On Performance Evaluation of Different QoS Mechanisms and AMC scheme for an IEEE 802.16 based WiMAX Network

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ABSTRACT

WiMAX is an emerging broadband wireless access system based on IEEE 802.16 specification which defines PHY and MAC layer for both fixed and mobile profiles. The WiMAX system effectively supports wide variety of broadband wireless access (BWA) technologies (including high speed internet and multimedia access) with high Quality of service (QoS) requirements. To support flexibility, efficiency and various requirements of QoS over a range of different applications and environments several provisioning and mechanisms are provided in the standard. In this paper various QoS provisions are analyzed for different application traffics. The effect of Adaptive Modulation Coding (AMC) mechanism on the QoS performance of WiMAX network is also studied. The results obtained show that these provisions and mechanisms enhance the QoS performance of the network in terms of throughput, packet loss and delay.

Keywords

WiMAX; QoS; QoS mechanisms; AMC

1. INTRODUCTION

Wireless networking has the potential to meet the increasing demands for broadband Internet services, video and audio streaming, and to emerge as an alternative to the PSTN for voice service. IEEE 802.16 standard [1], also known as Worldwide interoperability for Microwave Access (WiMax) has been specifically designed to provide wireless last mile broadband access in the Metropolitan Area Network (MAN). The IEEE 802.16 [2] caters to the need of Broadband Fixed and Mobile Wireless Access (BWA) and provides high quality broadband services to fixed, portable and mobile users [1,2] . WiMAX offers high speed, flexible, low cost and last mile services with performance comparable to that of wire line infrastructures T1, DSL, cable modem based connections, optical fiber or copper-wire with a variety of Quality of Service (QoS) requirements. WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed station and 3 to 10 miles (5-15 km) for mobile stations with theoretical data rats between 1.5 and 75 Mbps per channel. The 802.16e standard is an amendment to 802.16d standard and adds new major specifications enabling full mobility at vehicular speed with increased QoS to it (below 6 GHz NLOS operation). The new standards, IEEE 802.16j [3] and 802.16m [4], are also being developed for expanding the mobility further with enhanced coverage, performance and higher data rates (of the order of 100 Mb/s) for a WiMAX Network. The WiMAX standard air interface includes the definition of both the medium access control (MAC) and the physical (PHY) layers for the subscriber station and base station while the access network operability is defined by the WiMAX Forum, an organization consisting of operators and component and equipment manufacturers [5].

QoS refers to the collective effectiveness of the service as perceived by the user [6]. All the technical concerns in terms of packet loss, atmospheric interference, and in contention with other wireless services had been addressed as QoS by 802.16 standard [7]. As wide variety of broadband applications have different QoS requirements, WiMAX supports the desired in terms of variable bandwidth, delay, reliable packet routing for a given application with the challenge to accommodate all these on a bandwidth limited single access network. More specifically for a QoS demanding service introduced by WiMax minimum reserved traffic rate, maximum sustained traffic rate, maximum latency, and sometimes tolerated jitter are some of the needs to be explicitly specified. The IEEE 802.16 standard provides powerful tools in order to achieve different QoS constraints both at PHY layer and MAC layer levels. Various ongoing research areas in IEEE 802.16 are concerned on improving QoS performance in 802.16. The fundamental premise of the IEEE 802.16 MAC architecture is QoS differentiation for different types of applications. A number of QoS signaling mechanisms are included in the standard, but algorithms that use such signaling mechanisms were left out of the standard. This had allowed the flexibility to vendors to develop their own algorithms for bandwidth allocation and differentiate their own products, but remain interoperable with their core design [8].

Further, providing QoS for mobile access becomes more challenging with impairments like time variability and unpredictability of the channel, multipath fading, shadowing, latency and packet loss by frequent handovers and limited bandwidth. AMC is one of the efficient mechanisms provided in the WiMAX standard to mitigate the effect of these impediments. Using AMC mechanism, base station adaptively adjusts to the modulation and coding rate depending on the channel quality conditions thus increasing the spectral efficiency and data rates hence improving the overall QoS performance of the network [9].

In this paper the performance analysis of various service flows and AMC provided in the IEEE 802.16 standard for QoS provisioning and mechanism is done for different application traffics.

Following this introduction a brief description of QoS in IEEE 802.16 based WiMAX network is given in Section II. Section III describes the various simulation environments and results are discussed in section IV. Section V concludes the work done.

2. IEEE 802.16 BASED QOS

QoS determines if a wireless technology can deliver high value services successfully. The prominent issues to provide an efficient carrier grade service with good QoS are latency; jitter and packet loss. QoS support in wireless networks is a much more difficult task than in wired networks, mainly because the characteristics of a wireless link are highly variable and unpredictable, both on a time-dependent basis and a location dependent basis. To cope with such issues, QoS in wireless networks is usually managed at the medium access control (MAC) layer. Applications such as multimedia streaming require high bandwidth; whereas applications such as Voice over IP (VoIP), Push-to-Talk (PTT), online gaming require low delay and jitter; yet applications like video conferencing require both high bandwidth and low delay and jitter. QoS, therefore, means low latency, low delay and jitter, low loss, adequate bandwidth and above all, good end-user experience. However, all the metrics do not necessarily apply to all applications and hence it's a challenge for the service provider to build an infrastructure that can provide end-to-end QoS for applications with variety of QoS needs. The IEEE 802.16 standard defines only the behavior of PHY layer, the issue arises as how to guarantee the very diverse QoS requirements for different applications. To achieve QoS every WiMAX /802.16 implementation uses some combination of mechanisms in the PHY (Physical) layer and MAC layer while QoS provisioning is used to hand over the parameters based on the QoS requirements to the higher layers [10].

2.1. IEEE 802.16 MAC layer:

Support for QoS is a fundamental part of the WiMAX MAC-layer design which uses a connection-oriented MAC architecture, where all downlink and uplink connections are controlled by the serving BS with each connection identified by a *connection identifier* (CID), for data transmissions over the particular link. MAC layer assigns traffic to a service flow *service flow identifier* (SFID) for packets with a particular set of QoS parameters (traffic priority, maximum sustained traffic rate, maximum burst rate, minimum tolerable rate, scheduling type, ARQ type, maximum delay, tolerated jitter, service data unit type and size and bandwidth request mechanism to be used) and map it to MAC connection using a CID. The base station is responsible for issuing the SFID and mapping it to unique CIDs. Service flows may be provisioned through a network management system or created dynamically through defined signaling mechanisms in the standard to enable end-to-end IP-based QoS. The packets are transmitted from the queues to the network in the appropriate SS using the scheduler at SS as defined by Uplink Map Message (UL-MAP) sent by the BS. Multiple levels of QoS through its classification, queuing, and control signaling are also handled by the 802.16 QoS architecture [10].

WiMAX defines five scheduling services for several applications which vary from being real time with stringent QoS requirements to non-real time with relaxed QoS requirements [11-12]. Table 1 enlists various WiMAX services and their QoS requirements provided in the IEEE 802.16 standard.

Table 1: WiMAX Services and QoS requirements

QoS service class	Application	QoS Specifications
UGS (Unsolicited Grant Service)	VoIP	• Minimum reserved rate • Maximum sustained rate • Traffic priority • Maximum latency tolerance
rtPS (Real Time polling Service)	Streaming audio or video; Tele medicine; E-learning	• Minimum reserved rate • Maximum sustained rate • Traffic priority • Maximum latency tolerance
nrtPS (Non Real Time Polling Service)	FTP; document sharing	• Minimum reserved rate • Maximum sustained rate • Traffic priority
BE (Best Effort)	Data transfer, Web Browsing; E-mail.	• Maximum sustained rate • Traffic priority
ertPS (Extended Real Time polling Service)	VoIP with silence suppression	• Minimum reserved rate • Maximum sustained rate • Traffic priority • Maximum latency tolerance • Jitter tolerance

2.2 Adaptive Modulation and Coding:

WiMAX supports link adaptation techniques known as adaptive modulation and coding in which the modulation scheme changes depending on channel conditions. Using adaptive modulation scheme, WiMAX system can switch to the highest order modulation scheme depending on the channel conditions. As the signal-to-noise ratio (SNR) is very good near the base station (BS), so higher order modulation scheme is used in this area to increase the throughput. While for the areas where the SNR is poor the system switches to the lower order modulation scheme, farther from the base station to maintain the connection quality and link stability with increased throughput, figure1. The supported modulations are BPSK, QPSK, 16- QAM and 64-QAM.

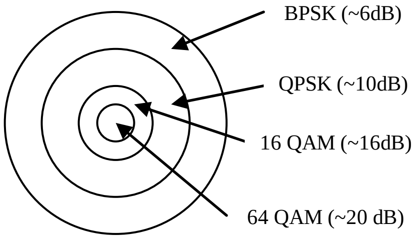


Figure1. Adaptive Modulation Radii

Table II. Different Modulation and Coding Rates

Modulation	**RS Code**	**CC code**	**Coding rate**
QPSK	(32,24,4)	2/3	1/2
QPSK	(40,36,2)	5/6	3/4
16-QAM	(64,48,8)	2/3	1/2
16-QAM	(80,72,4)	5/6	3/4
64-QAM	(108,96,6)	3/4	2/3
64-QAM	(120,108,6)	5/6	3/4

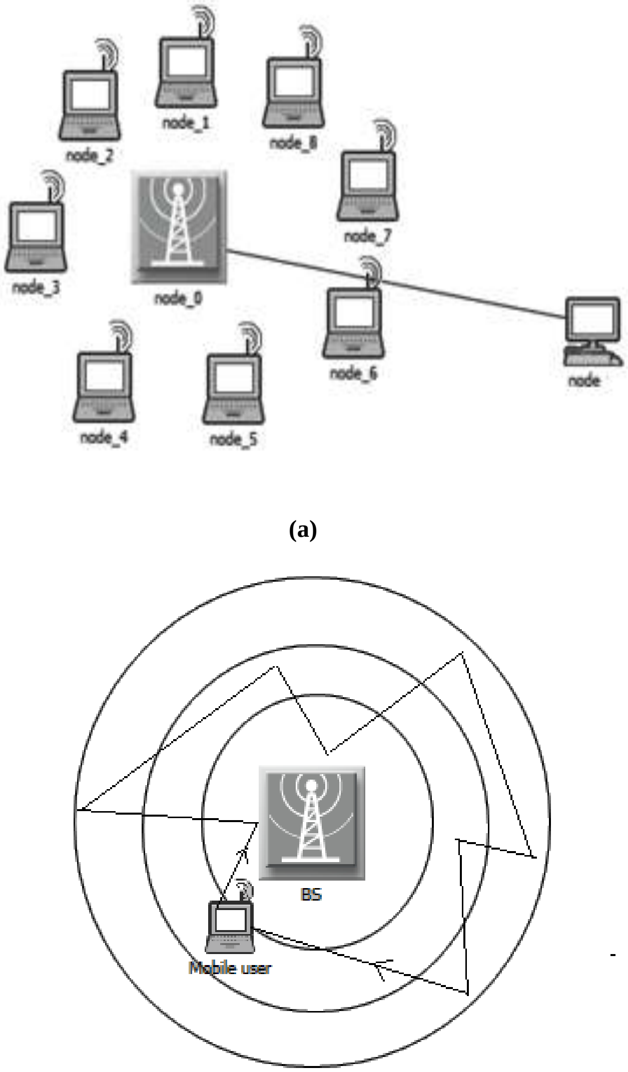
Table II summarizes several combinations of modulation and coding rates, which can be allocated selectively to each subscriber (both UL and DL) [6], specified by the PHY layer. AMC technique helps to reduce the time selective fading, increases the range that a higher modulation scheme can be used over when mobility of users is taken into account.

3. MODELING AND SIMULATION

Two scenarios have been developed for modeling and simulation. In Scenario I, the behavior of different service flows provided in the standard have been analyzed for different application traffics and their significance in achieving QoS for the WiMAX is realized using OPNET Modeler 14.5 [13] which is an extensive networking tool to analyze the performance of a network. In scenario II, the performance improvement is observed for a WiMAX system employing AMC is studied. The experimental set up for both the scenarios is shown in figure 2. The important parameters used in the simulation are summarized in table III.

Table III. Simulation Parameters

Bandwidth	20 MHz
Antenna Type and Gain	Omni directional ; 14 dB
Channel Model	ITU Pedestrian A,ITU Vehicular B
Duplex Mode	TDD
Application traffic ; Number of users	VoIP, FTP, Streaming multimedia, email, web browsing; 8



(a)

(b)

Figure 2. System model for (a) scenario I (b) scenario II

4. RESULTS AND ANALYSIS

4.1 Scenario I:

The performance analysis and validity of different service classes provided in the standard have been done by measuring several QoS parameters including throughout, average jitter, packet loss and delay for different applications types. The service flows are analyzed for 4 different types of applications for the corresponding QoS parameters.

4.4.1 FTP traffic:

The QoS performance is analyzed for the users incorporating FTP application with non real time traffic. The QoS is measured in terms of throughput, downlink response time and packet loss.

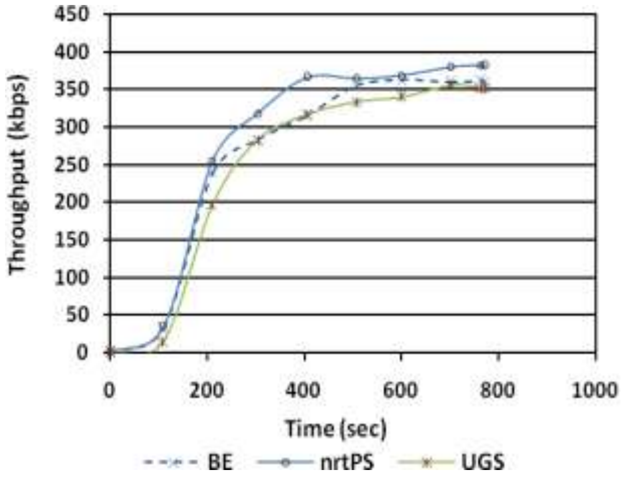


Figure 3. Average throughput for FTP application

Table IV. QoS parameters for FTP application traffic

Service Flow	QoS Parameters	
	Download Response Time (sec)	**Packet Loss (%)**
BE	3.33	11.28
nrtPS	3.19	9.10
UGS	5.32	12.82

From figure 3 and measured QoS values, enlisted in table IV, it is observed that nrtPS has highest throughput, lower download response time and lower packet loss followed by BE and UGS for the user incorporating FTP traffic. Thus results clearly indicate that nrtPS suits best for FTP traffic.

4.1.2 Video traffic:

The QoS parameters analyzed for users with video traffic are shown in figure 6 and table V. The results obtained show that the average throughput for rtPS is higher, while packet drop rate and average jitter is lower than the other three service flows.

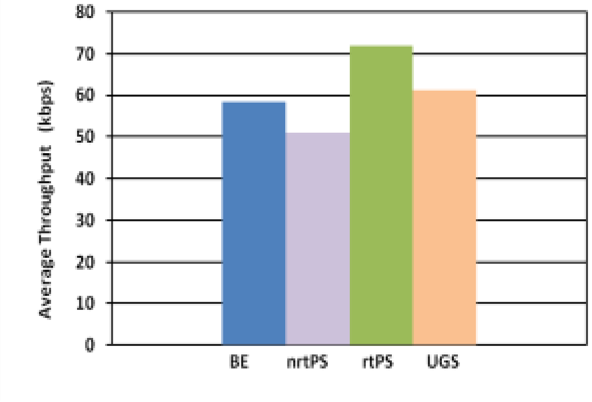


Figure 6. Average throughput for video application

Table V. QoS parameters for Video application traffic

Service Flow	QoS Parameters	
	Average Jitter (msec)	**Average Packet Loss**
BE	2.691	3.284
nrtPS	2.63	3.449
rtPS	0.239	0.028
UGS	0.348	0.026

As higher jitter degrades the quality of video to a larger extent, so for such applications rtPS are best suited. The results obtained further indicate that UGS have comparable performance with that of rtPS. However it is least preferred because it allocates bandwidth on periodic basis which is best suited for constant bit rate (CBR) traffic and proves to spectrally inefficient in case of variable rate traffic (video streaming).

4.1.3 VOIP:

The results obtained for VOIP traffic, shown in figure 7 and table VI, indicate that significant QoS parameters, i.e., delay, jitter and packet loss are lowest for UGS service flow. A UGS flow handles fixed size packets generated at regular intervals in contrast to variable rate traffic handled by rtPS. The suitability of UGS for CBR based VOIP traffic is hence validated by simulation results.

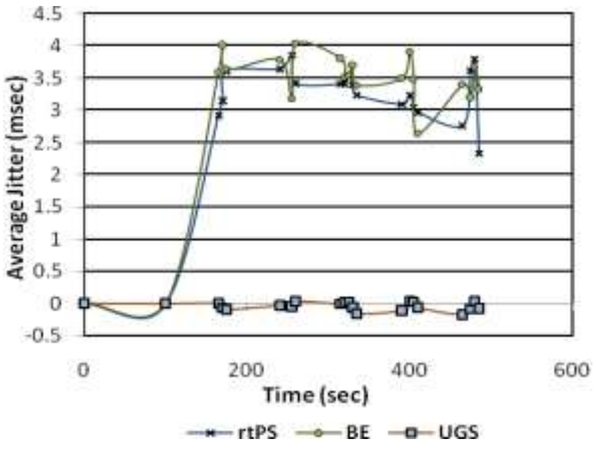


Figure 7. Average jitter (sec) for voice application

Table VI. QoS parameters for Voice application traffic

Service Flow	QoS Parameters	
	Delay (msec)	**Average Packet Loss (packets/sec)**
BE	127	5.28
nrtPS	109	5.11
UGS	5	0.676

4.1.4 Email:

Table VII enlists the various QoS parameters measured for users incorporating Email traffic.

Table VII. QoS parameters for Email traffic

Service Flow	QoS Parameters		
	Download response time (msec)	Average delay in WiMAX connection (msec)	Throughput (kbps)
BE	200	7.009	410.1744
UGS	209	7.404	272.9026
rtPS	208	20.275	309.7641

From the values obtained it can be inferred that download response time, throughput and average delay in WiMAX connection is lowest in BE, than rtPS and UGS. Since download response time and throughput are important in the Email application services it follows that BE serves best to this type of application.

4.2 SCENERIO 2:

The effect of introducing AMC in the WiMAX network is studied for mobile user with video traffic with rtPS. The improvement in QoS performance can be observed from the results obtained in figures 8, 9 and 10.

Higher throughput, lower packet drop rate and packet ETE delay indicates that AMC proves to be an efficient technique for the mobile users with improved QoS performance.

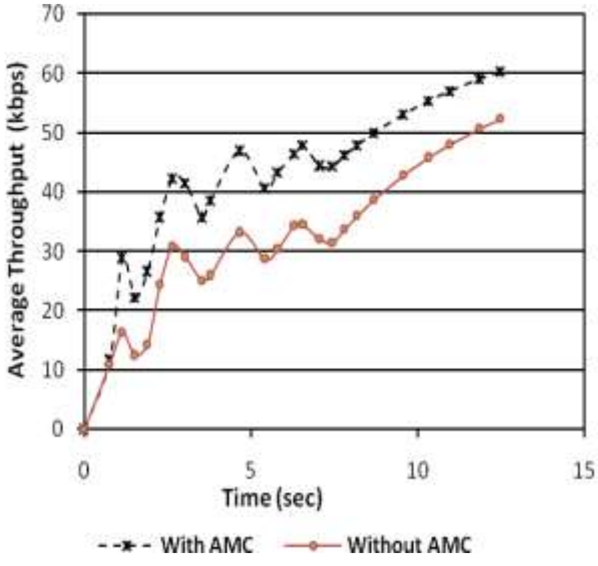


Figure 8. Average Throughput (kbps) for video application with and without AMC

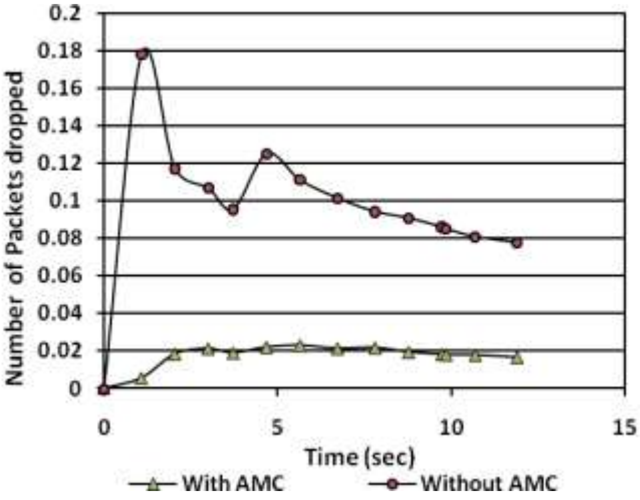


Figure 9. Packet loss for video application with and without AMC

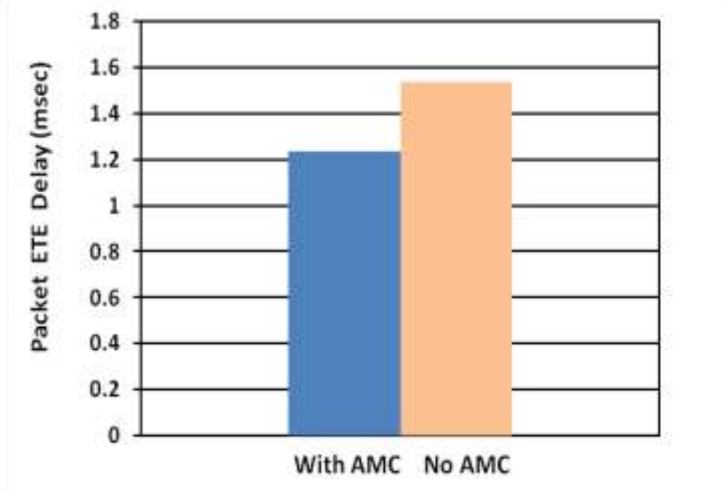


Figure 10 Average ETE delay for video application with and without AMC

5. CONLUSIONS

The performance of various QoS mechanisms provided in IEEE802.16 standard is studied for both the fixed and mobile environments and their significance on QoS performance of the WiMAX network is realized. The investigations are also carried out further with the implementation of AMC scheme and its effect on the QoS performance of WiMAX network is studied.

Various service flows have been analyzed for different application traffic types and their QoS performance is found to be in accordance with the provisions in the standard. It can be concluded that FTP traffic is best served with nrtPS; Video traffic with rtPS; Email with BE and VOIP with UGS.

As fading environments incorporated by mobile users severely degrade the performance of the system and affect the QoS performance of the system. The results obtained show that performance of WiMAX system is optimized to a higher throughput with the incorporation of AMC, based on the channel conditions, with lower modulation scheme for the increased range and switching to higher modulation scheme for the range closer to the base station. The QoS performance is further improved more significantly with lower packet drop rate, lower delay and increased throughput for the system.

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