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Performance Analysis of Triple Play Services over WiMax Access Broadband Technology

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Abstract- **The main objectives of this paper is to examine the performance of the wireless broadband infrastructures and their support for Triple Play services under different separated scenarios by using OPNET Modeler 14.5. This simulation network uses several features to study the performances of WiMax on Triple Play services, 3.5GHz band is chosen in our studies because it is widely used band all over the world. Moreover, this band is licensed, so that interfere is under control and allows using higher transmission power. The best bandwidth for a carrier frequency of 3.5GHz is needed to be tested. The pathloss for urban, suburban and rural is calculated, while multipath with pathloss is calculated for ITU channel model of pedestrian in different environments. WiMax does not offer a compelling reason to switch from other forms of residential broadband. When bundled with broadband internet access and VoD, a WiMax Triple Play becomes very attractive to residential subscribers. Given the QoS and reliability mechanisms built into WiMax in this simulation scenario, subscribers will find WiMax good.**

Keywords— WiMAX, Triple Play Service (IPTV, VoIP and Data), QoS with DiffServ architecture, simulation model design.

I. INTRODUCTION

Wired platform networks use the high capacity of fiber-optic-rich physical networks and the general-purpose capability of IP-based protocols to support a Triple Play of voice, video, and data services. To make things even more complicated, it is not always possible to provide customers with a wired internet access network like DSL or Cable Television (CATV). This is often the case in sparsely populated areas, where it would be too expensive to set up wires. For Triple Play services, wireless access network technology must be used in future. In the wireless domain, albeit with a lag, there is a similar trend towards increased capacity and towards providing a range of services over a common IP-centric network infrastructure. Recent wireless broadband networks such as 3G LTE and WiMax provide a general-purpose IP platform with over-the-top services at the application layer, which is similar to the design of wired IP platform networks. So, in this paper, WiMax technology is used which has become the easiest way for wireless communication and a solution to rapid requirement of internet connection for data, voice and video service. In 2007, more than one hundred WiMax carrier trials were planned worldwide. Furthermore, the WiMax forum in March 2008 issued a press release projecting 133 million subscribers by 2012. In February 2009, the WiMax Forum is reporting just under 460 WiMax fixed and mobile deployments worldwide along with over 800 million subscribers projected by 2010. Intel which has projected over 1.3 billion people will have access to WiMax by 2012 [1].

II. WIMAX BROADBAND ACCESS

The WiMax technology, based on IEEE 802.16–2004 standard [2], defines a fixed broadband wireless metropolitan area network. Mobile WiMax, based on IEEE 802.16e-2005 [3], adds functions and features to the original standard to support mobility. The most current IEEE 802.16–2009 standard [4] is a revision of IEEE 802.16–2004. Compared to Mobile WiMax, 3G data services provide a relatively low bandwidth and high price while Wi-Fi suffers from limited transmission ranges and from security issues. All of the above lead WiMax to be a multipurpose network, which can be used for wireless backhauling for Wi-Fi hotspots, fixed/nomadic access to network subscribers etc., as seen in Fig. 1.

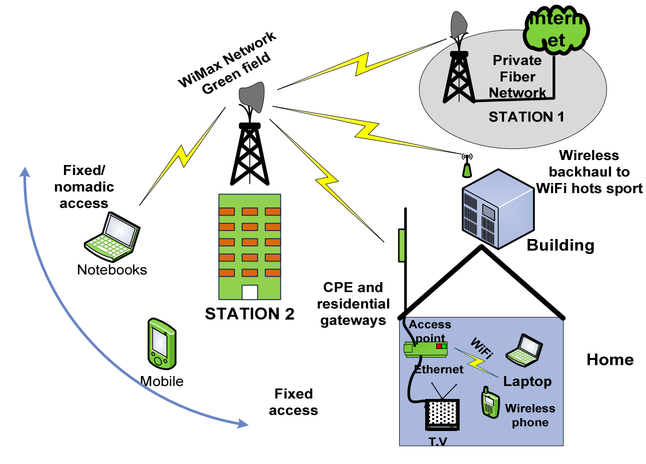


Fig. 1: WiMax can support various services depending on customer requirements

WiMax is a part of the evolution from voice-only wireless communications systems to ones that provide additional services like web browsing, streaming media, gaming, instant messaging, and other content. Being able to deliver a wide variety of services also requires a delivery system that is flexible and can efficiently allocate system resources. The 802.16 standard offers adjustable data rate to and from each user while maintaining the required QoS. Certain applications require higher error resilience and latency requirements that directly factor into the QoS [5]. However, WiMax is a serious contender for delivery of Triple Play services. With advanced antenna techniques, it offers data rates up to 70 Mbps and ranges up to 50 km, ensures secure delivery of content, and supports mobile users at vehicular speeds of up to approximately 100 km/hr. Fig. 12 shows the system model of a WiMax deployment for Triple Play services over an all IP backbone network. Triple Play content can either be classified at the IP layer and enter the WiMax system as Ethernet payload or each of the three types of content be individually provided for further classification and optimization, e.g., through Access Service Network (ASN) gateway as shown on the left part of Fig. 2 [6].

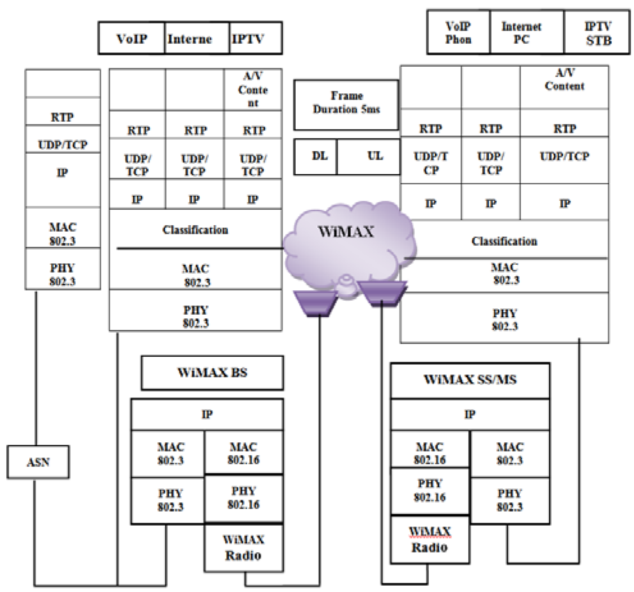


Fig. 2: Triple Play Services over WiMax - System Model [6]

III. TRIPLE PLAY SERVICES

The term "Triple-Play service" covers a large collection of voice, video and data services, including: Video telephony, IPTV (which is multicast video (T.V) channel), Video on Demand ((VoD) which is unicast video), Voice over IP (VoIP), Gaming, Internet access (HTTP, FTP traffic), E-mail, etc... In the following subtopics gives a description for each service of the Triple Play services, but our attention will be in focus on delivering the TV service. As a result, will focus our analysis in IPTV; believes that effectively transmitted video is the greatest challenge. Later, a brief review of the two other services, i.e. VoIP and data will be discussed.

- IPTV and VoD services need high bandwidth. Depending on the compression and coding technology the following transmission rates should be considered [7]:
  - A MPEG-2 coded SD VoD video stream or IPTV stream is 3.5 to 5 Mbit/s per TV channel,
  - A MPEG-4 coded SD VoD video stream or IPTV stream is up to 2 Mbit/s per TV channel,
  - A HD TV channel uses 8 to 12 Mbit/s when coded with H.264.

  Consequently the MPEG-2 video content was abandoned and the simulation focused on the MPEG-4 video content. To simulate VoD service, the video traces (2-hour MPEG-4 Matrix III movie trace) provided by Arizona State University is used, as shown in table 1 [8]. To import video to OPNET, the instructions of [9] is used.

Table 1: VoD application characteristics

Parameters	Matrix III
Resolution	**352x288**
Codec	MPEG-4 Part 2
Frame Compression Ratio	47.682
Minimum Frame Size (bytes)	8
Maximum Frame Size (bytes)	36450
Mean Frame Size (Bytes)	3189.068
Display Pattern	IBBPBBPBBPBB
Transmission Pattern	IPBBPBBPBBIB
Group of Picture Size	12
Frame Rate (frames/sec)	**25**
Number of Frames	180,000
Peak Rate (Mbps)	7.290
Mean Rate (Mbps)	**0.637**
DSCP	**AF33**

- VoIP is a technology that allows users to make telephone calls over an IP data network (Internet or Intranet) instead of traditional PSTN (Public Switched Telephone Network). Therefore; VoIP provides a solution that merges both data and voice which gains benefits include cost savings, high quality and value added services. There are many different audio codec's available for voice applications. The simplest and most widely used codecs are G.711, G.723 and G.729. The simplest encoder scheme is G.711 (64 kb/s). The acceptable packet loss factor of G.711 is up to 0.928% [10]. So, the encoder scheme G.711 (64 kb/s) is used for VoIP service in the simulation scenario. Voice service is simulated by setting up a VoIP application characteristic shown in table 2 between residential users and an Ethernet server located in the IP backbone subnet.

Table 2: Residential VoIP application characteristics

Encoder Scheme	**Voice Frame Per Packet**	**DSCP**	**Compression Delay(s)**	**Decompression Delay(s)**
G.711	1	EF	0.01	0.01

- Data services refer to activities familiar to all of us like web browsing, file downloading, e-mail, electronic purchases, electronic games and other applications using high-speed Internet. Web browsing application is defined with different characteristics in table 3 for residential users then In order to simulate users downloading and sharing files, an FTP application is setup with the characteristics in table 4.

Table 3: Residential HTTP application characteristics

Http Specification	Object Size(Kbytes)	Number of Object (Object Per Page)	DSCP
Http 1.1	Constant(1) Media Image (0.5-2) Large Image (2-10)	1 40 5	BE

Table 4: Residential FTP application characteristics

Download	Size File (MB)	DSCP
100%	5	AF13

IV. WIMAX CONFIGURATIONS AND SCENARIO DESIGNS

A. Network Topology

The network topology has the network architectures shown in fig. 3. First the "Backbone" subnet, see fig. 4, data, voice server and VoD sources are defined. DSR router is used in unicast mode for delivery unicast traffic (VoIP, Internet & VoD) to the BRAS at the aggregation subnet. The "BRAS" is a Broadband Remote Access Server router that forwards packets between the core and customer. It is a complex router that implements dynamic per-subscriber IP policies, QoS profiles, rate limiters, packet manipulation, address assignment, session termination, and forwarding.

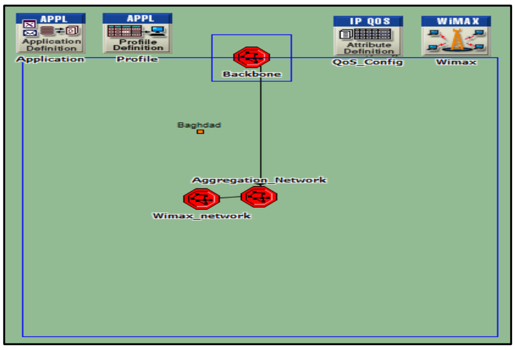


Fig. 3: Triple Play over WiMax network topology

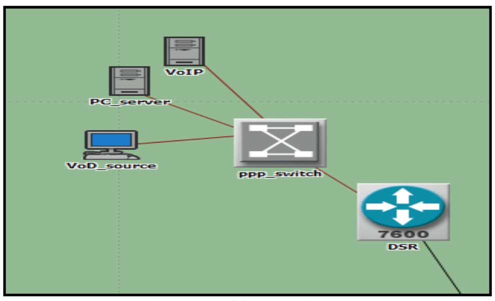


Fig.4: Backbone Subnet.

Second the "Aggregation" subnet, that received all traffic from backbone subnet by using PPP_SONET_OC24 with data rate (1244.16 Mpbs) then delivering it to BRAS router which receives traffic by using the same link, then delivering it to the Center_Office which connected to the Base station BS access network via a 45 Mbps Digital Signal 3 (DS3) WAN link at a customer side, see fig. 5.

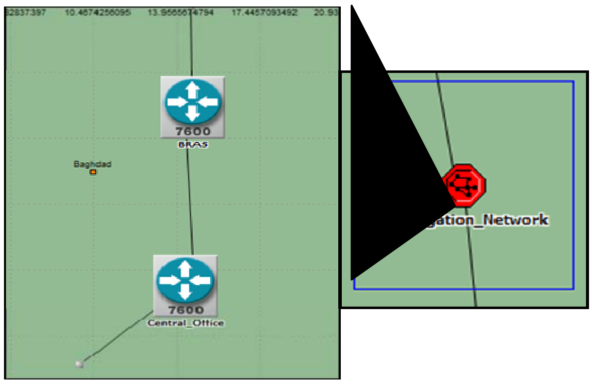


Fig. 5: Aggregation subnet.

Lastly WiMax_ network subnet, consists of these subnet are changed from scenario to another according to what is needed to be examined, and their BS and SS will be discussed accordingly later on.

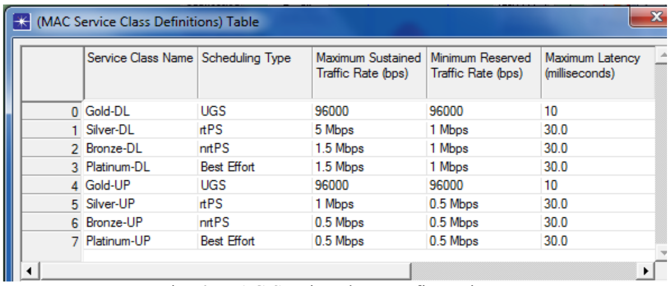
B. WiMax Global Configuration (MAC and PHY Characterization)

In this section, the MAC and PHY system parameters are designed to reflect a practical WiMax deployment that maximizes video, voice and data content traffic. Table 5 lists the values assigned to main parameters of the simulation experiment, regarding the WiMax profile.

Table 5: WiMAX Profile for this Study

Parameters	Value
Carrier Frequency	3.5GHz
Bandwidth used	5MHz, 10MHz, 20MHz
Frame duration	5ms
DL and UL bursts modulation	QPSK , 16-QAM, 64-QAM
Coding rate	1/2, 3/4
Subchannelization	PUSC
Subcarriers	512, 1024, 2048
Duplexing scheme	TDD
BS transmit power	20W
SS transmit power	0.5W
BS antenna gain	15 dBi
SS antenna gain	14 dBi

When purposes of this study for created 4 service classes for the downlink and uplink, such a creation is achieved using Gold, Silver, Bronze and Platinum. When configured with ertPS, nrtPS, rtPS, BE scheduling for the voices, video and data services. Fig. 6 shows the WiMax MAC service class configuration used for this simulation model.



(MAC Service Class Definitions) Table

	Service Class Name	Scheduling Type	Maximum Sustained Traffic Rate (bps)	Minimum Reserved Traffic Rate (bps)	Maximum Latency (milliseconds)
0	Gold-DL	UGS	96000	96000	10
1	Silver-DL	rtPS	5 Mbps	1 Mbps	30.0
2	Bronze-DL	nrtPS	1.5 Mbps	1 Mbps	30.0
3	Platinum-DL	Best Effort	1.5 Mbps	1 Mbps	30.0
4	Gold-UP	UGS	96000	96000	10
5	Silver-UP	rtPS	1 Mbps	0.5 Mbps	30.0
6	Bronze-UP	nrtPS	0.5 Mbps	0.5 Mbps	30.0
7	Platinum-UP	Best Effort	0.5 Mbps	0.5 Mbps	30.0

Fig. 6: MAC Service class configuration

C. QoS Management in WiMax

In this paper, setting QoS parameter by using the IP header field for Differentiated Services Code Point (DSCP) with the appropriate traffic class and setting queue priorities with Weight for WFQ with Low Latency Queue (LLQ) profile. The DiffServ architecture will be chosen because it is preferred over "Hard QoS" architecture. Moreover it applies perfectly to Triple Play, as it satisfies differing QoS requirements [11].

Specifically, in all scenarios considered along this network, a WiMax segment is included inside an IP network using the DiffServ protocol for QoS management. For a proper QoS transfer between the DiffServ and WiMax domains, it is necessary to map the traffic classes defined by DiffServ over the appropriate MAC 802.16 scheduling service. There are four scheduler types: ertPS (extended real time polling service), rtPS (real time polling service), nrtPS (non-real time polling service), and BE (best effort). The available bandwidth resources are allocated to ertPS first, then to rtPS and nrtPS flows. Lastly, any remaining resources are then assigned to BE flows. Based on the different features of the traffic classes, the traffic mapping proposed is depicted in Table 7. However, it is necessary to mention that this classification could be adapted to the specific requirements of different scenarios, traffic profiles, and applications.

Traffic	Example Application	DiffServ PHB	WiMax Service
Real time, highly intolerant to delay and jitter. Fixed packet size and rate.	VoIP	EF	UGS , ertPS
Real time, highly intolerant to delay and jitter. Variable packet size and rate.	Videoconfere nce	EF	UGS
No real time restrictions, high bandwidth, medium tolerance to delay, highly tolerant to jitter.	Video-On-demand (HD,SD)	AF43	rtPS
No real time restrictions, medium bandwidth, medium tolerance to delay, highly tolerant to jitter.	Video Streaming	AF33	rtPS
No real time restrictions, high tolerance to both losses and delay.	FTP	AF31	nrtPS
No real time restrictions, small bandwidth, medium tolerance to delay, highly tolerance to jitter, medium tolerance to losses.	E-mail, Web browsing HTTP	BE	BE

Table 7: Basic traffic classification according to QoS requirements

In an IP transport platform, there are a number of parameters which influence service quality used in the paper to evaluate different behaviors in our simulation. In relation to the Triple Play Services, these are: packet loss, network delay, jitter, FTP download response time, and HTTP page response time. The Y.1541 QoS recommendations adopted by IPTV, voices and internet service providers which have been compiled into table 8 below.

Table 8: Performance metrics

Services	QoS Requirements
Voice	Delay < ~150 ms Jitter < ~30 ms Packet loss < ~1%
Video	Delay < ~ 400 ms Jitter < ~ 30 ms Packet loss < ~1%
Interactive FTP ,telnet, web	Zero or near-sero packet loss Delay may be important

BSs are configured to map the higher level for Triple Play application traffic to a service class by setting service class to "Gold-DL" if the type of service (DCSP) parameter matches the "EF " , "Silver-DL" if the type of service (DSCP) parameter matches the "AF43 ", "Bronze-DL" if the type of service (DSCP) parameter matches the "AF13 " , "Platinum-DL" if the type of service (DSCP) parameter matches the "BE ", all these have previously been configured into the section III. Fig. 7 shows the service class mapping configuration at base station.

Fig.7: DL service class mapping

SS is also configured to map the higher level Triple Play application to the "Gold-UL", "Silver-UL", "Bronze-UL", and "Platinum-UL" service class as similarly performed with the BS as shown in fig.7.

D. Simulation Scenarios

Simulated scenarios will be discussed individually. Types of application, the profile configuration and different parameters are configured into the network topology have been, derived and explained in the previous subsections. At these scenarios the behavior of various propagation models in WiMax network at 3.5GHz with respect to path loss, packet end-to-end delay, delay-variation (Jitter), FTP download response time and HTTP page response for Triple Play applications is studied. The specifications of model components in each scenario will be discussed below that are shown in picture of table 9. In general, each scenario consists of N SS nodes and one BS to cover the geographical represented area.

Table 9: Simulation scenarios

#	Scenario Name	Saved	Results	Sim Duration	Time Units
1	2Km_4Km_6Km with _20MHz	saved	out of date	1,000	second(s)
2	2Km_4Km_6Km with _10MHz	saved	out of date	1,000	second(s)
3	2Km_4Km_6Km with _5MHz	saved	out of date	1,000	second(s)
4	Pathloss Wimax at 2Km	saved	out of date	1,000	second(s)
5	Pathloss Wimax at 4Km	saved	out of date	1,000	second(s)
6	Pathloss Wimax at 6Km	saved	out of date	1,000	second(s)
7	Pathloss and Multipath Wimax at 2Km	saved	out of date	1,000	second(s)
8	Pathloss and Multipath Wimax at 4Km	saved	out of date	1,000	second(s)
9	Pathloss and Multipath Wimax at 6Km	saved	up to date	1,000	second(s)

The main settings and parameters of these scenarios are:

1. Simulation Time: Simulation time was set to (1000 sec).
2. Efficiency Mode: Physical layer enable.
3. Bandwidth was ranging from 5 MHz to 20 MHz (scenario dependent).

Scenarios # 1, 2, 3: Fig. 8 shows the arrangement of objects in these scenarios; these scenarios that contain one BS serving with three SS's are located at 2, 4, and 6 km from the WiMax base station since the objective of these scenarios is to examine the effect of the different channel bandwidth for base frequency 3.5GHz with different distance environments that incorporate the modulation and coding parameter.

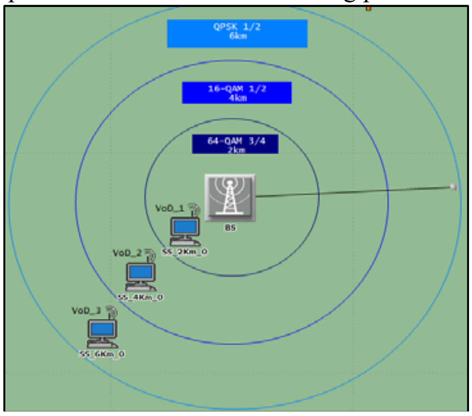


Fig. 8: The arrangement of objects in Scenario # 1, 2, 3

Scenarios # 4, 5, 6: The objective of these scenarios is to present experimental results of radio pathloss and distance for different environments. The scenarios model component shown in fig. 9 contains one operational BS sites and five subscribers. The one SS can be placed inside a building (Outdoor to Indoor and Pedestrian), the second SS standing in free space, the third SS standing in suburban (Terrain Type A) corresponding to hilly terrain with moderate-to heavy tree densities, the fourth SS standing in suburban (Terrain Type C) corresponds to mostly flat terrain with light tree densities and the fifth SS standing in suburban (Terrain Type B) corresponds to a compromise between the terrains A and C .

As shown in Table 10, there are some parameters changed from one scenario to another such as position of SS's to show how the pathloss increases with distance from the BS. Shadow fading standard deviation is used and it represents the default value of OPNET for each environment

Table 10: SS's parameters

User name	Pathloss Model	Terrain Type	Shadow fading Standard deviation (dB)	Position
SS_Free_Space	Free space	-	Disable	2Km,4Km,6Km
SS_Erceg_A	Suburban Fixed (Erceg)	A	10.6	2Km,4Km,6Km
SS_Erceg_B	Suburban Fixed (Erceg)	B	9.6	2Km,4Km,6Km
SS_Erceg_C	Suburban Fixed (Erceg)	C	8.2	2Km,4Km,6Km
SS_Pedstrain	Outdoor to indoor	A	10	2Km,4Km,6Km

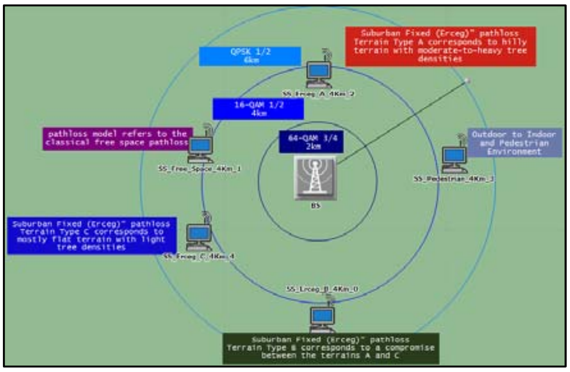


Fig. 9: The arrangement of objects in Scenario # 4, 5, 6

Scenarios # 7, 8, 9: The objective of these scenarios is to investigate the combined effect of terrain and multipath channel model (ITU Pedestrian_A) on Triple Play services, at these scenarios with 5 SSs in the range of BS as shown in fig. 10, the terrains are simulated by choosing the terrain type C in OPNET which is thereby selected by the simulator, based on the 2Km, 4Km and 6Km location and surrounding terrain of the transmitter-receiver pair.

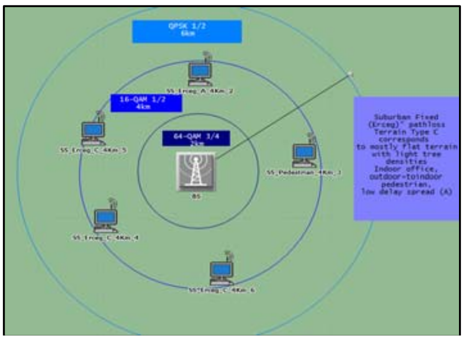


Fig. 10: The arrangement of objects in Scenario # 7, 8, 9

E. Simulation Results and Analyses

As mentioned in section IV-C, the simulation process is divided into 9 scenarios, as depicted in table 9; the computed and measured results for each scenario will be explained in the following subsections.

1. Scenarios # 1, 2, 3

In scenario #1 with 20 MHz channel bandwidth for frequency 3.5GHz, the system will be test at 6 km, 4 km and 2 km. The packet delay and delay-variation (Jitter) are the first performance metric used to quantify video services for the three WiMax stations as shown in figures 11 and 12.

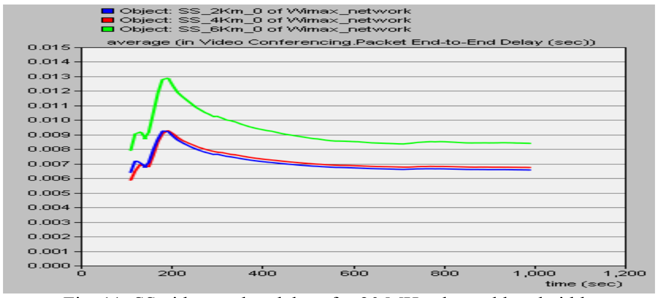


Fig. 11: SS video packet delays for 20 MHz channel bandwidth

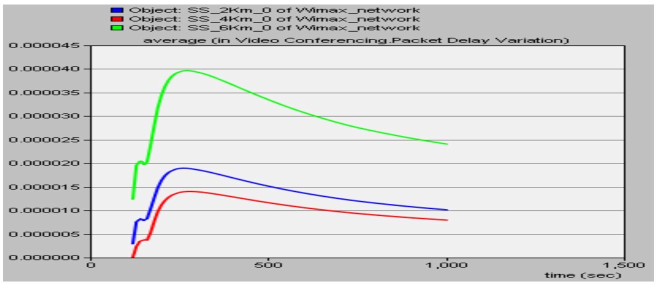


Fig. 12: SS video delay-variation for 20 MHz channel bandwidth

Packet end-to-end delay, delay-variation (Jitter), FTP downloads response time and HTTP page response time are the next performance metrics used to quantify Triple Play services content streaming over WiMax in the scenarios # 1, 2, 3. While observing these 3 scenarios have been simulated successfully, using 5ms frame duration for frequency 3.5GHz configuration without MIMO and retransmissions, a comparison is made against the 5MHz channel bandwidth and 10MHz channel bandwidth, for suggested distances. The mean traffic rate is specified corresponding to the metrics listed in table 8. The results have been collected and summarized in table 11, the red highlighted row indicates the poorest performing scenario for a given channel bandwidth while the orange highlighted row indicates the required specification correspond to the required standard of performing scenario for a given channel bandwidth. The yellow and green highlighted rows indicate the next case of the system performing scenarios for a given channel bandwidth.

Table 11: Relations between different channels and distances for frequency 3.5GHz

frequency (MHz)	coding and modulation	distance (Km)	channel bandwidth (MHz)	Services					
				VIDEO (msec)		VOICE (msec)		FTP (sec)	HTTP (sec)
				packet delay	Jitter	packet delay	Jitter	downloads response time	page response time
3500	64-QAM 3/4	2	5	872.984	58.5343	62.8553	3.27E-02	81.8385	15.2234
			10	278.472	11.6143	46.6126	1.81E-04	82.7951	17.6493
			20	35.1503	3.51E-01	4.58E+01	8.51E-06	58.1143	12.25
	16-QAM 1/2	4	5	934.588	72.3575	64.2455	2.59E-02	N/A	15.5451
			10	239.749	8.72437	46.8753	5.66E-04	57.5225	4.50959
			20	46.248	1.12E+00	4.58E+01	1.68E-04	46.1125	3.40472
	QPSK 1/2	6	5	991.453	79.5061	N/A	N/A	N/A	11.0449
			10	246.856	8.15633	51.7974	1.66E-04	N/A	5.35388
			20	59.2916	1.14E+00	45.754	9.81E-06	50.0823	4.90405

2. Scenarios # 4, 5, 6

In these scenarios, five different models for pathloss which have been proposed by the researchers at the operating frequency of 3.5GHz are analyzed. The pathloss model is measured at different distances 2Km, 4Km and 6Km. Different models for pathloss evaluations are calculated by the following equation.

- The free space pathloss equation in decibel is [12]:
  $Path\ loss\ (dB) = 20 \log (R) + 20 \log f\ (MHz) + 32.44$
  Where R (km) represents the distance between transmitter and receiver and f represents the carrier frequency in MHz
- Pathloss model for outdoor to indoor and pedestrian test environments has the following form [13]:
  $PL\ [dB] = 40 \log (R) + 30 \log (f) + X\acute{o} + 49$
  Where R (km) represents the distance between transmitter and receiver, f represents the carrier frequency in MHz and Xó is a normal distributed variable.
- The Erceg pathloss models are classified in three categories (Category A, Category C and Category B) were calculated by the following Equation [14]:
  $PL\ modified = PL + \Delta PL_f + \Delta PL_h$
  Here, PL is the pathloss given earlier, ΔPL_f is the frequency term, and ΔPL_h is the receive antenna height correction terms given as follows:
  $\Delta PL_f = 6 \log 10\ (f/2000)$
  $$\Delta PL_h = \begin{cases} -10.8 \log 10\ (h/2) & \text{for categories A and B} \\ -20 \log 10\ (h/2) & \text{for categories C} \end{cases}$$

The measured results and the calculated results are shown in table 12 represents the relation between pathloss and different distance.

Table 12: Pathloss simulation and calculate results for 3.5GHz freq. and different distance

frequency (MHz)	distance (Km)	free space		Outdoor to Indoor and Pedestrian Environment		Terrain Type A		Terrain Type B		Terrain TypeC	
		path loss (calculate)	path loss (simulation)	path loss (calculate)	path loss (simulation)	path loss (calculate)	path loss (simulation)	path loss (calculate)	path loss (simulation)	path loss (calculate)	path loss (simulation)
3500	2	109.342	109.313	177.3632	174.718	161.0772	162.003	155.8585	146.96	151.5312	128.986
	4	115.3626	115.009	189.4044	187.124	176.3695	175.843	170.0822	160.694	165.0776	140.174
	6	118.8844	118.798	196.4481	194.694	185.3149	185.987	178.4025	164.748	173.0017	146.057

3. Scenarios # 7, 8, 9

Finally, for the purposes of this study, it was important to factor pathloss and multipath channel model into the performance of our WiMax clients with Triple Play services, so at these scenarios, also a fixed suburban (Erceg) model and multipath channel model (ITU Pedestrian_A) which is indoor office, outdoor-to-indoor pedestrian, low delay spread (A) was employed with a conservative terrain model type C, which is close of the reality of terrain in Baghdad and accounted for mostly flat terrain with light tree densities. The measured results are shown in figures 13,14,15,16,17 and 18 represent packet end-to-end delay, delay-variation (Jitter), FTP download response time and HTTP page response time which are the performance metrics (Global statistics) used in the quantification of voice, internet and video services in pathloss with multipath channel model effect at a different distance.

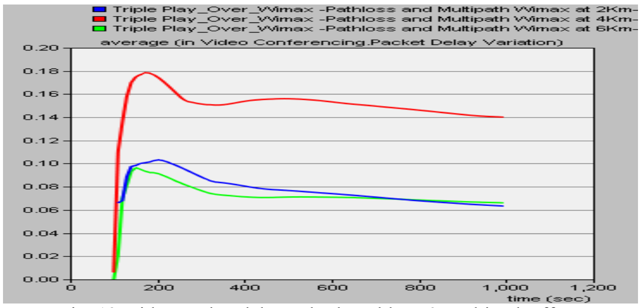


Fig. 13: video packet delay at both pathloss & multipath effect

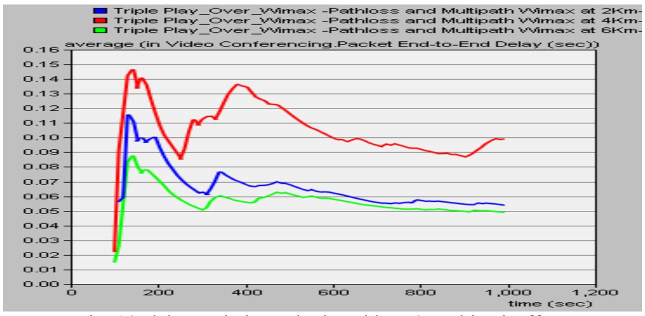


Fig. 14: delay variation at both pathloss & multipath effect

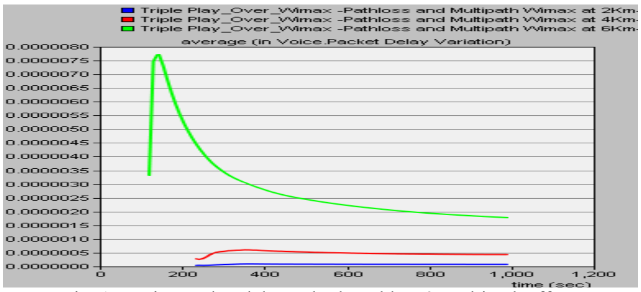


Fig. 15: voice packet delay at both pathloss& multipath effect

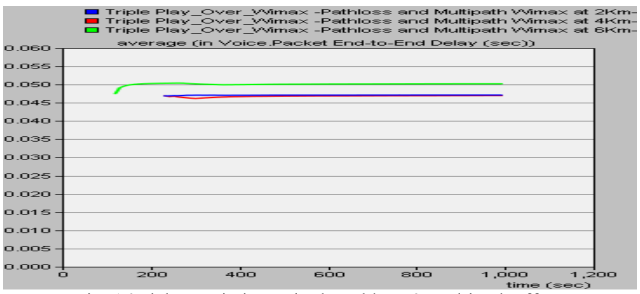


Fig. 16: delay variation at both pathloss & multipath effect

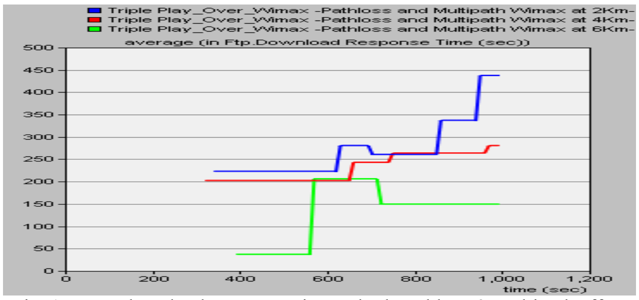


Fig. 17: FTP downloads response time at both pathloss & multipath effect

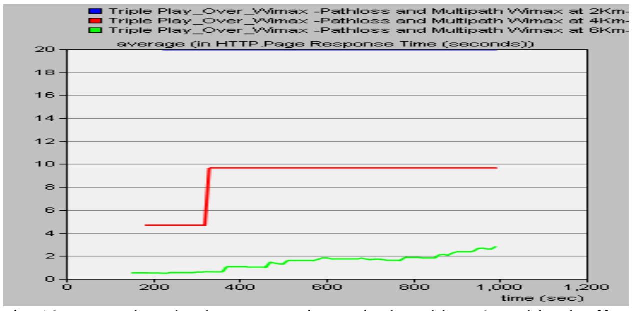


Fig. 18: HTTP downloads response time at both pathloss & multipath effect

4. **Results Analyses:** In this section what is understood from these results is that:

❖ The packet delay and delay-variation for video service of the three WiMax stations are shown in figures 11 and 12. It can be noticed from these result the 6km WiMax station (green curve) exhibits a much higher loss rate than the 4km and 2km stations over the 1000sec interval. A packet end-to-end delay, delay variation, FTP downloads response time and HTTP page response time have been studied for frequency 3.5GHz with different channel bandwidth and distances between BS and SS. It can be noticed in table 11 that the results are largest for the small channel bandwidth and also when the distance between BS and SS is increased.

❖ The pathloss is small for free space and large for the SS who is in outdoor to indoor and pedestrian environment: As for the SS in terrain type C, the pathloss will be more than that in free space and the SS in terrain type A the pathloss will be less than that in outdoor to indoor; while the SS in terrain type B, the pathloss will be between terrain types A and C. Also the pathloss is largest when the distance between BS and SS increased.

❖ It should be noted that if multipath channel modeling is enabled, the transmitted signal has been distorted due to the multipath and dispersion effects of the channel, it becomes more difficult to understand if the changes in delay, delay-various, FTP download response time and HTTP page response time are attributed to interference or to the direct path between Tx and Rx which is a function of the distances (2km, 4km and 6km). Since the multipath reflections are not easily realized also they are random in nature.

V. CONCLUSIONS

This study explored the technical details and performance of WiMax broadband access technology with triple play services. The simulation results indicated that the slope of the propagation losses is constant and in order to maintain a standard quality for delivered Triple Play services to keep the customer satisfied with that current follow ITU-T G.114 recommendation and the Y.1541 QoS recommendations for PLR, end-to end delay and jitter, the channel bandwidth for 3.5GHz frequency bands should be chosen to be between 10MHz and 20MHz. Radio pathloss and ITU multipath models in various environments was simulated where one of the main target of this work is to check the variation of the network performance due to varying pathloss and terrain models. This work shows the variation in the WiMax network performance with varying pathloss models deployed over suburban areas of terrain types varying from hilly terrain with moderate to heavy tree density to flat terrain with light tree density for Triple Play services.

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