PERFORMANCE AND ANALYSIS OF RESOURCE ALLOCATION IN IEEE802.16E AND IEEE802.16M WIMAX MODEL SYSTEMS

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ABSTRACT

IEEE 802.16e standard known as Mobile WIMAX is found to enhance the weak of the IEEE 802.16 fixed-broadband access system. At the same time, IEEE 802.16m is the extension of IEEE 802.16e. Based on the literature review studies and remarks it can be concluded that in IEEE 802.16e and IEEE 802.16m the methodologies mostly focus on how to serve real time applications and give them higher priorities. This in fact is good, but most of them do not show the required interest about the non-real time applications. Non-real time applications still required extensive studied. In order to give non real time applications high priority as much as possible the technique known as minimum allocation is used, which means to allocate the required bandwidth for every service flow as its minimum demand. Unfortunately the challenge of minimum allocation is that if the bandwidth is more than services flow's requirements then the remaining bandwidth will be lost. The purpose of this research is to use all the allocated bandwidth where if all allocated band width is used correctly then the throughput of the system will be higher. In order to solve this challenge of minimum allocation an important technique is used which is round robin, it reallocate the unused bandwidth to all services flow with equal amount of the remaining bandwidth. In this research, real time applications are served with high quality of services, higher priority and non-real time applications is given a chance to reduce packets drop. These objectives are performed with a combination of two technologies which are minimum allocation and round robin technologies. Besides that, a comparison between IEEE 802.16e and IEEE 802.16m in terms of resource allocation, average delay, packet drop, and total throughput of the whole system to show which one is affected by the algorithm more than the other is perform. In this case, the throughput of the total system is enhanced due to the reduction of non-efficiency packets drop. In conclusion, the results of the simulations have proved that the packet drop will become equal to zero. Subsequently, the throughput per service and the total throughput of the system give higher level of the performance.

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LIST OF APPREVIATIONS

A

AAS	-	Adaptive Antenna System
AES	-	Advanced Encryption Standard
AMC	-	Adaptive modulation and coding
ASN	-	Access Service Network

B

BER	-	Bit Error Ratio
BE	-	Best Effort service
BS	-	Base Station

C

CDMA	-	Code Division Multiple Access
CID	-	Connection Identifier
CPE	-	Customer Premise Equipment
CPS	-	Common Part Sub-layer
CS	-	Convergence Sub-layer
CSI	-	Channel State Information

D

DL	-	Downlink
DSL	-	Digital subscriber line

E

ERTPS	-	Extended Real Time Polling Service
EAP	-	Extensible Authentication Protocol
EDF	-	Earliest deadline first

CHAPTER 1

INTRODUCTION

1.1 Background

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 Megabit-per-second data rates, with the 2011 update providing up to 1 Gbit/s for fixed stations. The name "WiMAX" was created by the WiMAX Forum, which was formed to promote conformity and interoperability of the standard. 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 (Bian & Nix, 2008).

WiMAX refers to interoperable implementations of the IEEE 802.16 family of wireless-networks standards ratified by the WiMAX Forum. WiMAX Forum certification allows vendors to sell fixed or mobile products as WiMAX certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile.

IEEE 802.16e standard known as Mobile WIMAX is found to enhance the weak of the IEEE 802.16 fixed-broadband access system. At the same time, IEEE 802.16m is the extension of IEEE 802.16e. Mobile WiMAX is the revision that was deployed in many countries, and basis of future revisions such as IEEE 802.16m-2011. WiMAX is sometimes referred to as "Wi-Fi on steroids" and can be used for a number of applications including broadband connections, cellular backhaul, hotspots, etc. It is similar to Wi-Fi, but it can enable usage at much greater distances (Bian & Nix, 2008).

WiMAX is called the next generation broadband wireless technology which offers high speed, secure and last mile broadband services along with a cellular back haul and Wi-Fi hotspots. The evolution of WiMAX began a few years ago when scientists and engineers felt the need of having a wireless Internet access and other broadband services which works well everywhere especially the rural areas or in those areas where it is hard to establish wired infrastructure and economically not feasible. IEEE 802.16, known as IEEE Wireless-MAN, explored both licensed and unlicensed band of 2.66 GHz which is standard of fixed wireless broadband and included mobile broadband application. The IEEE 802.16e air interface based on Orthogonal Frequency Division Multiple Access (OFDMA) where it main aim is to give better performance in non-line-of-sight environments. IEEE802.16e is using the most improvement technology such as MIMO technology (multiple input multiple output antenna), OFDMA and AMC (Adaptive Modulation and coding) to support peak Downlink (DL) data rates (Andrew *et al.*, 2007). The use of bandwidth affects these features considerably because these techniques like OFDMA keep the allocated bandwidth. This is one of the most crucial problem because the number of users increase quickly therefore we have to allocate enough bandwidth (Johnston & Walker, 2004). The purpose of this study is to maximize the allocated bandwidth for all services flow.

1.2 Problem Statement

Based on the literature review studies and remarks it can be concluded that in IEEE 802.16e and IEEE 802.16m the methodologies are focus on how to serve real time applications and give them higher priorities. In fact it is good but most of them don't show the required interest about the non-real time applications. Non-real time applications still required extensive studied. In order to give non real time applications high priority as much as possible a technique known as minimum allocation is recommended which means to allocate the required bandwidth for every service flow as its minimum demand. Unfortunately the challenge of minimum allocation is that if the bandwidth is more than services flow's requirements then the remaining bandwidth will be lost. The purpose of this research is to use all the allocated bandwidth where if all allocated band width is used correctly then the throughput of the system will be high. Therefore to solve this challenge of minimum allocation an important technique is used which is known as round robin. It reallocates the unused bandwidth to all services flow with equal amount of the remaining bandwidth. An example to explain how it works; if we have 7.5 MHZ and if is allocated for five services flow in WIMAX, therefore every service flow needs at least 1 MHZ to send it's data (minimum allocation is used) then the remaining bandwidth (unused bandwidth) will be 2.5 MHZ. This unused bandwidth should be used otherwise it will be lost. Now the role of round robin starts where it reallocates the unused bandwidth equally for every service flow thus every service flow gets an extra of 0.5 MHZ, were everyone obtain the benefits of this band. If a user use normal level quality of video service then after obtaining 0.5MHZ the user can use HD quality video and for all services flow.

1.3 Research Objectives

The main objectives of the Research:

1. Develop real time applications with a high quality of services and a higher priority, and non-real time applications a chance to reduce packets drop.
2. Analysis the performance used round robin technique before/after round and then compare between them for IEEE 802.16e and IEEE 802.16m model.
3. Analysis the performance and compare between E and M model.

1.4 Significance of the study

The technique that will be used like resource allocation lets the system know when there is insufficient bandwidth and runs with minimum allocation for all types of services flow, to serve the real time applications only that have high priority and ignore non real time applications until sufficient bandwidth is available before it starts to serve them. Another important feature is in most present algorithms which do not monitor non real time applications the packet drop is high because every time they do not serve non real time applications then packet drop increase and the delay will increase but this algorithm serves non real time applications so that there is no need to retransmit.

1.5 Scope of the Study

The resource allocation in this research study focuses mainly on the bandwidth utilization for efficient spectrum usage to support multiple users' requirements at the same time with different requirements. In other words, to allocate specific part of available bandwidth to mobile stations is to use it in term of uplink and downlink directions. In more details, in this research is going to allocate slots and DRUs from OFDMA frame to IEEE 802.16e an IEEE 802.16m model ; for example, a mobile station needs to make a video call therefore this method will allocate the enough number of slots or DRUs as many to run the video call. All in all, the resource allocation will be depended on the bandwidth availability and number of resources which are available to support the network.

1.6 Organization of the thesis

The flow of the thesis started from chapter one which discusses the basic overview of WiMAX, IEEE 802.16e and IEEE 802.16m model, problem statement, objective, significance of the study and finally discusses the scope of the study.

Chapter two discusses the literature review and different methods of previous researchers work in development of WiMAX.

In chapter three explains the methodology, the main steps of the algorithm processes. The assumptions and input parameters are carefully model for ten iterations of sending data. In addition, it shows the data matrix of every service flow and how it is assigned using Matlab code of the resource allocation and round robin.

The fourth chapter, will explained the results for every type of services flow and how the algorithm runs with them and it shows how the packet drop will be canceled. A comparison between IEEE 802.16e and IEEE 802.16m model, in terms of throughput, resource allocation, average delay, packet drop, and total throughput of the whole system are discussed.

Finally, the fifth chapter covers the conclusion of this project and recommendation on further works and upgrades of the system.

CHAPTER 2

LITERITURE REVIEW

2.1 Introduction of WIMAX

WIMAX is promising technology is providing large coverage and high throughput. Besides that, it has enhanced many features in the IEEE 802.16 standards such as using flexible sub-channel and MIMO technology that enable the system to support maximum downlink data rates up to 128 Mbps using 20 MHz bandwidth (Srinivasan, 2008). The IEEE 802.16e standard upgraded as one of the Wireless Metropolitan Area Networks (WMAN) for Broadband Wireless Access (BWA). Moreover, IEEE 802.16e standard offers easy deployment, high-speed data rate, and expands the coverage area (Stanwood & Change, 2004). IEEE 802.16e supports real-time multimedia application services such as IPTV, the broadcast of live events; voice-over internet protocols (VOIP), rapid (speed) file transfer, and data services. IEEE802.16e is using most improvement technology such as MIMO technology (multiple input multiple output antenna), OFDMA (Orthogonal Frequency Division Multiple Access), and AMC (Adaptive Modulation and coding). Mobile WiMAX was built on Orthogonal Frequency Division Multiple Access (OFDMA). The OFDMA system divides signals into sub-channels to enlarge resistance to multipath interference. For instance, if a 30 MHz channel is divided into 1000 sub-channels, each user would concede some sub-channels which are based on distance.

2.2 Features of WiMAX

There are certain features of WiMAX that are making it popular day by day. Some important features of WiMAX are described below:

2.2.1 Interoperability

This is the main concern of WiMAX. The IEEE 802.16 standard is internationally accepted and the standard is maintained and certified by WiMAX forum which covers fixed, portable and mobile deployments and giving the user the freedom to choose their product from different certified vendors and use it in different fixed, portable or mobile networks (Fan *et al.*, 2008).

2.2.2 Long Range

Another main feature of WiMAX is long range of coverage. Theoretically, it covers up to 30 miles but in practice, it covers only 6 miles. The earlier versions of WiMAX provide LOS coverage but as technology advanced and the later version of WiMAX, e.g. mobile WiMAX, can support both LOS and NLOS connections. For that, it must meet the condition of the range for LOS 50 kilometres, and for NLOS 10 kilometres. The WiMAX subscriber may connect to WiMAX Base station by traffic model from their offices, homes, hotels and so on (Singh & Ahuja, 2011).

2.2.3 Mobility

The basic and most important feature of WiMAX technology is to support mobility applications as Voice over IP (VoIP). WiMAX offers immense mobility especially IEEE 802.16e as it adopted OFDMA (Orthogonal Frequency Division Multiple Access) as a modulation technique and MIMO (Multiple Input Multiple Output) in its physical layer. There are two challenges in wireless connectivity, one of them is for session initiation, which provides a mean to reach to inactive users and continue the connection service by extending it even the home location of that user has been changed and the other one provides an on-going session without interruption while on moving (specially at vehicular speed). The first is known as roaming and the second one is handoff. These two are described below (Andrew *et al.*, 2007).

2.2.3.1 Roaming

The centralized database keeps current information which sends to the network by the user base station when it moves from one location to another. In order to reach another subscriber station the network pages for it using another base station. The used subscriber station for paging depends on updating rate and movement of subscriber station - that means from one station to another. This operation is perform when there are several networking entities involved such as NSS (Network Switching Subsystem), HLR (Home Location Register) and VLR (Visitor Location Register). (Singh & Ahuja, 2011).

- Network Switching Subsystem (NSS) localization and updating of location
- Home Location Register (HLR) contains information of current location and
- Visitor Location Register (VLR) sends information to Mobile Station to inform HLR about the changes of location.

2.2.3.2 Handoff

The ability to maintain voice calls or packet sessions when moving from the coverage area of one call to another has been one of the most fundamental enabling features of mobile communication networks.Due to the absence of handoff technique, the Wi-Fi users may move around a building or a hotspot and be connected but if the users leave their location, they lose their connectivity. But with the IEEE 802.16e, the mobile users will be connected through Wi-Fi when they are within a hotspot and then will be connected to IEEE 802.16 if they leave the hotspot but will stay in the WiMAX coverage area (Agrawal & Zeng, 2011; Ramiro & Hamied, 2012).

2.2.4 Quality of Service

Quality of Service (QoS) refers to the collective effect of service perceived by the users. Actually it refers to some particular requirements such as throughput, packet error rate, delay, and jitters etc. The wireless network must support a variety of applications for instance, voice, data, video, and multimedia. Each of these has different traffic pattern and requirements which is shown in the Table 2.1 (Andrew *et al.* 2007).

Table 2.1: Sample Traffic Parameters for Broadband Wireless Application (Andrew *et al.* 2007).

Parameter	Interactive Gaming	Voice	Streaming Media	Data	Video
Data rate	50Kbps to 85Kbps	4Kbps-64Kbps	5Kbps-384Kbps	0.01Mbps-100Mbps	> 1Mbps
Applications	Interactive gaming	VoIP	Music, Speech, Video Clips	Web browsing, e-mail, instant messaging, telnet, file download	IPTV, movie download, p2p video sharing
Packet loss	Zero	<1%	<1% Audio <2% Video	Zero	$<10^{-8}$
Delay Variation	Not Applicable	<20ms	<2sec	Not Applicable	<2sec
Delay	<50ms-150ms	<100ms	<250ms	Flexible	<100ms

2.2.5 Interfacing

Interface installation is another feature of WiMAX. Each base station broadcasts radio signals to its subscribers to stay with connection. Since each base station covers limited range thus it is necessary to install multiple base stations after a certain distance to increase the range for network connectivity. Connecting multiple base stations is not a big deal and it takes only a few hours (Schroth, 2005).

2.2.6 Accessibility

In order to get high speed network connectivity, the only necessary thing is to become a subscriber of WiMAX service providers. Then they will provide hardware that is very easy to install. Most of the time hardware connects through USB ports or Ethernet and thê connection may be made by clicking button (Hawa & Peter, 2002).

2.2.7 Scalability

IEEE 802.16 standard supports flexible channel bandwidths for summarizing cell planning in both licensed and unlicensed spectrum. If an operator assigned 15 MHz of spectrum, it can be divided into three sectors of 5MHz each. The operator can increase the number of subscriber to provide better coverage and throughput by increasing the sector. For instance, 50 of hotspot subscribers are trying to get the network connectivity in a conference for 3 days. They also require internet access connectivity to their corporate network via Virtual Private Network (VPN) with T1 connection. For this connectivity, bandwidth is a big question as it requires more bandwidth. But in wireless broadband access it's feasible to provide service to that location for a small period of time. It would be very hard to provide through wired connection. Even though, the operator may re-use the spectrum in three or more sectors by creating appropriate isolation (Ergen *et al.,* 2003).

2.2.8 Portability

Portability is another feature like mobility that is offered by WiMAX. It offers mobility applications and also offers nomadic access applications.

2.2.9 Last Mile Connectivity

Wireless network accesses via DSL, T1-line or cable infrastructure are not available especially in rural areas. These connections have more limitations which can be solved by WiMAX standards.

2.2.10 Robust Security

WiMAX have a robust privacy and key management protocol as it uses Advanced Encryption Standard (AES) which provides robust encryption policy. Furthermore, it supports flexible authentication architecture which is based on Extensible Authentication Protocol (EAP) which allows variety of subscriber credentials including subscriber's username and password, digital certificates and cards (Mylavarapu, 2005).

2.3 IEEE 802.16e and IEEE 802.16m Connecting

WiMAX main objectives are to cover those remote areas where cable connection is not feasible or expensive and for better coverage especially for mobile networks where users are always moving than the other broadband technologies like, Wi-Fi, UWB and DSL. This subsection describes the network architecture, mechanism and some technical issues of WiMAX mobile in brief with potential diagrams.

2.3.1 WiMAX Architecture

WiMAX architecture comprises of several components but the basic two components are Base Station (BS) and Subscriber Station (SS). Other components are MS, ASN and CSN etc. as shown in Figure 2.1. The WiMAX Network Working Group (NWG) has developed a network reference model according to the IEEE 802.16e air interface to make sure the objectives of WiMAX are achieved. In order to support fixed, nomadic and mobile WiMAX network, the network reference model can be logically divided into three parts (Paul *et al.*, 2010).

Mobile Station (MS) It is for the end user to access the mobile network. It is a portable station able to move to wide areas and perform data and voice communication. It has the entire necessary user equipment such as an antenna, amplifier, transmitter, receiver and software needed to perform the wireless communication. GSM, FDMA, TDMA and CDMA devices etc. are the examples of Mobile station.

Access Service Network (ASN) It is formed with one or several base stations and ASN gateways (ASN-GW) which creates radio access network. It provides all the access services with full mobility and efficient scalability. Its ASN-GW controls the access in the network and coordinates between data and networking elements.

Connectivity Service Network (CSN): Provides IP connectivity to the Internet or other public or corporate networks. It also applies per user policy management, address management, location management between ASN, ensures QoS, roaming and security.

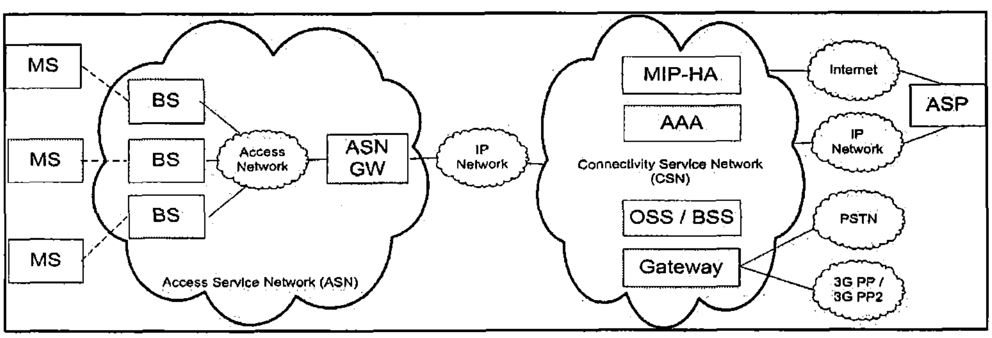

Figure 2.1: WiMAX Network Architecture based on IP (Paul *et al.,* 2010).

2.3.2 Mechanism

WiMAX is capable of working in different frequency ranges but according to the IEEE 802.16, the frequency band is 10 GHz - 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 (CPE) with the customer. This connection could be a Line-of-Sight (LOS) or Non-Line-of-Sight (NLOS).

2.3.2.1 Line of Sight (LOS)

The Line of Sight (LOS) indicates that there are no obstacles in the signal road between the receiver and the transmitter as shown in Figure 2.2. In other words, if the signal has been blocked by any types of obstacle, it will loss most of its strength and as a result of that, it will lead to the loss of both the connection and the information. Here are some of the advantages for LOS connections (Lihua, Wenchao & Zihua, 2007):

1- Operates at higher frequencies between 10 GHz up to 66 GHz.
2- LOS requires most of its first Fresnel zone is to be free of obstacles.
3- Negligible interference.
4- Fast data transfer between BS (base station) and SS (subscriber).
5- Wide range of coverage area.

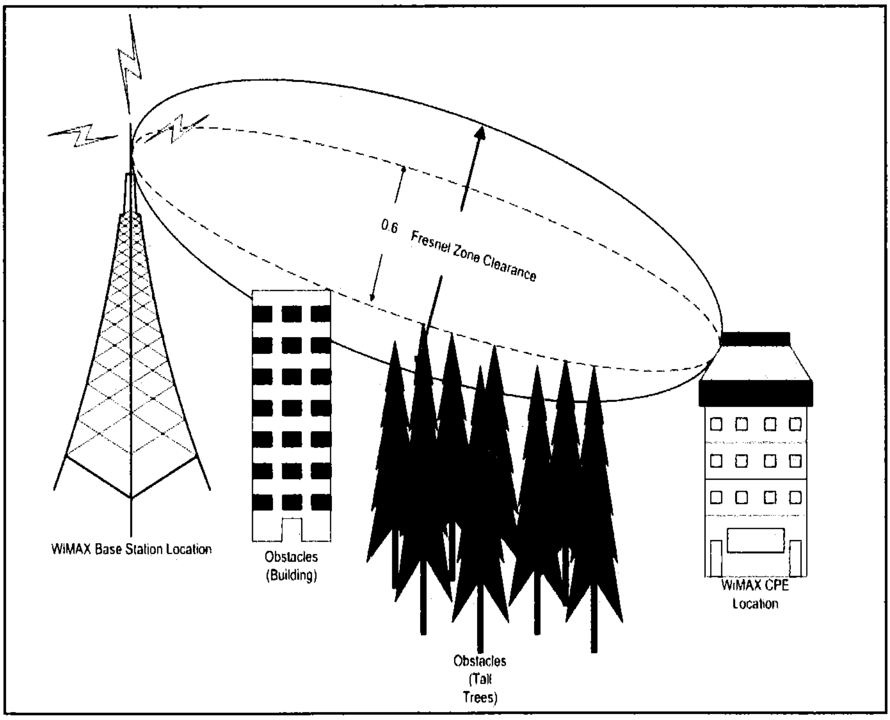

Figure 2.2: WiMAX in LOS Condition (Lihua, 2007).

2.3.2.2 Non-Line of Sight (NLOS)

When the signal propagates from the receiver to the transmitter, it influences by many obstacles that can degrade the signal in many ways such as made several reflections, refractions, diffractions, absorptions and scattering as shown in Figure 2.3. Consequently, the signals will arrive to the receiver in different times and in different strength. This will make the distinction and the recovery of the original signal quit tricky. Finally, WiMAX offers some other benefits that work fine in NLOS condition as follows (Lihua, Wenchao & Zihua, 2007):

1- Adaptive Modulation and Coding (AMC), MIMO, and AAS techniques help WiMAX to works efficiently in NLOS condition.
2- AAS directs WiMAX BS to a subscriber station.

In NLOS condition, the speed is high but the coverage area would be lower than that of LOS condition.

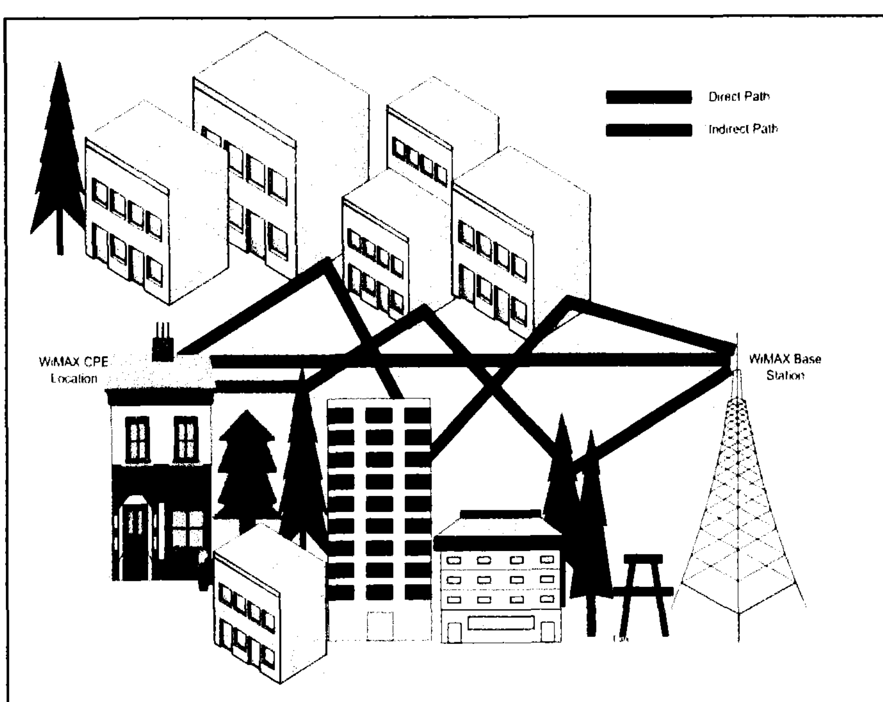

Figure 2.3: WiMAX in NLOS Condition (Lihua, 2007).

2.4 IEEE 802.16 Protocol layers

IEEE 802.16 standard WiMAX gives freedom in several things compared to other technologies. The focus is not only on transmitting tens of Megabits of data to many miles distances but also maintaining effective QoS (Quality of Services) and security.. WiMAX 802.16 is mainly based on the physical and data link layer in Open Systems Interconnection (OSI) reference model. Here, Physical layer can be single-carrier or multi-carrier (PHY) based and its data link layer is subdivided into two layers

- Logical Link Control (LLC) and
- Medium Access Control (MAC)

MAC is further divided into three sub-layers:

- Convergence Sub-layer (CS)
- Common Part Sub-layer (CPS) and
- Security Sub-layer.

2.4.1 PHY Layer Description

The physical layer in mobile WiMAX has two key technologies; Orthogonal Frequency-Division Multiple Access (OFDMA) and Multiple-input and Multiple-output (MIMO).

MIMO is the use of multiple antennas at both transmitter and receiver. For example, 4 x 2 MIMO means using four antennas at the base station and two antennas at the mobile device. An illustration about different antenna setups is shown in Figure 2.4. Comparing with the traditional Single-input Single-output (SISO) antenna model, MIMO increases the capacity and the spectral efficiency of the communication system greatly. Therefore, the system offers higher data rate with limited bandwidth, which increases the throughput regarding QoS.

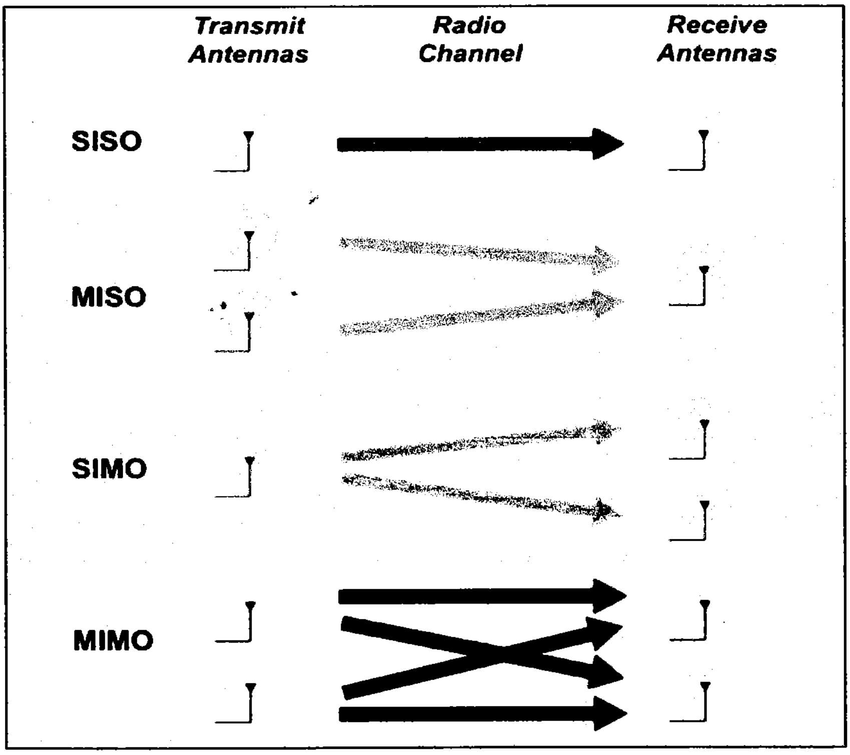

Figure 2.4: Illustration of differentiation between SISO, SIMO, MISO and MIMO wireless communication systems (Ahmadi, 2006).

OFDMA is a multi-user technology which is the evolution of Orthogonal Frequency-Division Multiplexing (OFDM). Mobile WiMAX physical layer uses MIMO together with OFDM to achieve good performance on frequency selective fading channels to provide support in NLOS conditions and mobility.

MIMO could increase the channel capacity by increasing the number of antennas. Furthermore, the technology of MIMO combined with OFDMA could offer a stable and low error service.

Physical layer set up the connection between the communicating devices and is responsible for transmitting the bit sequence. As well as, it defines the type of modulation and demodulation as well as transmission power. However, The IEEE 802.16 standard defines the following PHY layers which can be used with the MAC layer to develop broadband wireless systems (Ahmadi, 2006).

2.4.2 MAC Layer

The basic task of WiMAX MAC is to provide an interface between the physical layer and the upper transport layer. It takes a special packet called MAC Service Data Units (MSDUs) from the upper layer and makes those suitable to transmit over the air. For receiving purpose, the mechanism of MAC is just the reverse (Ahmadi, 2006).

Furthermore, the MAC layer contains three layers. The higher layer is called the Convergence Sub-Layer while the middle layer is known as the Common Sub-Part layer and finally the lower layer is considered to be a security layer as shown in Figure 2.5.

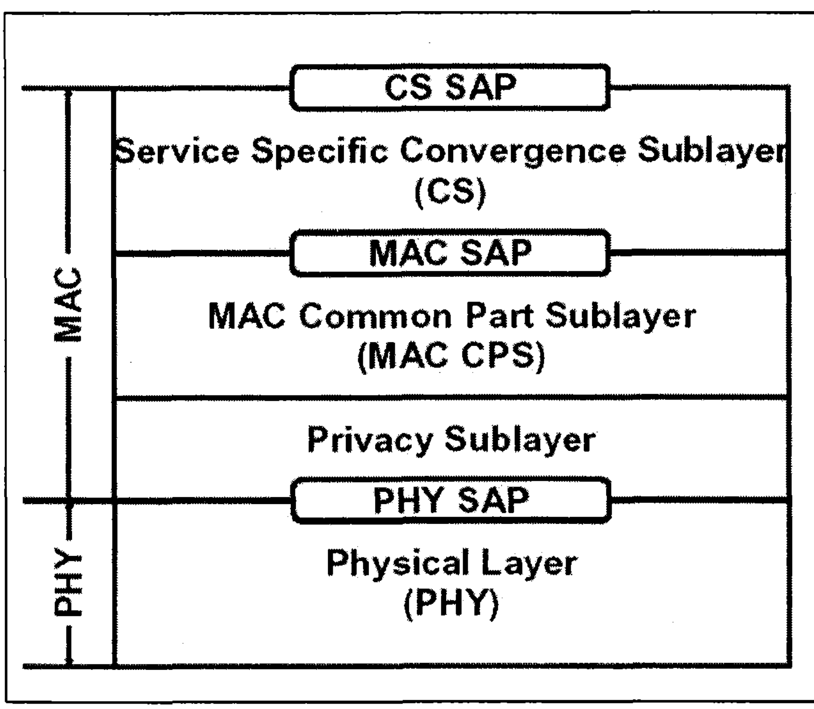

Figure 2.5: WiMAX Physical and MAC layer architecture (Ahmadi, 2006).

The Convergence Sub-Layer (CS) stays on the top of MAC layer architecture which takes data from the upper layer entities such as router and bridges. It is a sub-layer that is service dependent and assures data transmission. It enables QoS and bandwidth allocation and increase the link efficiency are other important task of this layer.

The Common Part Sub-layer (CPS) stays under of (SC) and above the Security Sub-layer and defines the access mechanisms. CPS is responsible for the major MAC functionalities like system access, establishing the connection and maintain and bandwidth management etc. Other responsibilities are, providing QoS for service flows and managing connection by adding or deleting or modifying the connection.

The lower layer of MAC is a security layer which consists of two components including protocols and the privacy key. The protocols are named as encapsulation protocols which are used for data encryption while the Privacy Key Management is used in order to describe the distribution of keys to clients as Figure 2.6 shown in the MAC layers task (Nuaymi *et al.,* 2007).

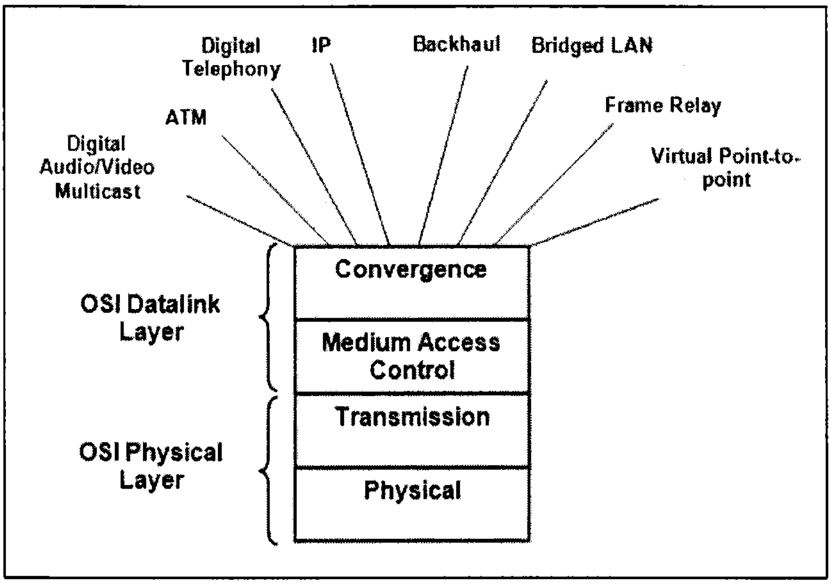

Figure 2.6: Purposes of MAC Layer in WiMAX (Nuaymi *et al.,* 2007).

2.5 QoS Scheduling Service Supported in IEEE 802.16e and IEEE 802.16m

There are many applications requires different types of services. For example, the IEEE 802.16e provides service classes for several different applications. Therefore, there are five types of QoS (quality of service) scheduling services which are supported by the standard. These services are discussed in the following reference:

2.5.1 Unsolicited Grant Service (UGS)

It is the one of the five QOS types that defined by IEEE 802.16. UGS has been used to support real time application like VOIP (voice over IP) but without the silence suppression. For UGS, the size of packet is fixed at periodic time interval. Thus, the advantages of UGS is reducing the overhead, reducing the number of SS requests, the Request and Transmission policy and finally Maximum Latency (Elgered *et al.*, 2008).

2.5.2 Extended Real Time Polling Service (ERTPS)

Generally, ERTPS is designed to support real time application. This scheduling service type is based on both UGS and rtPS. It is adequate for applications as VoIP, using silence suppression in which the data rate is variable (Haipeng *et al.*, 2008).

2.5.3 Real Time Polling Service (RTPS)

This service has designed for real-time applications. It offers variable packet size with variable data bit rates. It is useless for application such as VOIP, because of the delay that happened by the bandwidth request which could be 30 ms and that cannot be acceptable in this kind of applications. Furthermore, RTPS offers the Minimum Reserved Rate, the Maximum Sustained Rate, the Maximum Latency and the Request/Transmission policy. However, the major downfall of using this QoS is to reduce the total sector throughput and the polling overhead can reach up to 60% when using 3.5 MHz channel (Elgered *et al.*, 2008).

2.5.4 Non-Real-Time Polling Service (NRTPS)

This service class is intended to support non-real-time applications that require variable size data packets, and a minimum data rate, such as FTP (File Transfer Protocol). The bandwidth request can be either connection or connection-less mode. Thus, this is skilled by offering unicast polls on a regular basis which ensures that the service flow receives the requests even during network congestion (Elgered *et al.*, 2008).

2.5.5 Best Effort Service (BE)

BE is designed to support a data stream for non-real time application which does not require QoS guarantees. This scheduling mechanism can cause long delays when there is network congestion since it handles applications on best available basis. It has no support for applications but which have requirements of minimum service guarantees. An example of an application that uses this scheduling service is E-mail (Cicconetti *et al.*, 2006).

Table 2.2: Service Flows Supported in WiMAX (Andrew *et al.*, 2007).

Service Flow Designation	**Defining QoS Parameters**	**Application Examples**
Unsolicited gram services (UGS)	Maximum sustained rate. Maximum latency tolerance Jitter tolerance.	Voice over IP (VoIP) without silence suppression.
Real-lime Polling service (RTPS)	Minimum reserved rate. Maximum sustained rate. Maximum latency tolerance. Traffic priority.	Streaming audio and video. MPEG (Motion Picture Experts Group) encoded.
Non-real-time Polling service (NRTPS)	Minimum reserved rate. Maximum sustained rate. Traffic priority.	File Transfer Protocol (FTP).
Best-effort service (BE)	Maximum sustained rate Traffic priority.	Web browsing, data transfer.
Extended real-time Polling service (ERTPS)	Minimum reserved rate. Maximum sustained rate. Maximum latency tolerance Jitter tolerance. Traffic priority.	VoIP with silence suppression.

Table 2.2 lists the scheduling service types that could be used for some of the standard applications. For example, the voice over IP application requires real time application with high priority, because the delay cannot be ignored and the connection will be useless with the existence of the delay. As result it should apply service follow with high priority using the shortest delay. In this case, UGS would be the best choice. In contract, the email requires non real time application with no guarantee service. This means that the BE will be the good choice for email.

2.6 Uplink scheduling algorithms

In general, the scheduling algorithms can be classified as frame-based scheduling and sorted-based scheduling. The advantage of frame-based scheduling algorithms is their low computing complexity, while the disadvantage is the significant worst case delay. In the coming subsections the fundamental scheduling algorithms will be briefly described:

2.6.1 Round Robin

Round Robin as a scheduling algorithm is the most basic and least complex scheduling algorithm (Katevenis *et al.,* 1991). Basically the algorithm services the backlogged queues in a round robin fashion. Each time the scheduler pointer stop at a particular queue, one packet is de-queued from that queue and then the scheduler pointer goes to the next queue as shown in Figure 2.7.

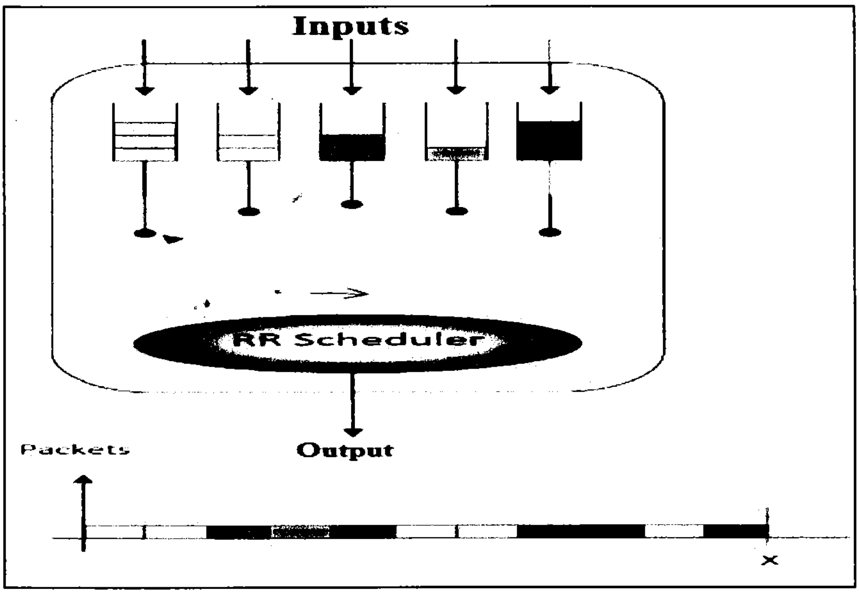

Figure 2.7: Round Robin Scheduler (Katevenis, 1991).

It distributes channel resources to all the SSs without any priority. The Round Robin (RR) scheduler is simple and easy to implement. However, this technique is not suitable for systems with different levels of priority and systems with strongly varying sizes of traffic.

2.6.2 Weighted Round Robin

Weighted Round Robin (WRR) an extension of the RR scheduler, based on static weights. WRR (Katevenis *et al.,* 1991) was designed to differentiate flows or queues to enable various service rates. It operates on the same bases of RR scheduling. However, unlike RR, WRR assigns a weight to each queue as shown in Figure 2.8.

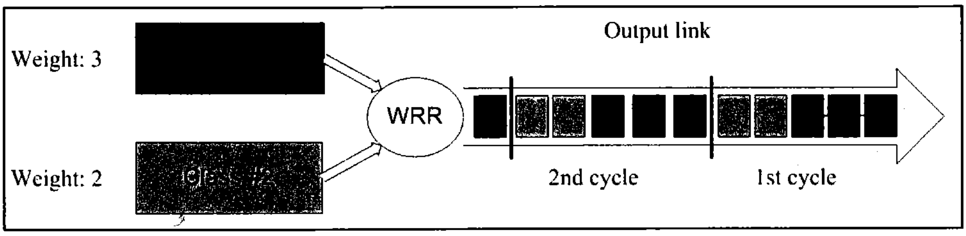

Figure 2.8: Weighted Round Robin Scheduler.

Supposing, normalized weights of depicted above queues are respectively 3 and 2, then number of packets taken in one cycle is 5. First, 3 packets are taken from Class 1 and after 2 from Class 2.

2.6.3 Earliest deadline first

It is a work conserving algorithm originally proposed for real-time applications in wide area networks. The algorithm assigns deadline to each packet and allocates bandwidth to the SS that has the packet with the earliest deadline. Deadlines can be assigned to packets of a SS based on the SS's maximum delay requirement. The EDF algorithm is suitable for SSs belonging to the UGS and rtVR scheduling services, since SSs in this class have stringent delay requirements. (Shreedhar & Varghese, 1996)

2.7 Scheduler Operation in Downlink

BS scheduler operation in downlink IEEE 802.16m provides a specific scheduling service to support real-time non-periodic applications. The MS and the serving BS negotiate supported QoS parameter sets during the service flow set-up procedure. In order to satisfy the latency requirements for network entry, handover, and state transitions, IEEE 802.16m supports fast and reliable transmission of MAC control messages. Therefore, to provide reliable transmission of MAC control messages, all MAC control messages can be fragmented. The IEEE 802.16 standard does not define a scheduling algorithm and the details of scheduler implementation remain proprietary and vendor-specific (Fallah, 2008). Hence, there are certain scheduling algorithms such as Round Robin.

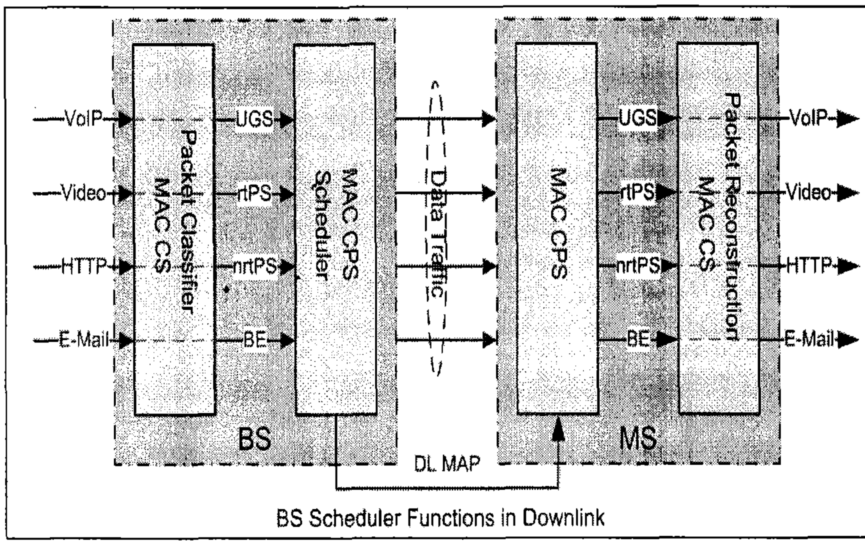

Figure 2.9: Scheduler functions in downlink.

Figure 2.9 describes the scheduler operation in downlink, when the data arrive to the packet classifier MAC CS level, this level can be receive various types of data which could be (VoIP, video, HTTP, EMAIL). In addition, this layer organized them based on the types of services flow (UGS, RTPS, NRTPS, BE). After that, scheduler sends them to mobile station as data stream.

2.8 OFDMA

Generally, Mobile WiMAX system based on IEEE 802.16e standard has many challenging multiuser communication issues. The most important issue is that many Mobile Stations (MSs) in the same region area demanding high data with low latency and efficiency bandwidth. Another communication issue is that many techniques allow MSs to share the available bandwidth by assigning for each subscriber some fraction of the total system resources. One of the most well-known multiple access techniques is OFDMA. This technique is so familiar to be used in Mobile WiMAX systems. Moreover, Subscribers are supported with many types of applications, data rates, and variety of quality of service (QOS) requirements.

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