHCP) (a colocated care-of address).
- The mobile node operating away from home then registers its new care-of address with its home agent through exchange of a registration request and registration reply message with it, possibly via a foreign agent.
- Datagrams sent to the mobile node's home address are intercepted by its home agent, tunneled by the home agent to the mobile node's care-of address, received at the tunnel endpoint (either at a foreign agent or at the mobile node itself), and finally delivered to the mobile node.
- In the reverse direction, datagrams sent by the mobile node are generally routing mechanisms, not necessarily passing through the home agent.

6.1.4 Mobile IPv4 Fast Handovers (FMIPv4)

FMIPv4 proposes a fast handover protocol on the basis of Mobile IPv4. This protocol avoids the delay due to movement detection and IP configuration and disengages Mobile IP registration delay from the time-critical path. The protocol provides the surrounding network neighborhood information so that a mobile node can determine whether it is moving to a new subnet even before the handover. The information provided and the signaling exchanged between the local mobility agents allow the mobile node to send and receive packets immediately after handover. In order to disengage the Mobile IP registration latency, the protocol provides routing support for the continued use of a mobile node's previous CoA[43].

6.2 Mobile IPv6 (MIPv6)

Mobile IP with IPv6 is simpler and more scalable than that with IPv4. It uses the inherent security mechanisms provided by IPv6 (i.e. IPSec) and supports route optimization. Goals of IPv6 mobility includes the following[45]:

- Always-on IP connectivity
- Session persistence
- Static IP addresses
- Roaming between L2 and L3 networks

MIPv6 was basically designed to overcome the limitations of MIPv4. It eliminates the need for foreign agents since it uses the IPv6 Neighbor Discovery instead of the address resolution protocol (ARP) which makes it decoupled from any particular link layer. Route optimization is considered as part of the protocol rather than a non-standard set of extensions and coexists efficiently with routers that perform "ingress filtering". This is because the MN uses its CoA while communicating with the CN, unlike MIPv4 where the MN uses its home address as a source IP address. Even though MIPv6 solves many MIPv4 bottlenecks, it still has its own weaknesses and concerns. Signaling overhead resulting from the location update and packet delivery procedures is still a problem[44].

For IPv6, there is no use of FA. The CoA is directly collocated with MS. When MS connects to a visited network, it gets a CoA and sends binding request to HA. The binding request is secured with IPSec ESP in transport mode. HA encapsulates every traffic with IPv6-in-IPv6 tunnel and sends it to the CoA of the MS. From MS, the packets are reverse tunneled CN via HA. In IPv6, route optimization is possible, MS sends binding update to CN with CoA as source address. This bypasses the anti-spoofing in the visited network. CN replaces the source address with the HoA of MS and passes the packet to the upper layer protocols. In the downlink direction, CN sends traffic to MS with CoA as destination address with a special routing header with HoA as second hop. MS removes the routing header and forwards the packet to the upper layers.

Security of binding is established between MS and HA with trust relationship via IPSec with ESP in transport mode. Between MS and CN, trust is established with Return Routeability procedure[45].

6.2.1 Fast Handovers for Mobile IPv6 (FMIPv6)

In [46], Koodli proposes a protocol to reduce handover latency and eliminate packet losses in Mobile IPv6. It achieves these goals through fast movement detection, fast binding update and buffer mechanisms. This protocol enables an MN to quickly detect that it has moved to a new subnet by providing the new access point and the associated subnet prefix information when the MN is still connected to its current subnet.

6.2.2 Hierarchical Mobile IPv6 Mobility Management (HMIPv6)

In order to reduce MIPv6 signaling cost, Soliman proposes an intermediate router named Mobile Anchor Point (MAP) in between MN and HA/CNs. When a MN first moves into a new MAP domain, it shall send registration request messages to its HA and CNs. When the MN roams inside this local MAP domain, it only performs regional registration with this local MAP instead of remote HA and CNs. All packets from CNs are tunneled to this local MAP and then rerouted to the MN. Hence both signaling transmission delay and overhead are reduced considerably[47].

6.2.3 Fast Handover for Hierarchical Mobile IPv6 (F-HMIPv6)

The HMIPv6 reduces the signaling overhead and transmission delay, but it omits the delay caused by NCoA validation. On the contrary, FMIPv6 eliminates movement detection delay and NCoA validation delay regardless of signaling overhead. Jung proposes a combination scheme of FMIPv6 and HMIPv6, which is renamed Fast Handover for Hierarchical Mobile IPv6 (FHMIPv6). In F-HMIPv6, handover signaling is exchanged between MAP and MN instead of between PAR/NAR and MN. Data packets from HA or CNs are forwarded by MAP to the PAR/NAR then to the MN[47].

6.2.4 Proxy Mobile IPv6 (PMIPv6)

A very recent proposal based on MIPv6 is the PMIPv6 mechanism, which is a network-based mobility scheme. PMIPv6 provides network-based mobility management support to MSs within a localized domain and is recently getting prevalent in the WLAN environments as well. PMIPv6 introduces a new functional entity, the Proxy Mobile Agent (PMA), a kind of MIPv4 foreign agent located on the AR. The PMA acts as a relay node between the HA and the MS. The MS does not participate in any sort of mobility related signaling activities, as they are performed by the PMA instead, on behalf of the MS.

6.2.5 Brief comparison between Mobile IPv6 Protocols

Table 2.3 provides a brief comparison of MIPv6 and its different advancements with respect to the handover techniques[48].

Parameters	MIPv6	HMIPv6	FMIPv6	PMIPv6
Complexity	Medium	High	High	Medium
Latency	High	High	Low	Medium
Scalability	Medium	Medium	Medium	Low
Packets Loss	High	Medium	Medium	Medium
Mobility	Host based	Host based	Host based	Network based
Signaling Overheads	High	Medium	High	Medium

Table 2. 3 Brief comparison between MIPv6 protocols

7 Conclusion

In this chapter we present the mechanisms and protocols dedicated to managing mobility in mobile WiMAX networks. We have seen that the IEEE 802.16e standard defines mobility mechanisms that allow mobile devices to maintain connectivity while moving. The handover procedure that will be adopted in the network deployments is of the Hard type, because of its simplicity and bandwidth economics, however it generates interruptions of the order of a few milliseconds, undesirable for the applications in real time.

The MIP protocol allows the mobile station after Handover procedures to continue communication with its correspondent following a triangular route that integrates the parent agent of its attachment network. The MIPv6 protocol offers additional options over MIP to avoid triangular exchange with the home agent, which significantly decreases the delay during the Handover.

The next chapter we work to reduce handover effect in WiMAX Network by using OPNET Modeler simulator.

CHAPTER 3 :

MOBILE WIMAX SIMULATION EXPERIMENTS

1 Introduction

OPNET (Optimum Network Performance) was chosen as a simulation tool for this research due to the number of benefits it provides such as an analysis tool and ease of designing a network model with graphical interface and a number of ready-made built-in objects available to use. Even with the ease of use WiMAX is not simple and it requires an understanding of all expects of the tool which including programming scripts for modified simulation. The main objective of this chapter is study of the Hard handover effect on WIMAX network where we explore and identify the parameters which directly effect on handover delay in mobile WiMAX and then modify them for ensure the handover delay is optimized and for batter WIMAX mobility.

2 OPNET Simulation tool

2.1 OPNET MODELER

OPNET (Optimum Network Performance) modeler is a simulation product from RIVERBED Technologies Inc. We are using the Optimized Network Engineering Tool (OPNET v14.5) for simulation of our networks which is one of the most powerful simulation tools regarding wireless communications. OPNET is a research oriented network simulation tool which provides a development environment for modeling and simulation of deployed wired as well as wireless networks and also provides multiple solutions for managing networks and applications e.g. network operation, planning, research and development (R&D), network engineering and performance management. OPNET 14.5 is designed for modeling communication devices, technologies, protocols and to simulate the performance of these technologies. User can create customized models and simulate various network scenarios. It is possible to simulate various wireless communication technologies such as MANET, 802.11, 3G/4G, Ultra-Wide Band, WiMAX, Bluetooth, ZigBee using OPNET tool. The OPNET modeler is object oriented and employs a hierarchical approach to model communication networks as shown in fig below. The OPNET usability can be divided into four main steps[49].

1. Modeling: This module is used to build or create a network model

2. Choose and select statistics: We can choose different statistics to collect from each network.

3. Simulate the network.

4. View and analyze results.

2.2 OPNET WiMAX Network

2.2.1 Models used:

The OPNET models used in project WiMAX are listed in Table 1

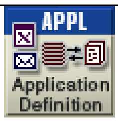
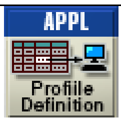
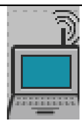
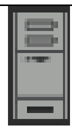
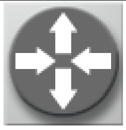
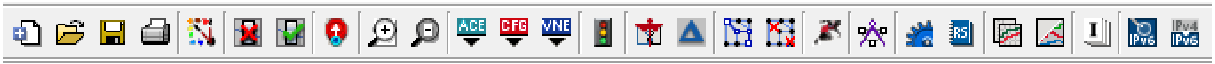
Application Config	Profile Config	WiMAX Config	WiMAX Base Station	Mobile Station	Server	Router
						

Table 3. 1 OPNET models used at WIMAX Network

2.2.2 Project Editor :

This is the main interface of the software. It allows to implement models resulting from OPNET libraries as well as user-created templates. It is also from Project Editor that the simulations can be configured and then launched and that the results from these simulations can be displayed. The main functions of this interface are available as icons.



1 2 3 4 5 6 7 8 9 10 11 12

Figure 3. 1 Project editor

1- New project
2- Open project
3- save project
4- Print
5- Open object palette
6- Go to parent subnet
7- Zoom to rectangle
8- Zoom to previous
9- Open traffic center
10- Configure/Run
11- View results
12- Hide/show graph panels

2.2.3 Node Model Editor

Displays a modular representation of an element of the on library of an element created by the user. Each module sends and receives packets to other modules. Modules represent applications, protocol layers, or physical resources.

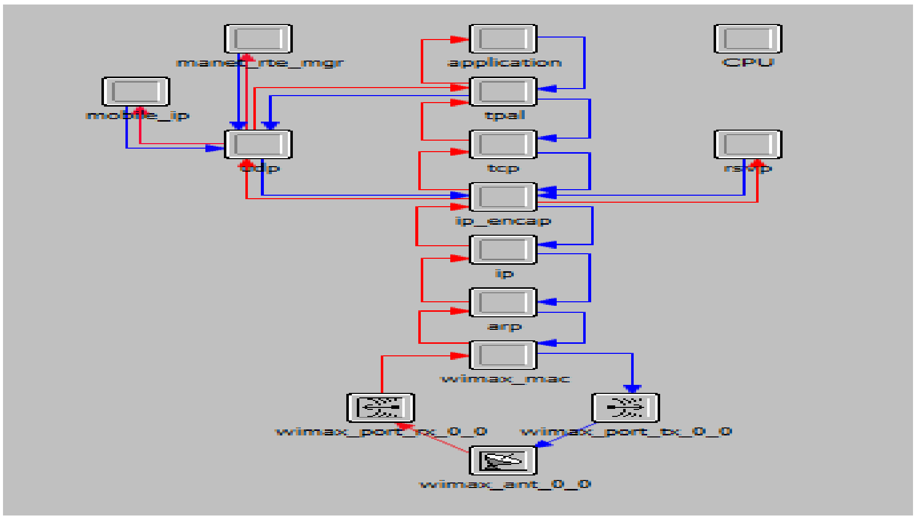


Figure 3. 2 Mobile station node model editor

2.2.4 WIMAX OPNET Topology:

This topology consists of a one Mobile Station node is Mobile IPv4 enabled, with Home Agent set to BS_1. The MS node moves away from the Home Agent and visits 3 Foreign Agent BS nodes. The BS is connected to the router and the server by a cable (ethernet), the server is configured for all network applications, in this project we chose the VOIP application. (Are shown in Figure 3.3).

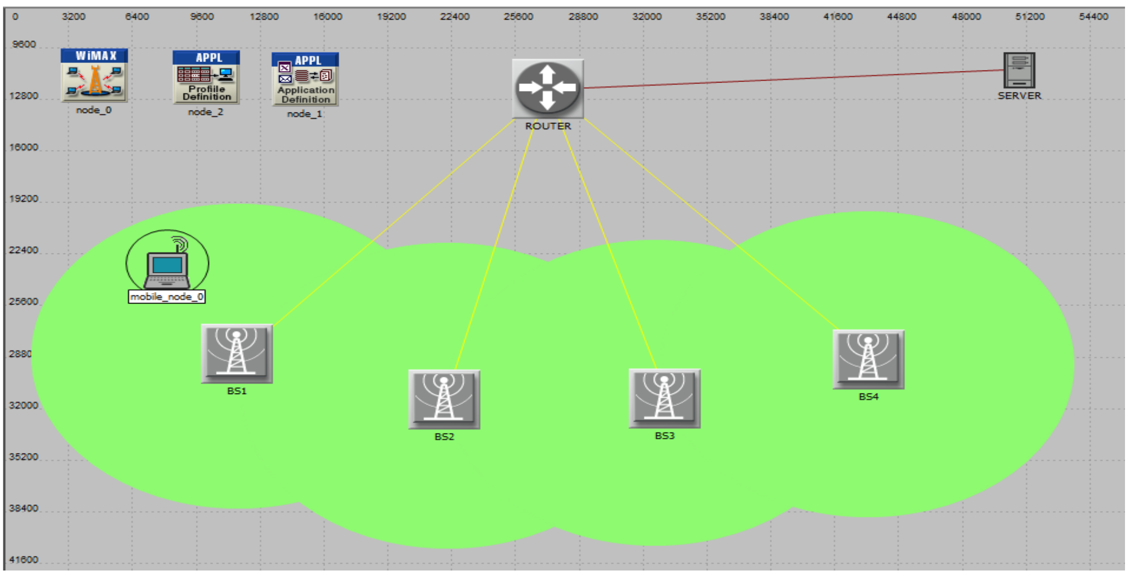


Figure 3. 3 WiMAX Network model in OPNET

The green circles correspond to areas around each BS outside which the best area covered by BS for high mobility and the radius of each circles is 10 Km.

2.3 Parameters Setup in the Simulation:

Once the basic model is configured which means simulation is ready to be tested, now comes the important step simulation configuration. The advanced parameters need to be set up and which changes the behavior of simulation each and every time change is done with the parameter setup (see table 3.2).

Parameters	Value
Numbers of BS	4
Numbers of MS	1
Maximum transmitting power [W]	0.5
MS Antenna gain [dB]	-1
BS Antenna gain [dB]	15
Distance between BS [Km]	10
MS speed [km/h]	60
MAC Addres	Auto assigned
Number of transmiter	SISO
Application definition	VOIP(G729A Codec)
PHY Profile	Wireless OFDMA 20 MHz
PHY Profile type	OFDM
OFDM PHY profiles: Base Frequency [GHz]	5
OFDM PHY profiles: bandwith [MHz]	20
OFDM PHY profiles: Duplexing technique	FDD
MS Scanning interval definitions: scanning threshold(dB)	27
BS Scanning interval definitions: scanning threshold(dB)	0.0
Scanning interval definitions: scan duration(N)	5
Scanning interval definitions: interleaving interval (P) (frames)	240
Scanning interval definitions: scan interaction(T)	10
Scanning interval definition: start frame(M) (frames)	6
Back off parameters: ranging back off start	2
Back off parameters: ranging back off end	4
Neighbor advertisement interval (frames)	10
Registration Mobile IPv4 parameters: interval (seconds)	4
Registration Mobile IPv4 parameters: retry(times)	4
Registration Mobile IPv4 parameters: lifetime request(seconds)	1800

Table 3. 2 Simulation parameters for the WiMAX model

3 Experiment N°1: handover study

3.1 Objective Of This Experiment.

The aim of the experiment is study Hard handover effect on WIMAX network and also test different mobile device speed and to identify speed effect to the handover delay when the mobile device is moving at a certain speed between one base station to another base station.

3.2 Handover effect in WiMAX Mobile

The network topology shown in Figure 3.4 consists of four WiMAX cells, an MS, a server, and a router. The MS migrates from BS1 to BS4 based on a predefined trajectory with speed 60km/h. The simulation results for WiMAX Scenario 1 are shown in Figure 3.5 and 3.6.

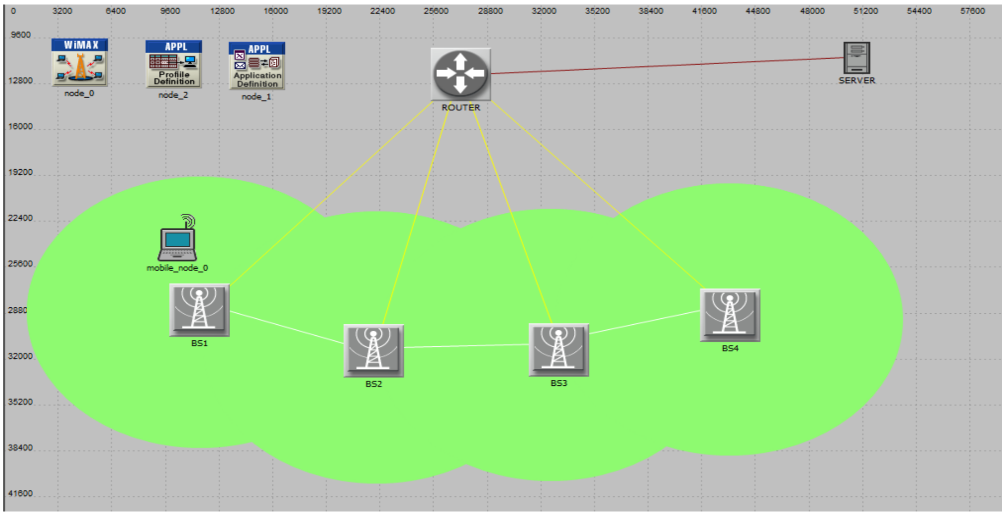


Figure 3. 4 Mobile station moving in specific trajectory

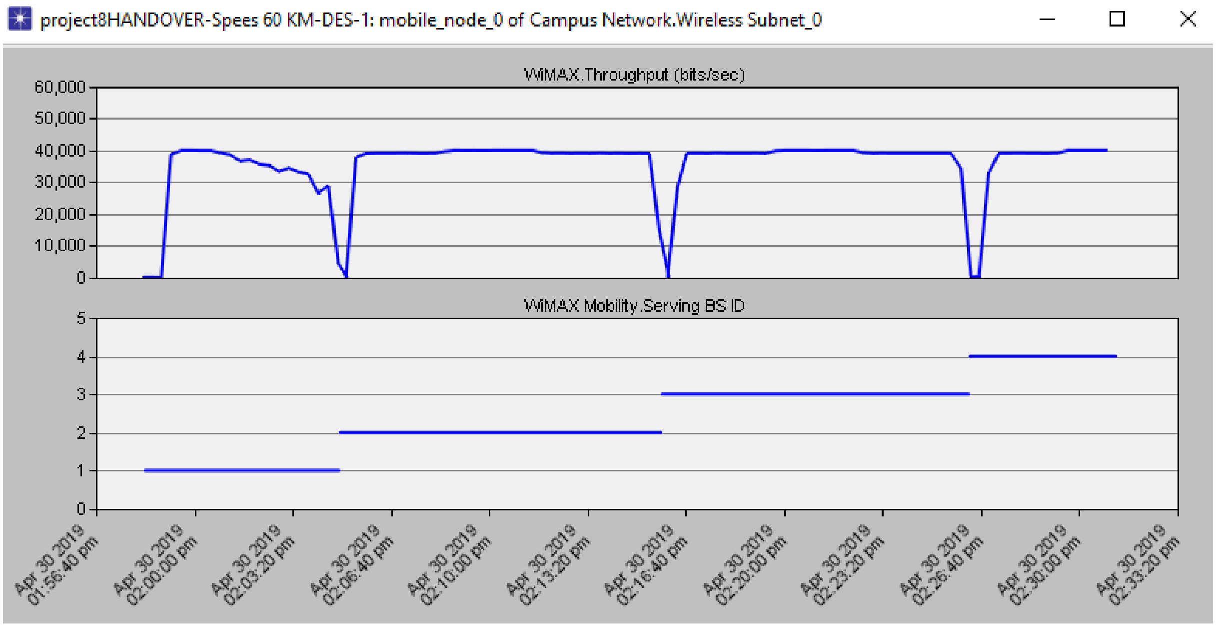


Figure 3. 5 The effect of the handover process on the wimax throughput

It could be observed in Figure 3.5 that during the time when mobile station is changing base station ID and the handover is processed, the rate of WiMAX throughput would drop from 40000 bits/sec to 0.

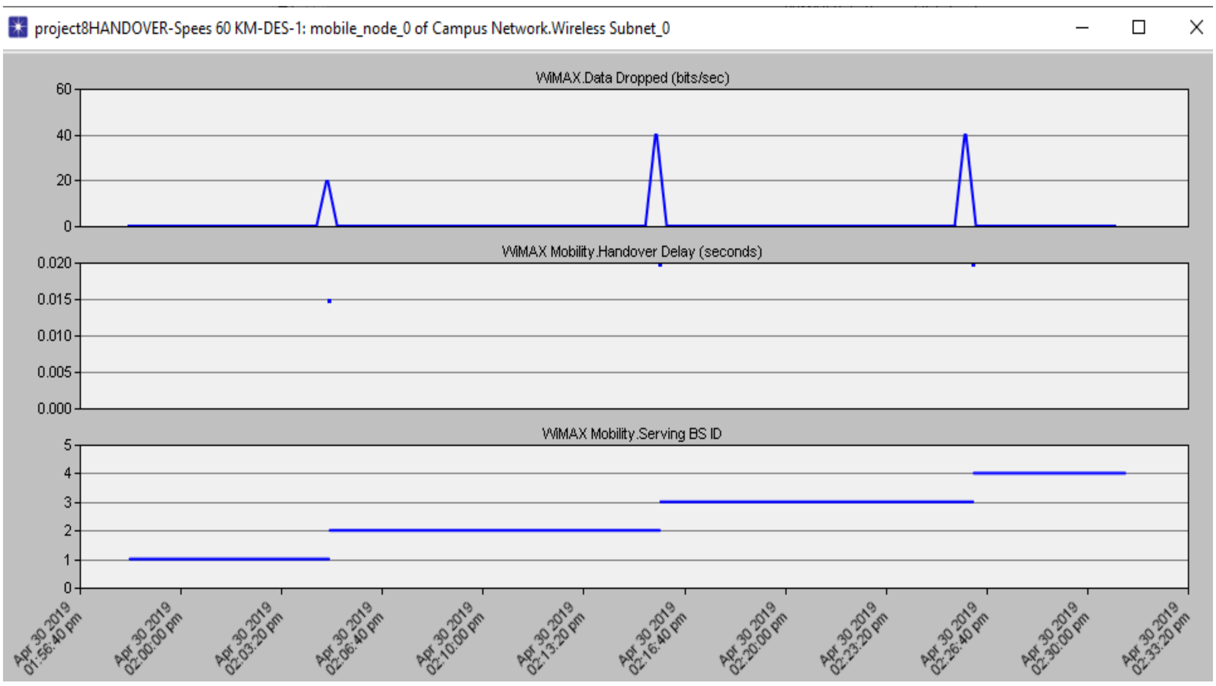


Figure 3. 6 The effect of the handover delay on the WiMAX Data dropped

In figure 3.6 shows us that during the time when mobile station is changing base station ID and the handover is processed, the WiMAX would drop 20 bits/sec when Handover delay is 15ms and dropped 40 bits/sec when Handover delay is 20ms. In this figure, it can be clearly seen that there is a minimum WiMAX data dropped when the handover delay values are lower.

As the results of this experiment show that handover delay has a direct effect on throughput and data dropped. it can be clearly seen that there is a minimum data dropped and highly mobility in WiMAX when handover delay is lower. These results create a basic building block for the current study where the goal is to minimize the handover delay in WiMAX signals while the mobile station is moving at a particular speed.

3.3 Speed effect

The experiment is repeated a number of times at different speeds and simulation is configured where each and every time the mobile device is moving at different speeds which are: 40,60,80,100,120 KM/H.

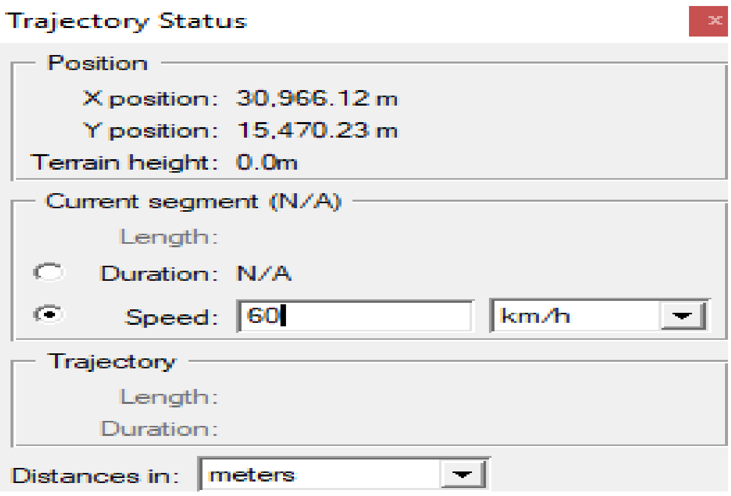


Figure 3. 7 Trajectory parameters (Change the speed of MS)

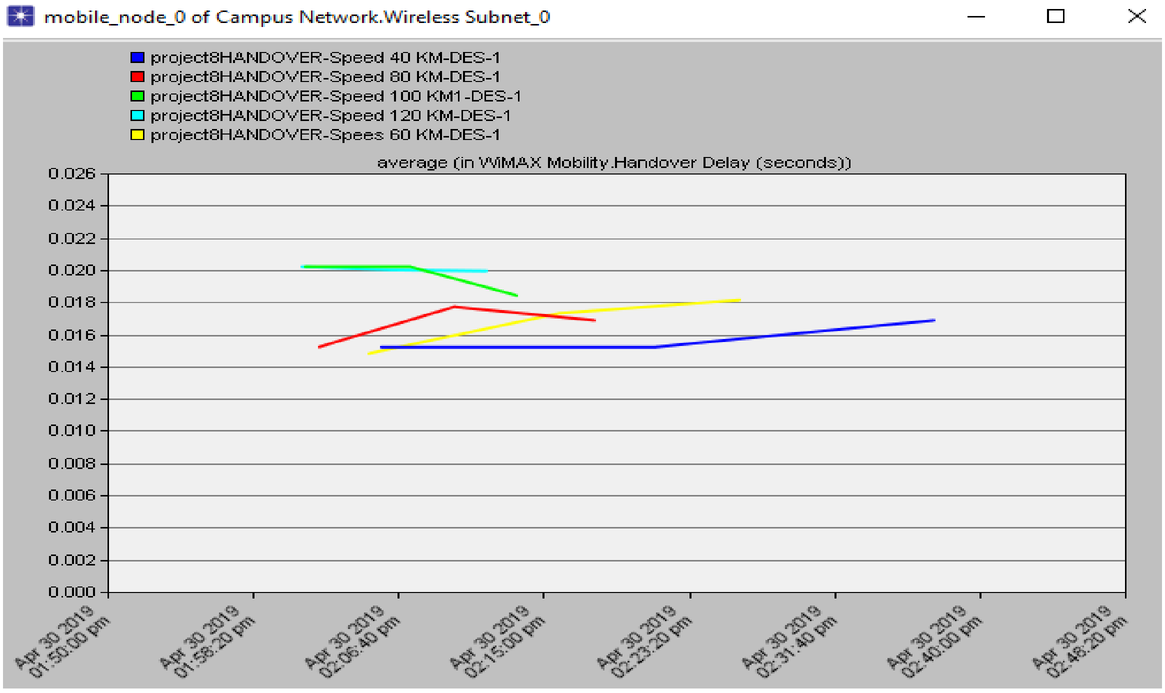


Figure 3. 8 Handover Delay While Moving at different Speeds

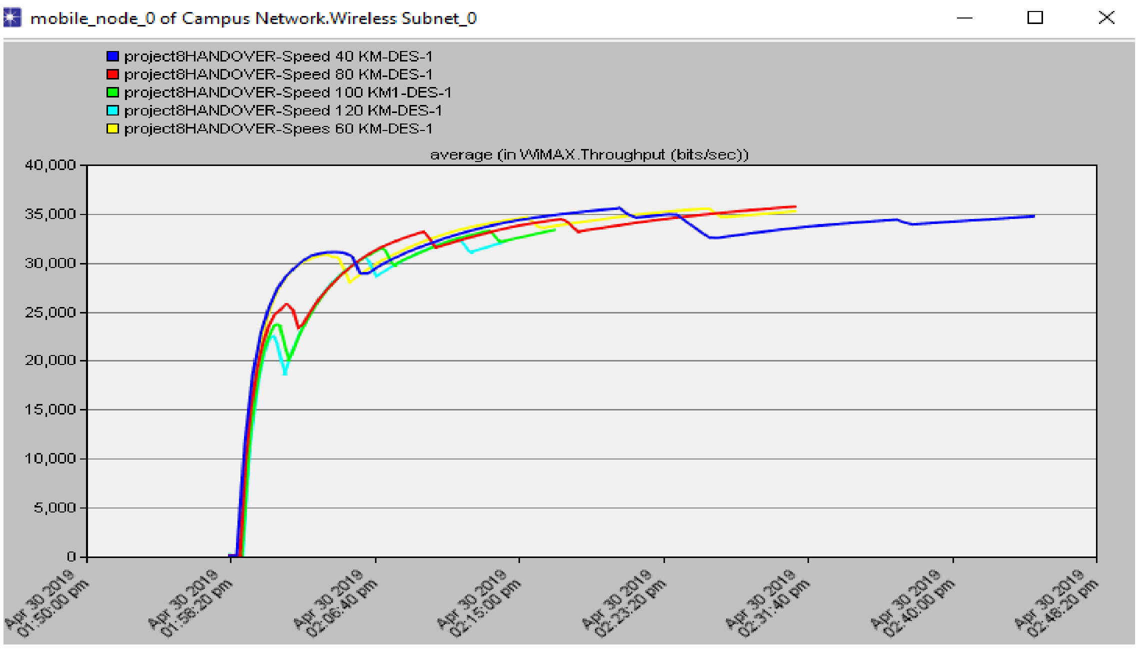


Figure 3. 9 WiMAX Throughput While Moving at different Speeds

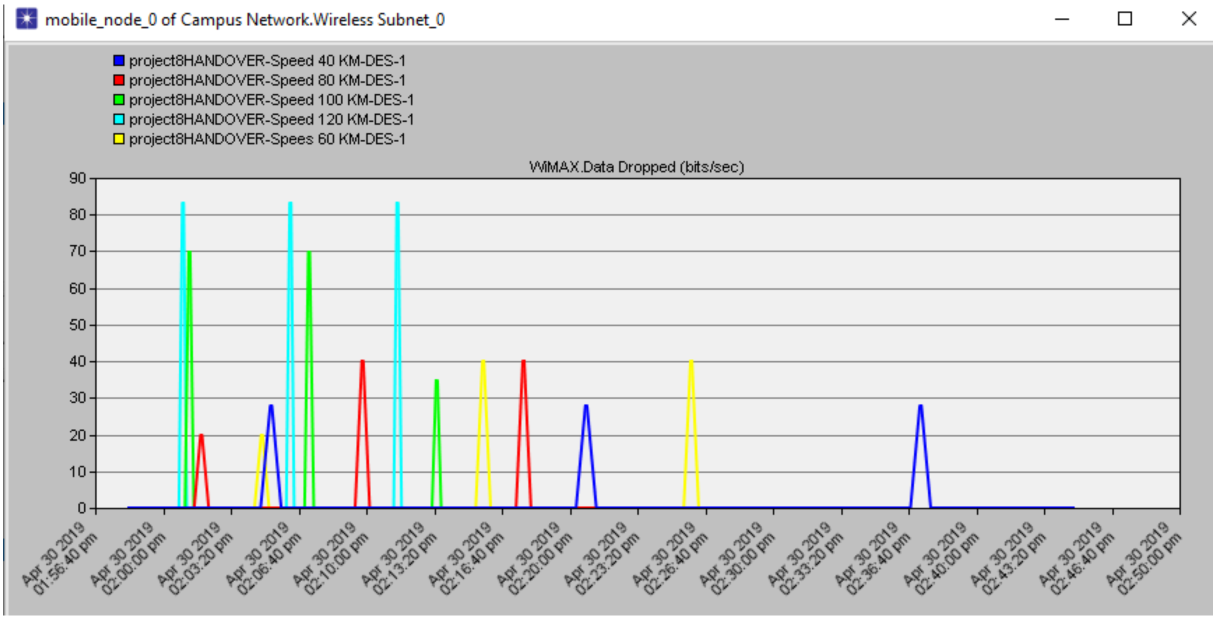


Figure 3. 10 WiMAX Data Dropped While Moving at different Speeds

When the experiment is tested a number of times at different speeds the outcome is very clear as shown in the figures 3.8, 3.9, 3.10 which taken from OPNET. In these figures, it can be clearly seen that there is a minimum handover delay and lower data dropped and high throughput when the mobile device is moving at Speed 40 km/h. The same can be seen from the table 3.3, where it can be seen clearly that handover delay values are higher at while moving at speed >80 Km/h.

Mobile Device Speed (km/h)	Average Handover delay (mS)	Average data Dropped (Bit/S)	Average Throughput(kBit/S)
40	16.25	28	32
60	16.5	33.3	31.5
80	16.75	33.3	29
100	19	58.3	26.5
120	20	82	25.5

Table 3. 3 Simulation Results when Moving at different Speed

As the results of this experiment show that the speed of MS has a direct effect on handover delay and when the mobile device is moving less than 80 km/h would result in a minimum handover delay and data dropped and a maximum WiMAX throughput. For that reason, the speed in the next experiment would be kept constant at 60 km/h. This creates the foundation for the next experiment.

4 Experiment N°2: HANDOVER OPTIMISATION

4.1 Objective Of This Experiment.

The aim of the experiment is to identify and test different WIMAX parameters which directly effect on handover delay in mobile WiMAX. Some of these parameters is about WiMAX network and other parameters about handover procedures on WiMAX. These parameters are tested in different sub-experiments and also identify when these factors give a minimum handover delay which would help us to standardize these factors in order to get the best mobility in WiMAX.

4.2 Distance between BSs:

In this experiment we have three scenarios:

Scenario 1: Distance between BSs is 10 Km.

Scenario 2: Distance between BSs is 20 Km.

Scenario 3: Distance between BSs is 30 Km.

The simulation is repeated many times while keeping everything else constant and only changing the distance between BS for each and every time. The simulation results show where the distance value will be result in a minimum handover delay as shown in the figure 3.11.

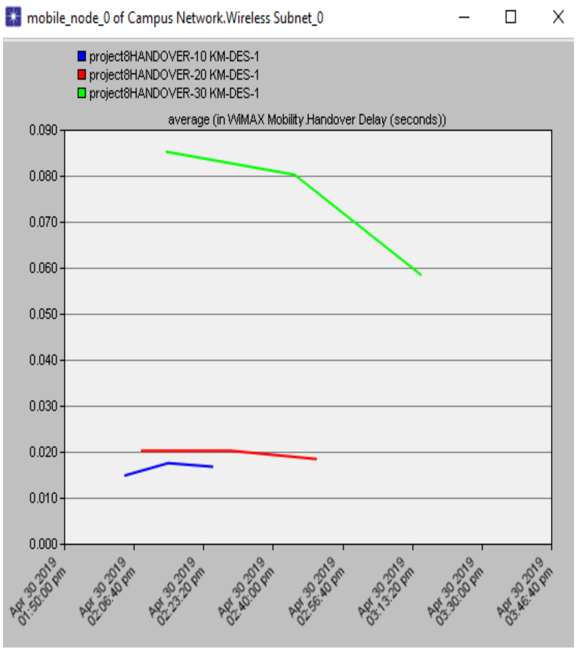


Figure 3. 11 Handover Delay at different distance

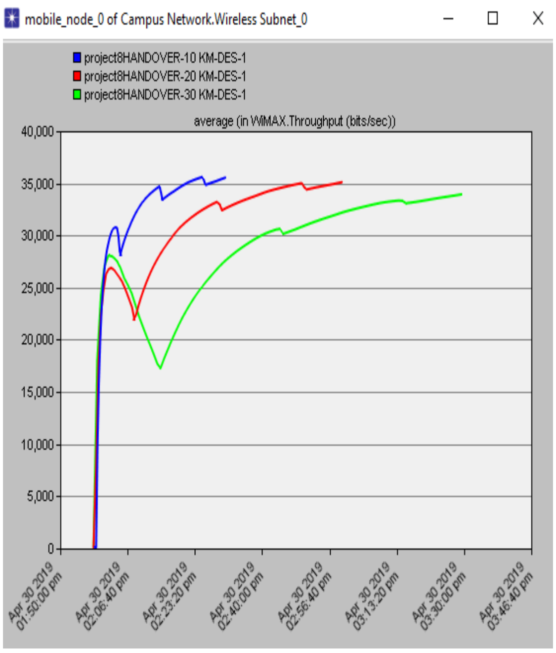


Figure 3. 12 WIMAX Throughput at different distance

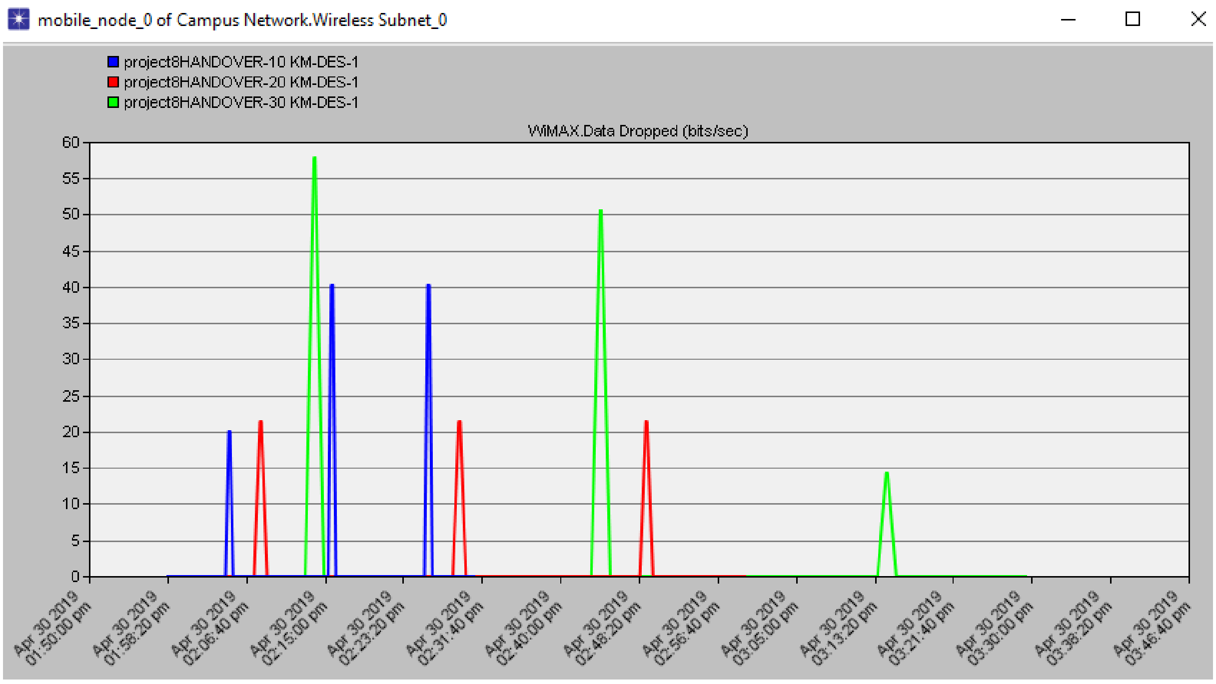


Figure 3. 13 WIMAX Data Dropped While Moving at different Distance

The simulation results show that the higher distance between BS will be resulting a higher handover delay time. Which clearly shows that in order to keep a handover delay low, we have to keep distance factor at a lower level which is 10 km.

Distance between BS (km)	Average Downlink SNR at Handover time (dB)	Average Handover delay	Average Data Dropped (Bit/S)	Average Throughput(kBit/S)
10	27.5	16.5	33.3	31.5
20	20	19.5	22	28.5
30	6	71.5	41	26

Table 3. 4 Simulation results at different distance

The Simulation results in table 3.4 show that at when distance between BS is kept less than 20 Km the WiMAX will have a minimum handover delay and highest throughput but we keep 10 km for best result and better WiMAX Mobility.

4.3 Number of transmitters:

The experiment is repeated a number of times at different number of transmitters, and the simulation is configured where each and every time the simulation is tested at MIMO and SISO.

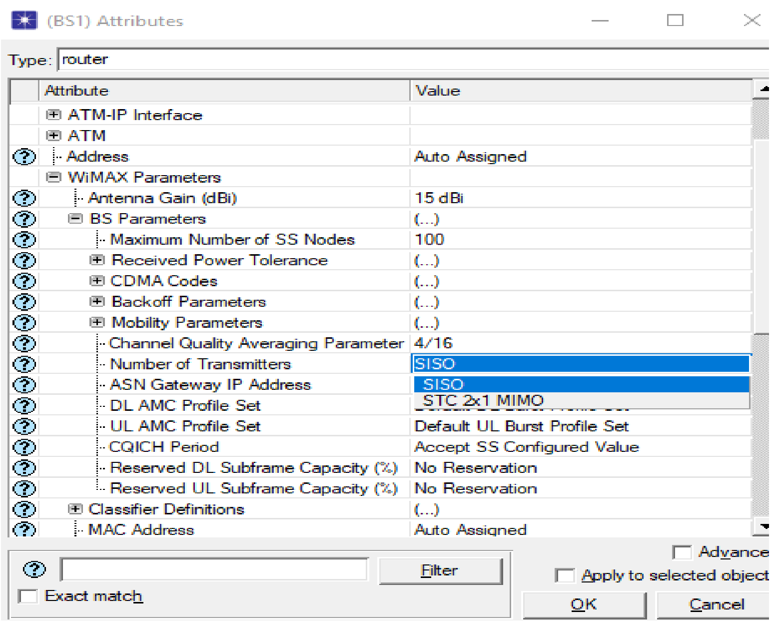


Figure 3. 14 Number of transmitters parameter setup in OPNET

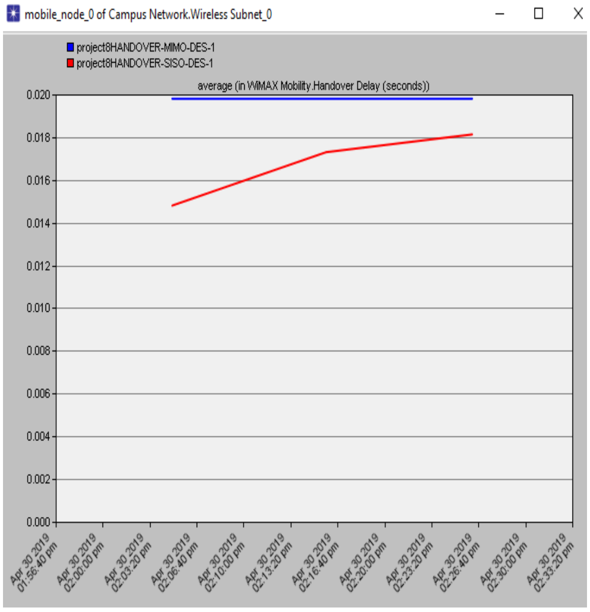


Figure 3. 15 Handover Delay at different number of transmitters

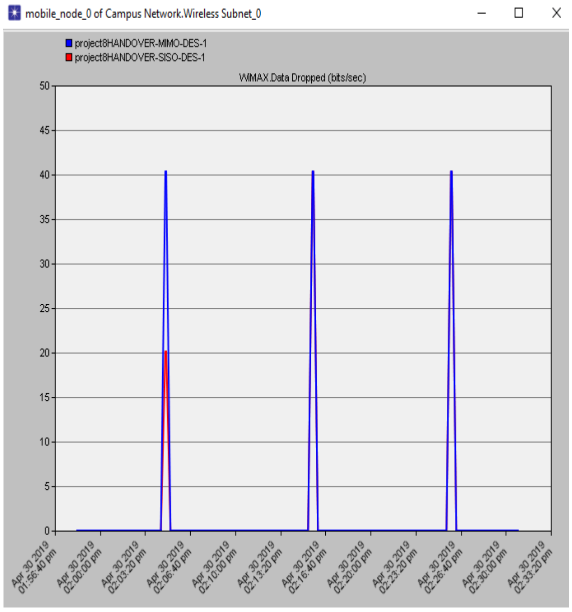


Figure 3. 16 Data dropped at different number of transmitters

When the simulation is repeated a number of times we get the results for number of transmitters effect on handover delay in WiMAX. The Table 3.5 shows that when the mobile station is moving at the speed of 60 km/h, the maximum throughput is at MIMO, but the handover delay is at a minimum and lower data drooped when number of transmitters factor is at SISO.

Duplexing	Average Handover delay (mS)	Average Data Dropped (Bit/S)	Average Throughput(kBit/S)
MIMO	20	40	33.5
SISO	16.5	33.3	31.5

Table 3. 5 Simulation results at Different number of transmitters

4.4 VoIP codecs :

In order to simulate and test VoIP codecs factor in OPNET simulation, it should be setup and configured at the application definition and the simulation is done changing this factor for each simulation and every time.

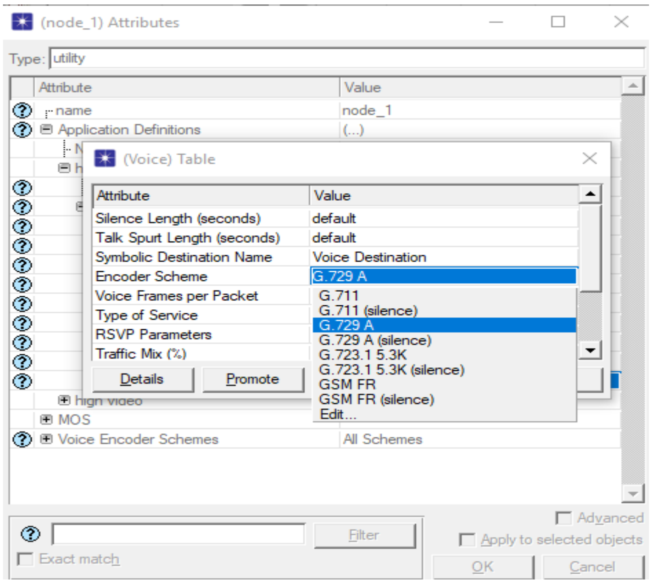


Figure 3. 17 VoIP Codecs in OPNET

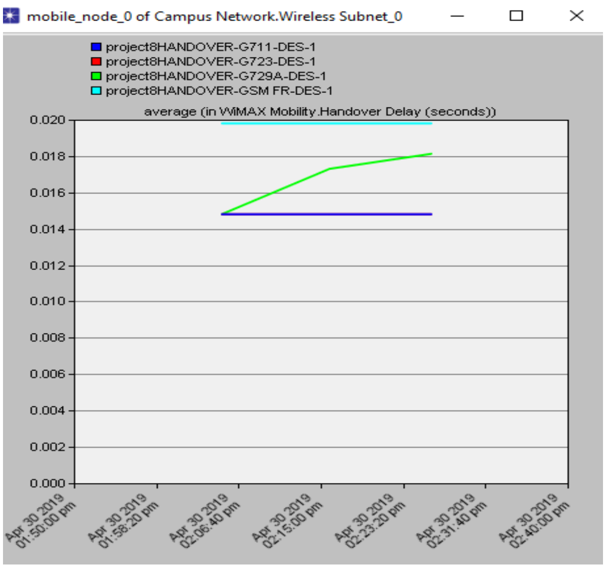


Figure 3. 18 Handover Delay at different VoIP codecs

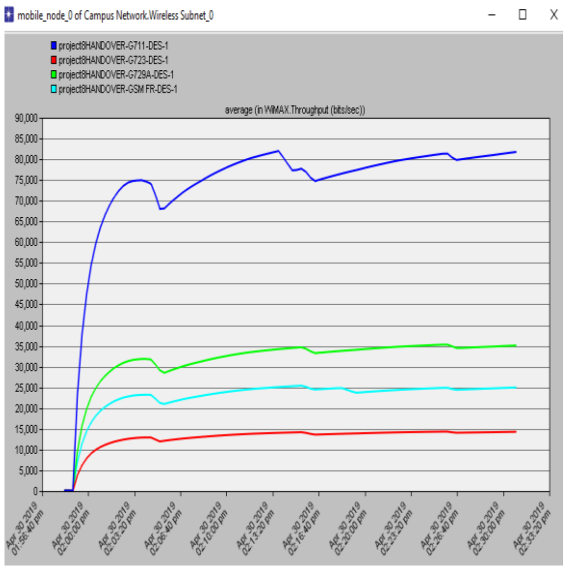


Figure 3. 19 WIMAX throughput at different VoIP codec

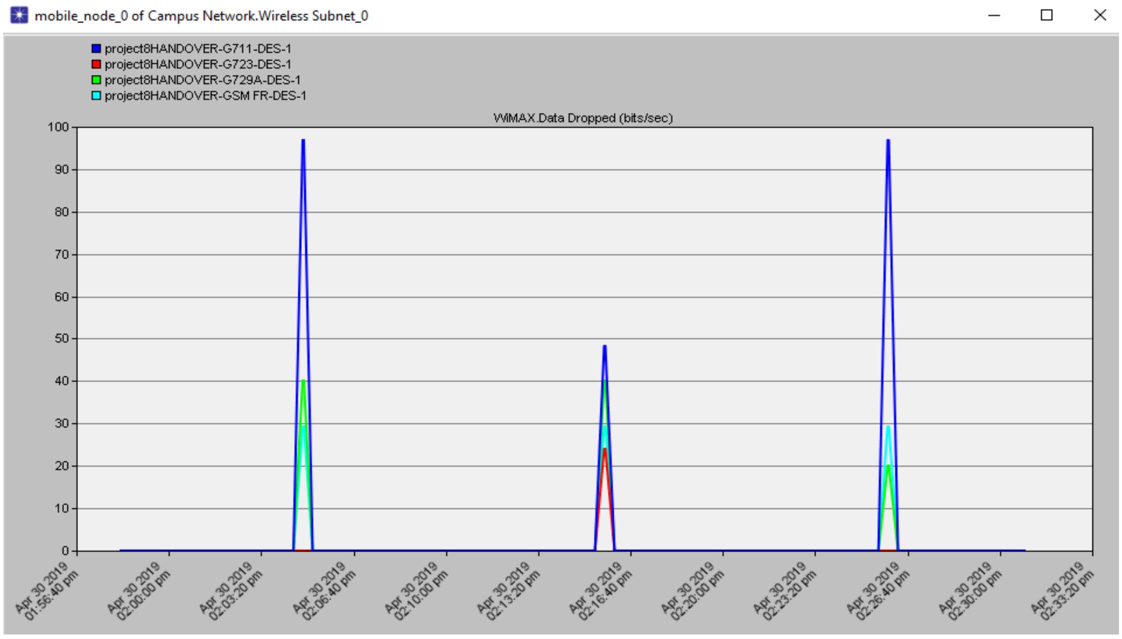


Figure 3. 20 Data dropped at different VoIP codec

A MOS value is normally obtained as an average opinion of quality based on asking people to grade the quality of speech signals on the five-point scale (Excellent =5; Good=4; Fair=3; Poor=2; Bad=1) under controlled conditions as set out in the ITU-T standard p.800.

While studying detail results which is shown in the table 3.6. In this table we can see when the VOIP application is using G729A codec the mos value is 2,4 and the throughput is 31 kbit/s and data dropped at handover is 33 bit/s that mean WiMAX drop 0.11% of throughput and when using G711 codec WiMAX also drop 0.11% of throughput at handover but the mos value is high 2.9 , however when using G723 codec WiMAX drop only 0.03% but the mos value is low 2, in GSM FR codec the mos value is 2.8 and WiMAX drop 0,21% of throughput.

VoIP Codec	Average Handover delay (ms)	Average MOS Value	Average Data Dropped (Bit/S)	Average Throughput (kBit/S)
G729A	16.5	2.4	33.3	31.5
G711	15	2.9	83.3	75
G723	15	2	7.3	23
GSM FR	20	2.8	30	14

Table 3. 6 Simulation Results At Different VOIP Codecs

The major observation of this experiment is that G.711 has highest MOS value 2.9 and G723 has less handover delay and data dropped (show table 3.6). This shows that G711 provides good speech quality as compared to the other VoIP codecs schemes but G723 provides the best mobility in WIMAX with a small loss of data.

4.5 Scanning threshold (dB):

The scanning threshold or the Link going down factor is considered important parameters in WiMAX, where it determines the sensitivity of detecting a falling link. This factor is set and configured to create a Link Going Down effect and this effect is generated when the received signal power is less than factor RXThresh and then trigger is generated which starts the scanning process for neighboring Base Stations[50].

In order to test the link down factor, the Scanning threshold values are configured as per show in the figure 3.21. This factor is set up a mobile station, which is inside the scanning parameters and Scanning threshold.

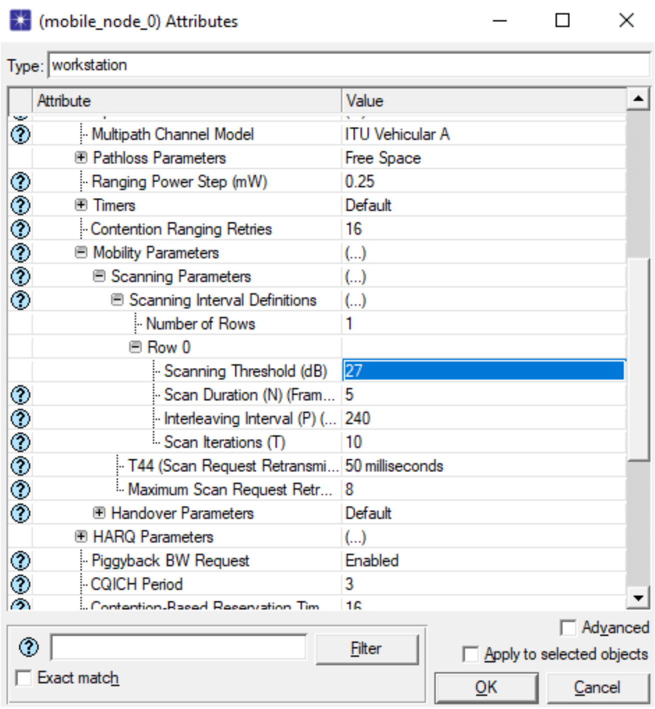


Figure 3. 21 Scanning threshold parameter in OPNET

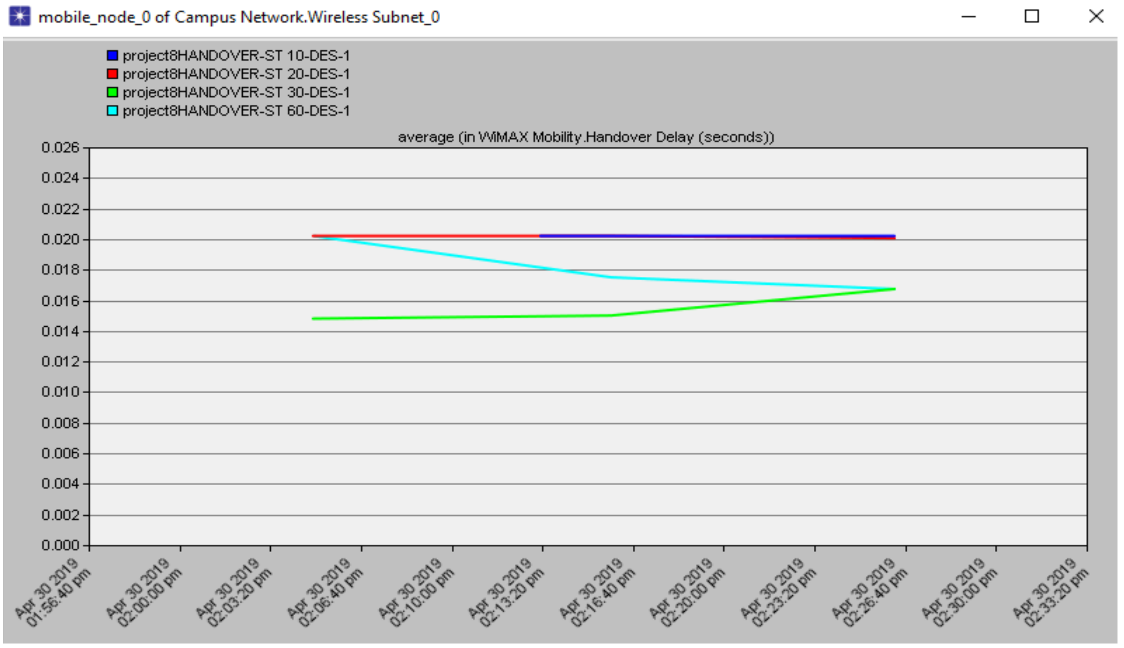


Figure 3. 22 Effect of Scanning threshold on Handover Delay

As the results of this experiment show that Scanning threshold have a direct effect on handover delay which can see a minimum handover delay when ST is 30. To get a best result we increase the simulation test by take more scanning parameters value (see figure 3.23).

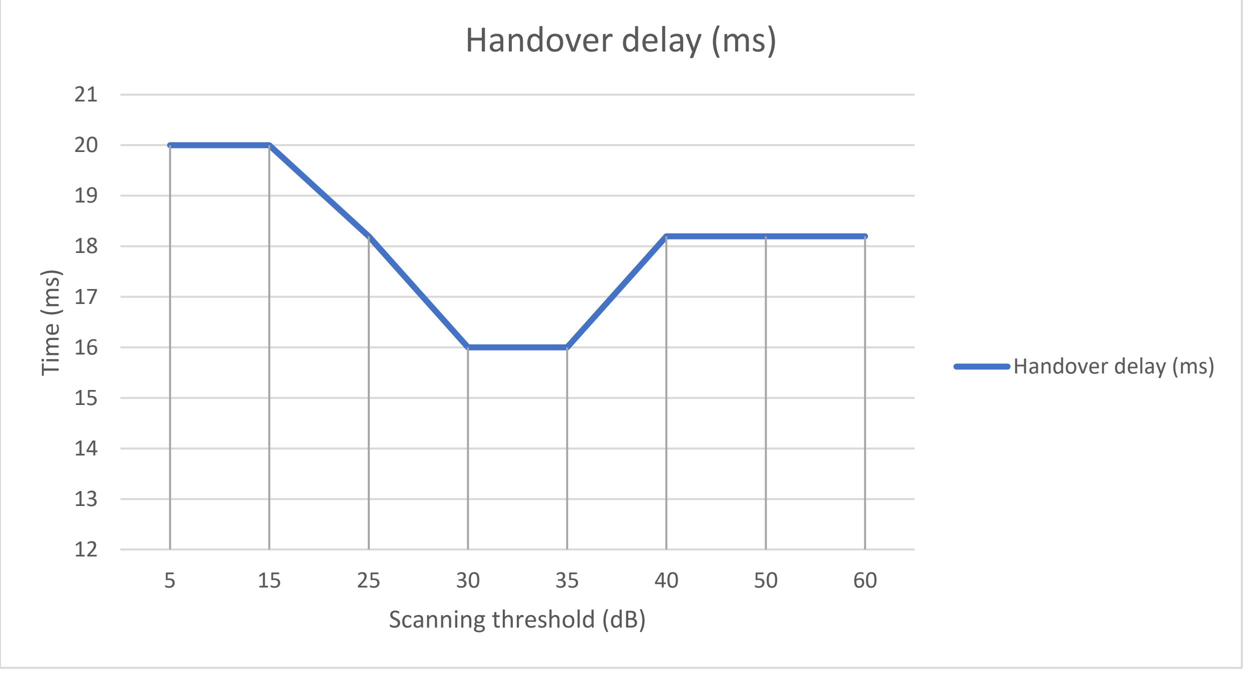


Figure 3. 23 Effect of Scanning threshold on Handover Delay after more experiment

the figure 3.23 shows that if the ST value is kept either between 30 and 35 dB the simulation result will show the minimum handover delay, but if the value is set up less than 30 the handover delay moves to the highest point.

4.6 Scan iteration:

SI (Scan iteration) can be described as it is the number of scanning interval which is required by mobile station[50]. To test this attribute the configuration is done at base station level (see Figure 3.24).

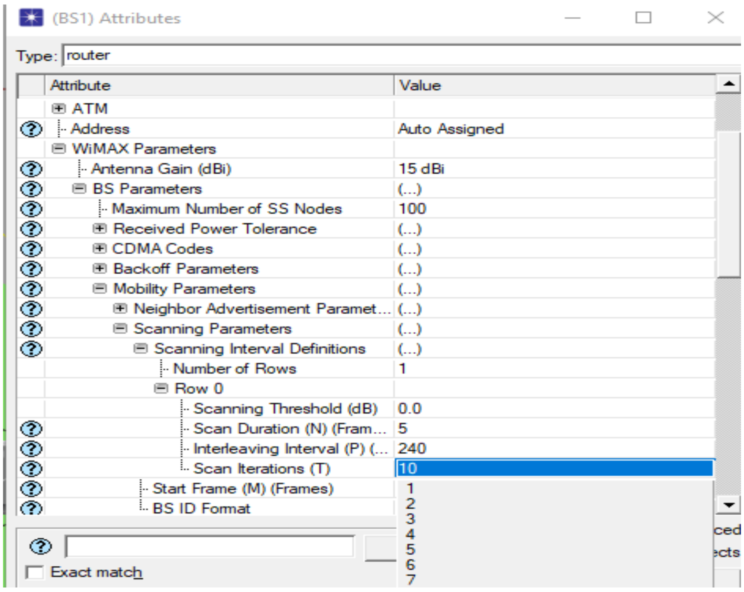


Figure 3. 24 Configuring Scan Iteration Value for Simulation

The simulation is repeated many times while keeping everything else constant and only changing the value of Scan Iteration for every time. The simulation results point towards that when scan interaction at 3 will be resulting in higher handover delay time and decreases when SI at 8. Which clearly shows that in order to keep a handover delay low, we have to keep SI factor at 8 (see figure 3.25).

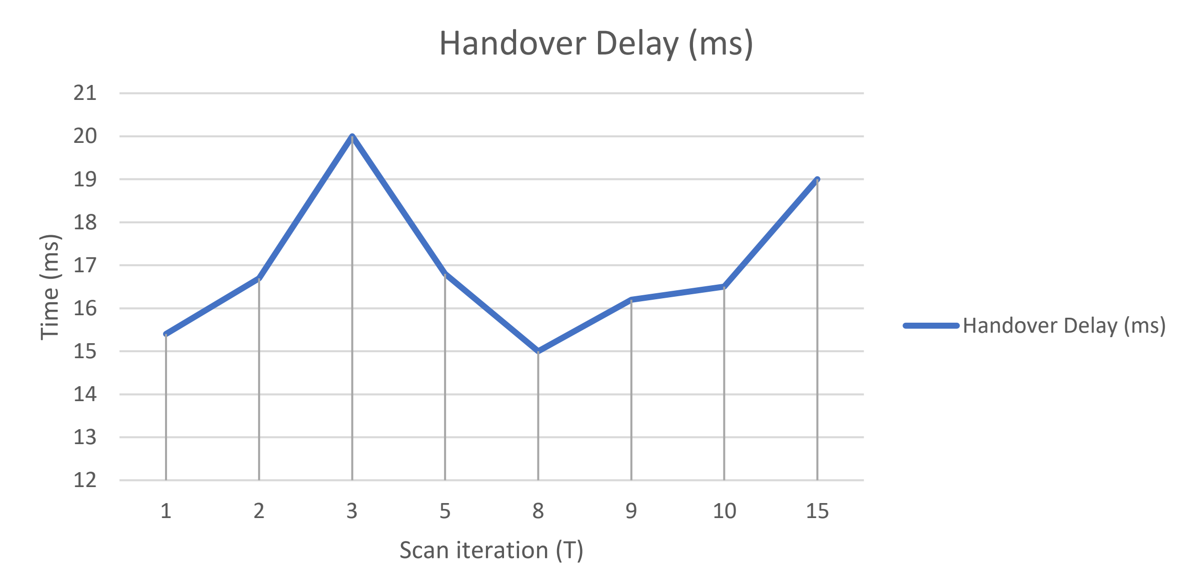


Figure 3. 25 Effect of Scan Iteration on Handover Delay

4.7 Interleaving Interval :

Interleaving interval can be explained as it as the time duration between scanning period and normal frames in mobile station. In other words, it can be also explained as it is the time duration between the normal operation and scanning periods of the mobile station in frames[50].

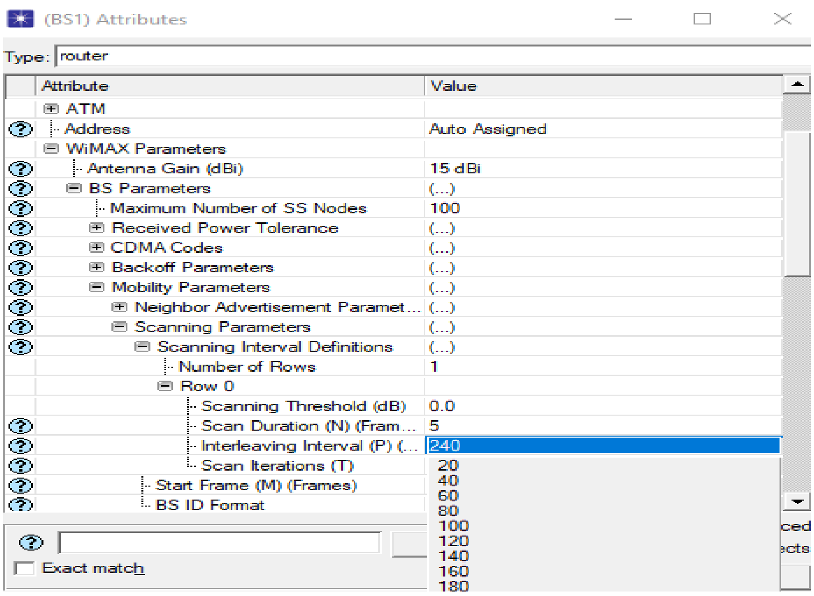


Figure 3. 26 Configuring Interleaving Interval Value for Simulation

When the simulation was configured all changes were done at the base station level and while changing Interleaving interval values for each simulation all other parameters were kept constant and standard. When the simulation was completed a number of times, the simulation results show that there is a minimum handover delay when the Interleaving interval value is at 150.

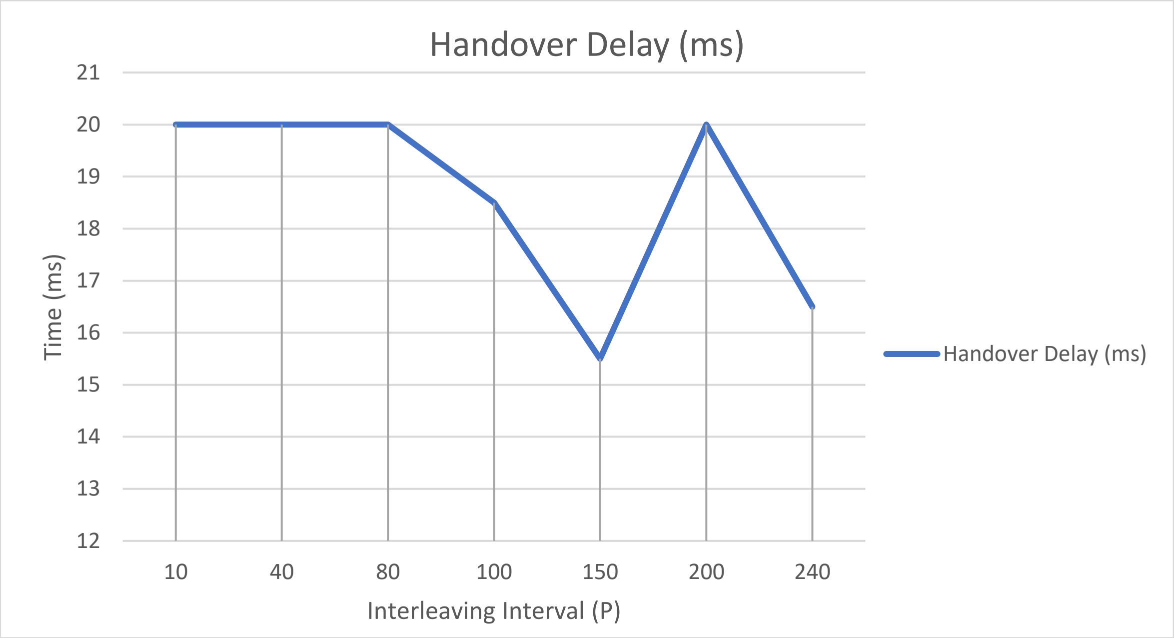


Figure 3. 27 Effect of Interleaving Interval on Handover Delay

4.8 Start Frame (M):

The start frame of the scan indicates to the MS the exact frame for performing the scan. To test this attribute the configuration is done at base station level. Figure 3.28 shows base station configuration configured during the simulation.

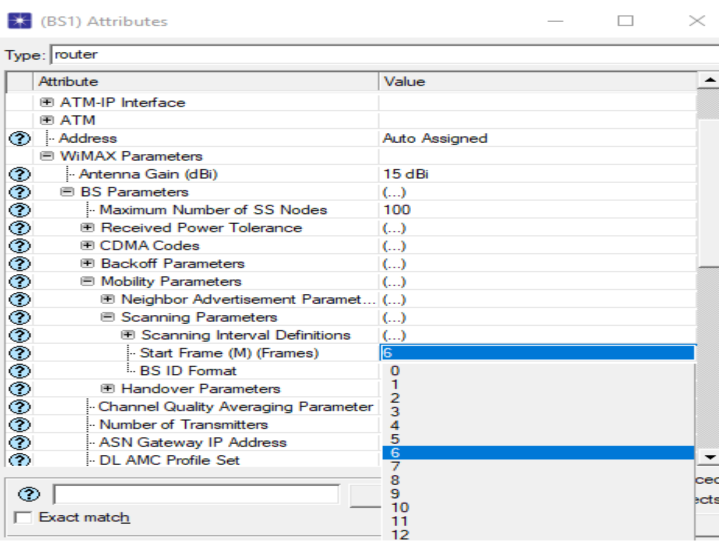


Figure 3. 28 Configuring Start Frame Value for Simulation

The simulation is configured in the same way as other simulation keeping the speed of mobile devices 60 km/h. It can be seen from this diagram that only when Start frame is kept at 15 will result in minimum handover delay time of 16ms while at other values it results higher handover delay.

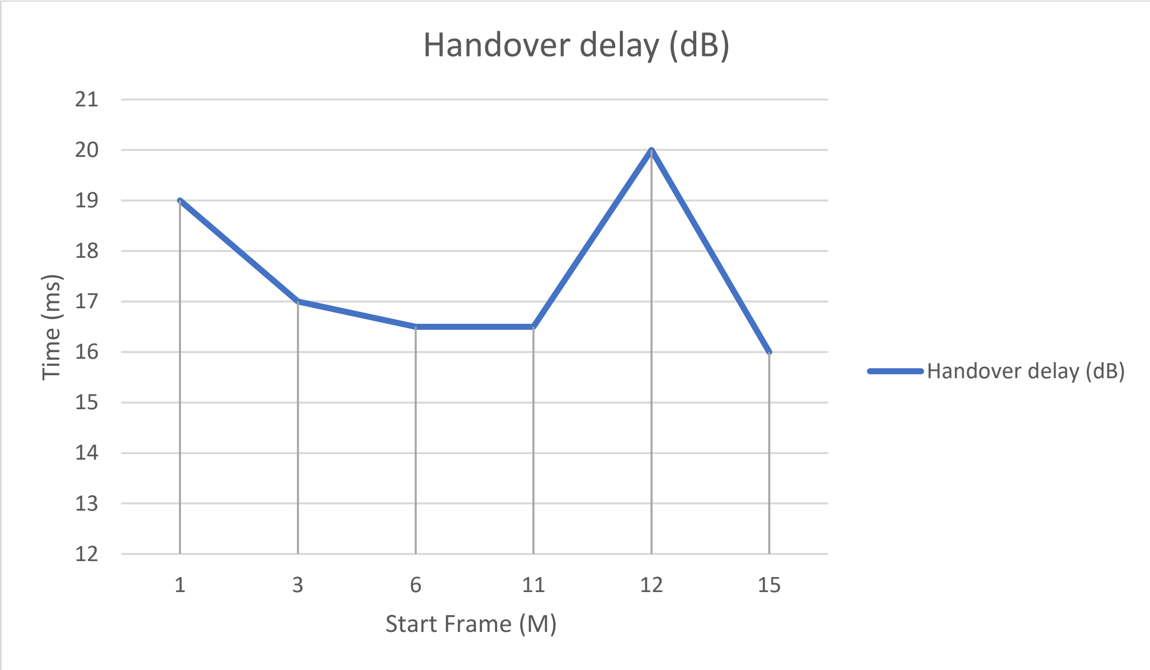


Figure 3. 29 Effect of Start Frame on Handover Delay

4.9 Ranging Backoff Start

This parameter is important during the training phase of handover and it's also used in the same phase, where it defines the size for the first backup window. The effect of this parameter is tested with configuring and running the simulation.

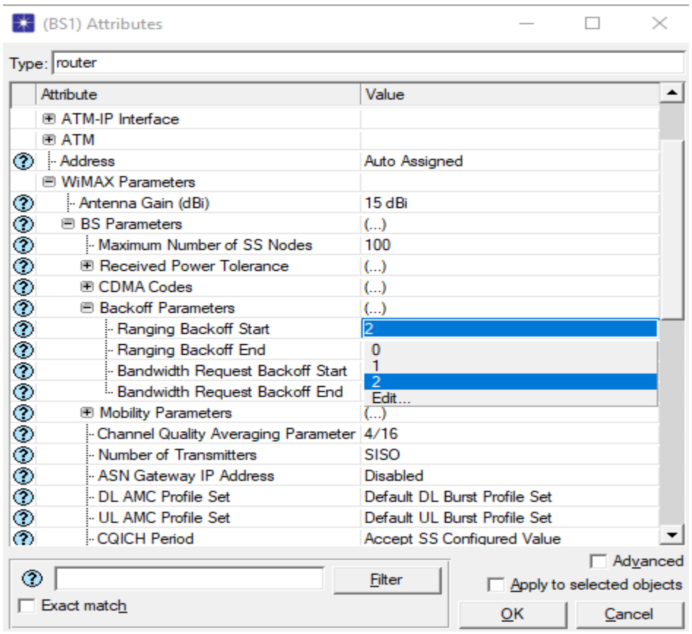


Figure 3. 30 Ranging Backoff Start parameter in OPNET

When the simulation was completed a number of times, the simulation results shows that if the Ranging Backoff Start value is kept either at 0 or at 1 the signal broadcast will show the minimum handover delay while if the value is set up more than 1 the handover delay moves to the highest point (see figure 3.32).

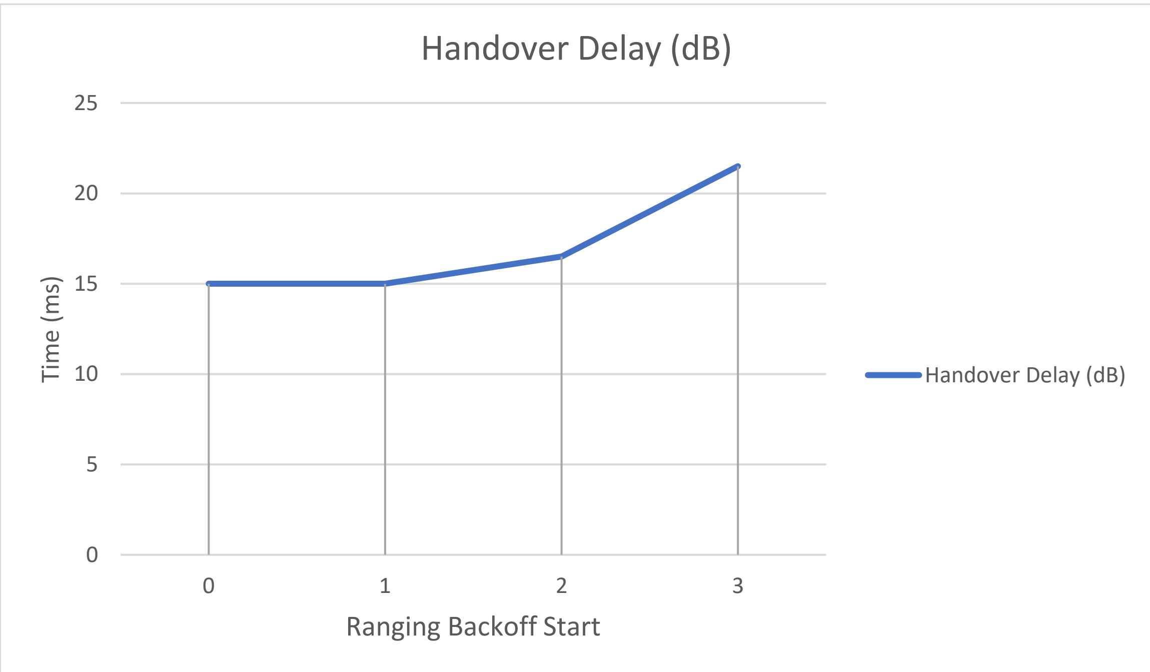


Figure 3. 31 Effect of Ranging Backoff Start on Handover Delay

4.10 Neighbors Advertisement Interval

A BS broadcasts each period information about the network topology using the MOB_NBR-ADV (Neighbors Advertisement) MAC management message. This message provides channel information about neighboring BSs normally provided by each BS's (for mor information see chapter 2). Figure 3.32 shows base station configuration configured during the simulation.

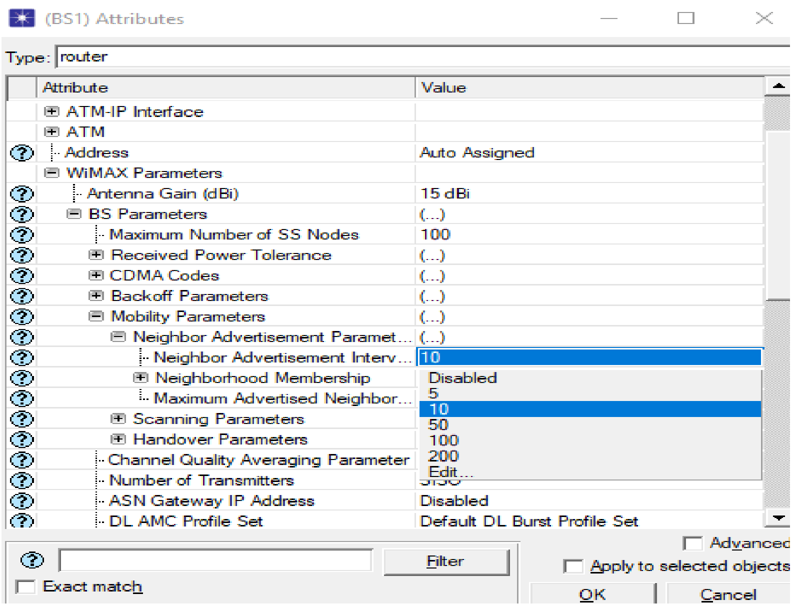


Figure 3. 32 Configuring neighbor Advertisement Interval

The analysis of the simulation results shows the Neighbors advertisement interval value needs to be between 100 and 150 for keep handover delay at minimum (see figure 3.33).

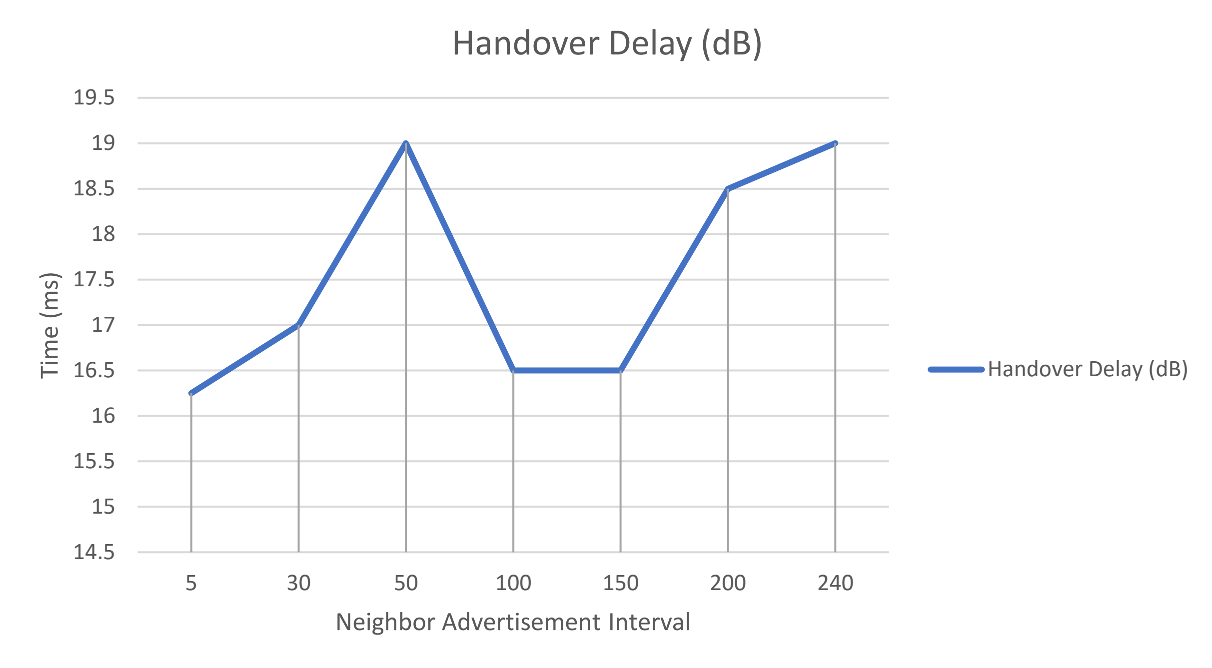


Figure 3. 33 Effect of neighbor Advertisement Interval on Handover Delay

4.11 Mobile IP registration lifetime request :

A mobile node registers with its home agent using a registration request message in each period so that its home agent can create or modify a mobility binding for that mobile node (for example, with a new lifetime). (More information in chapter 2)

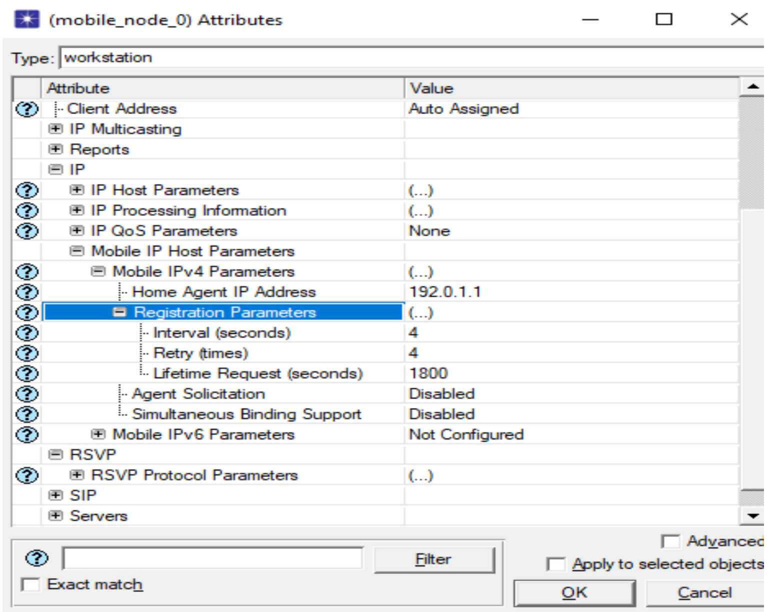


Figure 3. 34 Configuring Mobile IP registration lifetime request value

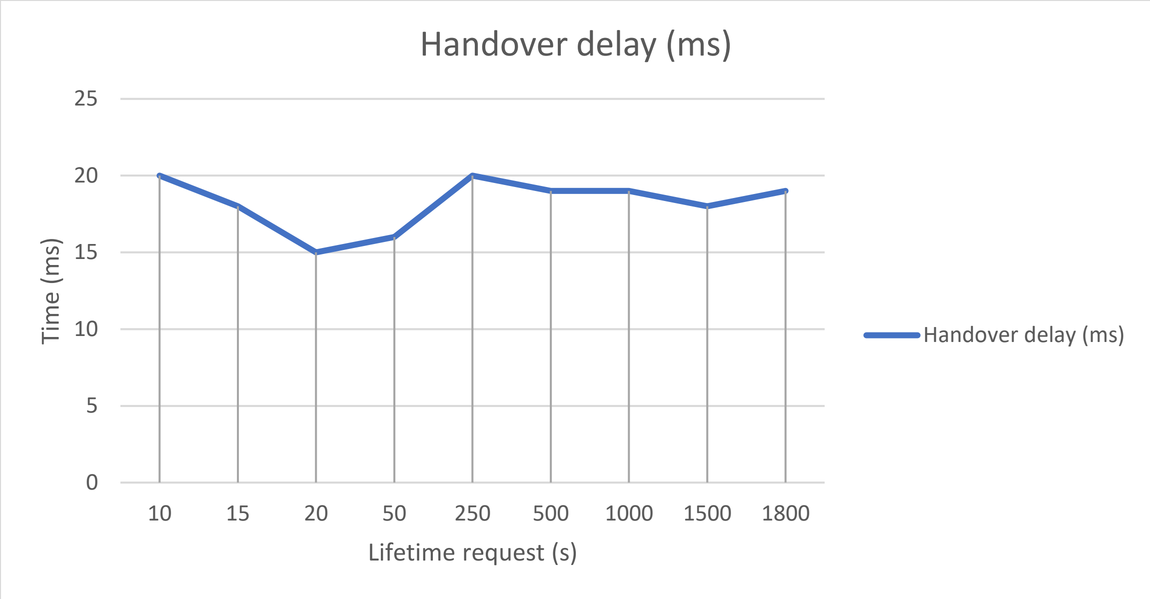


Figure 3. 35 Effect of Mobile IP registration lifetime request on Handover Delay

The figure 3.36 shows that if the Lifetime request value is kept either at 20s or at 50s the signal broadcast will show the minimum handover delay while if the value is set up more than 50s or less 20s the handover delay moves to the highest point. The results also identify when lifetime request factor is at 20s provide a best mobility and similar handover delay which is 0.015 S.

4.12 Using combined results to achieve maximum mobility

After individual simulations where we received maximum mobility and lower handover delay time. So, in order to achieve maximum mobility and minimum handover delay the individual results were combined and applied in simulation which showed improvements in handover delay. These factors are combined in table 3.7.

Experiments	**Value for Which WiMAX Shows best Mobility Results**
Mobile station speed	60 Km/h
Distance between Base station	10 Km
Number of transmitters	SISO
Scanning threshold (dB)	[30,35]
Scan iteration	8
Interleaving Interval	150
Start Frame (M)	15
Ranging Backoff Start	[0 , 1]
Neighbour Advertisement Interval	5

Table 3. 7 Showing the Values where these experiments have the higher mobility and lower handover delay time.

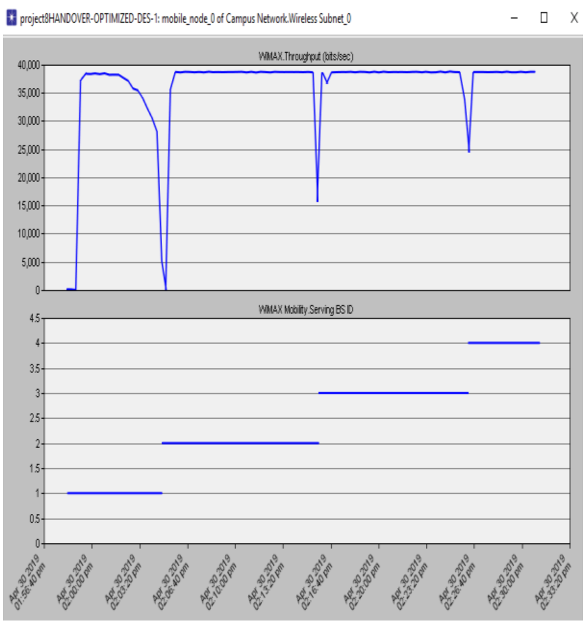


Figure 3. 36 WiMAX throughput optimized

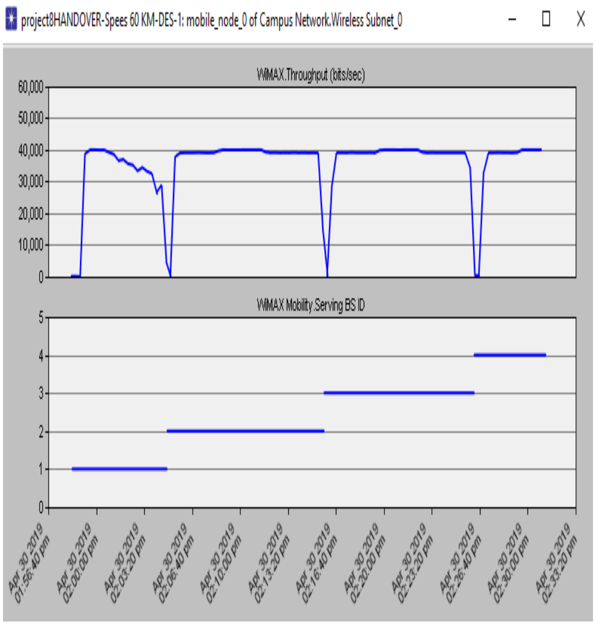


Figure 3. 37 WiMAX throughput before optimization

We show from this result that there is optimization on the WIMAX throughput level in which after the optimization WIMAX throughput does not drop to 0 when MS migrate from Base station 2 to 3 and 3 to BS4.

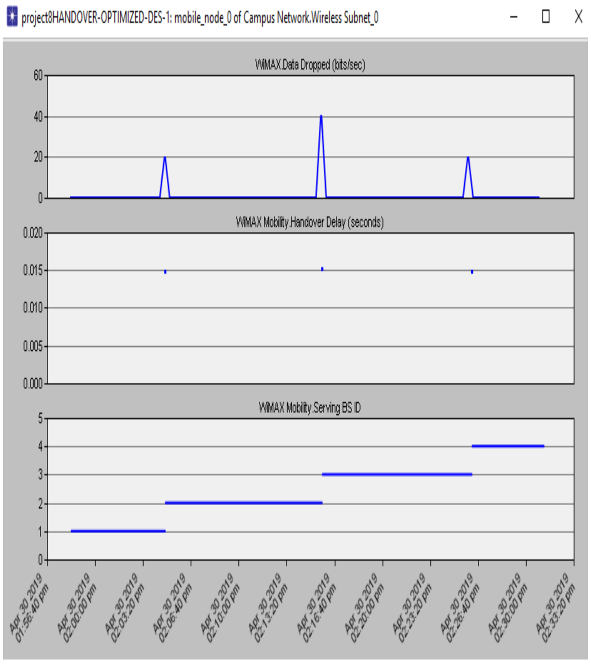


Figure 3. 38 Handover delay and data dropped after optimization

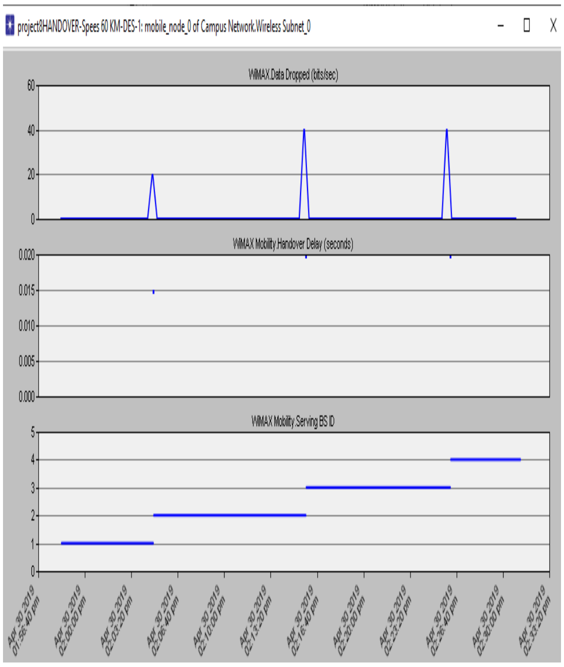


Figure 3. 39 Handover delay and data dropped before optimization

as this result show that handover delay decreased from 20ms to 15ms after optimization in third and second handover and also decreased WiMAX Data dropped in third handover from 40 to 20 bits/s

These results show clear indication that WiMAX performs better with better mobility if these factors are stabilized at values where they show low Handover delay time. The simulation showed improvements in handover delay and WiMAX throughput. There has been continues improvement with standardizing the factors, but they cannot fully remove or minimize the handover delay in WiMAX to minimal level.

5 Conclusion

We divided this chapter into two major experiments:

In experiment N°1 show that handover delay has a direct effect on WiMAX throughput and data dropped which is a minimum data dropped and maximum throughput when handover delay is lower. We also saw that the speed has an effect on handover delay where we concluded that that when the mobile device is moving less than 80 km/h would result in a minimum handover delay and highly mobility in WiMAX.

In experiment N°2 was to further identify those factors which directly affect the handover delay in WiMAX. The simulations were carried out on all these factors. After simulation, we identified that there are factors out of 10 that have a direct effect on handover delay in WiMAX signals and a change in these factors would directly result in either increase or decrease in handover delay in WiMAX. These factors are:

a) Distance between BS

b) Number of transmitters

c) VOIP codecs

d) Scanning threshold

e) Scan iteration

f) Interleaving Interval

g) Start frame

h) Ranging Backoff Start

i) Neighbour Advertisement Interval

g) Mobile IP registration lifetime request

As these factors were identified, we also identified in our simulations that these factors perform better when they are kept at a particular value and WiMAX show minimum handover delay times. (see table 3.7)

we have optimized the effect of a handover by minimizing the handover delay to a certain percentage that will improve the quality of service in the WiMAX network

GENERAL CONLUSION

The advent of 4G wireless cellular technology-mobile WiMAX based on IEEE 802.16e standard was basically destined to meet higher data rates with mobility along with enhanced Quality of Service (QoS). Mobile WiMAX has been designed at the outset as a broadband access technology capable of delivering triple play services (voice, data and video). However, the HO operation is one of the critical operations in mobile WiMAX, which can influence the continuity of real-time applications over WiMAX. The HO mechanism is one of the most important research areas in the field of mobile WiMAX, and the goal of reducing the HO latency to support real-time applications.

The object of this research to create the most efficient WiMAX Network by reducing Handover delay to a minimum. The optimization process done in this research included the experiments, parameters setup, collected data and results in order to improve WiMAX mobility with lower handover delay times and higher quality of service (QOS) and better WiMAX network. During the optimization process the key performance indicators were used to evaluate the system performance and to provide the final solution with minimum handover delay at higher QoS levels. There two main experiments conducted with a number of sub experiments in this research by using OPNET Modeler (version 14.5).

Experiment 1 worked to identify and study handover delay in WiMAX Network and we saw that handover delay have a direct effect on WiMAX throughput and data dropped which is a minimum data dropped and maximum throughput when handover delay is lower. We also the effect of speed on handover delay was identified, as the higher speed results a higher handover delay. As this study wanted to improve the basic parameters of the signal to ensure minimum handover delay, this experimentally identified that a speed less than 80 km/h will result in a minimum handover delay at given boundary conditions.

The Experiment 2 worked to identify the physical factors which effect the handover delay and there are several factors which can effect handover delay in WiMAX, but after the simulation experiment and results analysis, showed only 10 factors have a direct effect on handover delay. These 10 factors resulted in a lower handover delay, when they were kept at specific values which is called as best performing values. These factors is:

a) Distance between BS

b) Number of transmitters

c) VOIP codecs

d) Scanning threshold

e) Scan iteration

f) Interleaving Interval

g) Start frame

h) Ranging Backoff Start

i) Neighbour Advertisement Interval

g) Mobile IP registration lifetime request

Then, after individual results were combined and applied in simulation which showed a certain percentage in minimization of the handover delay that will improve the quality of service in the WiMAX network.

The future work would be to develop the handover system to reduce more handover delay and to be tested to support high speed mobility.

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