International Journal of
Science and Engineering Investigations vol. 6, issue 65, June 2017
ISSN: 2251-8843

A New QoS Architecture for IEEE 802.16 and IEEE 802.11e Standards

Youseef Alotaibi
Department of Computer Sciences, Umm Al-Qura University, Makkah, Saudi Arabia
(yaotaibi@uqu.edu.sa)

Abstract- There are several challenging issues to design a network when the integrated WiMAX/Wi-Fi networks are constructed. Literature shows that mostly of the existing researches may not have a strategy to map the QoS between WiMAX and WiFi networking. Therefore, this paper aims to propose new integration WiMAX/Wi-Fi architecture to improve the QoS. In this proposed architecture, a new strategy to map the QoS between WiMAX and WiFi networking will be designed.

We study our integration WiMAX/Wi-Fi module when the WiMAX SSs send or receive data to or from Wi-Fi STAs. QualNet version 5.0.2 is used to perform this simulation. The simulation results indicate that when the number of SSs or STAs in our integration WiMAX/Wi-Fi network increases, the average jitter, the average end-to-end delay and the throughput are increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher average jitter, average end-to-end delay and throughput than sending data from Wi-Fi STAs to WiMAX SSs.

Keywords- *WiMAX, IEEE 802.16, IEEE 802.11e, QoS, QualNet*

I. INTRODUCTION

The Wireless Local Area Network (WLAN) known as IEEE 802.11 standard has become a popular in offering different data services. The WLANs usually connect to each other or to the Internet throughout a wired network which is not that easy to implement in the suburban areas or remote countryside. Furthermore, the number of people using the wireless networks to login the Internet has increased because it is more suitable and it supplies the mobility. This leads to large operation of the wireless networks, such as Wi-Fi or the IEEE 802.11 standard [2]. Nevertheless, the 802.11 standard may have some weaknesses, such as the short transmission distances and the small transmission rates. As a result, the IEEE 802.16 standard or the Worldwide Interoperability for Microwave Access (WiMAX) is proposed to solve the previous disadvantages [7][27]. The broadband wireless access (BWA) is supplied by the 802.16 standard [15]. Furthermore, some high-quality features, such as the high speed access to the Internet, sustaining Quality of Service (QoS), the low cost, the broad coverage range and the fast deployment are supplied for the organizing and the sustaining networks by the 802.16 standard. It can reach 75 Mbps as the data rate and it can achieve up to 50 Km as the extreme distance [12][33].

There are several advantages by using the WiMAX network to connect Wi-Fi hotspots into the Internet. Firstly, the very costly wired network communications can be avoided. Secondly, the mobile hotspot services can be provided to appreciate the Intelligent Transportation System (ITS) applications. Furthermore, the users may obtain benefits from the performance enhancement and the higher data rate of the combination services [21].

There are several challenging issues to design a network when the integrated WiMAX/Wi-Fi networks are constructed. For example, designing capable links and Media Access Control (MAC) layer protocols in order to advance the QoS between the Wi-Fi and WiMAX components is one of these challenging [25]. Moreover, each network technologies may support different data rate. In addition, they are difference in QoS support. Thus, a QoS mapping scheme is required when there is different network types used because it is complicated to use the same QoS parameters and QoS classes for all application types.

There are several researches proposed to provide QoS for the integration WiMAX/Wi-Fi modules. However, literature shows that mostly of the existing researches may not have a strategy to map the QoS between WiMAX and WiFi networking. Therefore, this paper aims to propose new integration WiMAX/Wi-Fi architecture to improve the QoS. In this proposed architecture, we will design a strategy to map the QoS between WiMAX and WiFi networking.

We study our integration WiMAX/Wi-Fi module when the WiMAX SSs send or receive data to or from Wi-Fi STAs. QualNet version 5.0.2 is used to perform this simulation. The simulation results indicate that when the number of SSs or STAs in our integration WiMAX/Wi-Fi network increases, the average jitter, the average end-to-end delay and the throughput are increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher average jitter, average end-to-end delay and throughput than sending data from Wi-Fi STAs to WiMAX SSs.

The remainder of this paper is organized as follows: section 2 describes the IEEE 802.16, IEEE 802.11e standards and related work. Section 3 explains our proposed integration

WiMAX/Wi-Fi network architecture. Section 4 presents the simulation results and the performance analysis. Finally, section 5 gives some brief summary.

II. IEEE 802.16 & IEEE 802.11E

There are several differences between WiMAX and Wi-Fi. For example, WiMAX supports much longer distances than Wi-Fi and it may contain mobility between cells. Furthermore, Wi-Fi is the WLAN based on the IEEE 802.11 standard. However, WiMAX is the BWA system based on the IEEE 802.16 standard. Furthermore, Wi-Fi has 54 Mbps as data rate on 20 MHz channel while WiMAX has 26.2 Mbps as data rate on 7 MHz channel. Furthermore, while Wi-Fi uses for the short distance about 100 m, WiMAX uses for the long distance about 20 km [8]. These two standards will explain in the following two subsections.

A. *IEEE 802.16 Standard*

There are two fixed stations in the basic architecture of WiMAX: base station (BS) and SS. The BS is the essential tools set and it can offer connectively management and the control of some SSs located in different distances. However, the building prepared with the conservative wireless or wired LAN can be signified by the SS. The internetworking access to the buildings can be offered by the WiMAX throughout external antennas [1][17].

There are two different operation modes identified in the IEEE 802.16 standard: PMP and mesh mode. In the PMP mode, multiple SSs can be associated by the controlling BS to different public networks. On the other hand, in the mesh mode, a direct communications between the SSs can be maintained without using the BS (figure 1) [18][20][34].

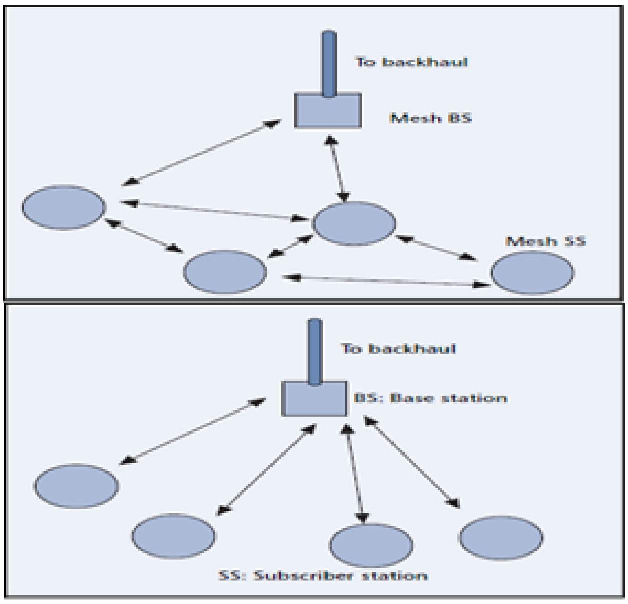

Figure 1. PMP Mode & Mesh Mode

Generally, there are three essential components to handle the QoS in the 802.16 standard: admission control, scheduling and buffer management. The admission control is used to conclude whether the new connection request can be approved or not. This is based on the remaining complimentary bandwidth. Furthermore, the number of flows admitting into the network can be restricted by the admission control. Thus, several services overflow and the starvation may be controlled [6][16]. The scheduling is used to decide the priority to assure the QoS requirements. In other words, it is adopted to decide the first packet to supply in the particular queue to assure the QoS requirements. The buffer management is used to organize the buffer size and to choose the deleted packets. In other words, the buffer size can be restricted by the buffer management which is used to determine the dropped packet [26].

There are four different service classes maintained in the IEEE 802.16 standard: (1) Unsolicited Grant Service (UGS); (2) Real-time Polling Service (rtPS); (3) Non real-time Polling Service (nrtPS); and (4) Best Effort (BE). The Extended Real-Time Polling Service (ertPS) service class is added in the IEEE 802.16e standard. These service classes will explain in the following subsections.

1) *Unsolicited Grant Service (UGS)*

The UGS service class is proposed to maintain the real-time data streams contained the data packets with the fixed-size concerned at the periodic intervals, such as Voice over IP (VoIP) with no silence suppression and T1/E1. The Maximum Sustained Traffic Rate, the Tolerated Jitter, the Maximum Latency and the Request / Transmission Policy are the compulsory QoS service flow factors for the UGS scheduling service. The Minimum Reserved Traffic Rate factor is equal to the Maximum Sustained Traffic Rate factor when it is present [3].

2) *Real-time Polling Service (rtPS)*

The rtPS service class is proposed to maintain the real-time data streams contained the data packets with the variable-size concerned at the periodic intervals, such as the Moving Picture Experts Group Video (MPEG). The Maximum Sustained Traffic Rate, the Minimum Reserved Traffic Rate, the Maximum Latency and the Request / Transmission Policy are the compulsory QoS service flow factors for the rtPS scheduling service.

3) *Non real-time Polling Service (nrtPS)*

The nrtPS service class is proposed to maintain the delay-tolerant data streams contained the data packets with the variable-size when the minimum data rate is involved, such as the File Transfer Protocol (FTP). The Maximum Sustained Traffic Rate, the Minimum Reserved Traffic Rate, the Traffic Priority and the Request / Transmission Policy are the compulsory QoS service flow factors for the nrtPS scheduling service [5].

4) *Best Effort (BE)*

The BE service class is proposed to maintain the data streams when there is no minimum service level involved, such as the HTTP. Hence, it can be held on the space-variable basic. The Maximum Sustained Traffic Rate, the Traffic Priority and the Request / Transmission Policy are the compulsory QoS service flow factors for the BE scheduling service [4].

5) Extended Real-Time Polling Service (ertPS)

The ertPS is inserted by the IEEE 802.16e standard. It is a scheduling scheme built on the competence of the UGS and rtPS service classes. The bandwidth request latency may be saved in the ertPS service class because the unicast grants in the unsolicited approach are offered by the BS in this scheduling service class as in the UGS. While the allocations of ertPS are dynamic, the allocations of UGS are fixed in the size. The ertPS service class is proposed to maintain the real – time data streams with the delay and data rate requirements contained the data packets with the variable – size concerned at the periodic intervals, such as the VoIP with no silence suppression [14].

Table I summarizes the obligatory QoS parameters using in different scheduling service classes.

TABLE I. OBLIGATORY QOS PARAMETERS OF THE SCHEDULING SERVICE CLASSES

Scheduling Types	MSTR	MRTR	Maximum Latency	Traffic Priority	Request/Transmission Policy	Tolerated Jitter
UGS	√	Can be present	√		√	√
rtPS	√	√	√		√	
nrtPS	√	√		√	√	
BE	√			√	√	

B. IEEE 802.11e Standard

The IEEE 802.11e standard has been enhanced the IEEE 802.11 standard to support QoS by introducing priority mechanism. The hybrid coordination function (HCF) is a new MAC layer function introduced in the IEEE 802.11e standard. The aspects of the mandatory distributed coordination function (DCF) and the optional point coordination function (PCF) are combined with the same QoS mechanism enhancement to offer different service in the HCF. Similar to the DCF and the PCF in the IEEE 802.11 standard, both the distributed and the controlled channel access methods are provided by the HCF in the IEEE 802.11e standard [10]. In other words, the contention-based channel access mechanism and the controlled channel access mechanism that is included polling are the two medium access mechanisms for the HCF in the IEEE 802.11e. The contention-based channel access is the enhanced distributed channel access (EDCA) and the controlled channel access is the HCF - controlled channel access (HCCA) (Figure 2). The CP and the CFP are the two operation phases for the super frame in the IEEE 802.11e [29].

In the IEEE 802.11e, QoS - enhanced AP (QAP) and the QoS - enhanced STAs (QSTAs) are the AP and the STAs implemented the QoS facilities respectively. In the IEEE 802.11e, the time duration during transmission the burst of data frame by the QSTA is called the transmission opportunity (TXOP). The TXOP can be called the EDCA-TXOP when it is achieved by succeeding the successful EDCA contention. Furthermore, it can be called the HCCA-TXOP or the polled-TXOP when it is acquired by receiving the CF – Poll frame from the QAP. The TXOP limit that is established by the QAP is the max value of the TXOP. Consequently, the TXOP can be granted when the medium is accessed by the QSTA and then the QSTA may send several frames that are divided by the SIFS interval time [22].

- There are some benefits by using the IEEE 802.11e standard as following.
- The latency via prioritizing different packets traffic types can be decreased.
- The packets overheads can be decreased.
- The wireless bandwidth efficiency can be developed.

The AP can be allowed to allocate the data rate resource and the latency supplies from each individual STA.

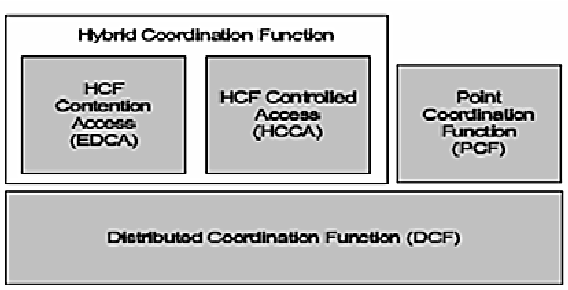

Figure 2. IEEE 802.11e MAC Architecture

1) Enhanced Distributed Channel Access (EDCA)

The EDCA is supplied prioritizing QoS by improving the contention-based DCF. In addition, the differentiation and the distribution access to the medium are provided by using different priorities for the different data traffic types in the EDCA. There are four access categories (ACs) known as first-in-first-out (FIFO) queues defined in the EDCA for different data traffic types, such as the background (BK), the best effort (BE), the video (VI) and the voice (VO). The frames of different data traffic types are mapped into different ACs. That is depended on the QoS requisites for each application. For instance, the first AC is used for the voice traffic types (AC_VO), such as VIOP. Furthermore, the second AC is used for the video traffic types (AC_VI), such as MPEG-4. Moreover, the third AC is used for the best effort traffic types (AC_BE) and the fourth AC is used for the background traffic types (AC_BK) [28].

The AC_VO has the highest priority and the AC_BK has the lowest priority. Furthermore, a particular user priority (UP) value is allocated for each data packets that are received from the higher layers before entering the MAC layer (Figure 3). In addition, there are eight different UP values ranged from 0 to 7 depended on the traffic types (Table II). Moreover, there are four independent enhanced distributed channel access function (EDCAF) enhanced the DCF. Also, there is one EDCAF for each AC [11][30].

TABLE II. MAPPING BETWEEN USER PRIORITY (UP) AND ACCESS CATEGORY (AC)

Priority	User priority in 802.11D	Access Category (AC)	Designation (informative)
Lowest	1	AC [0]	Background
	2	AC [0]	Background
	0	AC [1]	Best Effort
	3	AC [1]	Video
	4	AC [2]	Video
	5	AC [2]	Video
	6	AC [3]	Voice
Highest	7	AC [3]	Voice

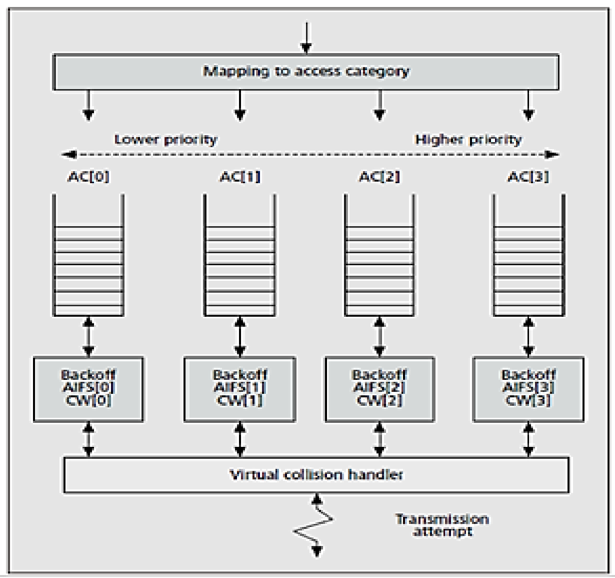

Figure 3. EDCA

Each AC has its own different parameters, such as the Arbitration inter – frame space (AIFS), the Contention Window (CW) and the Transmission Opportunity (TXOP) to connect to the medium. The list of the important parameters of the EDCA function is explained as flowing.

2) Arbitration inter – frame space (AIFS)

It is the min time duration when the medium is sensed idle before the transmission or the back – off producer are started by the STA. In other words, it is the average interval time for the traffic class (TC) waited to gain the TXOP. Furthermore, it is a variable value depended on each AC.

AIFS [AC] = AIFSN [AC] * aSlot time + a SIFSTime, [1]

Where:

AIFSN [AC] = The Arbitration Inter – Frame Space Number is employed to establish the AIFS length.

aSlot time = The slot time.

a SIFSTime = The SIFS time duration.

Each AC has its own AIFSN value. The low priority AC has the larger AIFSN value. On the other hand, the high priority AC has the smallest AIFSN value. Therefore, the STA will wait the shorter time before starting transmission when it has the smaller AIFSN value and the higher priority AC (Figure 4) [19].

3) Contention Window (CW)

It is used to exchange the back-off counter size. There are min contention window (CWmin) and max contention window (CWmax) size. They are variable depended on each AC. The lower priority AC has the higher CWmin and CWmax values. On the other hand, the higher priority AC has the smaller CWmin and CWmax values.

The AC has the smaller CW may be caused the STA to have smaller random back – off values. However, the AC has the larger CW may be caused the STA to have the higher random back-off values which will lead to long delay. In other words, each AC may have different contention parameters because the low priority class is provided a longer waiting time compared to the high priority class. Hence, the medium can be accessed by the high priority class earlier than the low priority class [9].

4) Random Back-Off Time

It is larger than the CWmin [AC] and it is smaller than the CWmax [AC]. Furthermore, it is set to the number between one and (1 + CW [AC]) - (1, 1 + CW [AC]). It is calculated for each AC when the medium of the time interval of the AIFS [AC] is sensed idle.

In summary, table III has shown the default EDCA parameter values. These values are different for different ACs. In general, the lower priority AC waits the longer AIFS time before accessing the medium. However, the higher priority AC waits the smaller AIFS time before accessing the medium. In addition, the higher priority AC has to access the medium for the longer durations. Nevertheless, the lower priority AC has to access the medium for the shorter durations. As a result, the higher priority AC always has smaller AIFS, CWmin and CWmax and larger TXOP limit. On the other hand, the lower priority AC always has larger AIFS, CWmin and CWmax and smaller TXOP limit [13].

TABLE III. DEFAULT EDCA PARAMETER VALUES

AC	CWmin	CWmax	AIFSN	TXOP Limit	
				FHSS	DSSS
AC_BK	CWmin	CWmax	7	0	0
AC_BE	CWmin	CWmax	3	0	0
AC_VI	(CWmin+1)/2-1	CWmax	2	6.016ms	3.008ms
AC_VO	(CWmin+1)/4-1	(CW+1)/2-1	2	3.264ms	1.504ms

5) HCF-Controlled Channel Access (HCCA)

The HCCA is designed to supply parameterized QoS maintain in the IEEE 802.11e standard. There are three major problems appeared by using the PCF in the IEEE 802.11 standard. They can be solved by using the HCCA in the IEEE 802.11e.

- The traffic streams (TSs), which are in different TC, are established in the HCCA. Therefore, the HCCA is designed to support different application types.
- The beacon delay problem of the PCF can be worked out by using the HCCA because the QSTA cannot transmit the next beacon of the data packets before the transmitted frame is not finished in the IEEE 802.11e network (Figure 5).
- The transmission time of the polled QSTA can be located by using the TXOP limit parameters.

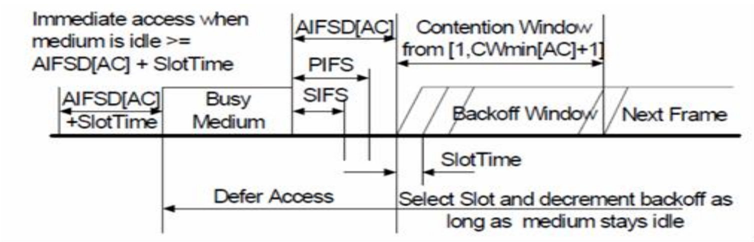

Figure 4. The relation between EDCA and AIFS

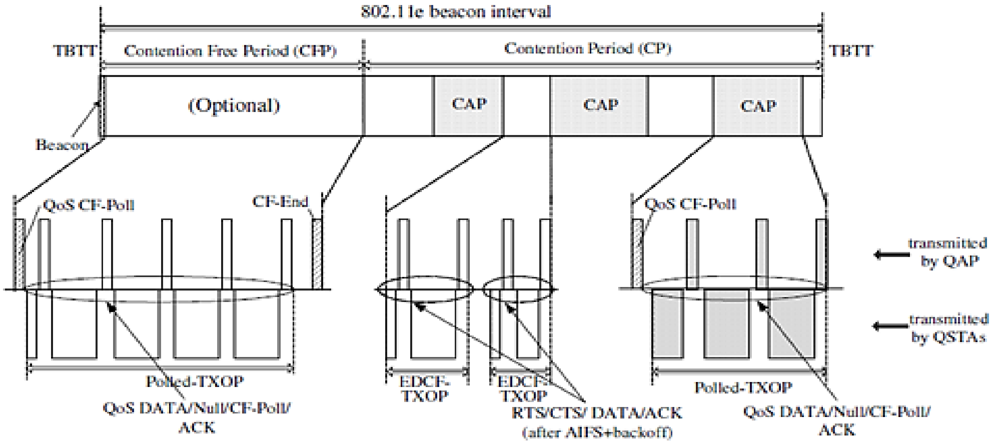

Figure 5. IEEE 802.11e HCF Beacon Interval

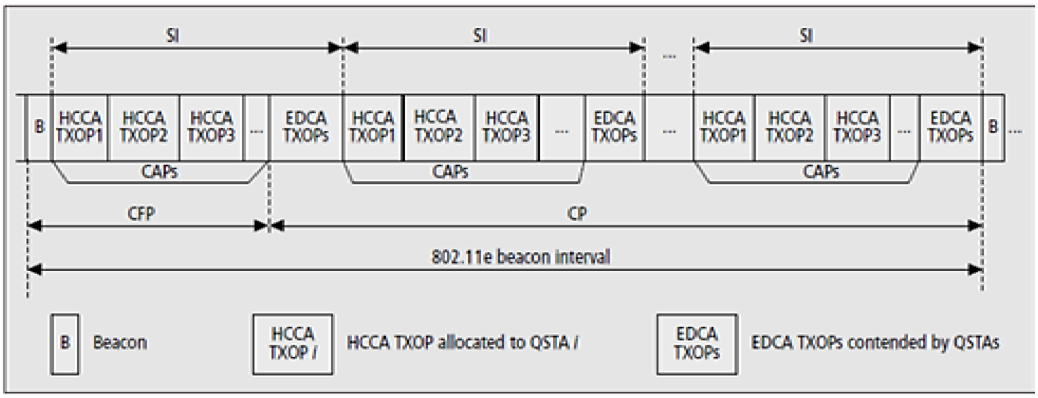

Figure 6. Bacon Interval

The CP in the HCCA can be operated by the controlled access phases (CAPs) known as the CP intervals (Figure 6). Firstly, the TS in the HCCA are created before transmitting any data frames, since each QSTA cannot have more than eight TSs with different priorities. Then, the QoS request frame consisted of the traffic specification (TSPEC) is sent to the QAP by the QSTA to begin the TS connection. Moreover, the TSPEC has some important parameters as following [22].

6) The mean data rate (P)

It is the average bit rate of the transmission packet in bits per second (bit/sec).

7) The delay bound (D)

It is the max delay time included the queue delay in the millisecond to transmit the packet transversely the wireless interface.

8) The maximum service interval (SImax)

It is the max time in microsecond for the neighbor TXOPs to distribute the same STA.

9) The nominal MAC Service Data Unit (MSDU) size (L)

It is the nominal packet size in octets.

10) The minimum PHY rate (R)

It is the min physical bit rate to evaluate the transmission time.

C. Related Work

There are several researches proposed to provide QoS for the integration WiMAX/Wi-Fi modules. For example, In [31], Zhang et al. (2010) proposed a QoS framework for the IEEE 802.16 and IEEE 802.11e networks applications in order to map the QoS requirements of the IEEE 802.11e applications into the IEEE 802.16 network. However, the QoS requirements, such as the scheduling, admission control and bandwidth manager have to be satisfied.

In [23], Pontes et al. (2008) proposed a call admission control (CAC) scheme in order to control the WiMAX cell bandwidth between the Wi-Fi networks and the subscribers station (SS) by the service providers.

In [32], Zhao et al. (2011) proposed the game theory based approach to model the WiMAX/Wi-Fi integrated in the point-to-multipoint (PMP) mode and the mesh mode.

However, literature shows that mostly of the existing researches may not have a strategy to map the QoS between WiMAX and WiFi networking. Therefore, this paper aims to propose new integration WiMAX/Wi-Fi architecture to improve the QoS. In this proposed architecture, we will design a strategy to map the QoS between WiMAX and WiFi networking.

III. PROPOSED SCHEME

A. Integration WiMAX/Wi-Fi System

Figure 7 shows the integration WiMAX/Wi-Fi network architecture. There is one WiMAX BS serves one or more SSs and APs inside its coverage area. In this architecture, the WiMAX network provides BWA to one or more APs in PMP mode. The APs are used to connect each Wi-Fi network to the BS. The WiMAX network may provide a backhaul service in order to connect one or more Wi-Fi hotspots to the Internet because the connection between the AP and BS is shared by all nodes in the same WLAN served by that AP.

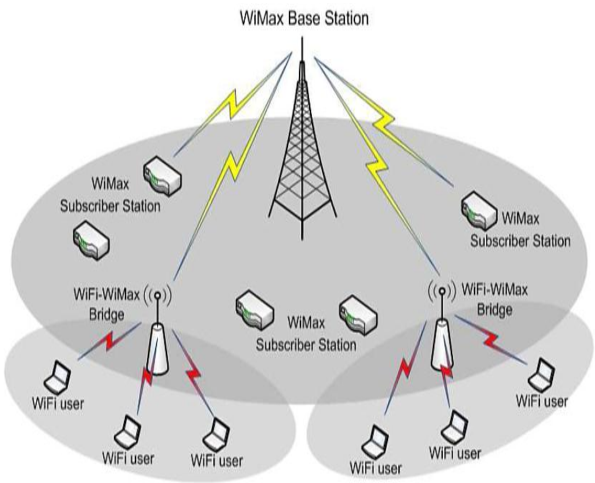

Figure 7. Integration WiMAX/Wi-Fi Network Architecture

B. QoS Mapping Scheme

As described in section 2 that WiMAX and Wi-Fi have different access methods and they support different QoS service classes. As a result, a strategy to map QoS between WiMAX and Wi-Fi is required for the BSs and SSs. We have to assign each service classes of WiMAX to each AC or QoS class of Wi-Fi. We only use CBR application for different service classes with different precedence values. Table IV shows QoS mapping between WiMAX and Wi-Fi service classes and the precedence values for each service classes.

TABLE IV. QOS MAPPING BETWEEN WIMAX AND WI-FI SERVICE CLASSES

IEEE 802.11e	IEEE 802.116	Application	Precedence
AC_VO	UGS	VOIP	7
AC_VI	rtPS	MPGE 4	3
AC_BE	nrtPS	FTP	1
AC_BK	BE	Email	0

IV. SIMULATION MODULE & RESULTS

The overall goal of this simulation study is to analysis the performance of different network types. First, we study the performance of the separate WiMAX and Wi-Fi networks when WiMAX SSs only send data to WiMAX BS and Wi-Fi STAs only send data to AP. Second, we study our integration WiMAX/Wi-Fi module when the WiMAX SSs send or receive data to or from Wi-Fi STAs. QualNet version 5.0.2 is used to perform this simulation [24].

A. Simulation Parameters

We simulate 2 channels one for WiMAX and one for Wi-Fi with a number of SSs 8, 16, 24 and 32 respectively. The important parameters using to configure the PHY and MAC layers for WiMAX and Wi-Fi interfaces summarizes in table V and VI respectively. There are eight queues configured to avoid queuing packets from different service types into one queue.

TABLE V. PHY & MAC LAYER PARAMETERS OF IEEE 802.16

System Parameter	Value
Channel Frequency	2.5 GHz
Transmission Power	20 dBm
Channel Bandwidth	20 MHz
FFT Size	2048
Cyclic Prefix Factor	8
ARQ & H-ARQ	Disabled
Path Loss Model	Two-Ray

TABLE VI. PHY & MAC LAYER PARAMETERS OF IEEE 802.11E

System Parameter	Value
Channel Frequency	2.4 GHz
Data Rate	2 Mbps
PHY Layer Type	802.11 b
Path Loss Model	Two-Ray

B. Simulation Results

We evaluate the performance of different network types. First, we study the performance of the separate WiMAX and Wi-Fi networks when WiMAX SSs only send data to WiMAX BS and Wi-Fi STAs only send data to AP. Second, we study our integration WiMAX/Wi-Fi module when the WiMAX SSs send or receive data to or from Wi-Fi STAs. This paper focuses in the most important factors for QoS: (1) average Jitter; (2) average end-to-end delay; and (3) throughput.

1) Separate WiMAX and Wi-Fi

a) Average Jitter

Figure 8 shows that when the number of SSs or STAs in WiMAX or Wi-Fi networks increases, the average jitter is increased. Wi-Fi network may have higher average jitter than WiMAX network since Wi-Fi network has smaller channel frequency than WiMAX network.

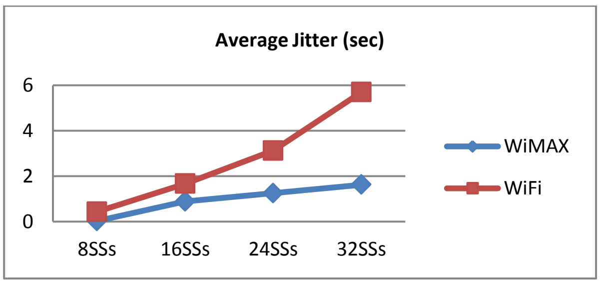

Figure 8. Average Jitter for WiMAX and Wi-Fi networks

b) Average End-to-End Delay

Figure 9 shows that when the number of SSs or STAs in WiMAX or Wi-Fi networks increases, the average end-to-end delay is increased. Wi-Fi network may have higher average end-to-end delay than WiMAX network since Wi-Fi network has smaller channel frequency than WiMAX network.

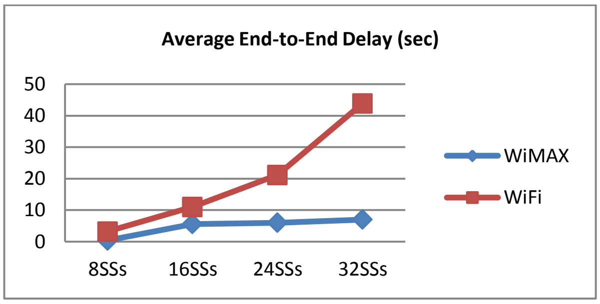

Figure 9. Average end-to-end Delay for WiMAX and Wi-Fi networks

c) Throughput

Figure 10 shows that when the number of STAs in Wi-Fi network increases, the throughput is increased. Wi-Fi network may have higher throughput than WiMAX network.

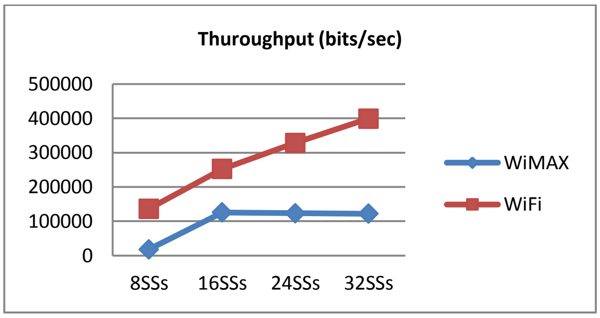

Figure 10. Throughput for WiMAX and Wi-Fi networks

2) Integration WiMAX/Wi-Fi

a) Average Jitter

Figure 11 shows that when the number of SSs or STAs in our integration WiMAX/Wi-Fi network increases, the average jitter is increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher average jitter than sending data from Wi-Fi STAs to WiMAX SSs.

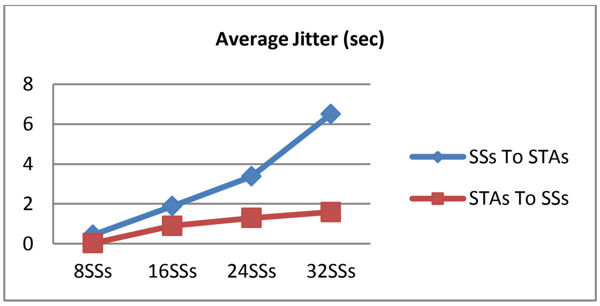

Figure 11. Average Jitter for Integration WiMAX/Wi-Fi networks

b) Average End-to-End Delay

Figure 12 shows that when the number of SSs or STAs in our integration WiMAX/Wi-Fi network increases, the average end-to-end delay is increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher average end-to-end than sending data from Wi-Fi STAs to WiMAX SSs.

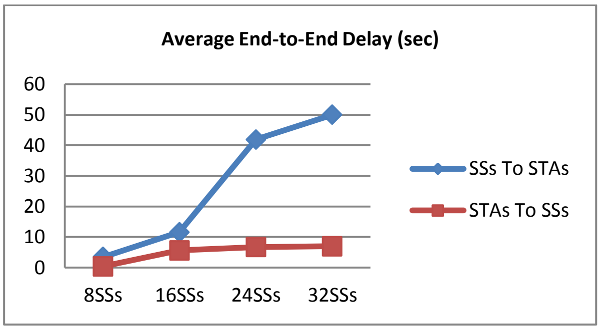

Figure 12. Average end-to-end Delay for Integration WiMAX/Wi-Fi networks

c) Throughput

Figure 13 shows that when the number of Wi-Fi STAs sending data to WiMAX SSs in our integration WiMAX/Wi-Fi network increases, the throughput is increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher throughput than sending data from Wi-Fi STAs to WiMAX SSs.

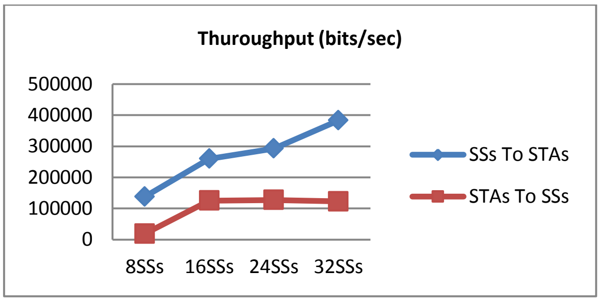

Figure 13. Throughput for Integration WiMAX/Wi-Fi networks

V. CONCLUSION

There are several challenging issues to design a network when the integrated WiMAX/Wi-Fi networks are constructed. Literature shows that mostly of the existing researches may not have a strategy to map the QoS between WiMAX and WiFi networking. Therefore, this paper proposes new integration WiMAX/Wi-Fi architecture to improve the QoS. It designs a new strategy to map the QoS between WiMAX and WiFi networking. We have to assign each service classes of WiMAX to each AC or QoS class of Wi-Fi. We only use CBR application for different service classes with different precedence values.

We study our integration WiMAX/Wi-Fi module when the WiMAX SSs send or receive data to or from Wi-Fi STAs. QualNet version 5.0.2 is used to perform this simulation. The simulation results indicate that when the number of SSs or STAs in our integration WiMAX/Wi-Fi network increases, the average jitter, the average end-to-end delay and the throughput are increased. Sending data from WiMAX SSs to Wi-Fi STAs may have higher average jitter, average end-to-end delay and throughput than sending data from Wi-Fi STAs to WiMAX SSs.

REFERENCES

[1] Ali Mohammed Aqlan, (2014). "Modeling and Verification of 802.16 MAC Protocol using Higher-Order Petri Nets", IJCNIS, vol.6, no.4, pp.21-28,

[2] Alotaibi, Y. (2015). A new multi-path Forward Error Correction (FEC) control scheme with path interleaving for video streaming. In Industrial Electronics and Applications (ICIEA), 2015 IEEE 10th Conference on (pp. 1655-1660). IEEE.

[3] Alotaibi, Y. (2015). A performance analysis of different coding and modulation schemes in WiMAX. In Industrial Electronics and Applications (ICIEA), 2015 IEEE 10th Conference on (pp. 1645-1649). IEEE.

[4] Alotaibi, Y. (2015). "A Performance Analysis of Different Scheduling Schemes in WiMAX". World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering Vol:9, No:3, pp 716-720.

[5] C. Cicconetti, A. Erta, L. Lenzini and E. Mingozzi, Performance evaluation of the IEEE 802.16 MAC for QoS support, IEEE Transactions on Mobile Computing, 6 (2007), pp. 26-38.

[6] C. So-In, R. Jain, and A.-K. Tamimi, (2009). "Scheduling in IEEE802.16e mobile WiMAX networks: key issues and a survey, "IEEE Journal on Selected Areas in Communications, 27 (2), 156–171.

[7] Cecília A.C. César, Author Vitae, and Solon V. CarvalhoAuthor Vitae. (2014). " An analytical framework for distributed coordinated scheduling in IEEE 802.16 wireless mesh networks" . Ad Hoc Networks. VOl. 13, Part A, 181‑190.

[8] Dar, K., Bakhouya, M., Gaber, J., Wack, M., & Lorenz, P. (2010). Wireless communication technologies for ITS applications [topics in automotive networking]. Communications Magazine, IEEE, 48(5), 156-162.

[9] Dehbi, Y., Benaboud, H., & Mikou, N. (2013). A geometric distribution for backoff time in IEEE 802.11 DCF: an analytical study. International Journal of Communication Networks and Information Security, 5(3), pp. 192-200.

[10] Fakhar Uddin Ahmed, Shikhar Kumar Sarma, (2014). "Enhancing QoS Through Dynamic and Fare AP Selection in a Wireless LAN", IJCNIS, vol.6, no.2, pp.23-29,

[11] Gao, D., Cai, J., & Ngan, K. N. (2005). Admission control in IEEE 802.11 e wireless LANs. Network, IEEE, 19(4), 6-13.

[12] Harpreet Kaur, Manoj Kumar, Ajay K. Sharma, Harjit P. Singh,(2016). "Implementation of SRRC Filter in Mobile WiMax with DWT Based OFDM System", International Journal of Computer Network and Information Security(IJCNIS), Vol.8, No.4, pp.62-69.

[13] Hui, J., & Devetsikiotis, M. (2005). A unified model for the performance analysis of IEEE 802.11 e EDCA. Communications, IEEE Transactions on, 53(9), 1498-1510.

[14] IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1, IEEE Std 802.16e-2005 and IEEE Std 802.16-2004/Cor 1-2005 (Amendment and Corrigendum to IEEE Std 802.16-2004) (2006), pp. 0_1-822.

[15] IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems, IEEE Std 802.16-2004 (Revision of IEEE Std 802.16-2001) (2004), pp. 0_1-857.

[16] J. Lu and M. Ma, (2010). "A cross-layer elastic CAC and holistic opportunistic scheduling for QoS support in WiMAX," Computer Networks, 54 (7). 1155 – 1168.

[17] Kuo-Feng Huang, Shih-Jung Wu, (2013). Real-time-service-based Distributed Scheduling Scheme for IEEE 802.16j Networks. Journal of Networks, 8 (3), 513-517.

[18] Liu, C.Y., Fu, B., Huang, H.J. (2014). Delay minimization and priority scheduling in wireless mesh networks. Wireless Networks pp. 1–11.

[19] Mangold, S., Choi, S., Hiertz, G. R., Klein, O., & Walke, B. (2003). Analysis of IEEE 802.11 e for QoS support in wireless LANs. Wireless Communications, IEEE, 10(6), 40-50.

[20] Naeini, V.S. (2014). Performance analysis of WiMAX–based wireless mesh networks using an M/D/1 queuing model. Int. J. Wirel. Mobile Comp. 7(1), 35–47.

[21] Nandiraju, N., Nandiraju, D., Santhanam, L., He, B., Wang, J., & Agrawal, D. P. (2007). Wireless mesh networks: current challenges and future directions of web-in-the-sky. Wireless Communications, IEEE, 14(4), 79-89.

[22] Ni, Q. (2005). Performance analysis and enhancements for IEEE 802.11 e wireless networks. Network, IEEE, 19(4), 21-27.

[23] Pontes, A. B., Silva, D. D. P., Jailton Jr, J., Rodrigues Jr, O., & Dias, K. L. (2008). Handover management in integrated WLAN and mobile WiMAX networks. Wireless Communications, IEEE, 15(5), 86-95.

[24] QualNet Simulator Home. [cited 2015 02/02]; Available from: http://www.scalable-networks.com/.

[25] Şekercioğlu, Y. A., Ivanovich, M., & Yeğin, A. (2009). A survey of MAC based QoS implementations for WiMAX networks. Computer Networks, 53(14), 2517-2536.

[26] Stephen Atambire Nsoh and Robert Benkoczi, (2013). "Routing and Link Scheduling with QoS in IEEE 802.16 Mesh Networks", IEEEWireless Communicationsand Networking Conference, (WCNC) NETWORKS, 233-238.

[27] Mostafavi Mohammad. (2016). A Novel Burst Mapping Algorithm for WiMAX with DL-MAP Reduction Approach. International Journal of Science and Engineering Investigations, 5(55), 115-122.

[28] Touil, H., & Fakhri, Y. (2014). A fuzzy-based QoS Maximization protocol for WiFi Multimedia (IEEE 802.11 e) Ad hoc Networks. International Journal of Communication Networks and Information Security, 6(3), pp. 217-225.

[29] Vergados, D. J., Vergados, D. D., & Douligeris, C. (2009). DPS: An architecture for VBR scheduling in IEEE 802.11 e HCCA networks with multiple access points. Mobile Networks and Applications, 14(6), 744-759.

[30] Yazdani, M., Kamali, M., Moghim, N., & Ghazvini, M. (2016). A fair access mechanism based on TXOP in IEEE 802.11 e wireless networks. International Journal of Communication Networks and Information Security, 8(1), pp. 11-17.

[31] Zhang, Y., Ansari, N., & Tsunoda, H. (2010). Wireless telemedicine services over integrated IEEE 802.11/WLAN and IEEE 802.16/WiMAX networks. Wireless Communications, IEEE, 17(1), 30-36.

[32] Zhao, L., Cong, L., Liu, F., Yang, K., & Zhang, H. (2011). Joint time-frequency-power resource allocation for low-medium-altitude platforms-based WiMAX networks. IET communications, 5(7), 967-974.

[33] Zhu, R., Qin, Y., & Lai, C. F. (2011). Adaptive packet scheduling scheme to support real-time traffic in WLAN mesh networks. KSII Transactions on Internet and Information Systems (TIIS), 5(9), 1492-1512.

[34] Zhu, R., W. Shu, T. Mao, and T. Deng, (2013). "Enhanced MAC protocol to support multimedia traffic in cognitive wireless mesh networks," Multi. Tool. App. 67 (1), pp 269-288.

Youseef Alotaibi is an Assistant Professor in the Department of Computer Science at Umm Al-Qura University, Saudi Arabia. He completed his PhD from the Department of Computer Science and Computer Engineering, La Trobe University in, Melbourne – Australia in 2014. He received his Master in Information Technology (Computer Network) from La Trobe University. His research interests include business process modelling, business process reengineering, information system, security, business and IT alignment, software engineering, QoS and WiMAX.