An Efficient Handoff Scheme for WiMAX Networks with Load Balancing

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ABSTRACT

The IEEE 802.16e-2005 standard Mobile WiMAX is the technology which provides wireless access to hundreds of users over long distances with high data rates. The Mobile users may have high mobility; to support this mobility and guarantee continuous connection in Mobile WiMAX when the mobile station travels far from the coverage area of its servicing base station, WiMAX must support handoff. Handoff is the process of switching between the base stations. During the period of the handoff process, the mobile station leaves the connection with the serving base station and hence leads to temporarily stopping running services. The efficiency of the mobile wireless network is affected by the handoff latency which occurs during the handoff process, as a result of scanning, ranging with the neighbor base stations and authentication, and registration with the target base station.

In this thesis, we propose a new handoff scheme for Mobile WiMAX using the handoff prediction table in order to minimize the handoff latency and also balance the load between base stations. The handoff prediction table is used to expect the next base station, so the mobile station does not need to scan all neighboring base stations.

Performance analyses of the proposed scheme were carried out and the results show that our proposed scheme can decrease the latency compared with the standard WiMAX and other previously proposed schemes. Also, the results show that load balancing can be achieved between base stations by using the proposed scheme.

Keywords: WiMAX, Handoff, Handoff prediction table, Handoff latency.

ÖZ

IEEE 802.16e-2005 standard "Mobil WiMAX", yüzlerce kullanıcıya yüksek veri oranları ile uzak mesafelere kablosuz erişim sağlayan bir teknolojidir. Mobil kullanıcıları yüksek hareketliliğe sahip olabilir; mobil istasyonu baz istasyonunun kapsama alanından bir diğerine hareket ederken bu hareketliliği desteklemek ve Mobil WiMAX ile sürekli bağlantıyı garantilemek için, WiMAX transferini desteklemesi gerekir. Transfers baz istasyonları arasında geçiş yapma işlemidir. Transfer işlemi sırasında, mobil istasyon hizmet veren ana istasyon ile bağlantıyı koparır ve dolayısıyla geçici olarak sağlanan hizmetin durdurulmasına yol açar. Mobil telsiz ağının verimliliği, transfer işlemi sırasında ortaya çıkan gecikmeden etkilenir. Bu gecikmeler, tarama, komşu baz istasyonla kimlik doğrulama, ve hedef baz istasyon ile kayıt yapma işlemlerden dolayı ortaya çıkmaktadır.

Bu tezde, geciden dolayı ortaya çıkan gecikmeyi en aza indirgemek ve geçis tahmin tablosunu kullanarak baz istasyonları arasındaki yükü dengeleme amacıyla Mobil WiMAX için yeni bir geçis düzeni önerilmektedir. Geçis tahmin tablosu bir sonraki ana istasyonu belirlemek için kullanılmakta ve bu nedenle mobil istasyonun tüm komşu baz istasyonlarını taramasına gerek olmamaktadır.

Önerilen düzenin performans analizleri yapılmış ve elde edilen sonuçlara gore, tez çalışmasında önerilen düzenin standart WiMAX ve daha once varolan diğer düzenlerle karşılaştırılması sonucu, önerilen düzenin gecikmeyi azaltmakta etkili olduğunu göstermektedir. Ayrıca, sonuçlar, önerilen düzen kullanılmasının, baz istasyonları arasında yük dengelemesinde olumlu etki yapacağını göstermektedir.

Anahtar Kelimeler: WiMAX, Geçis, Geçis tahmin tablosunu, Geçis gecikmesi.

To my lovely son (Hasan), who shared with me all moments and all the difficulties that I faced during my studies.

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LIST OF ABBREVIATIONS

AES	Advanced Encryption Standard
AMC	Adaptive Modulation and Coding
AMPS	Advanced Mobile Phone System
ATD	Arrival Time Difference
BE	Best Effort
BF	Beam Forming
BS	Base Station
CBR	Constant Bit Rate
CID	Connection Identifier
CINR	Carrier to Interference to Noise Ratio
CNR	Carrier to Noise Ratio
DL	Downlink
DSL	Digital Subscriber Line
Ertps	Extended real time variable rate
FBSS	Fast Base Station Switching
FCH	Frame Control Header
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIPS	Federal Information Processing Standard
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications

H	Hypothisis
HARQ	Hybrid Automatic Repeat Request
HO	Handoff
HHO	Hard Handoff
HUMAN	High- Speed Unlicensed MAN
IETF	Internet Engineering Task Force
IS-95	Interim Standard 95
ITU	International Telecommunication Union
LAN	Local Area Network
LOS	Line Of Sight
LTE	Long Term Evolution
MAC-L	Medium Access Control Layer
MAN	Metropolitan Area Network
MAHO	Mobile Assisted Handoff
MDHO	Macro diversity Handoff
MCHO	Mobile Controlled Handoff
MIMO	Multi Input Multi Output
MOB_NBR-ADV	Mobile Neighbor Advertisement
MOB_SCN-REQ	Mobile Scanning Request
MOB_SCN-RSP	Mobile Scanning Response
MOB_MSHO-REQ	Mobile Handoff Request
MOB_BSHO-REQ	Base Station Handoff Request
MOB_HO-IND	Handoff Indication
MS	Mobile Station
MTSO	Mobile Telephone Switching Office

NCHO	Network Controlled Handoff
NMT	Nordic Mobile Telephone
NLOS	Non Line Of Sight
Nrtps	Non real time polling service
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
PHY-L	Physical Layer
PBS	Previous BS
PDU	Protocol Data Units
QoS	Quality of Service
Rtps	Real time Polling service
RSSI	Received Signal Strength Indication
RNG-REQ	Ranging Request
RGN-RSP	Ranging Response
SC	Single Carrier
SBS	Serving Base Station
SNR	Signal to Noise Ratio
SDU	Service Data Units
SFID	Service Flow Identifier
TBS	Target Base Station
TACS	Total Access Communication Systems
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
UL	Up Link
UGS	Unsolicited Grant Service

VOIP	Voice over IP
WAN	Wide Area Network
WCDMA	Wideband CDMA
WiMAX	Worldwide Interoperability for Microwave Access
B	Beta
3DES	Triple Data Encryption Standard
1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation

Chapter 1

INTRODUCTION

1.1 Background

Wireless access technologies have completely indicated different evolutionary ways which were strived toward united goal: efficiency and performance in elevated traffic medium. The first generation (1G) has introduced the fundamental of mobile networks. Some of the most popular standards deployed for 1G system that were respectively Advanced Mobile Phone System (AMPS), Total Access Communication Systems (TACS) and Nordic Mobile Telephone (NMT). As for the second generation (2G), it has improved transmission quality and coverage. Besides, 2G has offered additional services, such as paging, faxes, text messages and voicemail. Global System for Mobile communications (GSM) and General Packet Radio Service (GPRS) Networks were introduced in this time period. This is followed by the third generation (3G), which has looked for information at higher speeds to open the gates for really mobile broadband experience [1] [2]. The fourth generations (4G) is faster and it uses more frequency channel than 3G. 4G coverage which is limited to large metropolitan areas, outside these areas the 4G retreats to the 3G standards [3]. Figure 1.1 below shows the wireless standard landscape.

Broadband indicates to a web connection that enables bolster for voice, data, and video info at high velocities, and it is generally offered by wired based high speed connectivity like Digital Subscriber Line (DSL) or cable services. It’s counted broad as a result of multiple types of services in which it can move across the extensive domain, and mobile broadband combines these services to mobile devices [1] [4].

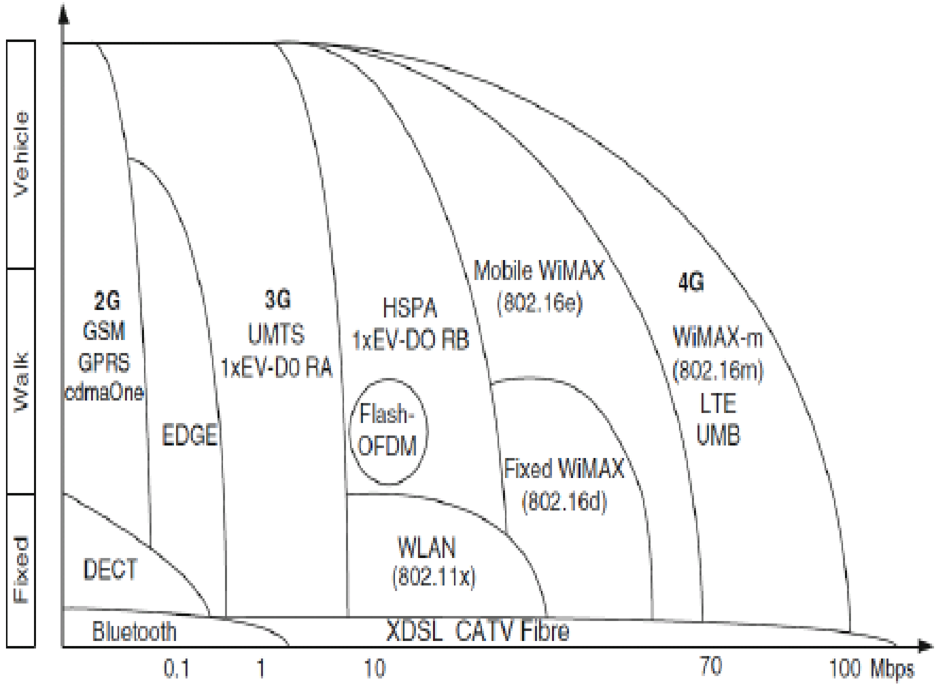

Figure 1.1: Wireless Standard Landscapes [4]

The IEEE 802.16, an answer to wide band wireless access, is called Worldwide Interoperability for Microwave Access (WiMAX). It is one of the closest technologies to meet the standards of real 4G, and it is also described as the first 4G offering.

Before WiMAX, Local Area Network (LAN), Metropolitan Area Network (MAN) and Wide Area Network (WAN) have been appeared to supply wireless communications within various communication ranges. WiMAX is defined as telecommunications technology which is geared toward providing wireless connection over long distances up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In WiMAX, when a user uses a 75 Mbps data rate; the bandwidth for this data rate can be up to 20 MHz [3]. WiMAX is dependent on the IEEE 802.16 standard and it is additionally called Wireless MAN.

Long Term Evolution (LTE) is a version of 4G, but it is still not real 4G. Mobile WiMAX Release 2 and LTE Advanced are the only two standards realized by the International Telecommunications Union (ITU), and they are considered as real 4G [5]. The fifth generation (5G) indicates the following major phase of mobile telecommunications standards after the current 4G, but till now the difference between 4G and 5G does not appear. Some sources proposed that a new generation of 5G standards may be presented almost in the early 2020s [6].

1.2 WiMAX Standards

First of all, The WiMAX standard was published first in 2001. It is specializing in point-to-multipoint broadband wireless access. It improves the practicality and approves completely different generations for this standard. The WiMAX standard is given a frequency band of 10 to 66 GHz with a theoretical most bandwidth (BW) of 120 Mbps and transmission band utmost of 50 km. However, this standard solely bolsters Line-Of-Sight (LOS) transmission, and the physical layer (PHY-L) is not suitable for lower frequency applications wherever Non-Line-Of-Sight (NLOS) operation is required; this means that it is not desirable deployment in urban areas [7]. For this reason, IEEE 802.16a-2003 has been confirmed in Apr.2003, and it supports NLOS transmission and depends on OFDM at the PHY-L. The IEEE 802.16a standard operates in licensed and unlicensed frequencies range between 2 to11 GHz. One of the most issues within the earlier standards of WiMAX is that it covers several profiles and PHY-Ls, which may cause potential interoperability problem.

The IEEE 802.16 standard has been approved in 2004 and the new version is known as IEEE 802.16d “Fixed WiMAX”. The 802.16d-2004 standard doesn’t support mobility. To resolve the problem of mobility, the IEEE 802.16e-2005 standard was published and had full support for mobility. It is called “Mobile WiMAX” because it is presented to support the mobility [8]. The mobile WiMAX air interface uses Orthogonal Frequency Division Multiple Access (OFDMA), which is the most popular varied access technique within the downlink (DL) and uplink (UL) to improve multipath performance and BW development [1]. WiMAX Release 2 is a second-generation with high-speed wireless communication technology released in late 2012. It is an upgrade to the Mobile WiMAX. It offers faster UL and DL speeds of up to 90 Mbps and 170 Mbps; it replaced the existing IEEE802.16e with IEEE802.16m.

The basic characteristics of IEE802.16 standards are summarized below in Table 1.1.

Table 1.1: Summaries of IEEE802.16 Standards [7]

Parameter	IEEE802.16	IEEE802.16d-2004	IEEE802.16e-2005
Frequency Range	10Gz-66Gz	2Gz-11Gz	2Gz-11Gz for fixed; 2Gz-6Gz for Mobile
Channel condition	Fixed LOS	Fixed NLOS	Fixed and Mobile NLOS
Modulation	QPSK; 16QAM;64QAM	QPSK; 16QAM;64QAM	QPSK; 16QAM;64QAM
Bit Rate	32-120Mbps	1-75Mbps	1-75Mbps
Channel Bandwidths	20,25,28 MHz	Scalable between (1.25 to 20) MHz	Scalable between (1.25 to 20 MHz)
Cell Radius	30 miles	(3 to 5) miles	(1 to 3)miles
Multiplexing	TDM/TDMA	TDM/TDMA/OFDMA	TDM/TDMA/OFDMA

1.3 WiMAX vs. Wi-Fi

The comparison between WiMAX and Wi-Fi can be summarized according to the following Table [4]:

Table 1.2: WiMAX vs. Wi-Fi

Parameter	WiMAX	Wi-Fi
IEEE Standards	IEEE 802.l6 Standard	IEEE 802.ll standard
Range	Up to 40 miles Or up to 211200 Feet	0.0189 miles Or 100 feet
Bit Rate	75MbPs	Up to 54Mbps
Scalability	1-1000 number of users	1-10 number of users
Channel Bandwidths	flexible channel sizes from l.5MHz to 20MHz	fixed channel sizes 20MHz
Frequency Range	2GHz to 11GHz	Up to 5GHz
Quality of Service	WiMAX can provide your several levels of QoS	Wi-Fi doesn't guarantee any QoS
Multiplexing	TDM, TDMA, OFDMA	CSMA
Duplexing	TDD, FDD	TDD
Modulation	QPSK, 16 QAM, 64 QAM	BPSK, QPSK, 16 QAM, 64 QAM

1.4 Motivation

In the course of present connectivity, a mobile station (MS) is equipped with an IEEE 802.16 interface which is probably reaching to travel across multiple base stations (BSs) so as to keep up the connection.

In general, the mobile device must scan multiple channels to search out neighboring BSs and choose an association for an acceptable target. This choice will be depended on completely various criteria, for instance: measured signal strength, error ratio, throughput, packet delay, and security levels. Before the MS is ready to do a handoff (HO), it is desirable to perform scanning and acquire a listing of neighboring BSs (NBSs). Therefore, channel scanning takes time and causes deterioration of the QoS. Indeed, the Mobile WiMAX extension standard supports the temporary suspending connection between each of the BS and MS so as to do channel scanning [1].

After scanning channels, HO processes are began to change the wireless association from the present BS to the new BS. HO processes are often divided into 2 categories: Medium Access Control layer HO (MAC-L HO) and network layer HO. In the MAC-L HO, the MS selects the new BS on the basis of QoS, signal quality or other metrics and communicates to the new BS within the PHY-L. In contrast, in network layer HO, a brand new routing path is found by the MS in order to keep up the connection with the suitable nodes. After the HO process, the MS ought to maintain any communication with suitable nodesthat existing actually prior the HO process [3]. This research concentrates on the MAC-L HO, and the main idea is to reduce the HO latency through waiving needless scans during the HO process by using HO prediction table.

1.5 Objectives

The main objectives of this research can be listed as follows:

- Survey the HO technology in WiMAX network such as HO initiation and decision, the types of HO, the mobile WiMAX HO phases, and most interesting proposed HO schemes for WiMAX.

- Improve the performance of HO in WiMAX using load balancing and reduce the HO latency, calculate dropping call probability, mean absolute load difference, and average number of overhead SMS messages and compare the proposed scheme with the WiMAX standard and other proposed schemes.

1.6 Thesis Outline

The remainder of this thesis is organized as follows: In Chapter 2, literature review of the features of WiMAX technology layers is presented; also the HO concepts for the WiMAX networks are introduced. Moreover, the HO types and phases are discussed, and the most interesting proposed schemes in WiMAX are also presented in this chapter. The proposed scheme is presented in details in Chapter 3. Chapter 4 discusses our simulation results. Finally, the conclusion and the future work are presented in Chapter 5.

Chapter 2

LITERATURE REVIEW

2.1 WiMAX Layers

The structure of Mobile WiMAX consists of five sub-profiles, namely, PHY, MAC, duplexing mode, power classes, and radio profile as shown in Figure 2.1 below. Although there are many various sets of channel BWs and center frequencies absorbing various regional spectrum regulations, the same PHY and MAC features are shared in mobile WiMAX products and also these products share same duplexing mode. The PHY-L and MAC-L in the mobile WiMAX system profile are presented in this section.

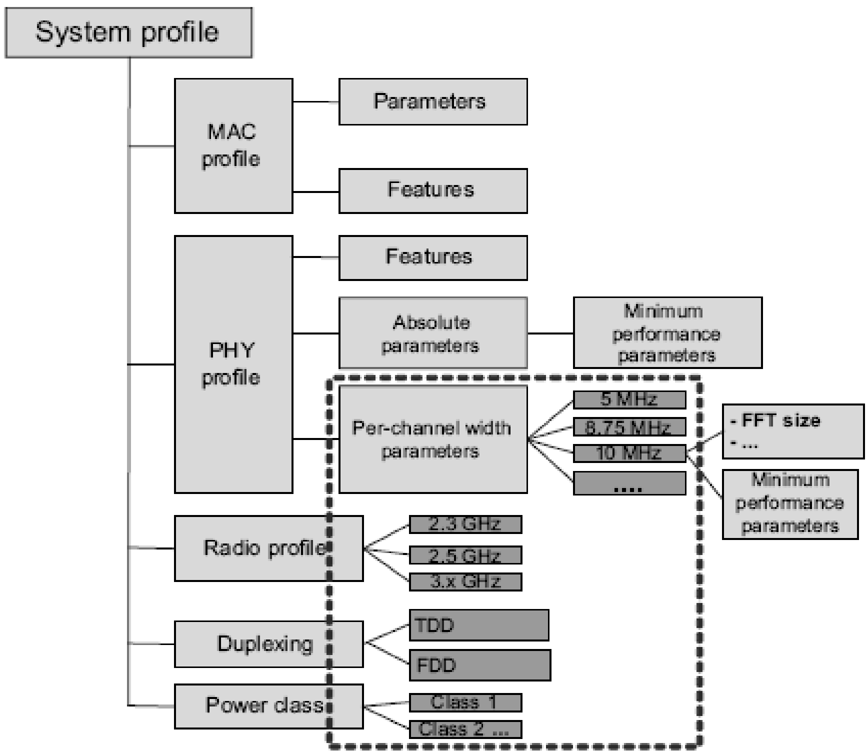

Figure 2.1: The Mobile WiMAX System Structure [1]

2.1.1 Physical Layers

IEEE802.16 standards support five Wireless MAN PHY-Ls and each of these layers can merge with the MAC-L [9].

Wireless MAN-SC is the first one which is introduced by the IEEE802.16 group. It is a point to point communication which operates in 10 to 66GHz frequency range, and at these ranges, the LOS is essential. It is supported by both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) mode. This standard supports QPSK, 16QAM, and 64QAM) modulation for single –carrier (SC).

Wireless MAN-SCa (or Wireless MAN-SC2) works in the 2 to 11GHz frequency range, and uses SC modulation. It is designed for NLOS and point to multipoint communication. This layer supports BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM modulation; it is supported by both TDD and FDD duplexing mode.

Wireless MAN-OFDM with 256 Subcarrier, works in the 2 to 11GHz frequency range. It is based on Orthogonal Frequency Division Multiplexing (OFDM). This is suitable for fixed access and NLOS environment. Both TDD and FDD duplexing modes support this layer.

Wireless MAN-OFDMA uses OFDMA which an extension of the OFDM. This layer introduced 128, 512, 1024 or 2048 carrier, and accommodated NLOS and provided both fixed and mobile access. It is supported by both TDD and FDD duplexing modes.

Wireless HUMAN, “High-speed Unlicensed MAN” is same as OFDM, but frequency chosen is compulsory for permit ranges between 2 to 11GHz, and it is supported by TDD duplexing mode.

2.1.1.1 Scalability of OFDMA

OFDMA creates the basis for Mobile WiMAX. It shows an outstanding performance in NLOS multi-path channels with its relatively easy transceiver structures. It permits efficient use of the available spectrum resources by time and frequency sub-channelization. The easy transmission and reception structure of OFDMA allows additionally possible implementation of advanced antenna techniques like Multi Input Multi Output (MIMO) with acceptable complexity. Scalable OFDMA means possibility to regulate the use of BWs and as such different environments through varying spectral requirements will be served. The OFDMA is using 128- 512- 1024- or 2048 bit “Fast Fourier Transform” (FFT) that enables to support scaling BWs between 1.25 to 20 MHz. Table 2.1 show the OFDMA scalability parameters [10].

Table 2.1: OFDMA Scalability Parameters [10]

Parameter	Values			
System Channel Bandwidth(MHz)	1.25	5	10	20
Sampling Frequency (MHz)	1.4	5.6	11.2	22.4
FFT Size	128	512	1024	2048
Number Of Sub Channel	2	8	16	32
Sub-Carrier Frequency Spacing	10.98KHz			
Useful symbol time (MS)	91.4			
Guard Time(MS)	11.4			
OFDMA symbol Duration(MS)	102.9			
Number Of OFDM Symbol	48			

2.1.1.2 Adaptive modulation and coding (AMC)

The WiMAX PHY-L provides different modulation and coding schemes that offer efficient and robust network access. The modulation schemes offered 64QAM, 16QAM, QPSK, and BPSK in sequence of increasing robustness and decreasing the efficiency. The 64QAM provides the highest BW and requires good Signal to Noise Ratio (SNR) while QPSK modulation requires less SNR than 64QAM, and it is the most robust. There are also few coding rates which are used to support flexible networking and used according to Carrier to Noise Ratio (CNR). The coding rates in which it can be used are respectively 1/2, 3/4, 2/3 or 5/6. Figure 2.2 shows the above mentioned modulation schemes [11].

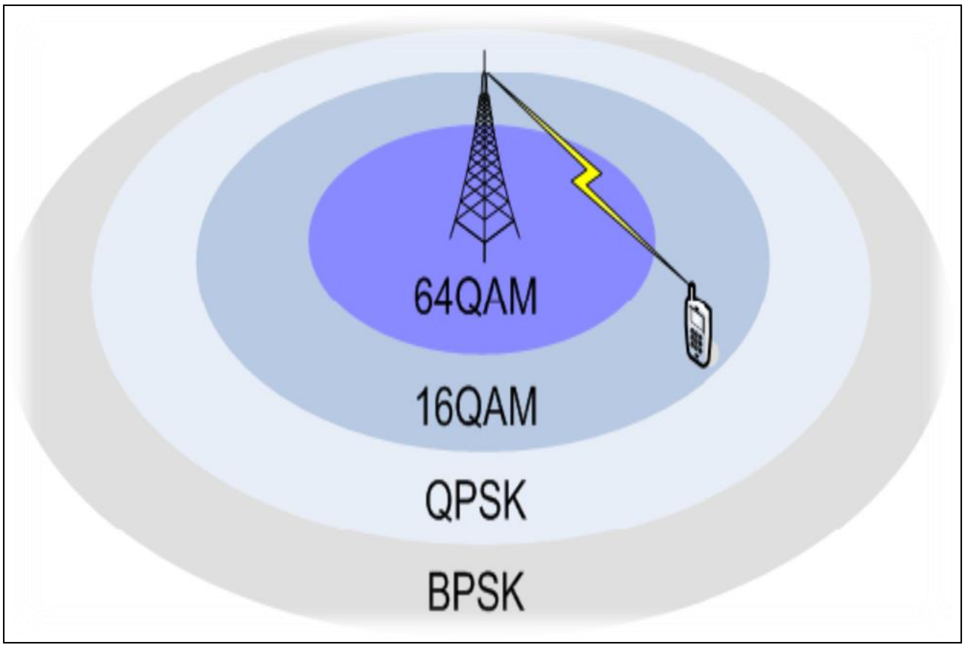

Figure 2.2: Adaptive modulation schemes [10]

2.1.1.3 Time Division Duplexing (TDD) frame structure

Mobile WiMAX has only TDD as a duplexing mode, but recently WiMAX standards add full and half FDD mode to be supported. This is because of local restrictions that are imposed by some areas. Although the WiMAX has TDD and FDD but there are many reasons of preferring the use of TDD [1].

At first, the ratio of DL/UL Internet traffic is usually asymmetric which means that the volume of DL traffic is exceeding the volume of UL traffic. The TDD duplexing can be adjusted to the DL and the UL ratios according to the needs of the networks. Whereas in FDD the amount of DL is same as the amount of UL which means that it can't provide the best use of resources [10].

Besides, TDD is more suitable for MIMO and other advanced antenna techniques, particularly Beam forming (BF) than FDD. TDD needs one channel for both UL and DL, while, on the other hand, FDD requires pair of channels one for UL and one for DL traffic. TDD is more flexible, less cost and higher spectral efficiency than FDD. The TDD frame structure is shown in Figure 2.3.

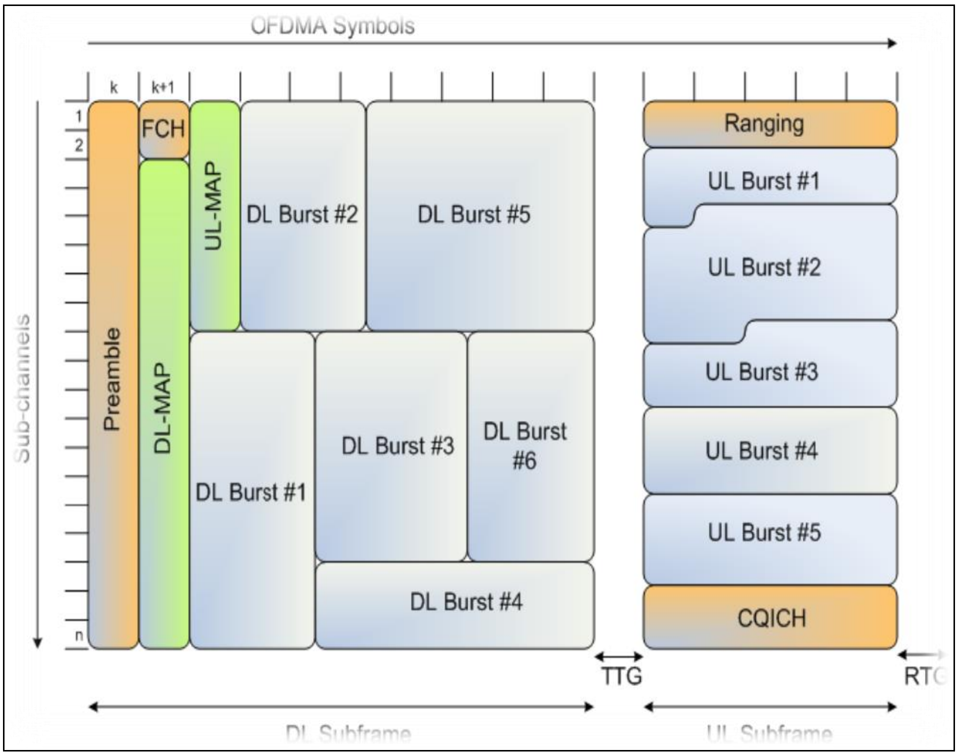

Figure 2.3: TDD frame structure [10]

The TDD DL sub-frame commences with DL preamble which is utilized for PHY-L approaches like synchronization, Carrier-to-Interference-and-Noise Ratio (CINR), and Received Signal Strength Indication (RSSI) measurement. The Frame Control Header (FCH) is following the DL preamble that contains frame information, like MAP message size, usable subcarriers, and coding and modulation scheme. DL-MAP and UL-MAP come after the FCH in the DL sub-frame. The MAP messages contain the burst profile for every user. Because of the MAP which contains vital information that is required to access to all users, it is sometime sent over an extremely trustworthy link, for example, repetition coding & BPSK with rate 1/2 coding [1].

The UL sub-frame starts with ranging sub-channels that the MSs used it for frequency and power adjustments, closed loop time, and for holding BW requests. The UL bursts include user data transmission from MS to BS. The CQI channel is used to transfer a channel quality information feedback [11].

2.1.1.4 The Data Rates of PHY Layer

Since the PHY-L of WiMAX is elastic, the difference of rate performance supports the operating parameters. The modulation, coding scheme, and the utilized of channel BW are the parameters which have a large effect on the PHY-L data rate. Also other parameters, like oversampling rate, OFDM guard time, and number of sub channels have effects as well. Table 2.2 below shows the PHY-L data rate at different channel BWs [12].

Table 2.2: PHY-layer data rate at different channel bandwidths [1]

Channel Bandwidth	3.5MHz		1.25MHz		5MHz		10MHz	
PHY mode	256 OFDM		128 OFDMA		512 OFDMA		1,024 OFDMA	
Oversampling	8/7		28/25		28/25		28/25	
Modulation & Code Rate	**PHY-Layer Data Rate (kbps)**							
	DL	UL	DL	UL	DL	UL	DL	UL
BPSK, 1/2	946	326	**Not applicable**					
QPSK, 1/2	1,882	653	504	154	2,520	653	5,040	1,344
QPSK, 3/4	2,822	979	756	230	3,780	979	7,560	2,016
16 QAM, 1/2	3,763	1,306	1,008	307	5,040	1,306	10,080	2,688
16 QAM, 3/4	5,645	1,958	1,512	461	7,560	1,958	15,120	4,032
64 QAM, 1/2	5,645	1,958	1,512	461	7,560	1,958	15,120	4,032
64 QAM, 2/3	7,526	2,611	2,016	614	10,080	2,611	20,160	5,376
64 QAM, 3/4	8,467	2,938	2,268	691	11,340	2,938	22,680	6,048
64 QAM, 5/6	9,408	3,264	2,520	768	12,600	3,264	25,200	6,720

2.1.1.5 Hybrid Automatic Repeat Request (HARQ)

HARQ is a choice part in mobile WiMAX MAC; it is supported by only the OFDMA PHY-L to provide a fast packet retransmission. Also, it works on this layer when the sending packets are probably not received due to the reason of bit errors. The cost of HARQ implementation is the negative side of it [11].

2.1.2 Mobile WiMAX MAC Layer

The main job of this layer is to support a connection between the upper layers and PHY-L, and it has been designed and improved in order to enable PMP wireless applications. The data is taken by the MAC-L from the higher layer which is known as MAC Service Data Units (SDU) and arranges them into MAC Protocol Data Units (PDU) for transmitting via the air. The reverse operation is done when the MAC-L receives transmission. Figure 2.4 shows the several sub layers of MAC-L [13].

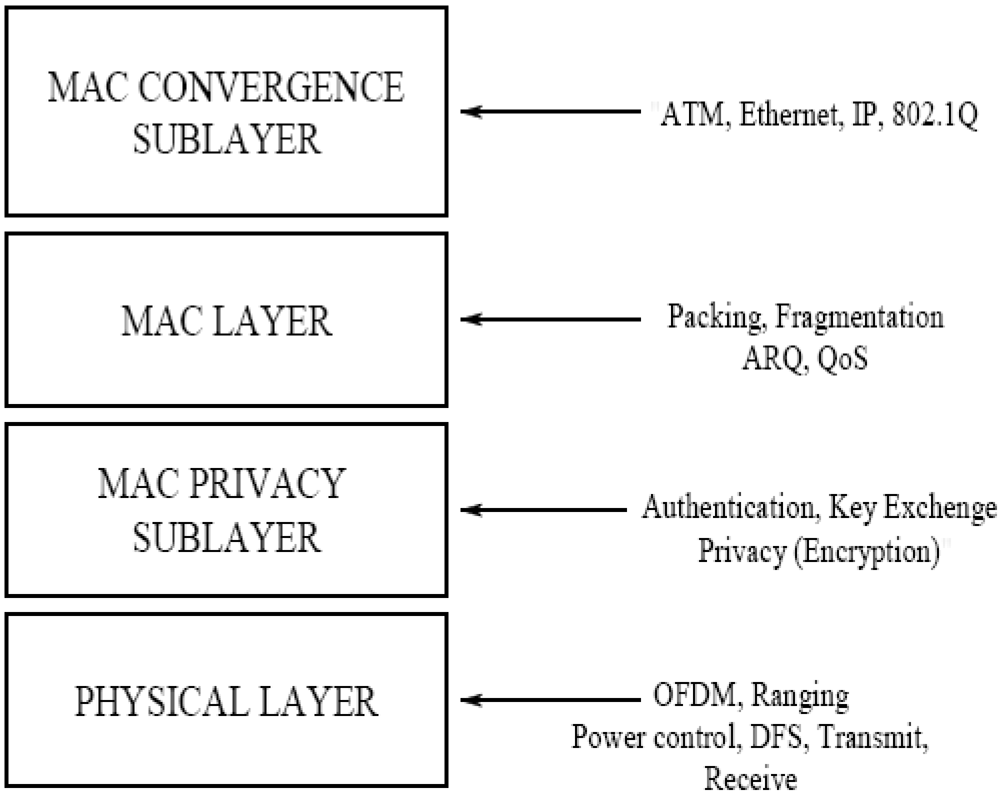

Figure 2.4: WiMAX Reference Models [7]

Fixed WiMAX and Mobile WiMAX MAC include a convergence sub-layer which can be interacted with a group of upper layer protocols, like Ethernet, IP, ATM, and the adoption of any future protocol (802.1Q).

The WiMAX MAC-L offers flexible allocation of capacity to different users and uses a different PDU length to enable their efficient transfer. Varied PDUs of same or different lengths can be collected into a single data burst to save PHY-L overhead; also, several SDUs from the upper layer can be aggregated into one PDU in order to save MAC overhead. Big PDUs can split into several small PDUs and sent via various frames [14].

2.1.2.1 Channel Access Mechanisms

In Mobile WiMAX, the MAC-L at the BS is taking full responsibility for assigning BW to MSs in the UL and the DL. The MS has some control over BW allocation only when it contains several connections and sessions with the BS. In this regard, the BW is allocated by the BS to the MS, and the decision is up to the MS to assign the BW between several connections. Allocating BW to the MS must be done by the BS according to meet the requirements of the incoming traffic, without intervention of the MS, this is for the DL. Allocations must be on the basis of demands from the MS; this is for the UL [4].

The WiMAX standard offers many of the techniques by which a MS can be asked and get UL BW. The BS assigns shared or dedicated resources periodically to each MS, with which it can be used to order BW, it is known as polling. Polling can be achieved either in Unicast or in Multicast manner. The Multicast is achieved when there is a lack in BW to poll each MS separately. When polling is completed in multicast, the allocated slot for creating BW requests is a common slot, and every polled MS tries to use it. Mobile WiMAX determines a resolution mechanism and contention access, these issues occur when more than one MS tries to utilize the common slot [1].

2.1.2.2 Quality of Service (QoS)

QoS Support is a basic section in the design of WiMAX MAC-layer. Strong QoS management is realized through using a connection-oriented MAC architecture, whenever all DL and UL connections are controlled by the SBS. WiMAX assigns a principle of a service flow. A service flow is a one directional flow of packets with a certain set of QoS parameters and is defined by a Service Flow Identifier (SFID) . A one direction logical link is built by the BS and the MS, it is known as a connection between the two MAC-L peers. A Connection Identifier (CID) recognizes each connection. This is done before any transmission occurs. Figure2.5 shows the connection between MS and BS with service follows. The QoS parameters can include maximum burst rate, maximum sustained traffic rate, minimum tolerable rate, ARQ type, tolerated jitter, traffic priority, maximum delay, service data unit type and size, transmission PDU formation rules, a BW request mechanism to be used, scheduling type, and others [4].

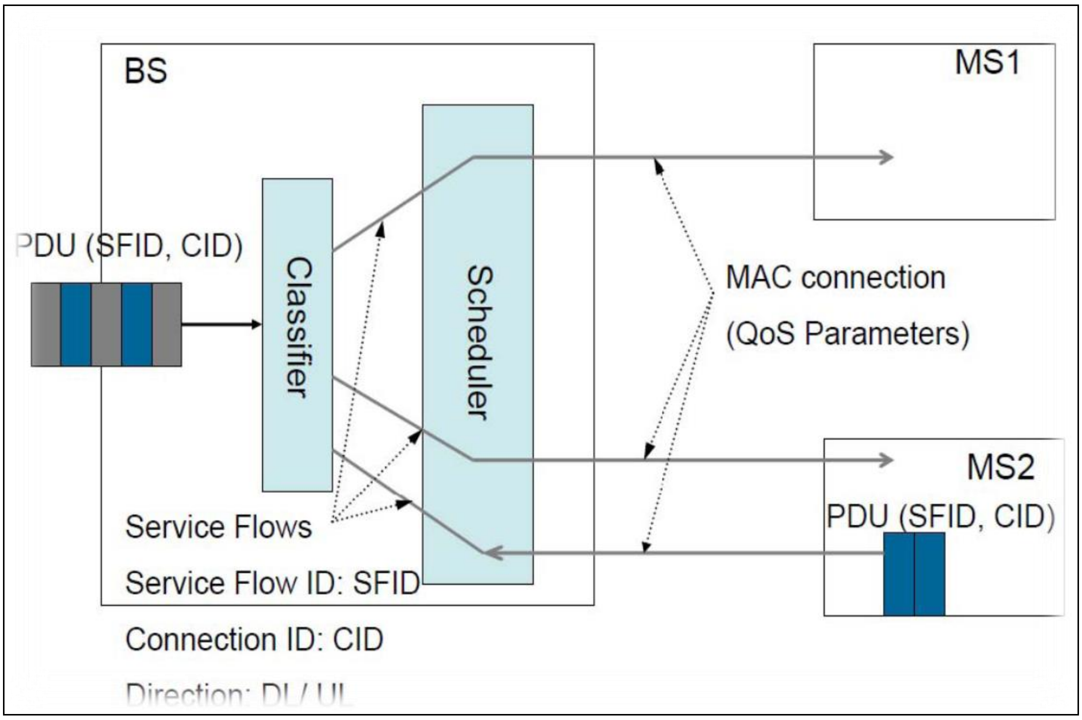

Figure 2.5: Mobile WiMAX QoS Support [1]

WiMAX specifies five scheduling types which must be bolstered by the BS MAC scheduler for data transmission over a connection as shown in Table 2.3 below:

Table 2.3: Service Classes Supported in WiMAX [1]

Service Flow Designation	Defining QoS Prameter	Application Examples
Unsolicited grand service	Maximum sustained rate Maximum latency tolerance Jitter tolerance	Voice over IP (VoIP) without silence suppression
Real-time Polling service	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Traffic priority	Steaming audio and video, MPEG (Motion Picture Expert Group) encoded
Non-real-time polling service	Minimum reserved rate Maximum sustained rate Traffic priority	File Transfer Protocol (FTP)
Best-effort service	Maximum sustained rate Traffic priority	Web browsing, data tranfer
Extended real-time Polling service	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic priority	VoIP with silence suppression

1. UGS – the Unsolicited Grant Service: It is designed to support fixed - size UL data packets at a Constant Bit Rate (CBR), this allows the use of real-time applications like Voice over IP (VoIP).

2. RtPS - the Real-time Polling Service: This provides support for real-time UL transmission with variable BW according to the size of data packets. This makes it useful for video transmission.

3. NrtPS - Non-real-time polling service: It is designed to support delay - tolerant data flows, which need variable-size data grants with an ensured rate, like an FTP. The intervals between polls are variable and short enough to offer an adequate service for the MS.

4. BE - Best Effort: This service type suits for Web browsing, and it does not need minimum requirements for the connection. It allows users to use contention request opportunities.

5. ErtPS - Extended real-time variable rate (ERT-VR) service: ERT-VR is an association of UGS and rtPS. This service is not defined in Fixed WiMAX; it is defined in Mobile WiMAX. It is designed to bolster real-time applications, like voice, video, and VoIP.

2.1.2.3 Power Management

Mobile WiMAX has power saving advantages which permit MSs to work for long periods without needing to recharging. Power saving is attained by shutting down portions of the MS in a control way when there isn't active transmission and reception [4].

Mobile WiMAX defines two modes of power efficient operation; these modes are called “Sleep Mode and Idle Mode”. In the sleep mode, the MS turns off its devices and becomes unavailable for predefined intervals; these periods are known by the BS. The sleep mode offers flexibility for the MS; during the sleep mode, other BSs can be scanned by the MS to gather information which helps for HO. This is also minimizing the MS power consumption. Ide mode allows more power saving than sleep mode, and it is optional in IEE802.16. Idle mode is a case in which the MS completely shuts down and also without registering with any BS just available for receiving DL broadcast traffic messaging. The MS does not have the ability to do HO or register, and also the network and BS eliminate HO traffic from ineffectual MS, these are the benefits of the Idle Modes [7].

2.1.2.4 Security Functions

WiMAX systems designed with flexible and robust security. It contains status of the art methods to guarantee user data privacy and preventing unauthorized users. Security is treated by a privacy sub-layer in the WiMAX MAC-L. There are many aspects of WiMAX security [12]:

- **Support for privacy**: The cryptographic schemes are used to encrypt the user data; these schemes are proven robustness to ensure privacy. Both Triple Data Encryption Standard (3DES) and Advanced Encryption Standard (AES) are bolstered. Most of the system executions will probably utilize AES, as it is the new encryption standard confirmed as compatible with (FIPS) Federal Information Processing Standard and it is easy to perform it. The 256 bits or 128 bits basic is utilized for extracting the cipher that is creating in the authentication stage.
- **Device/user authentication**: IEEE802.16 provides an elastic ways for authenticating MSs and users to avoid the use of unauthorized. The authentication is depended on the "Internet Engineering Task Force" (IETF) EAP that supports a variety of credentials, like username & password, smart cards, and digital certificates. IEEE802.16 terminal devices come with built-in X.509 digital certificates which have their MAC address and public key. WiMAX operators can utilize username/password and use the certificates for device authentication or smart card authentication for user authentication.
- **Flexible key-management protocol (Version-2)**: This protocol are utilized for safely transmitting keying material from the BS to the MS, periodically re permission and refreshing keys

- **Support for fast handoff**: To support fast HO, WiMAX enables the MS to use pre-authentication with a target BS (TBS) in order to assist accelerated Re-entry.

2.1.2.5 Mobility Support

The Mobile WiMAX supports mobility management. In particular, the Mobile WiMAX defines signaling techniques for MSs as they travel away from the coverage area of one BS to another. The MS can apply a scanning process when it moves far from the serving BS (SBS) to scan the wireless media for NBSs information that has been gathered during scanning, like central frequencies of the NBSs and then it can be sued in actual HO. The information about the parameters and central frequency of the NBSs is periodically announced by the SBS [4]. The HO mechanisms in Mobile WiMAX will be presented in details in the following section.

2.2 Handoff in Mobile WiMAX

In Mobile WiMAX, the HO or in some references called Handover is the process of tearing down the existing connection with the current BS and setting up a new connection with a NBS with better link quality. The transmitting of ongoing communication channel could be in the frequency range, code word, or time slot to a new BS.

At first, one of the basic requirements for HO to be possible is having at least 2 BSs, the SBS and the TBS(s), and a MS which can connect to the two BSs. In some cases the HO can occur in the same BS, but in different channels, this is called “Intra-cell HO”. In contrast, the other is called “Inter-cell HO”. It is also possible for HO to occur between different topologies for example (Wi-Fi to WiMAX); this is called vertical HO while horizontal HO can occur within the same topology [10].

The main reasons for HO can be summarized as below:

- Signal strength is dropped below and it is not enough to maintain the call wherever the MS travels away from the BS.
- All capacity of the BS is used up and there are more calls pending. The channel is allocated to the call from the other BS in the range of overlapping area to free-up capacity for other calls which can only connect with this BS.
- When the MS behaviors changes.
- To prevent the interference, when a channel is utilized by the MS, it becomes interfered with other MS, and it uses same channel in another cell [15].

2.2.1 Handoff Initialization

HO initialization is referred to the decision of HO request. The RSS of the SBS deteriorates when the MS travels away from it. Figure 2.6 elucidates the RSSs of SBS1 and one NBS2. The strength of received signal becomes weaker when the MS travels far from the BS1 and more powerful when it goes nearer to the BS2, because it changes according to the distance [16].

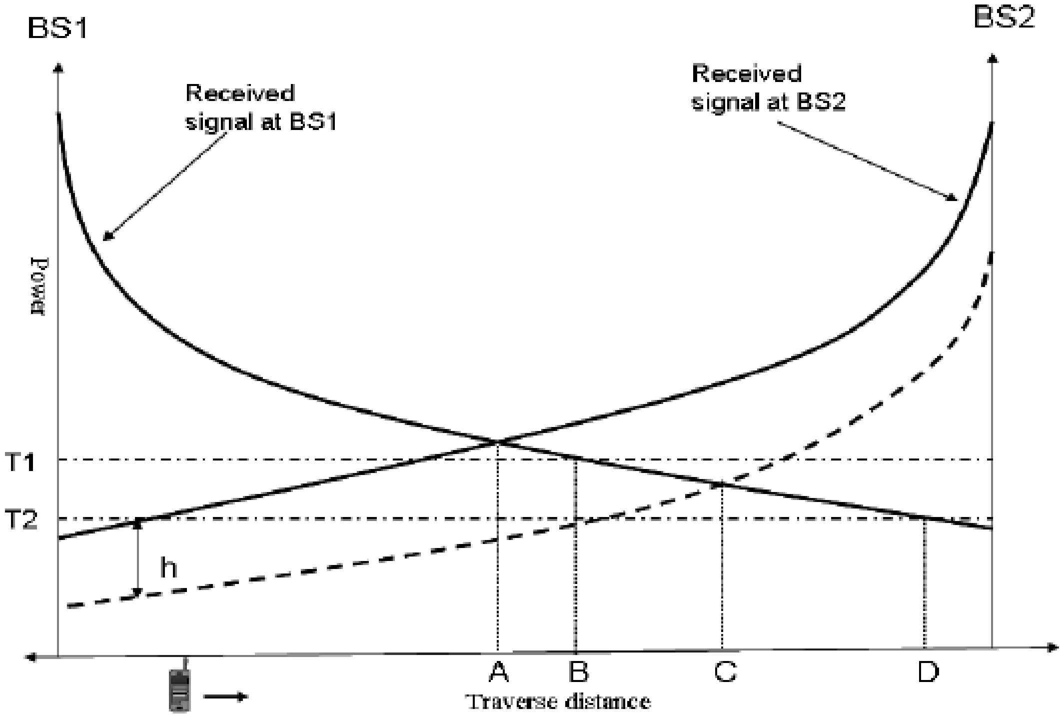

Figure 2.6: HO Decision as a Function of HO Scheme [16]

A. ***Relative Signal Strength:*** At point A, in Figure 2.6 the HO is requested, but the signal fluctuates. At this point, the HO is unnecessary, because several HOs can be requested and the signal strength of the BS1 is still at a satisfactory level. It is known as ping-pang effect.

B. ***Relative Signal Strength with Threshold:*** The HO occurs only when the signal strength of BS1 is weaker than the signal strength of BS2. At point B, the HO is unnecessary, because the threshold value (T1) is introduced in this technique in order to overpower the ping-pang effect. The HO is started when the RSS of BS1 is weaker than that of BS2 by the threshold amount.

C. ***Relative Signal Strength with Hysteresis:*** At point C, the HO is required when the RSS from BS2 exceeds the RSS from BS1 with hypothesis value (*h*). This value is used in order to initiate HO.

D. ***Relative Signal Strength with Hysteresis and Threshold:*** Both the threshold and *h* margin are combined in this technique so as to decrease the number of HOs. The HO occurs if the signal levels of BS1 falls below the threshold, and the signal of BS2 is stronger than the first by h.

2.2.2 Handoff Decision

HO decision is dependent on RSS from SBS and NBSs. The HO initiation indicates time that the HO is requested. 3 types of HO decision protocols are utilized in different cellular systems [17].

A. ***Network Controlled Handoff (NCHO):*** This protocol is utilized in 1G systems like, AMPS and NMT where the Mobile Telephone Switching Office (MTSO) is responsible for the aggregate HO decision. In this protocol, the needful RSS measurements of NBSs and HO decision are handled by the network, which leads to high load in the network.

B. ***Mobile Assisted Handoff (MAHO):*** Conducting the RSS measurements and then sending these measurements periodically to the BS is the responsibility of the MS in this protocol. So, this protocol is used to decrease the load of the network. The time of HO is decided by either the BS or Mobile Switching Center depending on the RSS measurements. GSM uses this protocol.

C. ***Mobile Controlled Handoff (MCHO):*** This protocol expands the task of the MS by awarding full control to it. The necessary measurements are made by both MS and BS and these measurements are sent by the BS to the MS. Then the time of HO is decided by the MS according to information obtained from itself and the BS. WiMAX and Digital European Cordless Telephone (DECT) use this protocol.

2.2.3 Handoff Types in WiMAX

There are two types of HO mechanisms: Hard HO (HHO) or “break before make” and Soft HO “make before break”. In WiMAX, soft HO is splitted into two types: Macro-Diversity HO (MDHO) and Fast Base Station Switching (FBSS). Shore HHO is compulsory while the MDHO and FBSS are elective [10].

During HHO, the MS is connected with only one BS at a time. In HHO, the connection of the MS with the old BS is released before it is connected with the new one. This type of HO is utilized by the systems that utilize Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA), like GPRS and GSM systems [17]. The HHO occurs when the signal strength from NBS is exceeding the signal strength of the current BS as shown in Figure 2.7. Our work highlights on the HHO.

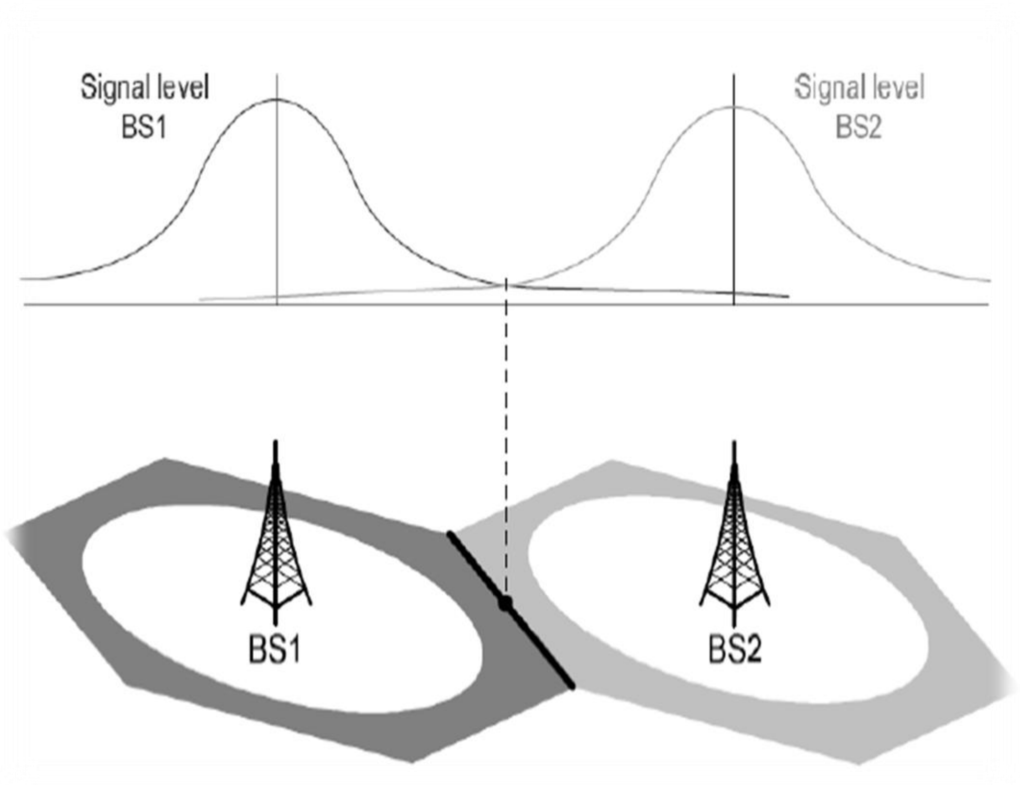

Figure 2.7: Hard HO [10]

Unlike to the HHO, a soft HO can set up several connections with NBSs. It is possible for the MS to communicate simultaneously with two BSs (the prior BS and the new BS). This type of HO is utilized by the Code Division Multiple Access (CDMA) systems where the cells utilize same frequency, but various code words. Wideband CDMA (WCDMA) and Interim Standard 95 (IS-95) are an example for the systems which use this type of HO.

The MDHO should be supported by both MS and BS, because it is an optional scheme for the Mobile WiMAX. The diversity set is a group of BSs which is found in MDHO coverage area as shown in Figure 2.8 that the MS connects with all BSs at the diversity set (UL and DL communication are included in traffic). There are also BSs which are kept outside and the diversity set which can be connected to the MS, but the signal strength is too feeble for communication. When the MS moves toward the NBS, at some point, its signal strength can be strong, then we can add this BS to the diversity set [10].

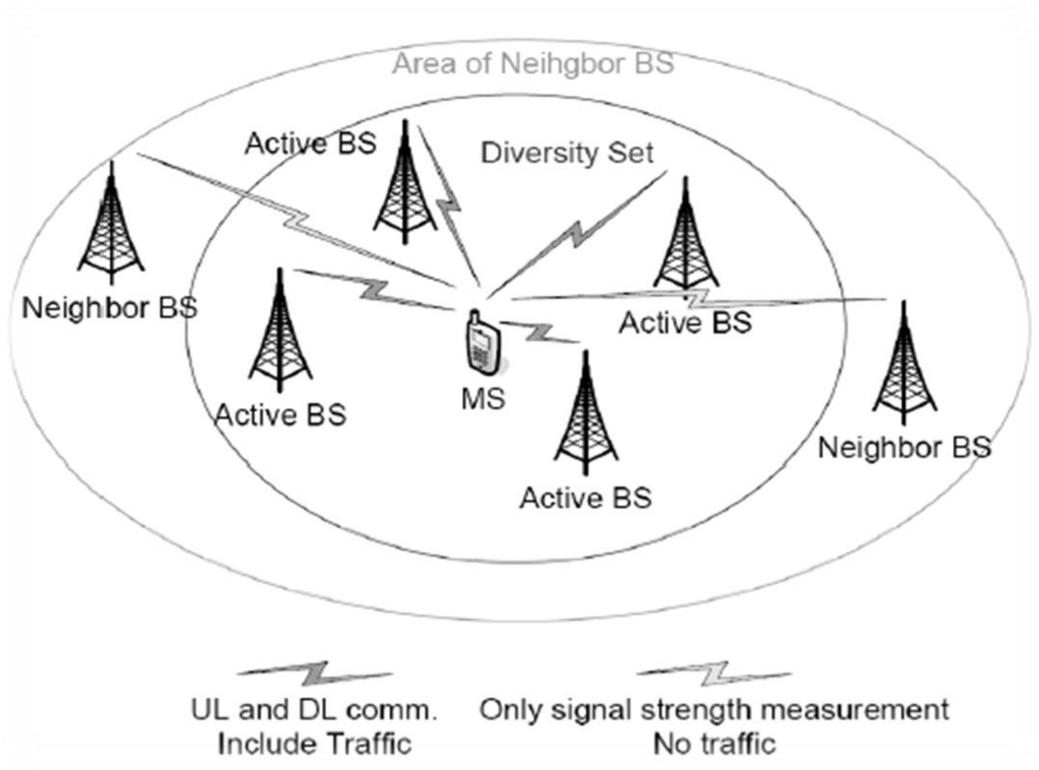

Figure 2.8: Macro Diversity HO [10]

The FBSS is similar to MDHO; it is also supported by both MS and BS, but the MS solely connects with one BS in the diversity set with all UL and DL traffic, as shown in Figure 2.9 below. This current SBS is called an anchor BS. All the BSs in the diversity set receive the data directed to the MS, but just one of them sends the packets across the air and the other BSs fall the received data. That means, each frame can be sent via various BS in diversity set because the anchor BS can be changed from frame to frame on the basis of the BS selection scheme [10].

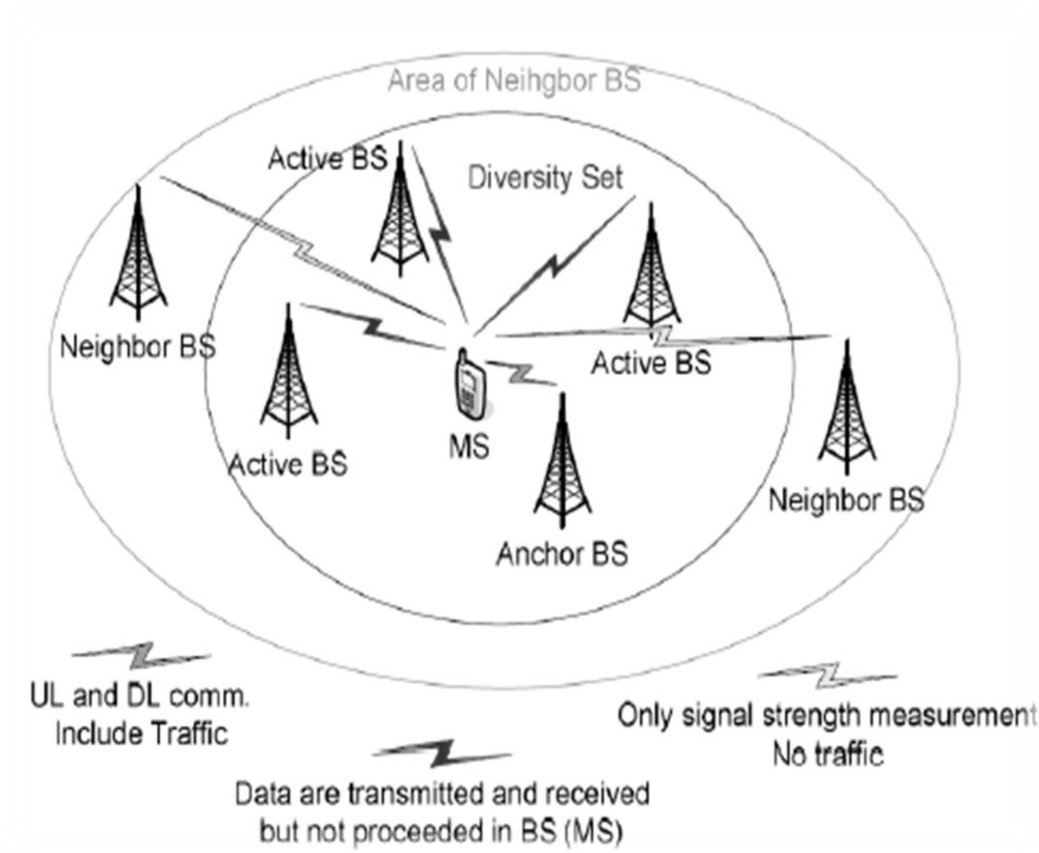

Figure 2.9: Fast Base Station Switching [9]

2.2.4 Mobile WiMAX Handoff Phases

The Mobile WiMAX HO process includes four phases; these phases can be explained in details in this section. [18].

- ***Network Topology Advertisement:*** The SBS periodically sends Mobile Neighbor Advertisement (MOB_NBR_ADV) messages to the MS. These messages provide information (ex. Radio range, MAC address) to the MS about NBSs for potential HO. In this regard, the MS becomes aware of the NBSs. Then the MS starts with the second-phase.
- ***Scanning & Ranging Processes:*** In this Phase, the MS initiates the scanning process by sending Mobile Scanning Request (MOB_SCN-REQ) message to SBS. This message indicates one or more NBSs as HO targets. The SBS sends a Mobile Scanning Response (MOB_SCN-RSP) to the MS. This

message includes a list of TBSs and their position to be used in the HO process as shown in Figure2.10.

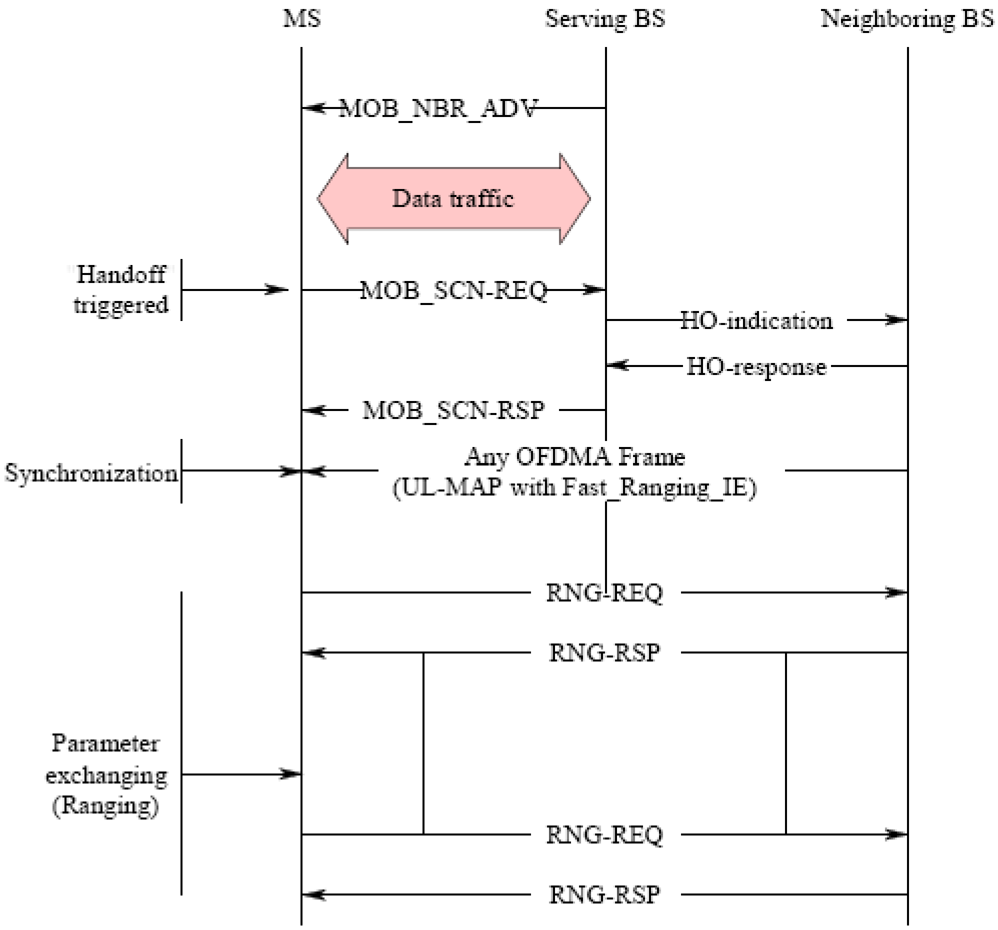

Figure 2.10: Scanning/Ranging Processes [18]

The MS starts the ranging process with the NBSs, after the scanning was successful. This process contains Ranging Request (RNG-REQ) message from the MS to the NBS and Ranging Response (RNG-RSP) from NBS to the MS message. The Ranging procedure finishes after the MS has finished ranging with all NBSs. In this phase, the MS may lose the connection with the SBS and switch to a new channel. All scanning types occur during this phase.

- ***Handoff Decision and Initiation***: This process can be taken by both the SBS and the MS. MS HO Request message (MOB_MSHO-REQ) is used, if the HO decision is taken from the MS. A BS HO Request message (MOB_BSHO-REQ) is used, if the HO decision is adopted by the SBS. Here we use MOB_MSHO-REQ as an example, (as shown in Figure 2.11).

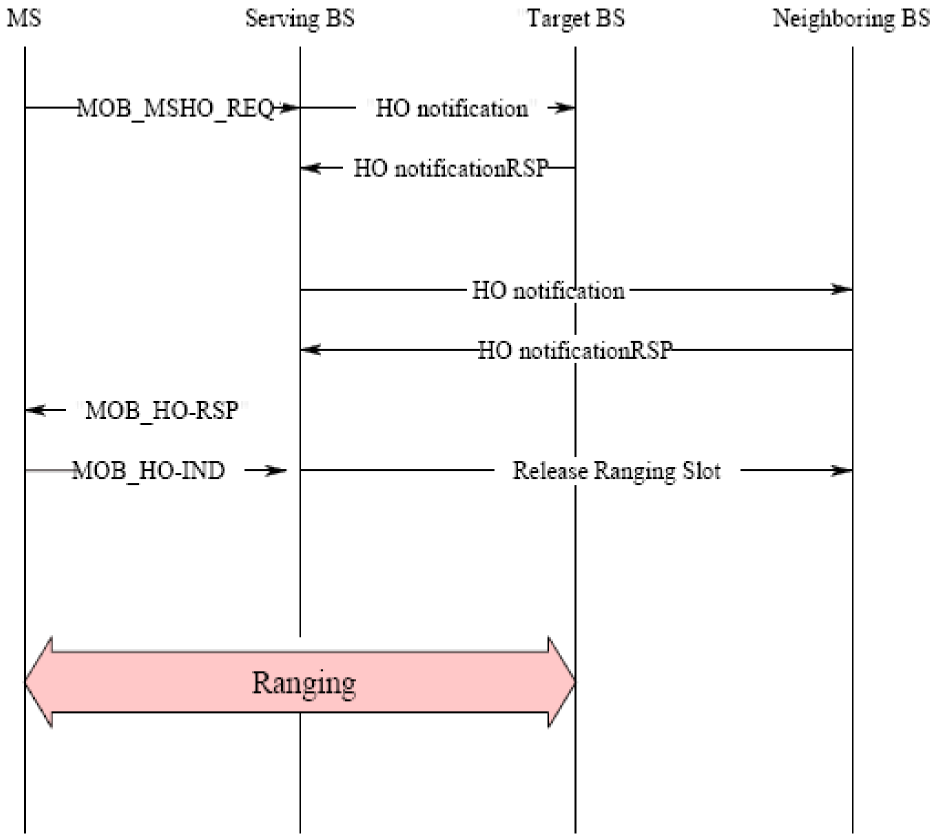

Figure 2.11: HO decision and Initiation [18]

A HO starts when a (MOB_MSHO-REQ) message is sent by the MS to the SBS pointing 1 or more probable BSs as a HO target. The SBS combines information about NBSs and notifies the MS with MOB _HO-RSP messages. The MS informs the SBS about its decision and begins the actual process of HO by sending HO Indication message (MOB_HO-IND). This message may also contain SBS release, HO cancel, or HO reject. Then the MS may begin ranging after MOB_HO-IND message.

- ***Network Re-entry:*** This phase begins after completing all the physical parameter adjustments successfully. This phase establishes the connection between the MS and the TBS. Also, it includes ability to negotiation, registration, and authentication transactions as shown in Figure2.12 below.

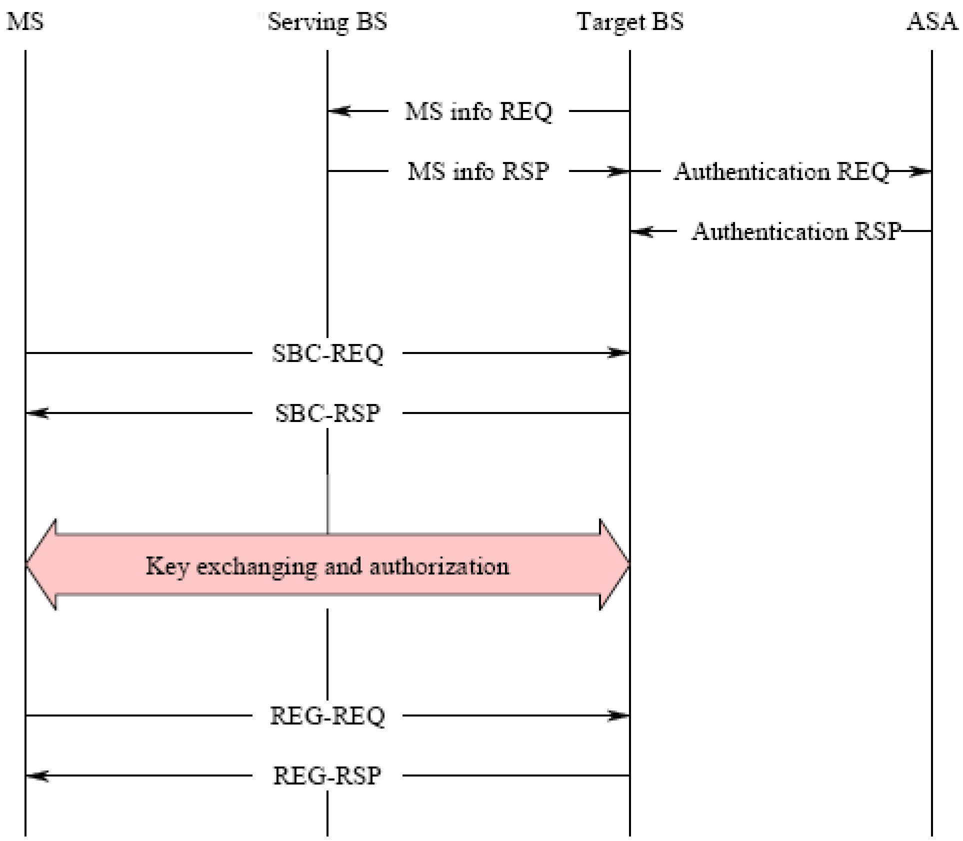

Figure 2.12: Network re-entry Process [18]

The period of this procedure should be taken consideration into the entire HO latency because the MS must wait until this process is completed.

2.3 Related Works

Several proposals have been suggested in the literature in order to reduce the HO latency. In [19], the authors propose an algorithm using Arrival Time Difference (ATD) and Carrier-to-Interference plus Noise Ratio (CINR) to estimate the TBS. This scheme can reduce the HO latency by avoiding needless NBS scanning. But the MS cannot recover full physical info of all neighbors BSs for choosing the final TBS.

In [20], (Fast DL MAP IE) message is presented in order to assist the MS receives the DL traffic from the SBS during the HO process before synchronizing the UL traffic with the TBS. The MS still uses the old Connection Identifier (CID) which has not changed till the MS receives a new CID mandated by a TBS; it is potential that the old CID is indeed utilized by other MS. However the throughput will be dropped down because of collisions.

In [18], the network layer transmits some of the MAC-L control messages by creating a layer 2tunnel between the SBS and the MS and a layer three tunnel between the SBS and the TBS. And also this proposed cancels the network re-entry latency, because the MS still connects with the SBS during the network re-entry procedure.

In [21], the authors proposed a scheme called MDHOnew where they could decrease the HO latency by selecting the best potential TBS according to QoS information on the MS. When the MS receives a MOB_NBR-ADV message is containing information about NBSs, it begins to build a list of NBSs which are arranged based on the QoS parameter. However, this scheme can only be applied to the MDHO but not to the HHO case.

In [22], the authors decreased the HO latency when the MS moves at a higher speed. In order to achieve successful HO at high speed, they proposed an adaptive Forward Error Correction (FEC) scheme that adaptively adjusts the number of unnecessary bits according to the MS speed with retransmission.

In [23], the authors proposed an improved HO scheme for mobile WiMAX by increasing the velocity factor of the MS, but they used beta (β) = 1, which means path loss exponent has no effect on the received signal strength (RSS). The value of β must vary based on the environment; because of this, the proposed scheme is not realistic

In [3], the authors presented an efficient MAC-L HO scheme by utilizing mobility patterns table; it is introduced to reduce the latency. The mobility table is supported to assist the MS to expect the TBS and reduce the scanning time. The TBS is chosen according to the BS that has highest HO times. Sometime the prediction of TBS is incorrect when the mobility table is inexact or includes errors, and then the MS will scan the incorrect BS.

In this thesis, we improved the scheme given in [3] by adding the load factor to the mobility pattern table and renamed it as HO prediction table. The prediction table is formed based on the standard scan results to be more accurate. The selection of the TBS will be according to the minimum BS load, so that load balancing can be achieved.

Chapter 3

THE PROPOSED HANDOFF SCHEME

In this chapter, we present the proposed scheme using Handoff prediction tables. The main goal is to decrease HO delay time by canceling unnecessary scans during the HO process. The HO prediction table is introduced at the BSs. It is used to assist the MSs to predict the TBS. In the proposed scheme, the prediction table is formed on the basis of the standard scan results, and its contents are updated after every complete HO process on the basis of the HO decisions received from the MSs.

In the proposed scheme, the prediction table is retained by the SBS. It includes five elements: previous BS'sID (PBS's ID), target BS'sID (TBS's ID), number of HO, RSS, and the average load as shown in Table 3.1. The PBS is the BS with which the MS was connected before its current connection. The TBS is the BS which the MS will be connected with after the current BS. Number of HO means the number of HO times which occurred on the BS. RSS represents strength of the TBS signal and the load means the average load on the TBS.

Table 3.1: Example of the HO prediction table

Previous BS	Target BS	No. of HO	RSS (db)	Load
BS1	BS2	8.2	-65.5	0.50
BS1	BS3	9.55	-66.45	0.56
BS1	BS4	10.15	-65.9	0.55
BS1	BS5	10.35	-66.15	0.53
BS1	BS6	10	-65.4	0.546
BS1	BS7	9.7	-64	0.53

In Mobile WiMAX when the MS moves far from the SBS the signal strength will decrease, then the MS comes in the scanning phase to search for the next BS to connect with. The MS can obtain basic channel info of the NBSs because during the MS transmission, it will receive MOB_ NBR –ADV messages from the SBS. When the MS starts to scan for the TBS, firstly, it sends MOB _SCN-REQ to the present SBS meaning that the MS will begin the scanning process. In this message, the MS adds the nominee BSs list. This list is selected based on the physical channel info of NBSs and just the NBSs that satisfy the needs of the MS are listed in it. And also this message contains PBS ID and TBS ID. Figure 3.1 shows the proposed scheme flowchart.

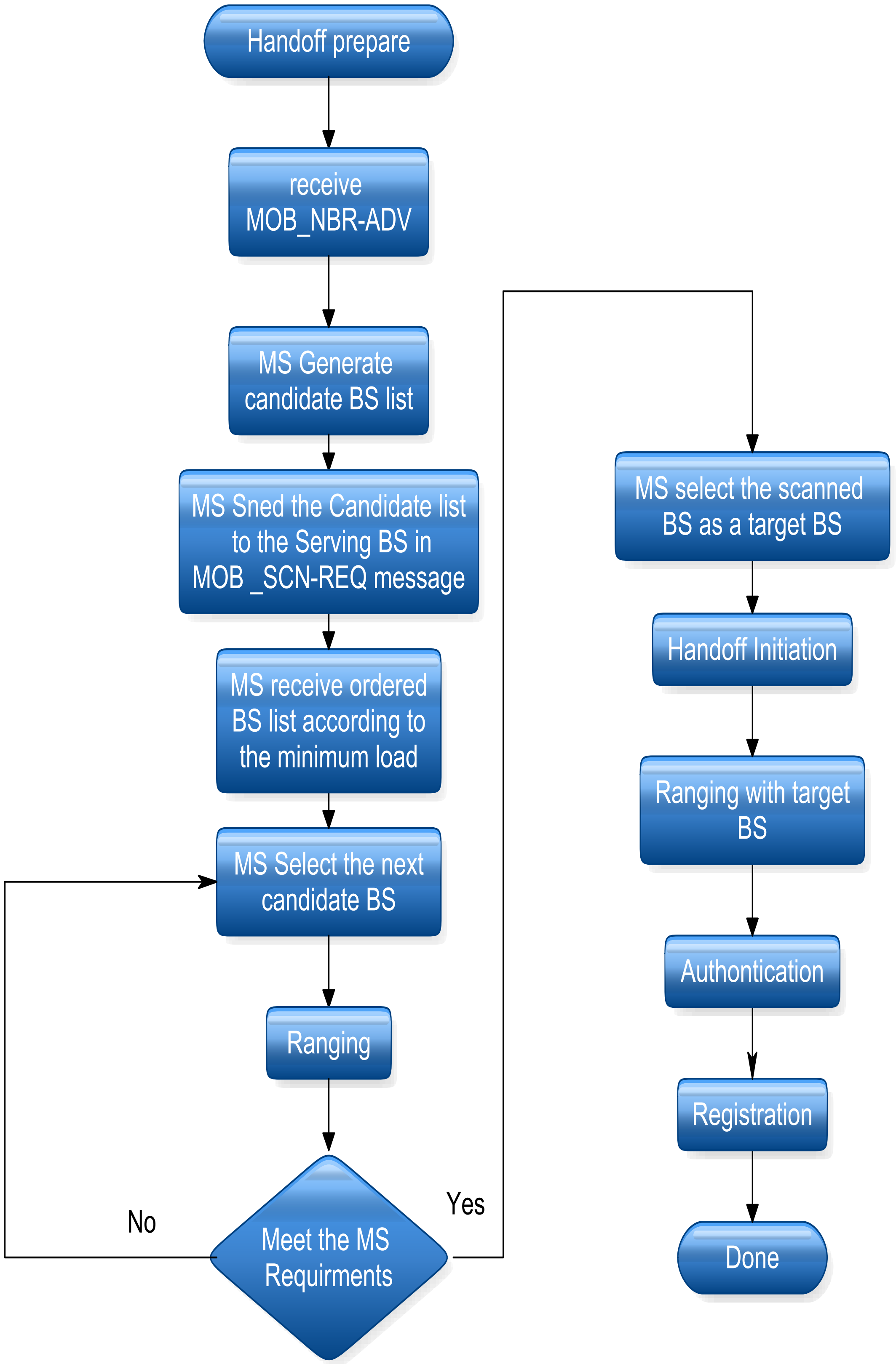

Figure 3.1: Flowchart of the Proposed HO Scheme

When the SBS receives the scan request message, it looks for the prediction table and finds nominee BSs depending on PBS. If the ID of PBS in the scanning message is like as the ID of PBS in the prediction table, then these BSs are treated as the obtainable BS list for scanning, else the SBS will add these BSs to the HO prediction table. To reduce the scanning time in the proposed scheme, the SBS arranges the available BSs in the list according to their loads (with the minimum BS load being first) in the HO predication table. Then the SBS sends this list to the MS in MOB_SCN-RSP message.

After that, the MS stops connection with the SBS and begins the scanning procedure based on the arranged BSs list. At first, the MS attempts to concurrency with the BS which has minimum load and get more physical channel info about it. If the channel case meets the MS requirements, the scan process is terminated. Else the MS should scan the next BS.

When the MS chooses the TBS, it sends MOB_HO-IND message to the SBS. This message contains the PBS ID and the TBS ID. Then the SBS updates the HO prediction table according to this message. The SBS will transmit all of the DL data packets of the MS to the new BS, because the MS is going to stop connection from the SBS and all connections between the MS and the SBS will be terminated after sending the MOB HO-IND message.

3.1 A Scenario to Demonstrate the Proposed Scheme

In this section, we give an example to demonstrate the proposed scheme. Figure 3.2 shows this example. There are 7 BSs, and the MS moves between these BSs. Since the HO prediction table needs previous and current BSs, assume that BS1 is the previous BS and BS7 is the current BS.

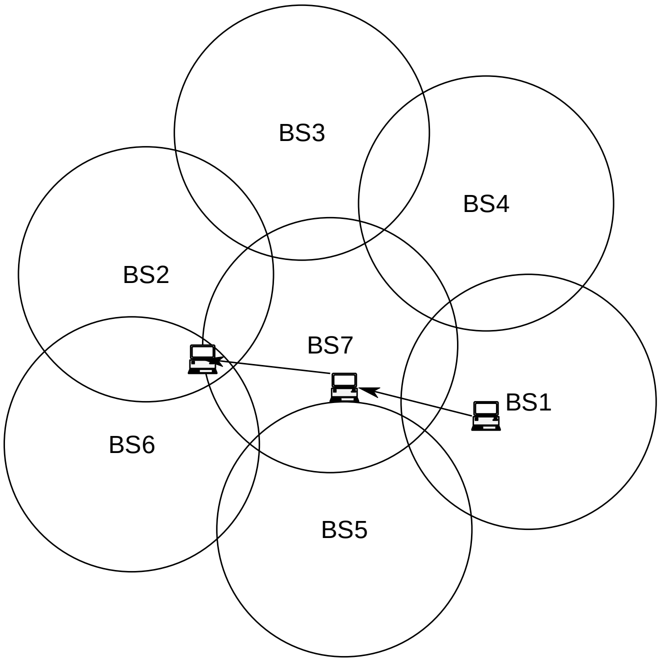

Figure 3.2: A Simple Scenario

When the MS travels far from BS7, the signal strength decreases, then the MS begins the scanning phase to detect a new BS to connect with it. The MOB_NBR-ADV message is listened by the MS to choose the nominee BSs list for example BS2 and BS6.Then the MS sends a MOB_SCN-REQ message to the SBS (BS7) which contains the candidate BSs list. When BS7 receives scanning request message, it looks for the HO predication table and orders the candidate BSs list according to the minimum BS load. Then the BS7 sends the list in the "MOB_SCN-RSP" message to the MS. The BS2 has the minimum load as shown in Table.3.2. In this table we take the average values of 20 runs. At first the MS starts to scan BS2, if it meets the MS requirements, the MS selects it as a TBS and sends MOB_HO-IND message to the BS7. The BS7 updates its HO predication table; therefore the load of the pair (BS1, BS2) becomes 0.57, the RSS becomes -64db and the No. of HO become 13.7.

Table 3.2: The HO prediction table of BS7

Previous BS	Target BS	No. of HO	RSS(db)	Load
BS1	BS2	11.2	-65	0.5
BS1	BS3	11.25	-80.45	0.67
BS1	BS4	12.4	-77.9	0.65
BS1	BS5	13.6	-73.15	0.64
BS1	BS6	13.1	-65.15	0.66

One possible drawback of our scheme is that sometimes it may give an incorrect decision, then the MS has to make second handoff to the correct BS.

In the next chapter we will show the performance analysis and simulation results and how the proposed scheme improves the performance of the HO in WiMAX by balancing the load of the BSs and reducing the scanning time.

Chapter 4

SIMULATION RESULTS

In this chapter, we present the performance analysis and the simulation results of the proposed scheme, and we compare the results with WiMAX standard HO scheme. We used MATLAB program in the simulation. In our HO scheme, the HO delay is studied in Mobile WiMAX OFDMA/TDD model, and the frame duration is assumed to be 5ms. And the SBS is the BS7 and (BS1, BS2 … BS6) are the NBSs, and the number of MSs is deployed randomly among the BSs based on the capacity of the BS, which means the maximum number of MSs in the BS is 30. Also, we assume there is a road between SBS to reach to each NBS. Table 4.1 demonstrates the simulation parameters [3]. The HO latency for WiMAX standard is ranging between 50-950 ms for all scanning types at different load ratios [3] [13] [18] [19]. In the WiMAX standard each BS is scanned sequentially, and then the SBS negotiates with the BS that provides the strongest signal to the MS. Whereas in the proposed scheme only the BS that has minimum load is scanned. Figure 4.1 shows the comparison between the scanning time required for WiMAX standard and the proposed scheme.

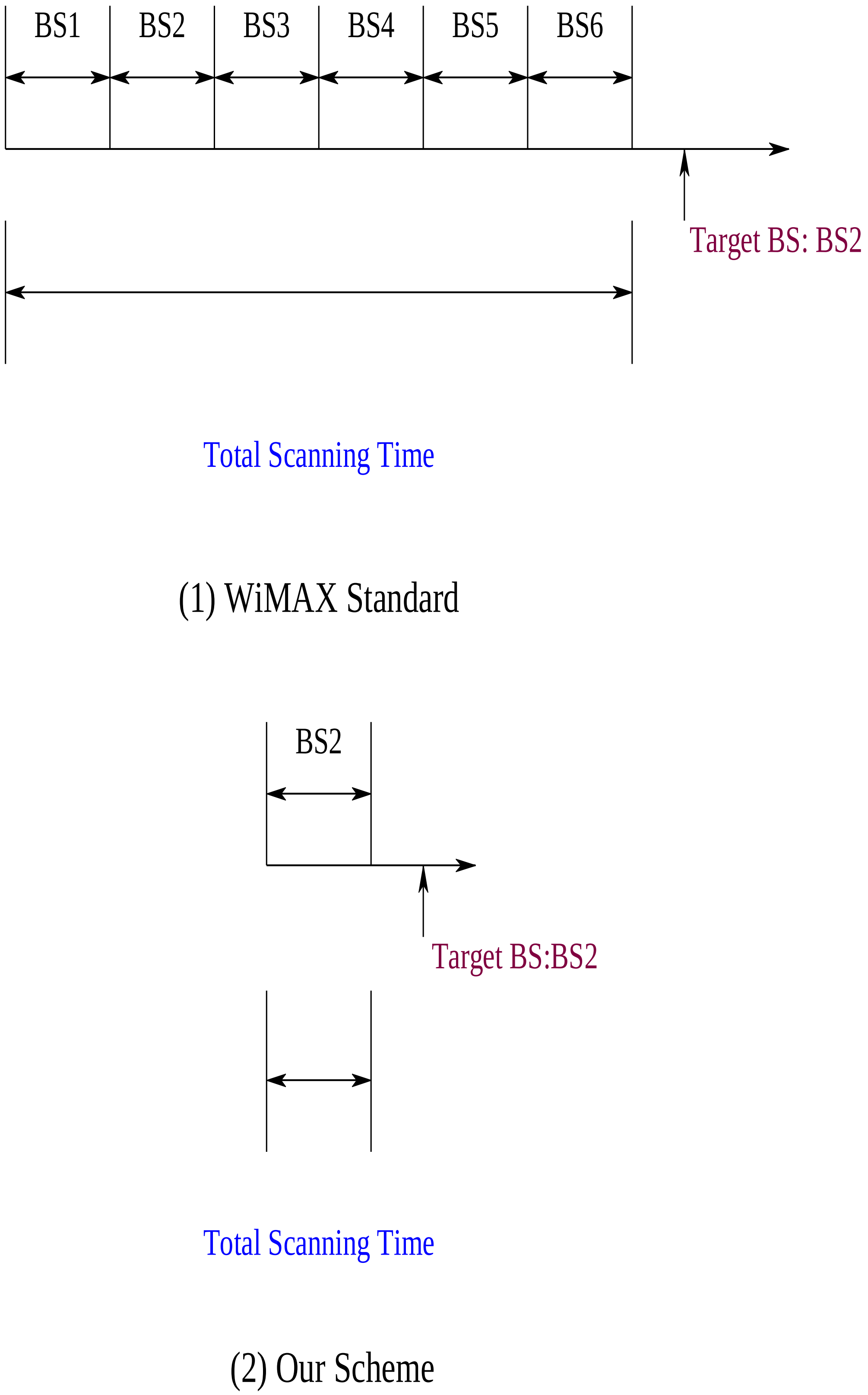

Figure 4.1: The required Scanning time for WiMAX Standard and Our proposed

Table 4.1: Input Parameters

Parameter	Value
No. of Runs	**40 runs**
Maximum speed of MS	**20m/s**
Number of BSs	**7**
Capacity per BS	**30**
Overlap range	**200m**
Radio Range (BS radius)	**1 km**

Table 4.2 below shows the performance metrics we used for the performance analysis.

Table 4.2: Output Parameters

Handoff Latency
Average Number of Overhead SMS Messages
Dropping Probability
Mean Absolute Load Difference
Standard Deviation
Scanning Time
Speed up

We can determine the Speed up factor as:

$$Speed\ up \triangleq \frac{Handoff\ latency\ of\ WiMAX\ Standard}{Handoff\ Latency\ of\ our\ Scheme} \tag{4.1}$$

4.1 Handoff Latency

The handoff is affected by the latency which occurs during the scanning and ranging process with NBSs. Also, in the network re-entry phase the TBS needs time to obtain the authorization information for the MS (T_{Auth}). After the authorization, T_{Reg} is the time required for registration. Four types of scanning processes are tested in order to analysis the proposed scheme performance, these types are [3] [13]:

SCN Type_0: Scan NBSs without association. Just DL synchronization is required for MS in order to obtain the physical channel info of the TBS. The scanning time for SCN Type_0 can be calculated as:

$$T_{Sc_0} = n \times T_{Sync} \tag{4.2}$$

Where T_{Sync} is assumed to be 2 frames, which means 10ms, and n is the number of NBSs that need to be scanned.

Figure 4.2 demonstrates the comparison between WiMAX standard and our HO scheme.

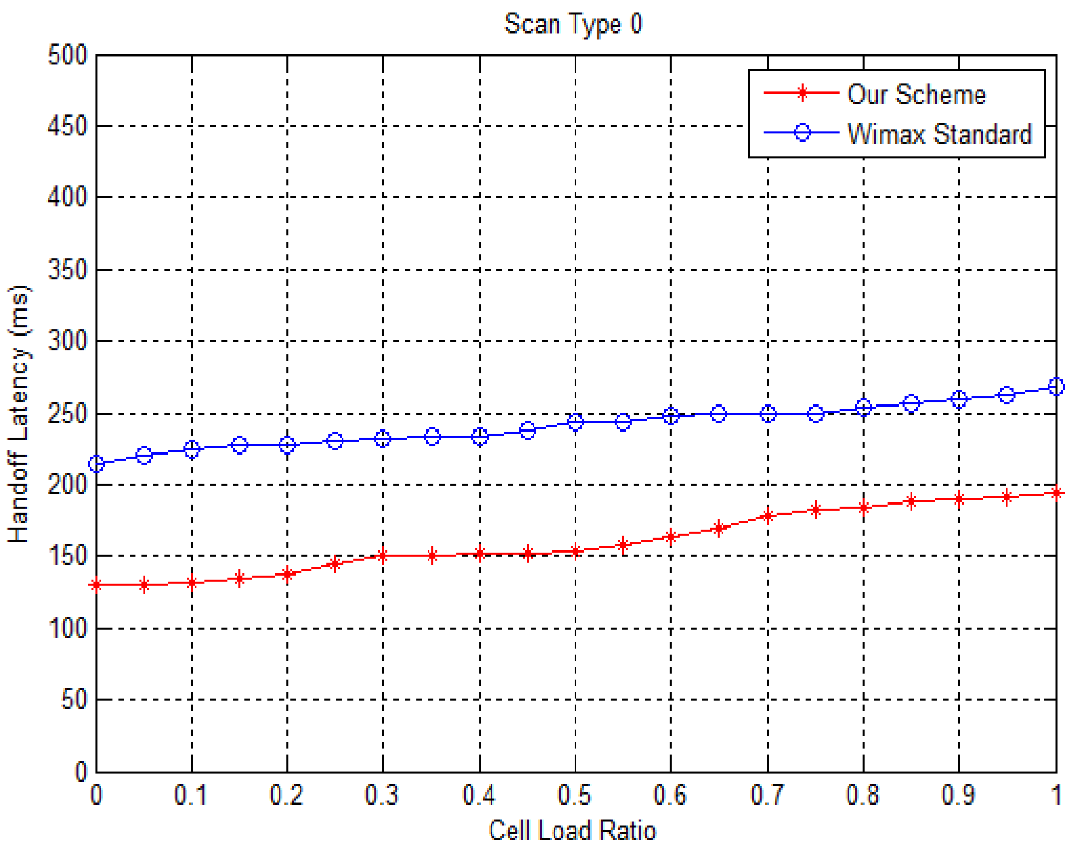

Figure 4.2: Handoff latency using Type 0

This type of scan is the simplest one, because the scan time is not much affected by load increasing. From the Figure 4.2 we see the proposed scheme performs better than the standard WiMAX scheme in terms of HO latency. The achieved speed up factor for this type of scanning is 1.67 at low load ratio and 1.4 at high load ratio.

SCN Type_1: Scan/association without coordination. The MS needs to finish the contention-based ranging after the DL synchronization in order to exchange physical information with the BS. The scanning time for SCN Type_1 can be calculated as:

$$T_{Scn_1} = n \times (T_{Sync} + T_{Cont\_rng}) \tag{4.3}$$

Where T_{Cont_rng} is assumed to be relative to the cell load ratio, because when the cell load ratio increases, the probability of collision in ranging process will increase. The comparison is shown in Figure 4.3.

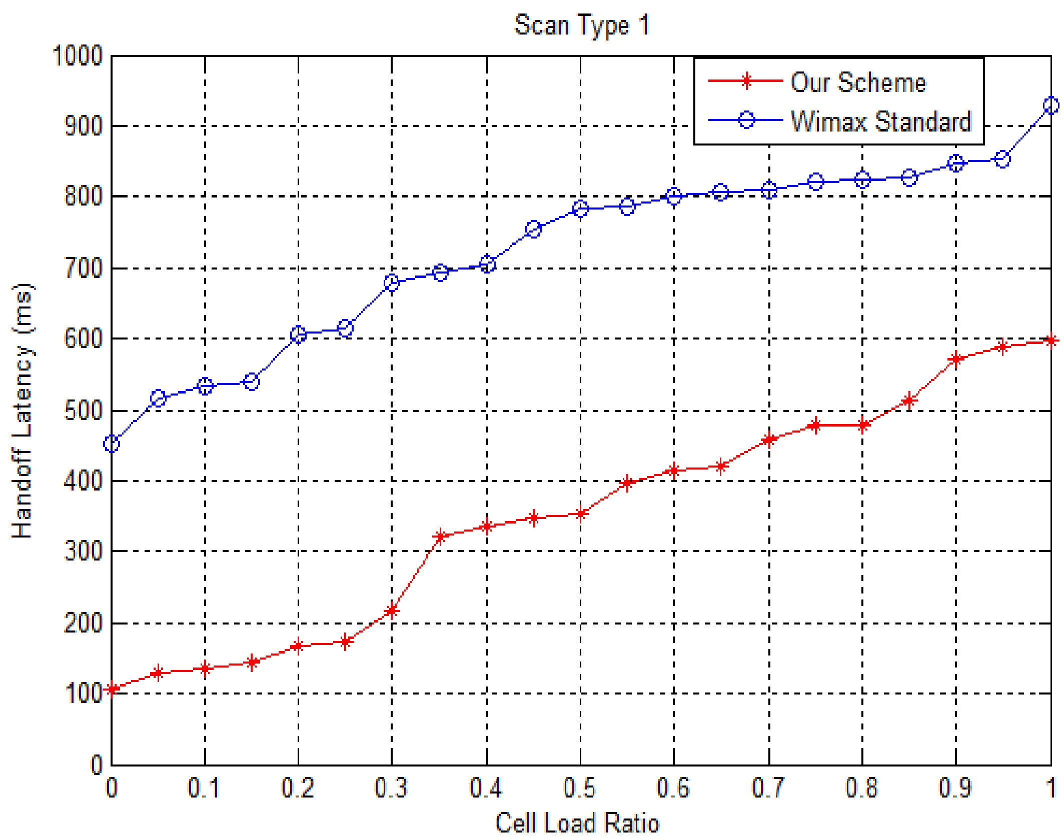

Figure 4.3: Handoff latency using Type 1

Because of this type of scan depends on contention- based ranging, the increasing of cell load ratio will cause more collision, then the scanning time can easily be affected by cell load ratio. The achieved speed up factor for this type of scanning is 4.3 at low load ratio and 1.5 at high load ratio.

SCN Type_2: Association with coordination. A fast ranging process is executed by the MS, after synchronization with the DL in order to reciprocity physical parameters with the BS. The scanning time for SCN Type_2 can be calculated as:

$$T_{Scn\_2} = n \times (T_{Sync} + T_{Rng}) \tag{4.4}$$

Where T_{Rng} is also assumed to be relative to the cell load ratio. The comparison is shown in Figure 4.4.

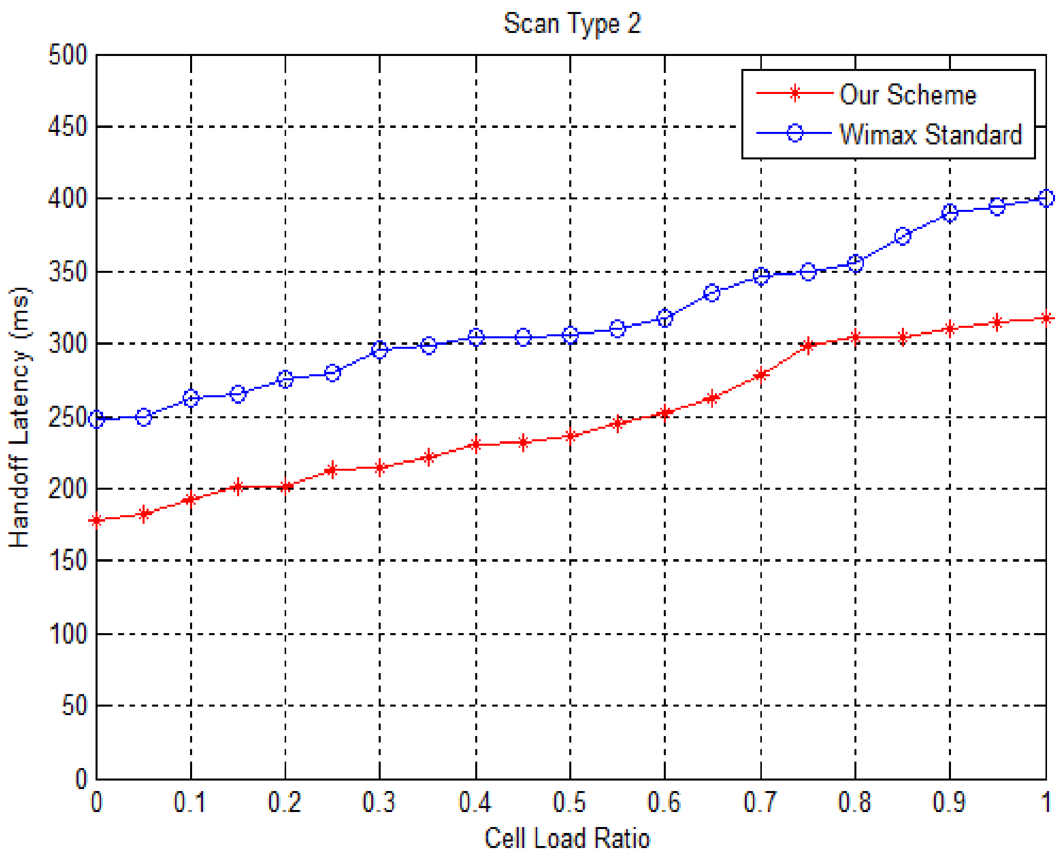

Figure 4.4: Handoff latency using Type 2

The scan time of this type is also affected by the cell load ratio but less than the scan time of type 1. The achieved speed up improvement of the proposed scheme over the standard one for this type of scanning is 1.4 at low load ratio and 1.3 at high load ratio.

SCN Type_3: Network assisted association reporting. The TBS doesn't send ranging response message directly to the MS but at first the TBS sent it to the SBS, then the

SBS sends RNG_RSP message to the MS in to MOB_ASC-REPORT message. The scanning time for SCN Type_3 can be calculated as:

$$T_{Scn\_3} = n \times \left(T_{Sync} + \left\lceil 1/2 \times T_{Rng}/5 \right\rceil \times 5\right) \qquad (4.5)$$

The comparison is shown in Figure 4.5 below.

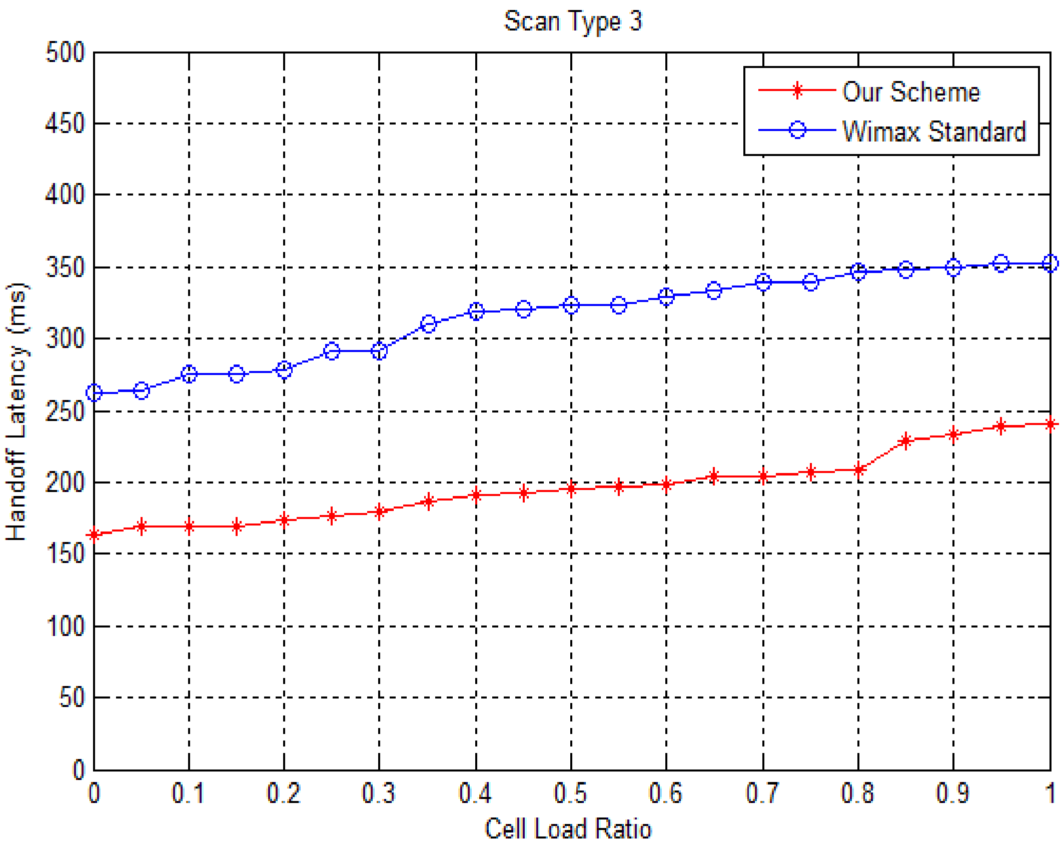

Figure 4.5: Handoff latency using Type 3

The time of this type of scan is also affected by the cell load ratio, but less than the time of scan type 1 and scan type 2. The achieved speed up factor for this type of scanning is 1.6 at low load ratio and 1.4 at high load ratio.

It is clear from the scanning types that the proposed scheme reduces the HO latency in the comparison with the standard WiMAX scheme, because needless scans are avoided using the HO prediction table. Also, the achieved speed up factor of our scheme compared with the WiMAX standard scheme is ranging between 1.3 and 4.3 for all scanning types.

4.2 Overhead SMS Messages and the Dropping Probability

The proposed scheme also reduces the average number of overhead SMS messages as shown in Figure 4.6 below:

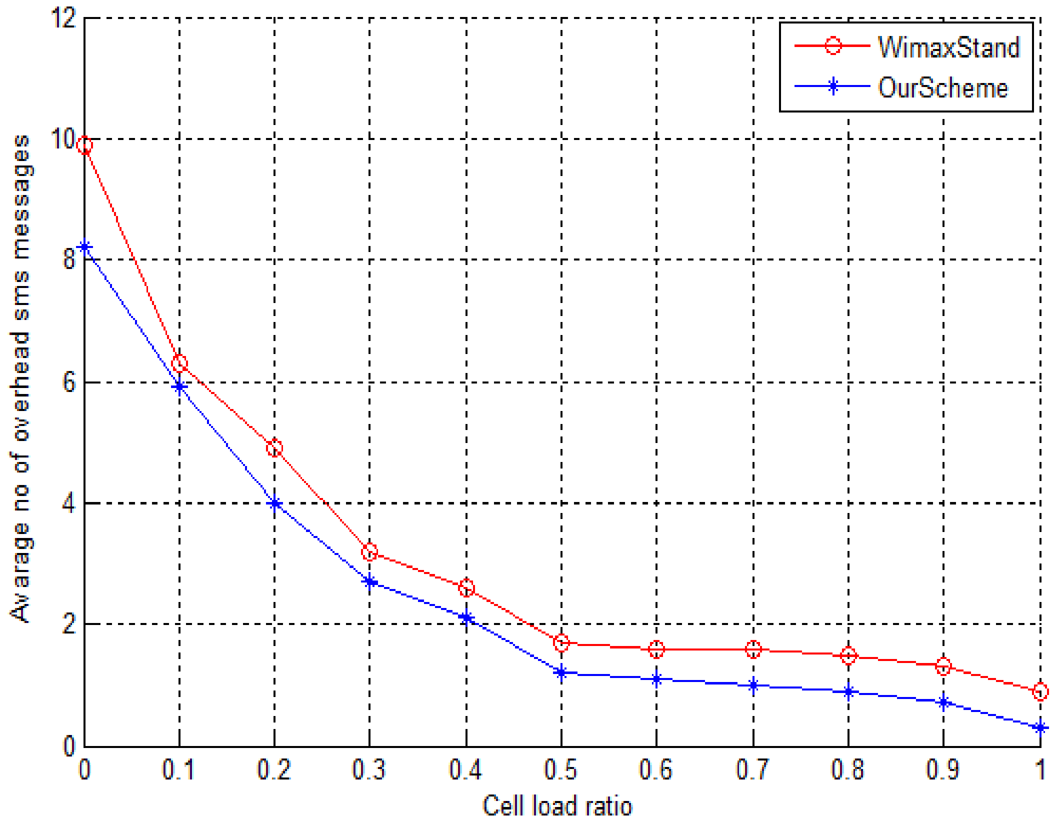

Figure 4.6: Average Number of Overhead SMS Messages

When the cell load ratio increases the numbers of HO going out from the cell will increase which leads to a decrease in the average numbers of overhead SMS messages. The average numbers of overhead SMS messages means the number of send HO request messages from the MSs over the numbers of HO. Hence, the proposed scheme performs better than the standard WiMAX scheme with around 25% less overhead messages.

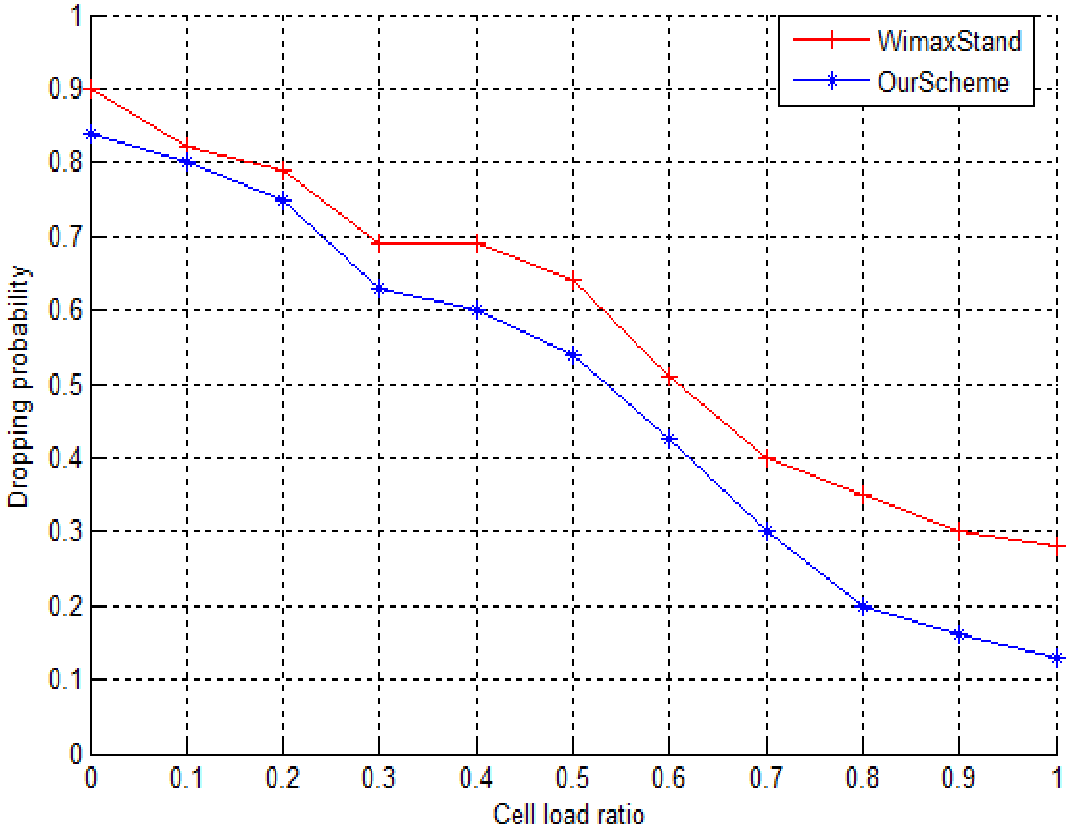

Figure 4.7: Dropping Probabilities

The call dropping probability results are shown in Figure 4.7. The proposed scheme reduces the call dropping probability better than WiMAX standard. When the load ratio increases, the dropping probability decreases because the number of HO going out from the cell increases. The proposed scheme out performance the WiMAX standard scheme by improving the calls dropping probability with around 23%.

4.3 Load Balancing

An important goal of the proposed scheme is balancing the load between BSs by giving channels to the MS from the BSs that have minimum loads.

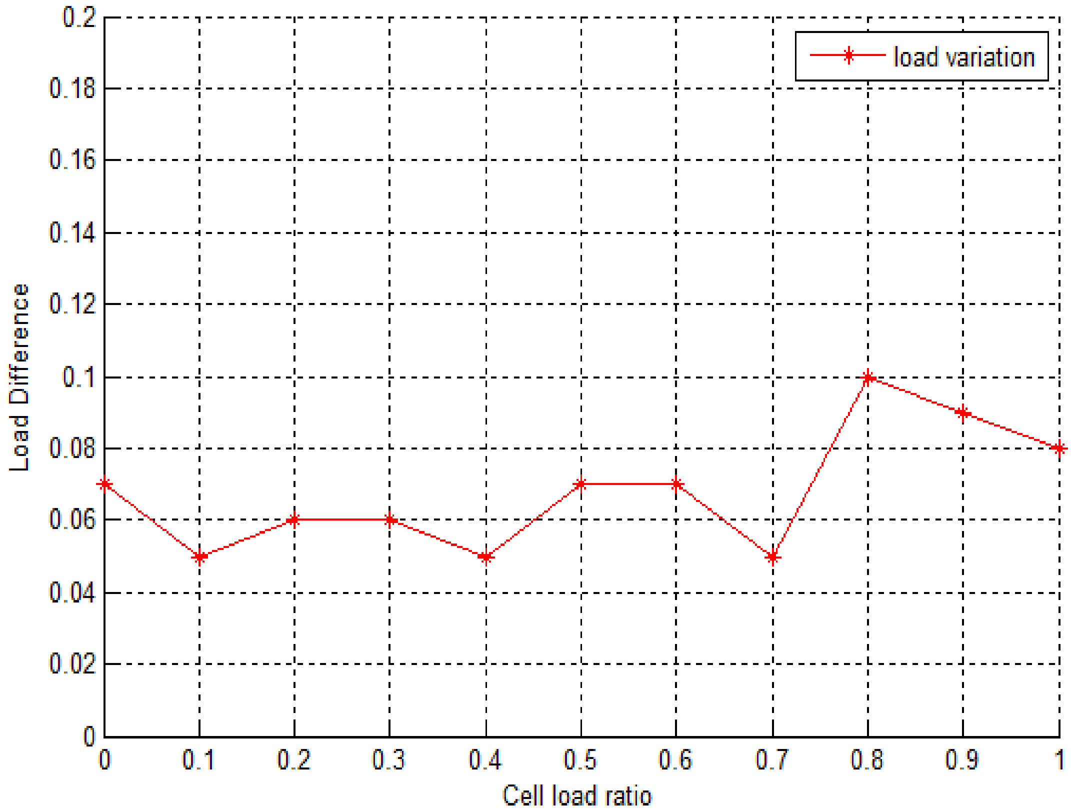

Figure 4.8: Mean Absolute Load Difference

As shown in figure 4.8, the average load on the BSs varies between 0.05 and 0.1, which means just %5 difference.

Also the load standard deviation of the proposed scheme varies between 0.5 and 1, which means only0.5 deference, as shown in Figure 4.9 below. Hence, load balancing can be achieved with the proposed scheme.

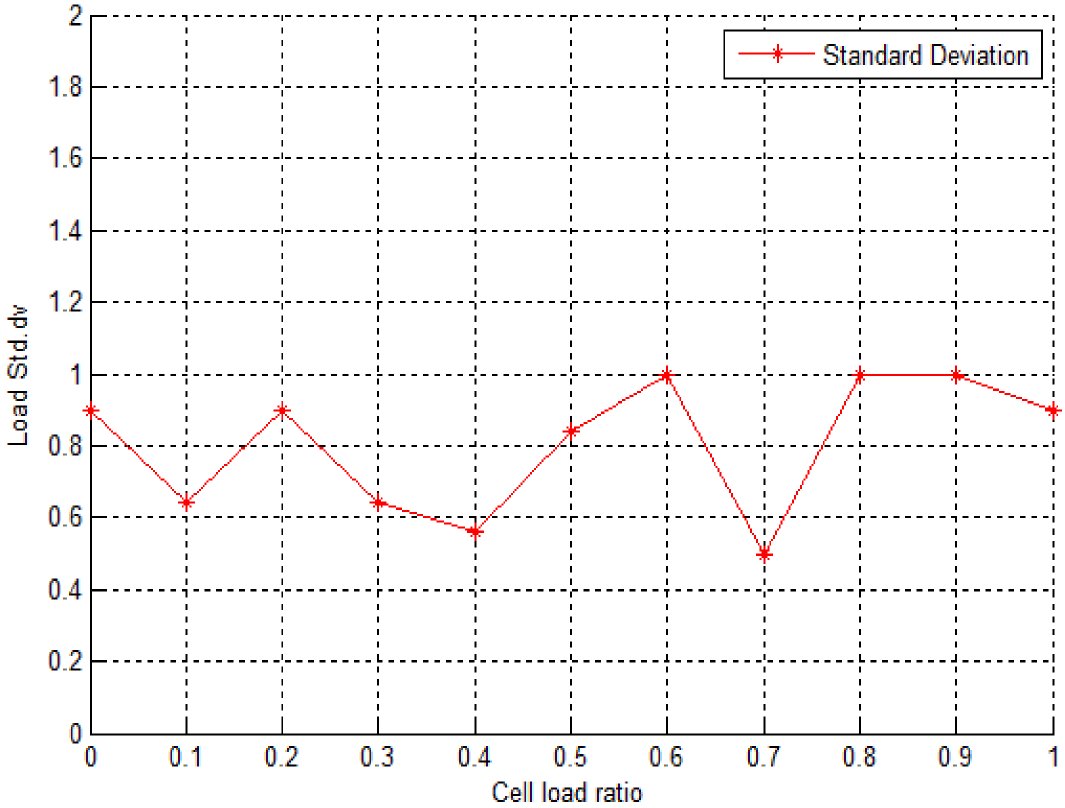

Figure 4.9: Load Standard Deviations

4.4 Comparison with other Studies

To show the effectiveness of the proposed scheme, we did comparisons with other recently proposed schemes. The comparison results with the MDHOnew scheme proposed in [21]. In this scheme the authors selected the best possible BS which supports service flow (QoS) at the MS. Although MDHO basically reduces the latency, we find that our proposed scheme performs better than MDHOnew scheme in the scanning process period. We take just one type of scanning to make the comparisons (SCN Type_2). Also, the speed up factor for the scanning time can be calculated as:

$$Speed\ up \triangleq \frac{Scanning\ Time\ of\ WiMAX\ Scheme}{Scanning\ Time\ of\ our\ Scheme} \tag{4.6}$$

The comparison results are shown in Table 4.3 below:

Table 4.3: Time Comparison between Our Scheme and MDHOnew Scheme

Load Ratio	MDHOnew[21]	Our Scheme	Speed up
0	55ms	35ms	1.6
0.5	80ms	60ms	1.3

The difference between the scanning times for each scheme is almost 20ms in the low and high load. We achieved an acceptable speed up factor of the proposed scheme over the MDHOnew scheme; it is 1.6 for low load ratio and 1.3 for high load ratio.

Also, we make comparison to the HO latency for the proposed scheme with the schemes proposed in [3] and [21]. The comparison results are shown in Table 4.4 below:

Table 4.4: Handoff Latency Comparison of Our Scheme with Other Schemes

Load Ratio	MDHOnew [21]	Scheme of [3]	Our Scheme	Speed up over MDHOnew	Speed up over Scheme of [3]
0	240ms	175 ms	166ms	1.45	1.05
0.5	260ms	245 ms	245ms	1.06	1

MDHOnew and Scheme of [3] are also taking the best possible TBS; MDHOnew takes the TBS according to the QoS parameters which is supported at the MS.

Whereas the scheme of [3] selects the TBS which has highest handoff time from the mobility pattern table. As it seen from the Table 4.4, the HO latency for the proposed scheme at low load ratio is less than the MDHOnew latency by almost 75ms and less than the latency of scheme of [3] by almost 9ms. In the 50% load ratio our proposed scheme has less HO latency than the MDHOnew by 15ms and almost same as the HO latency of Scheme of [3]. The achieved speed up of our scheme with MDHOnew scheme is 1.45 at low load and 1.06 at high load. Also, compared with scheme of [3], although our proposed scheme has same performance at high load, the achieved speed up at low load is 1.05.

Also, we make comparisons with scheme of [3] for all scanning types at low and high load ratios, and the results as in Table 4.5 and Table 4.6 below.

Table 4.5: Comparison of Our Scheme with Scheme of [3] when Cell Load Ratio (0)

Type of Scanning	Scheme of [3]	Our Scheme	Speed up
Scan Type_0	150	130	1.15
Scan Type_1	220	105	2.1
Scan Type_2	175	166	1.05
Scan Type_3	165	163	1.01

Table 4.6: Comparison of Our Scheme with Scheme of [3] when Cell load Ratio(0.5)

Type of Scanning	Scheme of [3]	Our Scheme	Speed up
Scan Type_0	170	151	1.2
Scan Type_1	380	350	1.08
Scan Type_2	245	245	1
Scan Type_3	200	195	1.02

We see our scheme performs better than the scheme of [3] in all scanning types at high and low load ratios. Also, we achieved an acceptable speed up factor of the proposed scheme over the scheme of [3] at low and high load ratios.

Chapter 5

CONCLUSION

WiMAX is a telecommunication technologies geared toward providing wireless connection over long distances and large frequency band compare with other technologies, but the distance is still limited and HO processes are needed to keep wireless connections. So, preparing a fast HO in the WiMAX under the high velocity state has become a difficult task. In HHO the MS spends hundreds of milliseconds for scanning, ranging, authentication, and registration. During this time period, the MS disconnected from the current BS, and hence its services are temporarily stopped.

In this thesis, we improved the performance of the HO in WiMAX by balancing the load and reducing the HO latency through using the HO prediction table. HO prediction table are supported in order to assist the MS predicts the TBS and reduce the scanning time.

The results show that the proposed scheme can significantly reduce the scanning time by waiving unnecessary scans. It can reduce the average number of overhead SMS messages by almost 25% and the dropping probability by almost 23% comparing with the WiMAX standard scheme. Also, the proposed scheme can balance the load of the BSs through giving channels to the MSs from the BSs which have minimum load, then the load varies between BSs only 0.05 and the standard deviation is between 0.5 to 1. When comparing the performance analysis of the proposed scheme with other previously schemes, we showed that our proposed needs less time than others for scanning. Hence the HO latency for the proposed scheme is less than others in especially at high load ratio. The achieved speed up factor of our scheme compared with the WiMAX standard scheme is ranging between 1.3 and 4.3 for all scanning types. Also, we achieved an acceptable speed up over other interesting schemes proposed in literature.

The proposed scheme does not consider the type of traffic in the HO process. As a future work the algorithm can be modified to consider multimedia traffic and give some priority for real-time traffic in the HO process.

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APPENDICES

Appendix A: Confidence Intervals

This test for Figure 4.6 When cell load ratio = 0.3

The Confidence interval =0.95

$$\alpha = 1 - 0.95$$

$$\alpha = 0.05 \qquad\qquad n = 20$$

Y=

Values				
6	3	1.625	7.5	1.5
3	1.5	3	1.5	3
1.5	2.571	2.571	1.5	2.571
1.44	1.5	6	1.5	6

$$Y^{-} = \frac{\sum_{I=1}^{20} Y_i}{20}$$

$$Y^{-} = 2.4889$$

Standard deviation $\longrightarrow$ $St.d = \frac{\sum_{i=1}^{20}(Y_i - Y^{-})^2}{n-1}$

$$St.d = 1.88905$$

$$H = t_{\frac{\alpha}{2},n-1}\frac{s}{\sqrt{n}}$$

$$H = 2.093 * \frac{1.88905}{20}$$

$$H = 0.8841$$

$$H \leq St.d$$

$$Y^{-} - H \leq M_0 \leq Y^{-} + H$$

$$2.4889 - 0.8841 \leq M_0 \leq 2.4889 + 0.8841$$

$$1.6048 \leq M_0 \leq 3.373$$

$$E = 2\%$$

$$n \geq \left(\frac{t_{\frac{\alpha}{2},n-1} * S}{E}\right)^2$$

$$n \geq \left(\frac{2.093 * 1.88905}{2}\right)^2$$

$$n \geq 4 \qquad \dots\dots\dots\dots \qquad 20 \geq 4$$

Appendix B: MATLAB Code

```
clear all; clc;
close
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
index=2; % choose index according to the above table
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
switch index
case 2
m=2;
M=2^m;
sigconst=qammod(0:M-1,M);
scale = modnorm(sigconst, 'avpow', 1);
TITLE ='QPSK, RS(32,24,4) , CC(2/3), Overall r= 1/2 ';
Modulation_Type='QPSK';
N=32;
K=24;
T=4;
p=2;
q=3;
r=0.5;
puncpat=[1 1 0 1];
case 3
m=2;
M=2^m;
sigconst=qammod(0:M-1,M);
scale = modnorm(sigconst, 'avpow', 1);
TITLE ='QPSK , RS(40,36,2) , CC(5/6), Overall r= 3/4';
Modulation_Type='QPSK';
N=40;
K=36;
T=2;
p=5;
q=6;
r=3/4;
puncpat=[1 1 0 1 1 0 0 1 1 0];

end

our_mac()

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
%Subcarreries numbers
Nc=256;Ntotal=Nc;%total no of subcarriers
Ndata=192; %No of data subcrriers
Npilots=8; %No of pilot subcarriers
Nguard=56; %No of guard subcarriers
```

```
Nused=Ndata+Npilots;%No of used subcarriers
BW=5; %nominal channel bandwidth in MHz
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


%%oversampling rate NN=Fs/BW
if (rem(BW,1.75)==0)
NN=8/7;
else if (rem(BW,1.5)==0)
NN=86/75;
else if (rem(BW,1.25)==0);
NN=144/125;
else if (rem(BW,2.75)==0)
NN=316/275;
else if(rem(BW,2.0)==0)
NN=57/50;
else %otherwise
NN=8/7;
end
end
end
end
end
BW=BW*1e6; %nominal channel bandwidth in Hz
%%---------------------------------------------------
% Derived OFDMA Symbol Parameters -
%%---------------------------------------------------
Nfft=2^ceil(log2(Ndata)); % smallest power of 2 > Nused
Fs=floor((NN*BW)/8000)*8000;% sampling frequency in Hz
delta_f=Fs/Nfft;%subcarrier spacing in Hz
Tb=1/(delta_f);%useful symbol time in seconds
G=1/4; %cyclic prefix (G=Tg/Tb)
Tg=G*Tb; %CP time
Tsym=Tg+Tb; %totla symbol time
Ts=1/Fs; %sampling time in seconds
BWused=Nused*delta_f;%used bandwidth
Tframe=5e-3; %Frame period in s.
Ns=Tframe/Tsym; %Number of OFDMA symbols per frame.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%


%Multipath CHANNEL Parameters of SUI-3 channel model for WiMAX
fd=0.5; %doppler frequency in Hz for WiMAX
%for mobile WiMAX fd must be calculated as follows
%c=3e8; % light speed in m/s
%fc=2; %carrier frequency in GHz
%V= 30 ; % mobile receiver velocity in km/h
%fd=fc*1e9*V*1e3/(3600)/c;%Doppler shift, in Hertz
```

```
P_db=[0 -11 -22]; %paths power in dB
tau=[0 0.4 0.9]*1e-6; %path delay vector in seconds
k=[3 0 0];%k-factor of Rice distribution in db
k=10.^(k/10);%k factor of Rice distribution in linear scale
chan = ricianchan(Ts,fd,k,tau,P_db); %construct the channelobject object
chan.DopplerSpectrum=doppler.rounded; %define the doppler fillter frequency
spectrum
chan.StoreHistory=0;chan.ResetBeforeFiltering=1;%to reset before every filtering
chan.NormalizePathGains=1; %to normalize path gain
D=chan.ChannelFilterDelay; %delay of the channel object
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```