Sudan University of Science and Technology

College of Engineering

Electronics Engineering

Performance Analysis of WLAN and WiMAX Integration

A Research Submitted In Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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October 2017

إستهلال

بسم الله الرحمن الرحيم

قال تعالى:

(وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ ۚ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ (88))

سورة هود

Dedication

We dedicate this work to our families, friends and loved ones.

Acknowledgement

We are grateful to the God for the good health and wellbeing that were necessary to complete this research.

First and foremost, we have to thank our research supervisors, Dr.Ashraf Gasim abdalla. Without his assistance and guidance and insightful suggestions and dedicated involvement in every step throughout the process, this research would have never been accomplished. We would like to thank you very much for your support.

The completion of this work could not have been possible without advice and assistant of many people whose all names can't be mention, we would like to thank you all.

Also, special thanks and deep appreciation to two friends whom helped us to accomplish this work, Hajja Zainb and rafa Alfadel .

Abstract

With wireless communication becoming an integral part of human life, the improvement of the performance of any wireless network has become a topic of keen interest of the researchers. The path of propagation being wireless, the performance of the network is affected consequently by the topology and the environmental conditions of the area where the network is deployed. Hence, a study of the performance of WiMAX and WLAN network is performed .Voice over IP is expected to be low cost and popular application in the next generation communication networks. The target of this research is to analyze performance of VOIP traffic Among the most competing networks like WiMAX,Wifi. An integrated network using WiMAX backbone and WLAN hotspots has been developed and VoIP has been setup using Session Initiation Protocol (SIP). OPNET 14.5 which provides a real life simulation environment is chosen as the simulation tool. Quality of the service is critically analyzed with parameters like jitter, MOS and delay for two cases, without silence suppression in the network and when silence suppression is used. Finally, it is concluded that the WiMAX-WLAN integrated network provides improved and optimal performance over WLAN and WiMAX networks with respect to network capacity and quality of service.

المستخلص

اصبح مجال الاتصالات اللاسلكية يشكل دور مهم في حياة الإنسان ، و العمل على تحسين الأداء للشبكة اللاسلكية اصبح من المواضيع التي تلقى كثير من الاهتمام من الباحثين. بما أن المسار الذي تنتقل فيه الاشارة هو مسار لاسلكي ، فإن اداء الشبكة يتأثر باستمرار بالاعتماد على بنيتها و الظروف البيئية المحيطة التي تعمل فيها الشبكة. و لهذا السبب، تم اجراء هذه الدراسة التحليلية على اداء شبكة وايفاي وشبكة وايماكس . الصوت عبر بروتوكول الإنترنت من التطبيقات التي يتوقع ان تلقى انتشار واسع و ان تكون رخيصة الثمن في الاجيال القادمة من شبكات الاتصالات. الهدف من هذا البحث هو تحليل اداء حركة الصوت عبر بروتوكول الإنترنت خلال الشبكات اللاسلكية المتنافسة مثل شبكة وايفاي وشبكة وايماكس . أجريت عملية التكامل بين الشبكتين، حيث تم استخدام شبكة وايماكس كداعم اتصال رئيسي او كعمود فقري لشبكة وايفاي ، الصوت عبر بروتوكول الإنترنت تم تطبيقه باستخدام بروتوكول انشاء الجلسة. في عملية محاكاة الشبكة تم اختيار تطبيق يوفر بيئة محاكة واقعية . المعلومات التي تشير الى جودة الخدمة تم تحليلها بصورة واسعة مع الاخذ في الاعتبار عوامل أخرى مثل التغير في تاخر الحزم والتاخير من طرف الى طرف و وذلك في حالتين الحالة الاولى بدون حجز الصمت ، و الحالة الثانية عندما نحجز الصمت في المكالمة . في الختام بإمكاننا القول أن التكامل بين شبكة وايماكس وشبكة وايفاي يعطي اداء افضل مقارنة بشبكتي الوايماكس و الوايفاي كل على حدة، من حيث السعة و جودة الخدمة.

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Abbreviations

AAA	Authentication, Authorization and Accounting
AMC	Adaptive Modulation and Coding
AP	Access point
ASN	Access Service Network
ASP	Application Service Provider
BE	Best Effort Service
BPSK	Binary Phase Shift Keying
BSS	Base Service Set
BWA	Broadband Wireless access
CBR	Constant Bit Rate
CID	Connection Identifier
CS	Convergence Sub-layer
CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
CSN	Connectivity Service Network
CCA	Clear Channel Assessment
CE	Consumer electronic
CDMA	Code Division Multiple Access
DCF	Distributed Coordination Function
DHCP	Dynamic Host Control Protocol
DL	Downlink
DLC	Data Link Control Layer
DL-MAP	Downlink Map
DOCSIS	Data over cable service interface specification
DS	Distribution System

DSL	Digital Subscriber Line
DSSS	Direct Sequence Spread Spectrum
EAP	Extensible Authentication Protocol
ertPS	extended real time Polling Service
ESS	Extended Service Set
FDD	Frequency Division Duplexing
FHSS	Frequency Hop Spread Spectrum
FTP	File Transfer Protocol
GFSK	Gaussian Frequency Shift Keying
HSPA	High speed packet Access
IETF-EAP	Internet Engineering Task Force-Extensible Authentication Protocol
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IR	Infra-Red
ISM	Industrial, Scientific and Medical
ISP	internet service provider
ITU-T	Telecommunication Standardization Sector of The international telecommunication union
LAN	Local Area Network
LLC	Logical Link Control
LOS	Line Of Sight
MAC	Medium Access Control
MAC	CPS MAC Common Part Sub-layer
MN	Mobile Node
MOS	Mean Opinion Score
MS	Mobile Station
MIMO	Multiple Input Multiple Output
NLOS	Non-Light Of Sight

nrtps	non-real time Polling Service
NSP	Network Service Provider
NWG	Network Working Group
OFDMA	Orthogonal Frequency Division Multiple Access
PC	Point coordinator
PCF	Point Coordination Function
PHY	Physical layer
PLCP	Physical Layer Convergence Protocol
PMD	Physical Medium Dependent
PPP	Point to Point Protocol
PSTN	Public Switched Telephone Network
PTM	Point To Multipoint
PTP	Point To Point
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RLC	Radio Link Control
rtps	real time Polling Service
RTS/CTS	Request-To-Send/ Clear-To-Send
SIP	Session Initiation Protocol
SISO	Single Input Single Output
SONET	Synchronous Optical Network
SS	Subscriber Station
TDD	Time Division Duplexing
TDM	Time Division Multiplexed
TDMA	Time Division Multiple Access
UGS	Unsolicited Grant Service
UL	Uplink
UL-MAP	Uplink Map

VBR	Variable Bit Rate
VoIP	Voice over IP
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
Wireless MAN	Wireless Metropolitan Area Network
Wireless HUMAN	Wireless High-Speed Unlicensed Metropolitan Area Networks
WAN	Wide Area Network
WLAN	Wireless Local Area Network
WWAN	Wireless Wide Area N**et**work
OPNET	Optimized Network Engineering Too

Chapter One

Introduction

1.1 Preface

Wireless networking has become an essential part in the modern telecommunication system. The demand of high speed data transfer with quality has led to the evolution of technologies like WiMAX and WLAN and is still increasing. WiFi has dramatically increased productivity and convenience. Today there are nearly pervasive WiFi that delivers the high-speed Wireless Local Area Network (WLAN) connectivity to millions of offices, homes, and public locations, such as hotels, cafés, and airports. The integration of WiFi into notebooks, handhelds and Consumer Electronics (CE) devices has accelerated the adoption of WiFi to the point where it is nearly a default feature in these devices [1].

On the other hand, the WiMAX takes wireless Internet access to the next level, and over time, could achieve similar rates to devices as WiFi. WiMAX can deliver Internet access miles from the nearest WiFi hotspot and blanket large areas called wide area networks (WANs), be they metropolitan, suburban, or rural with multimegabit per second mobile broadband Internet access. Although the wide area Internet connectivity offered by 2.5 and 3G cellular data services are mobile, these services do not provide the broadband speeds to which users have become accustomed whereas WiMAX can deliver these services. In the last few years, WiMAX has established its relevance as an alternative to wired DSL and cable providing a competitive broadband service that can be rapidly and cost effectively deployed [2].

Together, the WiMAX and the WiFi are ideal partners for service providers to deliver convenient and affordable mobile broadband Internet services in more places. Both are open IEEE wireless standards built from the ground up for Internet Protocol (IP)-based applications and services. IEEE 802.11 has accelerated the network deployment for providing high transmission rate in limited geographical coverage, while IEEE 802.16 offers more flexibility while maintaining the technology data rate and transmission range. The limited coverage range of WiFi makes it difficult to meet the future ubiquitous networks need while IEEE 802.16 can provide the high speed Internet access in a wide area. A natural trend is the combination of the IEEE 802.16 and the IEEE 802.11 to create a complete wireless solution for delivering high speed Internet access to businesses, homes and hotspots. However, both techniques have their own sets of advantages and disadvantages. On the one hand, WiFi may offer a high data rate up to 54 Mb/s, but its power is limited due to the use of unlicensed band and are therefore much more confined in coverage, while on the other hand, even though WiMAX is data rate limited up to 75 Mb/s fixed, it can provide extensive coverage much like the cellular systems [3].

Since, WiMAX is expected to create the opportunity to successfully penetrate the commercial barrier by providing higher bandwidth, establishing wireless commons becomes an important factor. Also, bandwidth crunch and network integration are some of the major technical and social challenges. Instead of global Internet connectivity, many current applications and businesses are expected to be better utilized by using the localized Wi-Fi constellation. With a step towards the next generation, it is expected that an integrated network comprising of both the WiMAX and WLAN network and using mobile nodes with dual stack is expected to provide a better performance than a similar WiMAX or WLAN network [4].

1.2 Problem Statement

The growth of mobile broadband subscriptions created huge demand for ubiquitous connectivity, the maximum utilization of the spectrum has also become a concern. To accommodate maximum number of users with considerably good quality of service has become a concern of the researchers. Innovative methods and techniques are coming up each day to suffice the needs.

1.3 Proposed Solution

This research is to assess the performance of WLAN and WiMAX networks and to find out to what extent the QoS experienced varies. Our target is to analyze the performance of WLAN-WiMAX integrated 4G network. The performance comparison is focused.

1.4 OBJECTVES

The aim of this research is to analyze the performance of WIMAX-WLAN integrated network main objectives of our research include :

To propose a design for WIMAX-WIFI integrated architecture.

To simulate IEEE 802 .11 and IEEE 802.16.

To evaluate the results of the simulation.

To find the best of the three topologies.

1.5 METHODOLGY

To accomplish this project we have to implement three different models, the first is for WLAN and the second is for WIMAX. WLAN and WIMAX networks are consist of 4 cells connected to the core network by a server backbone via an IP backbone. The third model is for integrated design of WIMAX and WIFI. In the integrated design WiMAX network is used as a backhaul for WLAN network, in the topology two base stations are connected with two WLAN network via three routers .the analysis is taken for the three networks in which VOIP application is considered. Every model with two scenarios, when silence suppression is not used in the network and when silence is suppressed .Then an evaluation and comparison of the three models in terms of QOS parameters like jitter, MOS and End-to-End delay is done So as to study the performance of VOIP application in the scenarios. Optimized Network Engineering Tool (OPNET) is used to implement and design the network models and then simulate and collect the results for the analysis. Finally the results are obtained and thesis is documented.

1.6 THESIS OUTLINES

In general the thesis will be divided into five chapters. Each chapter will discuss on different issues related to the project. The following are the issues discussed.

- ⇒ Chapter one: states the problem, proposed solutions and methodology.
- ⇒ Chapter two: literature of topics related to the project is reviewed and having background knowledge of WIMAX and WIFI networks and a comparison between them is studied.

- ⇒ Chapter three: the proposed method is used for implementing the models along with design considerations.
- ⇒ Chapter four: the OPNET network model is deployed and executed and then the results are analyzed of chosen statistics.
- ⇒ Chapter five: conclusion of this work is presented as well as future work.

Chapter Two

Literature Review

2.1 Background

Several competing broadband wireless technologies exist to provide enterprises with wireless coverage on local and/or global scale. These wireless technologies include 3G/4G cellular networks such as Wideband CDMA, High Speed Packet Access (HSPA), Worldwide Interoperability for Microwave Access (WiMAX), Long Term Evolution (LTE) and Wireless Fidelity (WiFi) 802.11. Majority of enterprises have adopted Wireless Local Area Network (WLAN) deployments for their infrastructure which are based on WiFi. WLANs are fixed networks, have relatively small coverage area but have very high throughput. Extending WLAN coverage to the Internet usually requires enterprises to connect their wireless Access Points (APs) to the wired networks. Enterprises located in remote areas far from Internet Service Provider's (ISP) core have a choice of several technologies to use to backhaul their traffic. WiMAX is one of the contending 4G technologies that can extend long range coverage to WLANs.

Due to widespread adoption of WLAN and level of consumer comfort resulting by its low cost and ease of maintenance, WiMAX is not introduced as a replacement, but rather a complement to the technology. WiMAX has been proposed as an ideal backhaul to WiFi networks, which could provide an end-to-end wireless network if deployed in an integrated WiFi-WiMAX infrastructure.

Wireless technologies are consistently improving many different aspects of their functionalities such as transmission speed, coverage, and QoS support. The prevalence of WLANs in the consumer and enterprise market made IEEE 802.11 the de-facto standard that has been deployed around the globe; give that there are limitations inherit to WiFi standard.

Conventionally WiFi setups still would require a wired connection as their backend to be able to connect to Internet. This is not the desirable prerequisite in many instances such as rural or less developed areas which lack the required infrastructure. This need justifies a new wireless schema that would provide the required backhaul between the WiFi spots and the internet backbone in a reasonable and cost effective manner. One such solution is the IEEE 802.16 family of Wireless Metropolitan Area Network (WMAN) technologies that showcase an encouraging resolution to provide WLAN hotspots with required backend support. This hybrid approach would provide an ideal answer to our requirements for having a cost effective and broadband wireless network solution [5].

2.2 background on WiMAX and IEEE802.16

2.2.1 WIMAX

WiMAX is not a standard, it is only a marketing trend trademarked by WiMAX Forum to describe the IEEE 802.16 based technology WiMAX standard refers to a set of capabilities that are likely to experience widespread implementation. WiMAX has evolved from the market and technological perspective. The original IEEE 802.16 specification was designed to provide a high-data rate, point to point communication and with LOS (Line of Sight) conditions between fixed locations. This application was created to provide wireless bridging between fixed locations within the network infrastructure. The typical example of this usage is a tower that is wirelessly backhauled to a fixed location which is attached to a larger wired network [5].

The scope was expanded to offer direct support of end-user networks interconnecting end-users with network infrastructure. WiMAX can offer high-data rate over long distances so it is an adequate technology to solve the problem space of the Internet Service Provider

(ISP) in wireless local loop where low-rate wired infrastructure often limits the capabilities of the connection for the costumers. This technology is explained in the standard IEEE 802.16a and in the IEEE 802.16d (or also 802.16-2004) which unified the original 802.16 and 802.16a. Although there are already other technologies in the market for solving this problem space, WiMAX can be very successful in regions without a good wired infrastructure like in developing regions or in rural regions in developed countries. WiMAX is the air-interface for the actual radio interface network, where both fixed and mobile users can have access to the network. The basis of mobile WiMAX is explained in the IEEE 802.16e (or802.16-2005) standard. WiMAX is a very flexible and scalable standard that may be adapted to different frequency bands.

2.2.2 IEEE802.16

The IEEE 802.16 group was formed in 1998 to develop an air interface standard for wireless broadband. The group's initial focus was the development of a LOS based point-to-multipoint wireless broadband system for operation in the 10-66 GHz millimeter waveband. The resulting standard – the original IEEE 802.16 standard completed in December 2001 – was based on a single carrier physical (PHY) layer with a burst time division multiplexed (TDM) MAC layer Many of the concepts related to the MAC layer were adapted for wireless from the popular cable modem DOCSIS (data over cable service interface specification standard.

The IEEE 802.16 group subsequently produced 802.16a, an amendment to the standard, to include NLOS applications in the 2 GHz – 11 GHz band using orthogonal frequency division multiple access (OFDMA), were also included Further revisions resulted in a new standard in 2004, called IEEE 802.16d – 2004 which replaced all prior versions and formed the basis for the first WiMAX solution. These early WiMAX solutions based on IEEE 802.16d – 2004 targeted fixed applications, and are referred to as Fixed WiMAX. In December 2005 the IEEE Group completed and approved IEEE 802.16e – 2005, an amendment to the IEEE 802.16d – 2004 standard that added mobility support. The IEEE 802.16e – 2005 forms the basis for the WiMAX solution for nomadic and mobile applications and is often referred to as mobile WiMAX [5]. IEEE802.16 protocol standard consist of two layer structure, which defines a physical layer and MAC layer. MAC layer include three parts: converges sub layer (CS) MAC common part sub layer (CPS) and a privacy sub layer.

IEEE 802.16 physical layer defines two duplex modes: Time division Duplex (TDD) and a Frequency division Duplex (FDD), and these two methods use burst data transfer format. This transmission mechanism support adaptive burst business data. Transmission parameters (modulation, coding, transmit power) can be dynamically adjusted, but requires the MAC layer to help the process [6].

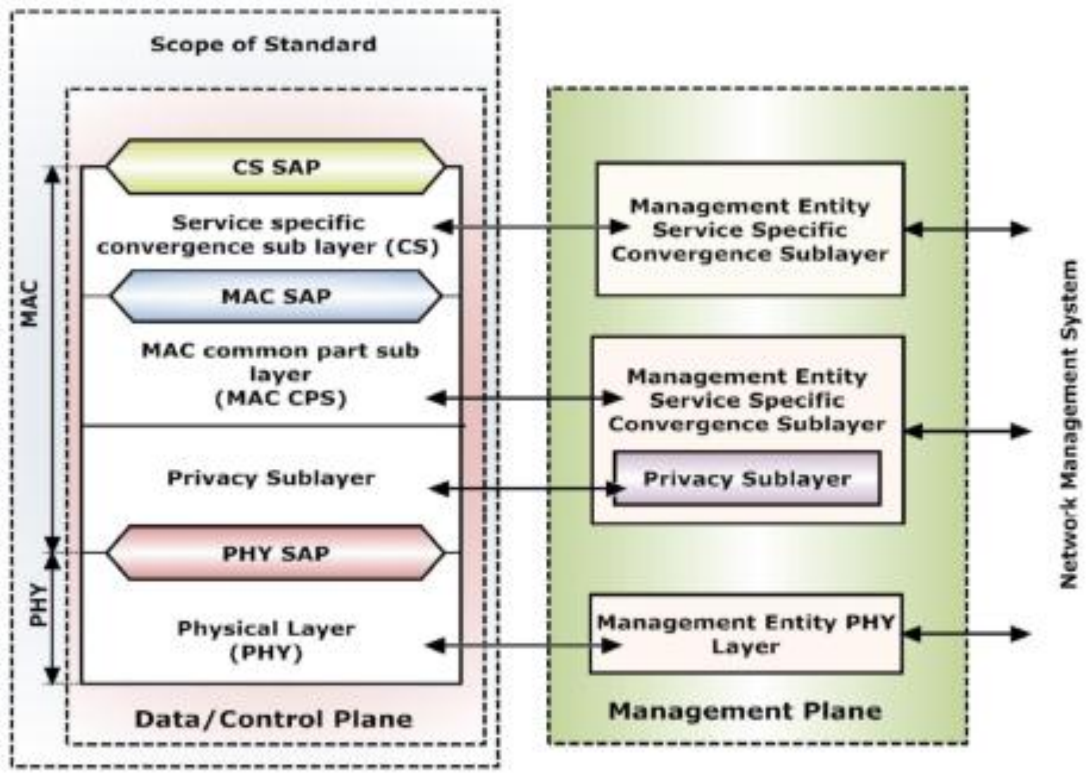


Figure 2-1: NETWORK Reference model of IEEE 802.16

2.2.3 WiMAX Network Architecture

The IEEE 802.16e – 2005 standard provides the air interface for WiMAX but does not define the full end-to-end WiMAX network. The WiMAX Forum's Network Working Group (NWG) is responsible for developing the end-to-end network requirements, architecture, and protocols for WiMAX, using IEEE 802.16e – 2005 as the air interface. The WiMAX NWG has developed a network reference model to serve as an architecture framework for WiMAX deployments and to ensure interoperability among various WiMAX equipment and operators [7].

The network reference model envisions unified network architecture for supporting fixed, nomadic, and mobile deployments and is based on an IP service model. Below is simplified illustration of IP-based WiMAX network architecture. The overall network may be logically divided into three parts:

o **Mobile Stations (MS)** used by the end user to access the network.

o **The Access Service Network (ASN),** which comprises one or more base stations and one or more ASN gateways that form the radio access network at the edge. The ASN gateway typically acts as a layer 2 traffic aggregation points within an ASN. Additional functions that may be part of the ASN gateway include intra-ASN location management and paging, radio resource management and admission control, caching of subscriber profiles and encryption keys, AAA client functionality, establishment and management of mobility tunnel with base stations, QoS and policy enforcement, and foreign agent functionality for mobile IP, and routing to the selected CSN.

o **Connectivity Service Network (CSN),** which provides connectivity to the Internet, ASP, other public networks, and corporate networks. The CSN is owned by the NSP and includes AAA servers that support authentication for the devices, users, and specific services. The CSN also provides per user policy management of QoS and security. The CSN is also responsible for IP address management, support for roaming between different NSPs, location management between ASNs, and mobility and roaming between ASNs.

o **Base station (BS):** The BS is responsible for providing the air interface to the MS. Additional functions that may be part of the BS are micro mobility management functions, such as handoff triggering and tunnel establishment, radio resource management, QoS policy enforcement, traffic classification, DHCP (Dynamic Host Control Protocol) proxy, key management, session management, and multicast group management.

The network reference model developed by the WiMAX Forum NWG defines a number of functional entities and interfaces between those entities. Figure 3.3 below shows some of the more important functional entities [7].

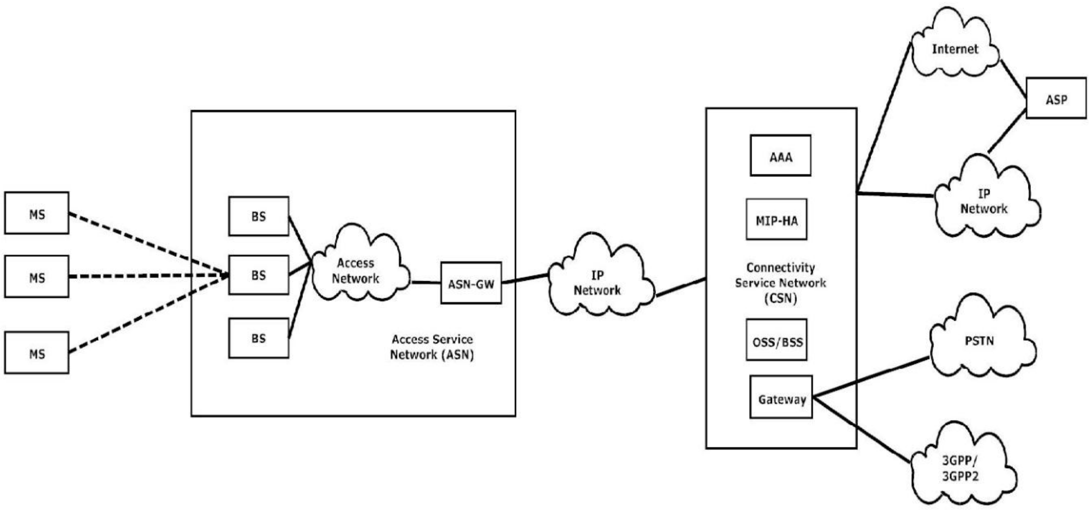


Figure 2-2 WiMAX Network Architecture

Each WIMAX connection is specified to support one of five available QOS classes [8]:-

A. Unsolicited Grant Service (UGS): Short, consistent delay service for real-time Voice over IP (VoIP) services, where a station is allocated dedicated inbound transmission capacity.
B. Real-Time Polling Service (rtPS): Another short, consistent delay service for VoIP applications with voice activity detection.
C. Extended Real-Time Polling Service (ertPS): Short, consistent delay service for VoIP applications with voice activity detection.

D. Non-Real-Time Polling Service (nrtPS): Prioritized variable delay data service with a minimum reserved rate or File Transfer Protocol (FTP) traffic.
E. Best Effort (BE): An IP-like best effort data service for Web surfing and general purpose data transfers.

Table 2-1: services classes of WIMAX 802.16

Service classes	QoS Parameters	Application
Unsolicited Grant service (UGS).	Maximum sustained rate. Maximum latency tolerance. Jitter tolerance.	Voice over IP (VoIP) without silence suppression.
Real Time Polling Service (rtps).	Minimum reserved rate. Maximum sustained rate. Maximum latency tolerance. Traffic priority.	Streaming audio and MPEG (Motion ،video Picture Experts Group) encoded.
Extended Real time Service (ertPS).	Minimum reserved rate. Maximum sustained rate. Traffic priority.	File Transfer Protocol (FTP).
Non real time polling	Maximum sustained	Web browsing, data

service (nrtPS).	rate. Traffic priority.	transfer.
Best Effort (BE).	Minimum reserved rate. Maximum sustained rate. Maximum latency tolerance. Jitter tolerance. Traffic priority.	VoIP with silence suppression.

2.3 background on WIFI and IEEE802.11

2.3.1 WIFI

Wi-Fi based-systems may be used to provide broadband wireless. Wi-Fi is based on the IEEE 802.11 family of standards and is primarily a local area networking (LAN) technology designed to provide in-building broadband coverage. Current Wi-Fi systems based on IEEE 802.11a/g support a peak physical-layer data rate of 54Mbps and typically provide indoor coverage over a distance of 100 feet. Wi-Fi has become the de-facto standard for “last feet” broadband connectivity in homes, offices, and public hotspot locations. In the past couple of years, a number of municipalities and local communities around the world have taken the initiative to get Wi-Fi systems deployed in outdoor settings to provide broadband access to city centers and metro zones as well as to rural and underserved areas. [2].

Metro-area Wi-Fi deployments rely on higher power transmitters that are deployed on lamp posts or building tops and radiating at or close to the maximum allowable power limits for operating in the license-exempt band. Even with high power transmitters, Wi-Fi systems can typically provide a coverage range of only about 1,000 feet from the access point. Consequently, metro Wi-Fi applications require dense deployment of access points, which makes it impractical for large-scale ubiquitous deployment. Nevertheless, they could be deployed to provide broadband access to hot zones within a city or community. Wi-Fi offers remarkably higher peak data rates than do 3G systems, primarily since it operates over a larger 20MHz bandwidth. The inefficient CSMA (carrier sense multiple access) protocol used by Wi-Fi, along with the interference constraints of operating in the license-exempt band, is likely to significantly reduce the capacity of outdoor Wi-Fi systems. Further, Wi-Fi systems are not designed to support high-speed mobility. One significant advantage of Wi-Fi over WiMAX and 3G is the wide availability of terminal devices. A vast majority of laptops shipped today have a built-in Wi-Fi interface. Wi-Fi interfaces are now also being built into a variety of devices, including personal data assistants (PDAs), cord less phones, cellular phones, cameras, and media players. The large embedded base of terminals makes it easy for consumers to use the services of broadband networks built using Wi-Fi. As with 3G, the capabilities of Wi-Fi are being enhanced to support even higher data rates and to provide better QoS support. In particular, using multiple-antenna spatial multiplexing technology, the emerging IEEE 802.11n standard will support a peak layer 2 throughput of at least 100Mbps IEEE 802.11n is also expected to provide significant range improvements through the use of transmit diversity and other advanced techniques.

2.3.2 IEEE802.11 .

In recent times IEEE 802.11 wireless local area networks (WLAN) have become ubiquitous cross the world in the license-free spectrum of 2.4 and 5GHz bands .802.11 protocol groups are a wireless local area network standard developed by the International Institute of Electrical and Electronics Engineers (IEEE). The 2.4GHz ISM band is adopted by most of the countries in the world. In some countries and regions, the usage situation of 5GHz ISM band is more complicated. The high carrier frequency has a negative effect, making the popularity of 802.11a limited, although it is the first version of the protocol group.802.11a standard was an amendment of the original 802.11 standard, which was approved in 1998[8].

IEEE802.11 standards have a big family, including about 22 types of standards. In the past ten years IEEE802.11a/b/g were utilized widely. However now the popular usage is for 802.11n standard that operates in the 2.4GHz and 5GHz bands, with speeds of 400 to 600Mbps (theoretical value). In terms of coverage, 802.11n uses smart antenna technology, through multiple groups of independent antennas to utilize antenna arrays. It can dynamically adjust the beam to ensure that each user receives stable WLAN signals, and can reduce interference from other signals. As its coverage can be extended to few hundred meters through additional devices, the mobility of WLAN has greatly improved.802.11n mainly combines the optimizing of the physical layer and MAC layer to fully enhance the throughput of WLAN technology. Main physical layer technology involves MIMO (Multiple Input Multiple Output), MIMO-OFDM Orthogonal Frequency Division Multiplexing), 40MHz wide channels, short guard interval and other technologies to make the physical layer throughput up to 600Mbps.

Since the transmission of information is sent through partitioned slots, not only is a single data flow reduced, but the transmission distance can increase with increased antenna range. As a result MIMO technology can increase the existing wireless network spectrum data transmission speed OFDM is a high-speed transmission technology in the wireless environment. The main idea of OFDM technology is that the given frequency domain is divided into orthogonal sub-channels each sub-channel uses a sub-carrier to modulate and each sub-carrier transmits in parallel [8].

The standards of WLAN are as follows:

o IEEE 802.11b (Wi-Fi 2.4 GHz): The goal of the Task Group b was to increase the maximum bit rate in the 2.4 GHz frequency range while maintaining interoperability with the original standard. The MAC layer was kept and the PHY was redefine to only work with DSSS (Direct Sequence Spread Spectrum), thus increasing the spectral efficiency with bit rates of up to 11 Mbps.

o IEEE 802.11a (Wi-Fi 5.2 GHz): The goal of this group was to provide higher data rates and to port IEEE 802.11 to the newly available U-NII at 5.2 GHz. The original MAC layer was kept and the PHY was reworked to provide rates up to 54 Mbps. Since the available band at U-NII is about 300 MHz, eight non-overlapping bands were defined. The spread spectrum technology used in this case was OFDM (Orthogonal Frequency Division Multiplexing), as DSSS was not efficient at working with these high bit rates.

o IEEE 802.11g: Task group g is working on an extension to IEEE 802.11b at 2.4 GHz, enabling transmission at symbol rates of 54 Mbps.

Table 2-2 Characteristic feature of Wireless LAN

Standard	Maximum bit rate	Channels Provided	Frequency Band	Radio Technique
8012.11b	11Mbps	3	2.4GHz	DSSS
802.11a	54Mbps	12	5GHz	OFDM
802.11g	54Mbps	3	2.4GHz	OFDM

2.3.3 WLAN System Architecture

The architecture of a WLAN system is described according to the IEEE802.11 standard. The main building block of such architecture is the Base Service Set (BSS). There are two modes of configuration that can be used within the standards:

- WLAN Infrastructure.
- Ad-Hoc.

2.3.3.1 Infrastructure mode:

In the “Infrastructure” mode, the different BSS are interconnected with each other via a component called the Distribution System (DS). Each BSS has one Access Point (AP), through which the Mobile Nodes (MNs) access to the DS. These interconnected components form the Extended Service Set (ESS). The ESS is a large coverage area where MNs can get handed over from one BSS to another without changes or notification to higher layers in the protocol stack. Finally, a “Portal” is required to integrate the WLAN architecture into the wired network(e.g., Ethernet)and may be integrated with an AP in a single device attached directly to the DS. Fig 4.3 shows the WLAN topology in infrastructure mode [9].

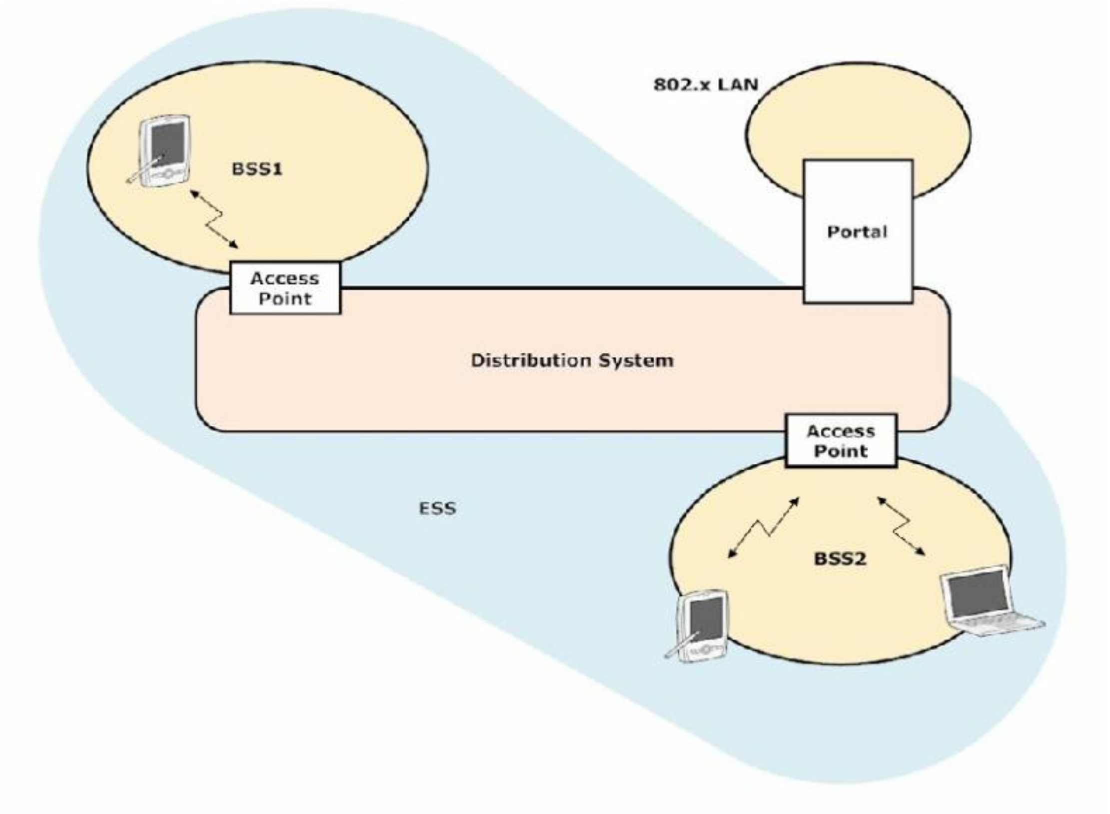


Figure 2-3: WLAN Infrastructure based architecture

2.3.3.2 Ad-Hoc mode

In the "Ad-Hoc" mode, each MN can directly reach any MN within the BSS without going through an intermediate node (i.e., AP). There is no backbone network or distributed system associated with the mobile nodes and the BSS are not connected to the wired network. The Ad-hoc mode of connection usually covers small area and the nodes are allowed to move only within their BSS. There is no concept of handover to support mobility across a large area. Fig 4.4 shows the topology of WLAN in Ad-hoc Mode.

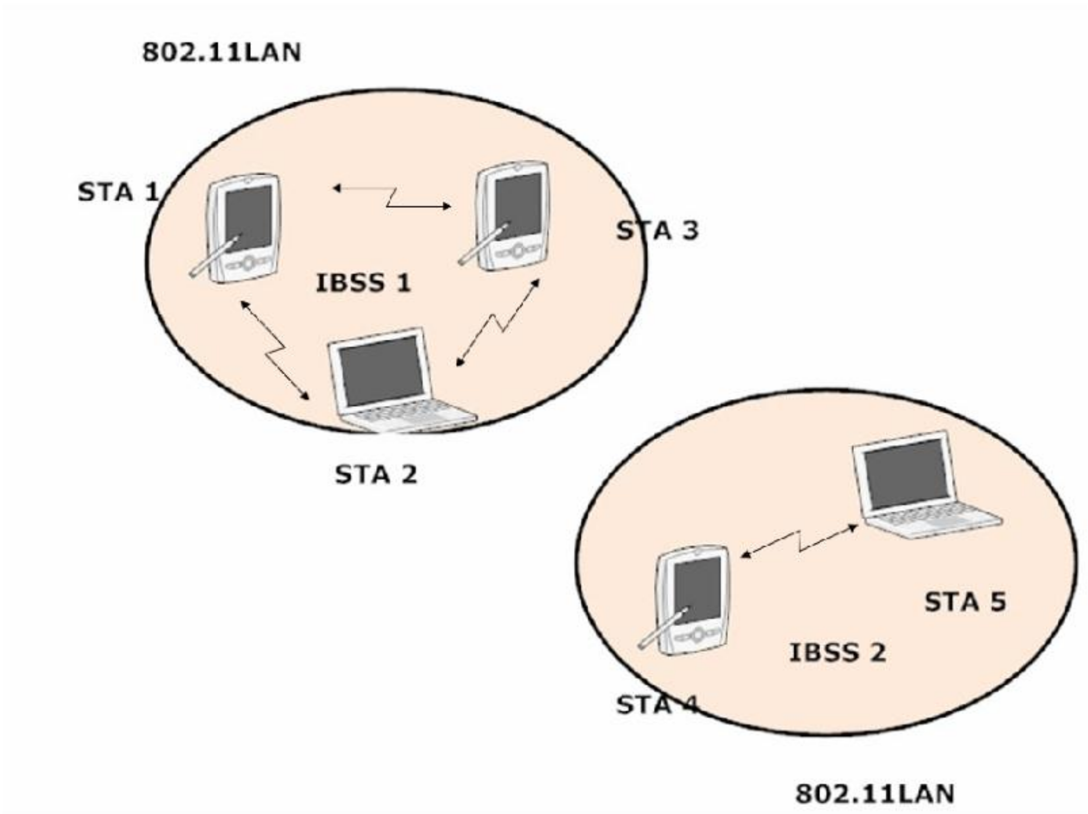


Figure 2-4: Ad-hoc Architecture

2.4 Comparison between WIFI and WIMAX

Wi-Fi has been defined under IEEE 802.11x standards where x is various Wi-Fi versions. WiMAX is standardized under 802.16y family of wireless networking where y refers to various WiMAX versions. Depending on several factors such as frequency, range, encryption, application etc., Wi-Fi has several versions of it such as 802.11b, 802.11g, and 802.11n. , On the similar factors, WiMAX has a number of different versions too; 802.16a, 802.16d and 802.16e are some popular WiMAX versions. Wi-Fi has been defined under ISM bands where user has to pay no extra charging for utilizing those bands. On the contrast, there is no bar on frequency usage in the WiMAX. This means that WiMAX protocols might work in the ISM bands or they might use a licensed frequency version for which the user probably would be charged. An ideal Wi-Fi based network reaches around 100metres as it maximum range whereas an ideal WiMAX network can reach about 80-90kilometers in terms of range. Wi-Fi based networking can transfer data at speeds up to 54mbps. On the other hand, WiMAX networks exchange data at speeds up to 75Mbps. In WiMAX, data transfer rates have more variation as distances to be covered are quite larger. Wi-Fi networks have a channel bandwidth of 20MHz; whereas WiMAX networks have a flexible bandwidth option which ranges from 1.25MHz to 20MHz. bandwidth efficiency is a term that refers to bits of information sent per second per unit frequency. This is a measure of how qualitatively the channel is managed by the network. Bandwidth efficiency of a WiMAX channel (up to 5bps/s/Hz) is theoretically twice as efficient as Wi-Fi based networks (up to 0.44bps/s/Hz for 802.11a and 2.7bps/s/Hz for b/g/n standards).

MAC layer is an essential part of an OSI model. It defines communication procedures that a protocol uses. Wi-Fi's MAC layer uses CSMA/CA protocol which is not connection oriented while that in WiMAX is connection oriented. Encryption techniques in WiMAX include Triple Data Encryption Algorithm and Advanced Encryption Standards. On the other hand, in Wi-Fi, encryption techniques are Advanced Encryption Standard (AES) and RC4. Authentication is process under Network Security where connection is checked for its identity before being established. Both these wireless networking technologies apply different set of protocols for authentication purposes. Wi-Fi uses Extensible Authentication Protocol (EAP) Wired Equivalent Privacy (WEP) security algorithms depending on the Wi-Fi version. On the other hand, WiMAX uses X.509 or PKMv2 as authentication algorithms. Though being used for same purpose of data exchange, are designed to cater two completely different needs. Wi-Fi is needed to serve for household and corporate needs of interconnectivity. Wi-Fi technology connects printers to computer, gaming consoles to router etc. WiMAX serves a larger inter-operable network. WiMAX can be used to provide internet services to a larger area where it can serve households, mobile phones and even Wi-Fi spots. WiMAX has a different hardware specification and currently WiMAX serving towers tend to be as tall as Wi-Fi towers. On the other hand, Wi-Fi antennas are small enough to be placed on 5 inch by 3 inch routers [9].

Table 2-3: Comparison between WIFI and WIMAX [10]

Feature	**WiFi**	**WiMAX**
Standard	802.11a/b/g/n	802.16d/e
Data rate (MAX)	54Mbps	70Mbps
Operating Frequency	2.4 GHz and 5GHz	2-11 GHz
Channel Bandwidth	20 to 25MHz	Ranging from 1.25 to 20BMHz
Transmission distance (MAX)	300m	50Km
Encryption	RC4 and Advanced Encryption Standard (AES)	Triple Data Encryption Algorithm (3DES) and Advanced Encryption Standards (AES)

2.5 Wi-Fi And WiMAX Integration

Both Wi-Fi and WiMAX can be integrated and overlay. If they can be integrated, it means that WiMAX and WiFi will support each other. Both of them will be synergized to serve bigger and many more subscribers. WiMAX and Wi-Fi can offer some potentially significant cost savings for mobile network operators by providing an alternate means to backhaul BS traffic from cell site to the BS controllers. Mobile network operators typically utilize some type of wired infrastructure that they must buy from an incumbent operator. A Wi-Fi or WiMAX mesh can offer a much more cost-effective backhaul capability for BSs in metropolitan environments. Using Wi-Fi and WiMAX open broadband wireless standards and implementing mobile computing, governments and partners can quickly and cost-effectively deploy broadband to areas not currently served, with little or no disruption to existing. Standards-compliant WLANs and proprietary Wi-Fi mesh infrastructures are being installed rapidly and widely throughout the world [9]. Standards-compliant WiMAX products can provide NLOS backhaul solutions for these local networks and WiMAX subscriber stations can currently provide Internet access to customers such as schools and other educational institutions and campuses. If they can be made to overlap in coverage they can be functioned to support each other (if they were in one operator) and will be opponent if they were in different operators. Various configurations that can be applied by WiMAX and WiFi operators if they were integrated are as follows [10] :-

2.5.1 BACKHAUL

The configuration is shown in fig. 2-7. By combining the two technologies, WiMAX functioning as a backhaul while Wi-Fi connected directly to the subscriber WiMAX has been used directly as a part of Wi-Fi Mesh Network. Subscriber Terminal of WiMAX is put on access point of Wi-Fi Mesh Network so that the Wi-Fi network automatically will be more reliable in wider coverage area and reduce cost connection that is caused by cable drawing in each AP installation. The solution principally can increase performance and robustness of the Wi-Fi network.

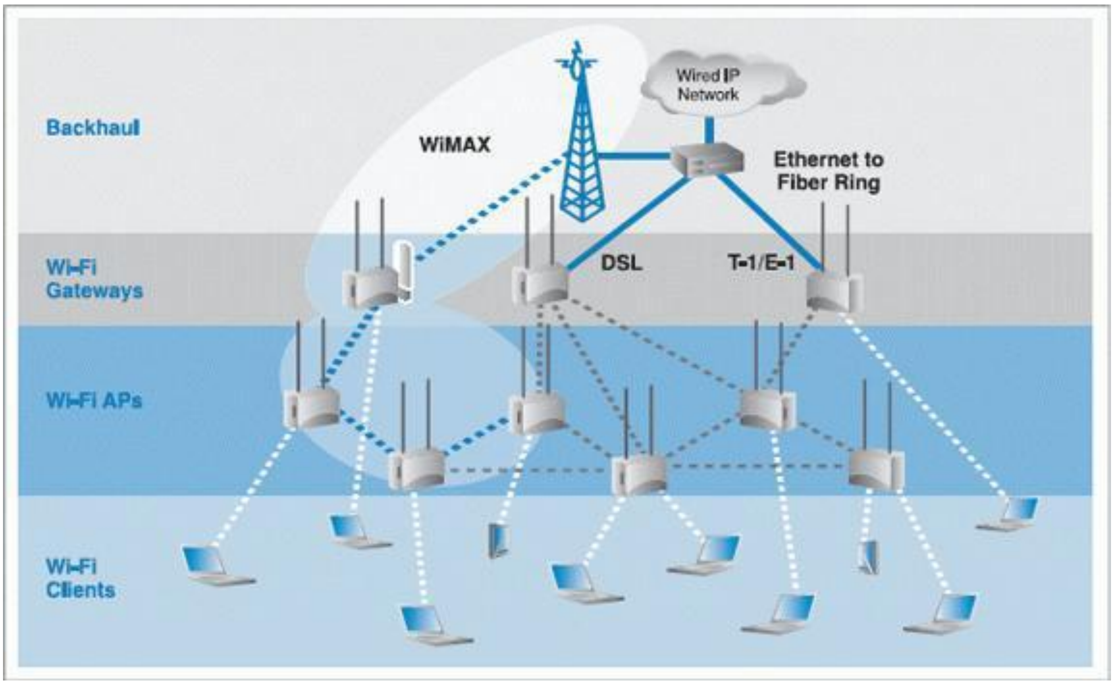


Figure 2-5: Backhaul Architecture

2.5.2 WIFI-WIMAX Full Integrated

Figure 2-8 shows another combination between Wi-Fi and WiMAX. Here in this case, communication can be done up to client level. WiMAX coverage is overlapping with Wi-Fi coverage. It gives better service choices, more flexible to the changes of network and is more user friendly with connection ease compatible with terminal that has been owned. Moreover with dual AP radio implementation (Wi-Fi and WiMAX), integration will be easier and network development also can be faster [11].

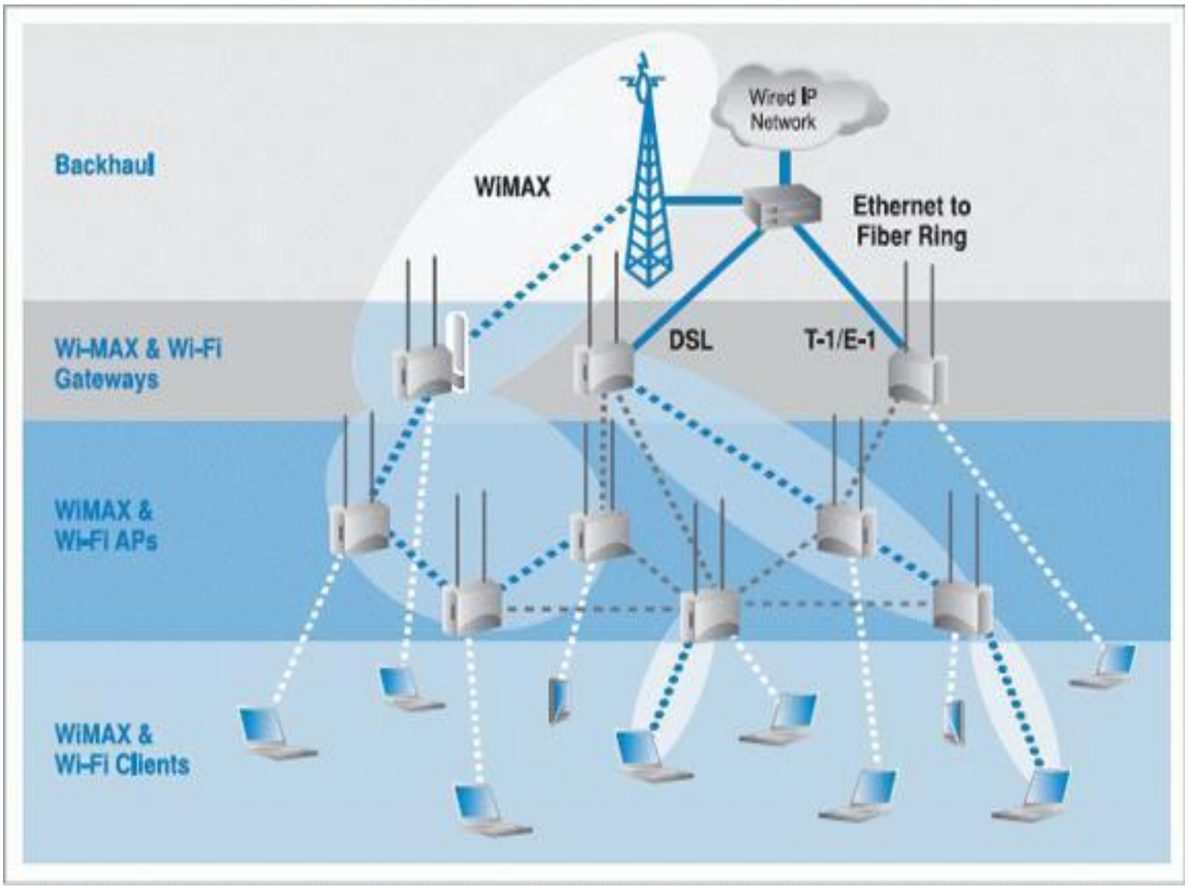


Figure 2-6: Wi-Fi –WiMAX Fully Integrated Architecture

2.6 Voice over IP (VOIP)

Voice over Internet Protocol or more commonly known as ―VoIP‖ is simply defined as the digitized voice traffic intrinsically transmitted using a data network to make telephone calls. This differs from using a traditional analogue circuit switched public network, as now the data has been split into packets. These packets can take any route to reach the destination. Packetized data travel through a virtual circuit which differs from a circuit switched network in that the circuit does not need to be reserved for the entire duration of the call between the sender and the receiver with packet switching.

2.6.1 VOIP Operation

The VoIP procedure includes voice digitization, filtering of unwanted noise, compression using codec, then packetization and sending through Internet. VoIP is supported by number of protocols such as session initiation protocol (SIP) or H.323, real-time transport protocol (RTP) and real-time transport control protocol (RTCP). Those protocols have been employed to initiate, maintain, and terminate the VoIP call. The call parties need to be identified by IP-address and sufficient bandwidth capacity needed to be available to finish the call successfully [12].

2.6.2 VOIP Components

VOIP system consist of three parts, codec, packetizer and playout buffer

- Codec: The function of codec is to compress and encode the analog signals into digital voice signals. Codec provide good quality of voice even after compression, with minimum delay which is one of the main advantages of using codec.
- Packetizer: is used to pack digital signal into voice packets.
- Playout buffer: is at the receiver end to decrease the delay jitter.

International Telecommunication Union-Telecommunication (ITU-T) developed various standards in voice communication field there are some common codecs used in VOIP. G711 is the international standard for encoding telephone audio. It has a fixed bit rate of 64kbps. G.723 and G.729 are low bit rate codecs at the expense of high codec complexity. G.723 is one of the most efficient codecs with the highest compression ratio and is used in video conferencing applications. G.729 is an industry standard with high bandwidth utilization for toll-quality voice calls [13].

2.6.3 QoS parameters

The QoS parameters of VoIP traffic varies, and can be quantified by a range of divergent metrics, such as the: jitter, end-to-end delay and Mean Opinion Score (MOS) [14].

- **The Mean Opinion Score (MOS)** has been used to subjectively measure the voice quality in a telephone network. It is based on a perceptual scale of 1 to 5, 5 is excellent and 1 is bad.
- **Jitter —**is the variation in the arrival time of consecutive packets‖ Jitter is calculated over an interval of time It should be noted that the buffers can both under-fill and over- fill, triggering packet drops, and the acceptable range of jitter is between 0-0.5ms.
- **The packet end-to-end (ETE**) delay is measured by calculating the delay from the speaker to the receiver including the compression and decompression delays, the acceptable range of ETE delay is 0-150ms.

2.7 RELATED WORK

The Ministry of Food and Agriculture, Ghana (MOFA) was established to create an environment for sustainable growth and development in the agricultural sector. The Ministry has fixed Local Area Networks coupled with Wireless Local Area Networking (WLAN) or Wireless Fidelity (WiFi) technology deployed successfully in the Directorates located in the Accra Metropolis. With existing broadband access, MOFA wants to expand connectivity to all its units. MOFA Internet Service Provider has deployed Worldwide Interoperability for Microwave Access (WIMAX) connecting its clients. This WIMAX enables broadband connectivity beyond Wi-Fi hotspots [15].

Integrated WiFi/cellular network architecture has been studied. Usually cellular network has a much smaller bandwidth than that of WiFi network. In most of the work, the cellular network is considered as the main network, and WiFi as the auxiliary. Most research efforts are put on the architecture design and QoS support of such network [16], [17]. Usually, the performance of the integrated WiFi/cellular network is compared with the cellular network where the gain is obvious due to additional resources. And [18], [19] discusses the performance and capacity of the WLAN networks while [21] discusses the capacity and performance of WiMAX network. Among them [20] discusses the capacity improvement of WLAN network for voice traffic while quality of the voice traffic has been taken care of in [21] .In [22] it is proposed that an integrated architecture of WiMAX and WLAN is expected to perform better than the conventional WiMAX or WLAN network. In this thesis we provide comparative discussion of the performance of a WLAN-WiMAX integrated network with respect to the upcoming application voice over IP.

Chapter three

Simulation design

Chapter Three

Simulation design

In this project OPNET 14.5 modeler is used to present the models and the assumption suggested achieving the goal of this research which is analyzing the performance of WIFI-WIMAX integration. In according to perform this OPNET is used to simulate three different topologies (WLAN Network topology, WIMAX network topology, WIMAX-WIFI Integrated network topology) each with two different scenarios (static scenario, mobile scenario). And to test the scenarios we applied VOIP service over the topologies. The WIMAX and WIFI models and its corresponding object palette tools are used, these sets are to study the performance metrics of the networks like throughput, end to end delay, average jitter to VOIP service the simulation is run for 600 seconds, and then results extracted and evaluated.

3.1 OPNET Modeler

OPNET [23] provide comprehensive development environment supporting the modeling of communication networks and distributed systems. Both behavior and performance of the modeled systems can be analyzed by discrete event simulation Tool for all phases of our study including model design, simulation, data collection and data analysis are incorporated in OPNET environment. Various constructs pertaining to communication and information processing are provided by OPNET. Thus it provides high leverage for modeling and distributed systems. Graphical specifications of a model are provided by OPNET most of the times. All OPNET simulations automatically include support for analysis by a sophisticated interactive debugger. Technology developers leverage advanced simulation capabilities and rich protocol model suites to design and optimize proprietary wireless protocols.

3.2 Network models

3.2.1 WIMAX Topology

Using Wireless Deployment Wizard of OPNET a 4 celled WiMAX network, with 7 subscriber stations in the range of a base station is deployed. The base station is connected to the core network by a server backbone via an IP backbone. The server backbone is further connected to the voice server which is configured as SIP server. The cell radius is set to be 30 km. The Base Station transmission power is set to 20W and the subscriber station is set to 0.5W and the service class used is Gold. The Figure 3-1 shows the WIMAX network which contains seven subscriber station (SS) in each cell. The total number of SS is 28.

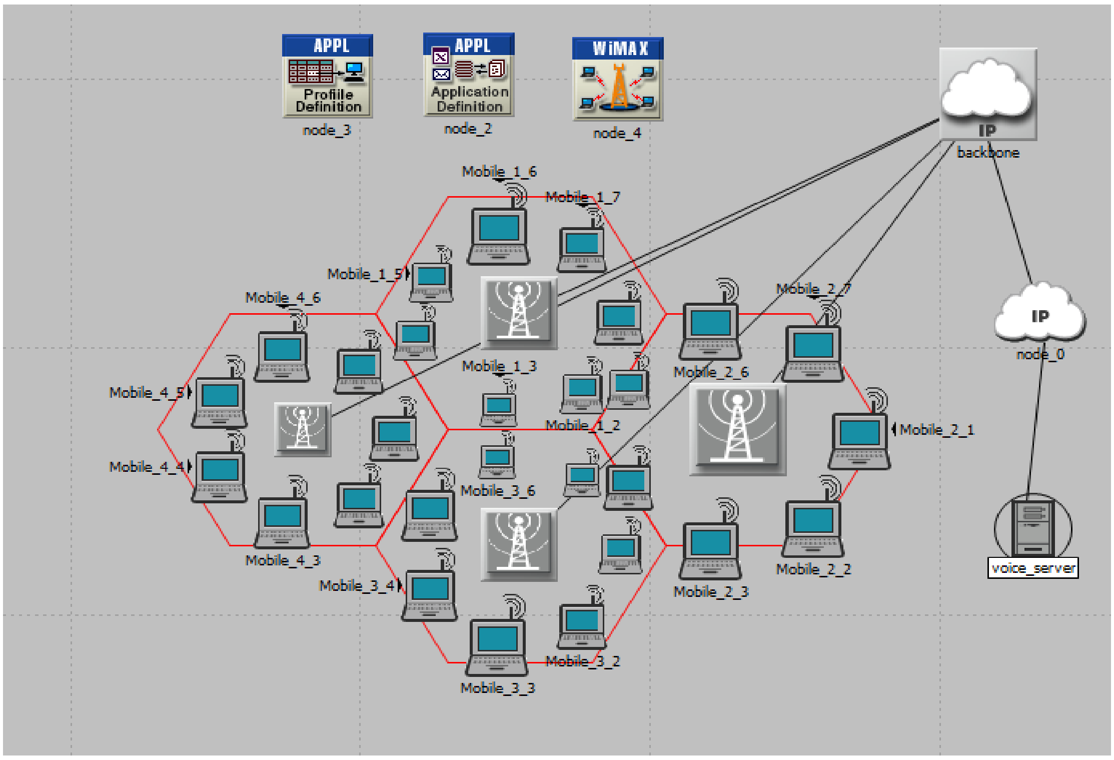


Figure 3-1: WIMAX network topology

Figure 3-2 shows the parameters for WIMAX base station and Figure3-3 shows subscribe station parameters.

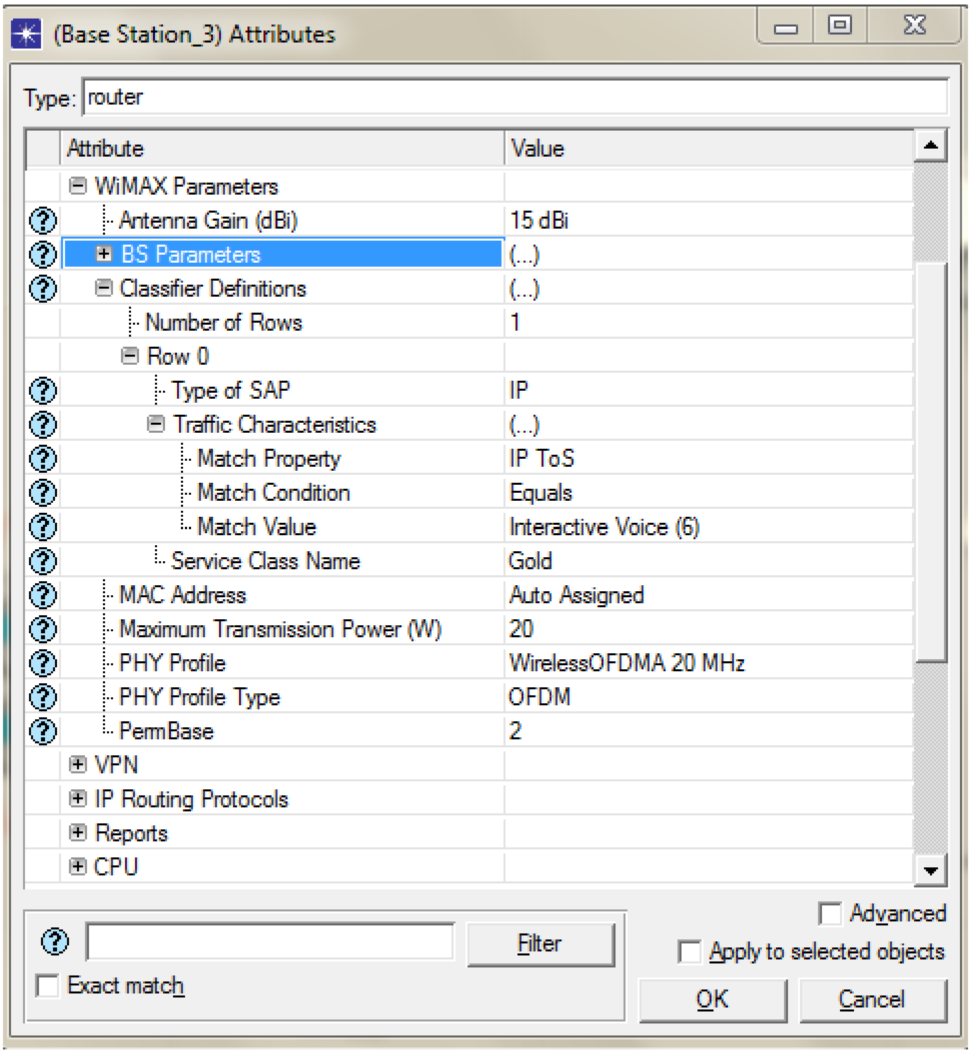


Figure 3-2: Base station parameters

With the simulation setup as mentioned, the voice codec being used for the Voice over IP calls is G.711 and the corresponding variation in voice jitter, MOS (Mean Opinion Score), Packet End-to-end delay and are noted.

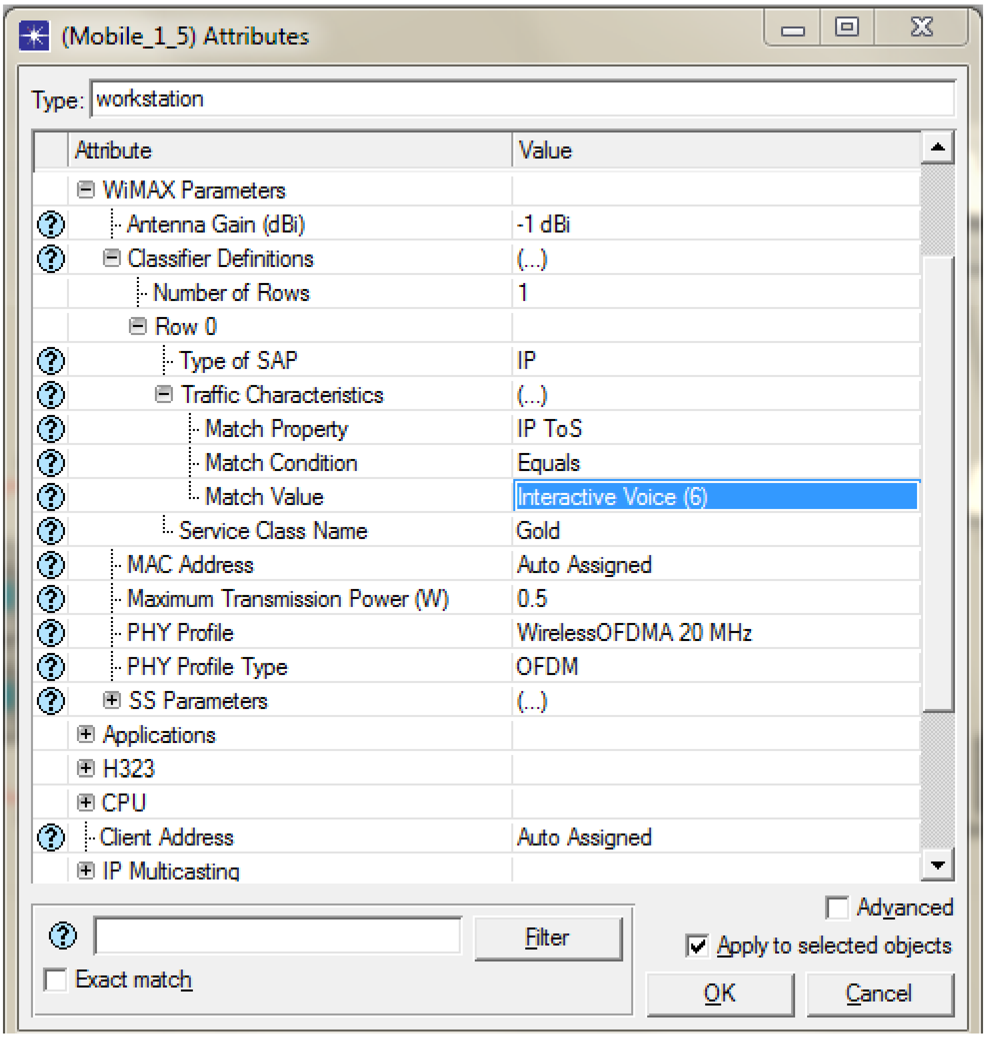


Figure 3-3: subscriber station (SS) parameters

3.2.2 WLAN NETWORK TOPOLGY

Figure 3-4 shows WLAN (IEEE 802.11b) network. Using the Wireless deployment wizard of OPNET a 4 celled WLAN network, with 7 subscriber stations in the range of an Access Point (AP) is deployed. The AP is connected to the core network by a server backbone via an IP backbone. The server backbone is connected to the voice server which is configured as the SIP server. The cell radius is set to be 100 m and the maximum transmission power set to be 0.005W. The numbers of subscribers in cells are 7. Voice over IP calls are setup in the network .The parameters set in the Access Points and the Subscriber Stations are shown in figures 3-5 and 3-6 respectively.

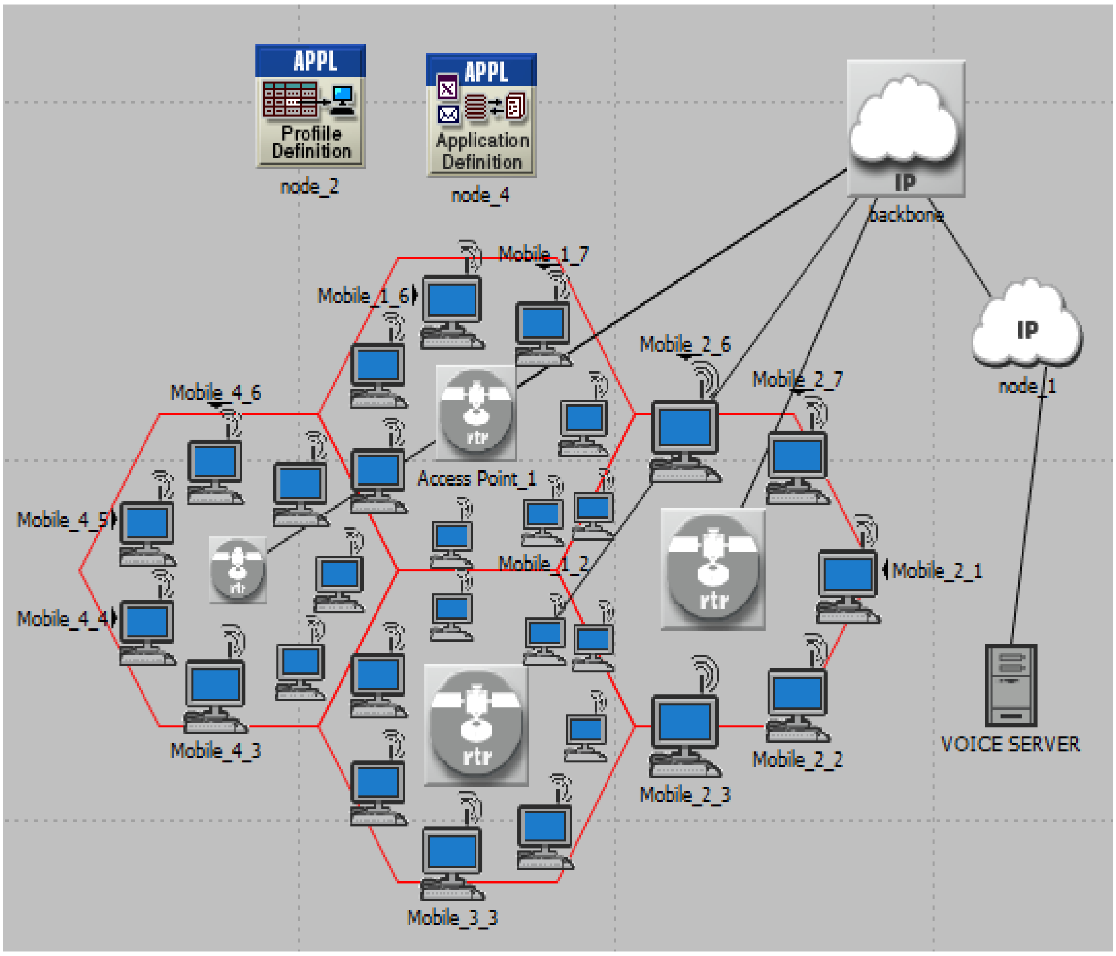


Figure 3-4: WLAN network topology

With the simulation setup as mentioned, the common voice codec being used for the Voice over IP calls is G.711 and the corresponding variation in voice jitter, MOS (Mean Opinion Score), Packet End-to-end delay and are noted.

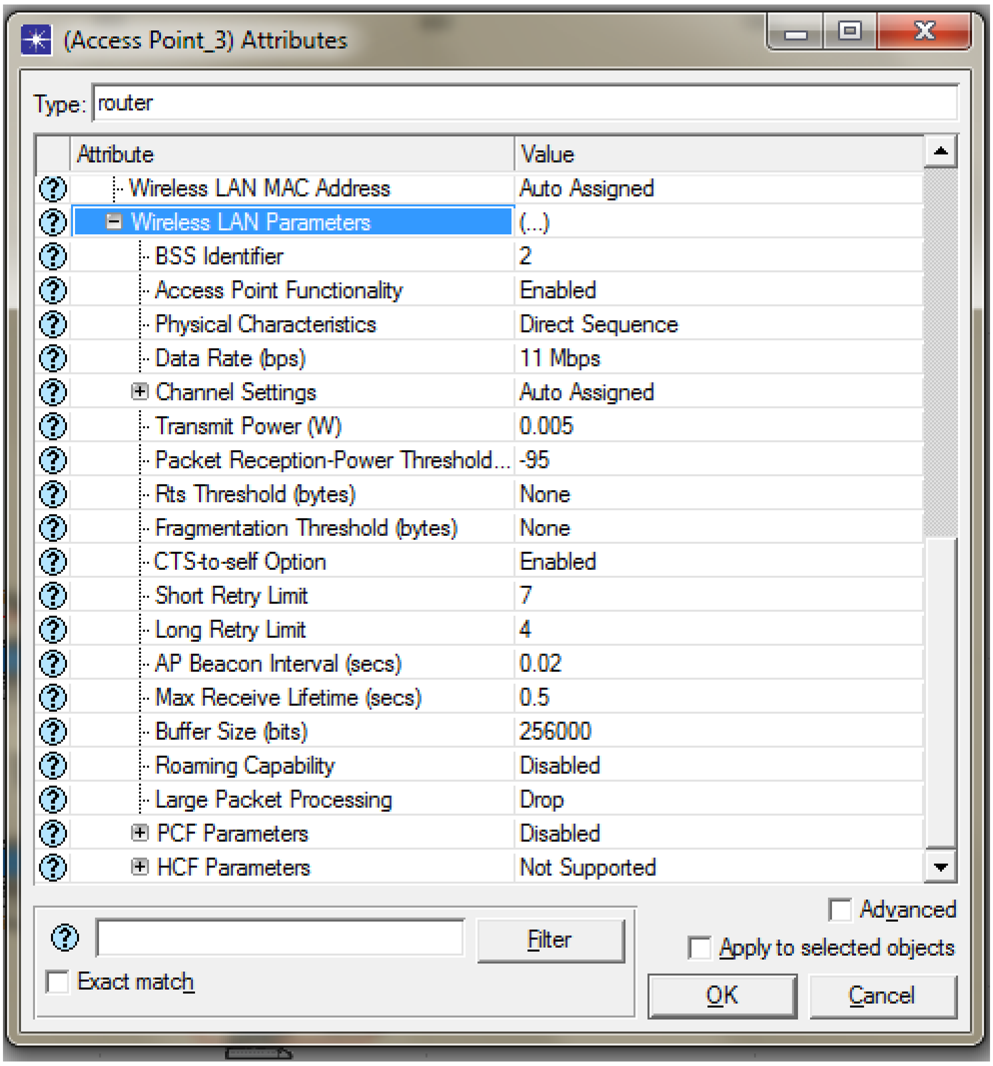


Figure 3-5 : Access point parameters

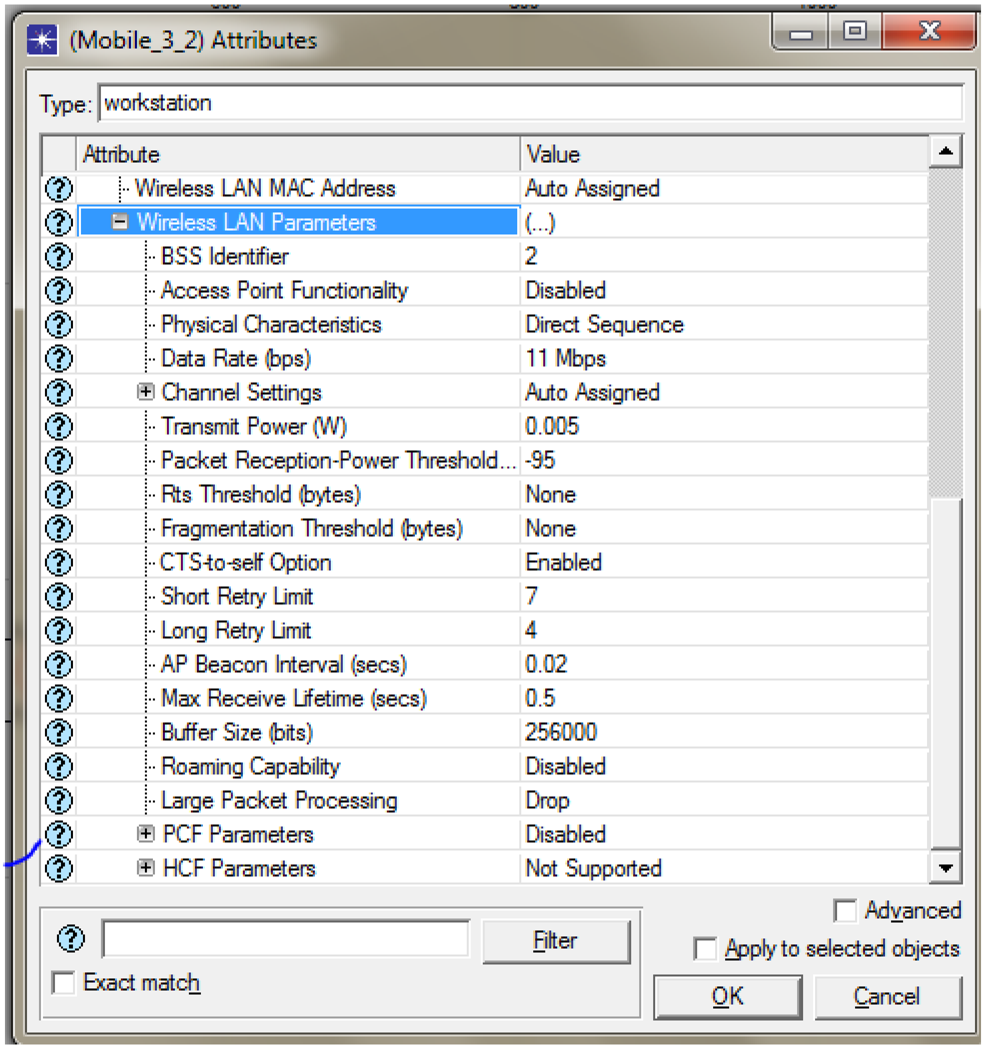


Figure 3-6: WLAN subscriber station parameters

3.2.3 WLAN-WIMAX Integrated Network Topology

An integrated scenario comprising of WLAN hotspots and WiMAX backbone is developed. The WiMAX backbone comprises of two base stations which are connected to the SIP server via three routers. A special type of node called SS_WiMAX_WLAN_AP having dual stack and behaving both as WLAN AP and WiMAX subscriber station is placed under the coverage of the Base Station. This node at the same time behaves both as the Subscriber Station of the WiMAX network and Access Point of the WLAN hot spot and acts like a bridge. There are 7 WLAN workstations under each such Access Points and VoIP calls are setup between the workstations of the two APs.

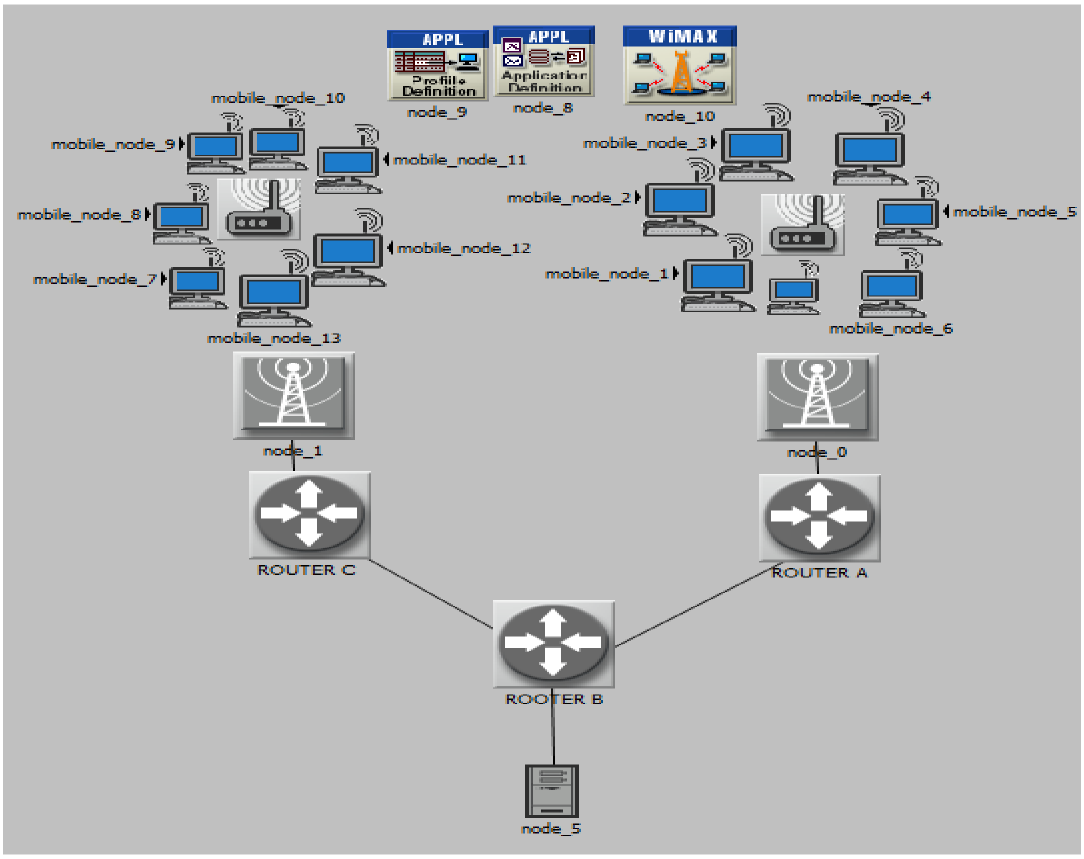


Figure 3-7: Network Model for WiMAX-WLAN Integrated Network

3.3 Network Configuration

3.3.1 Application Configuration

Application named VOIP-APP is created in the application definition at the application configuration node and the modulation scheme used is PCM with quality speech when silence suppression not used. When we use silence suppression we use PCM Quality speech with silence option. The attributes are shown in the figure 3-8.

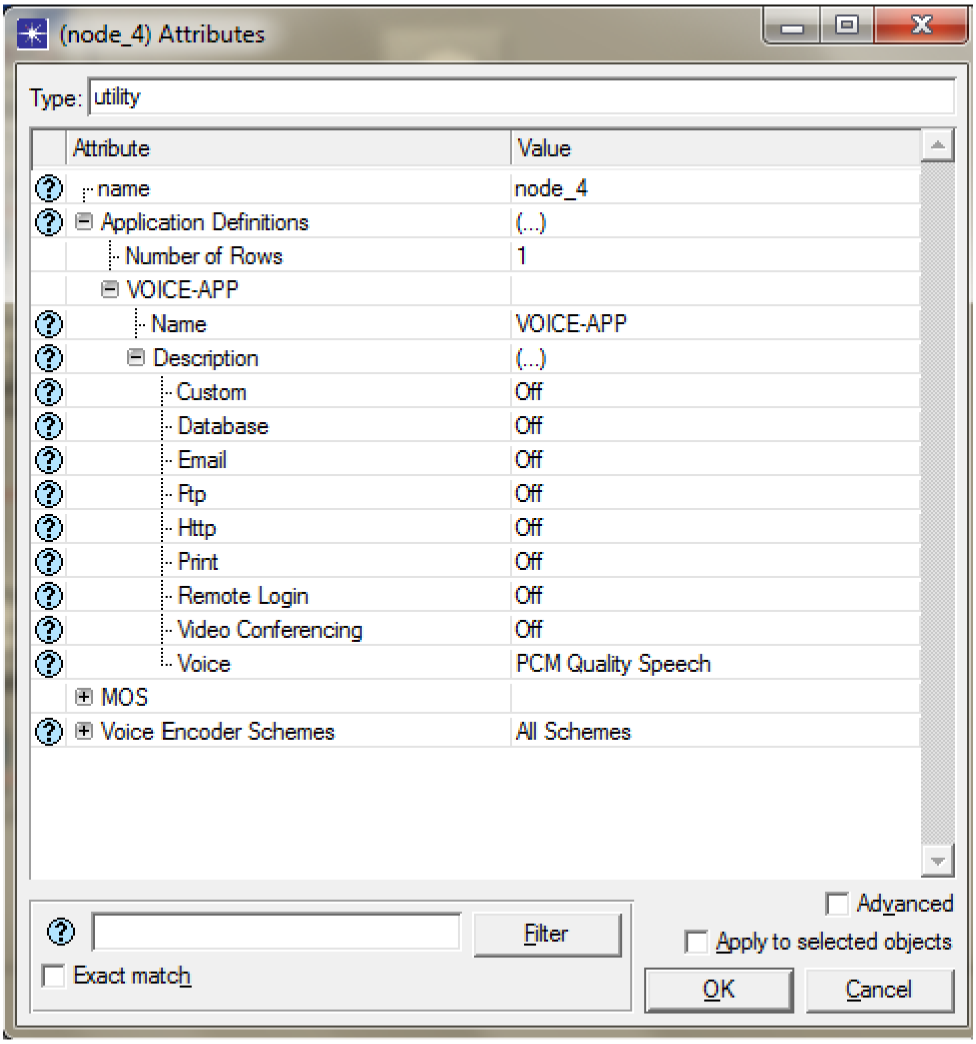


Figure 3-8: application configuration

3.3.2 Profile Configuration

Profile named VOIC-PRO is created in profile configuration node. This profile is used by mobile nodes to generate traffic. Profile is set to use by VOIP application and is set to begin at the start of the simulation and continues till the end of it. The attributes of profile configuration is shown at figure 3-9.

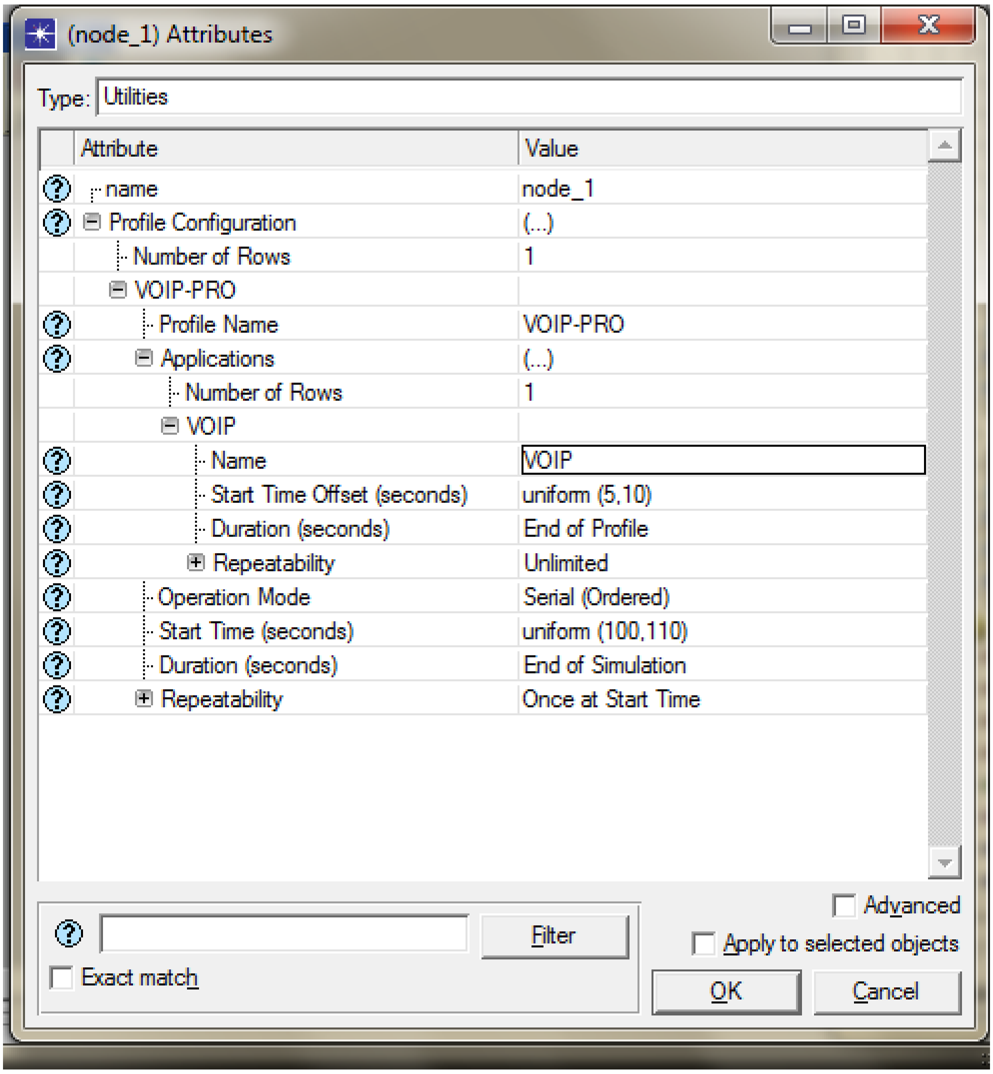


Figure 3-9: Profile configuration

Chapter four

Simulation result and analysis

Chapter Four

Simulation Result and Analysis

In this chapter a detailed analysis of the modeled networks performance of voice over IP for the three topologies is presented each with two scenarios, without silence suppression and with silence suppression. The three topologies is simulated to study the quality of service variation between WLAN,WIMAX and WLAN-WIMAX integrated in term of jitter, MOS value and packet End to End delay. The results of OPNET simulations are shown in the next section.

4.1 WiMAX Topology

4.1.1 Average MOS

In term of MOS figure 4-1 shows the mean opinion score (MOS) scored by VOIP application for VOIP without silence suppression which provide a MOS of 3.47 and with silence suppression it provide a MOS of **3.62.**The variance in MOS value for WiMAX is low because MOS value depends on numbers of packets dropped and the packet drop is low.

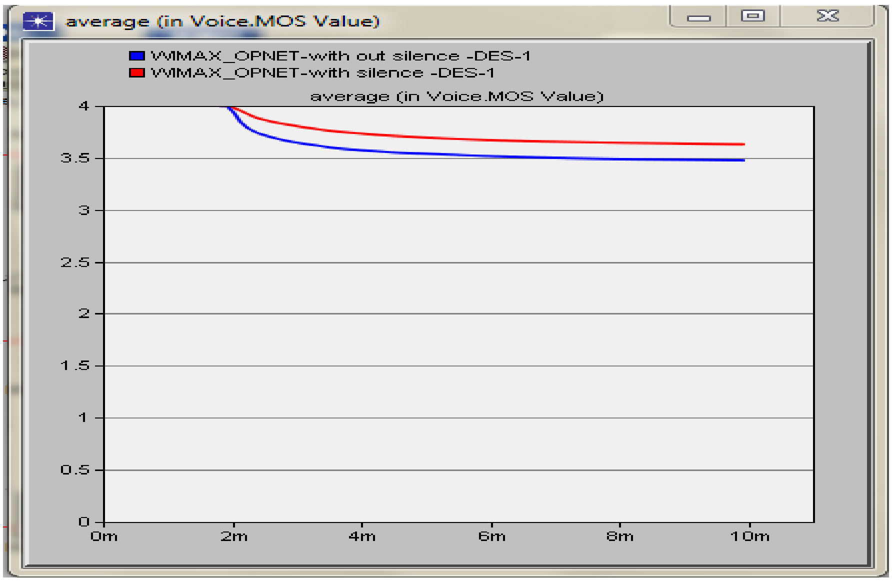


Figure 4-1: WiMAX average MOS value

4.1.2 Average packet delay variation

Figure 4-2 compares the packet delay variation (jitter) when using silence suppression and without using silence suppression. Without Silence suppression gives us a higher jitter with a value of **0.0011 sec** and when using silence suppression jitter is lower with a value of **0.0008**. Voice communication has 35% voice and 65% silence in it, to accommodate more users silence need to be suppressed this will save the bandwidth.

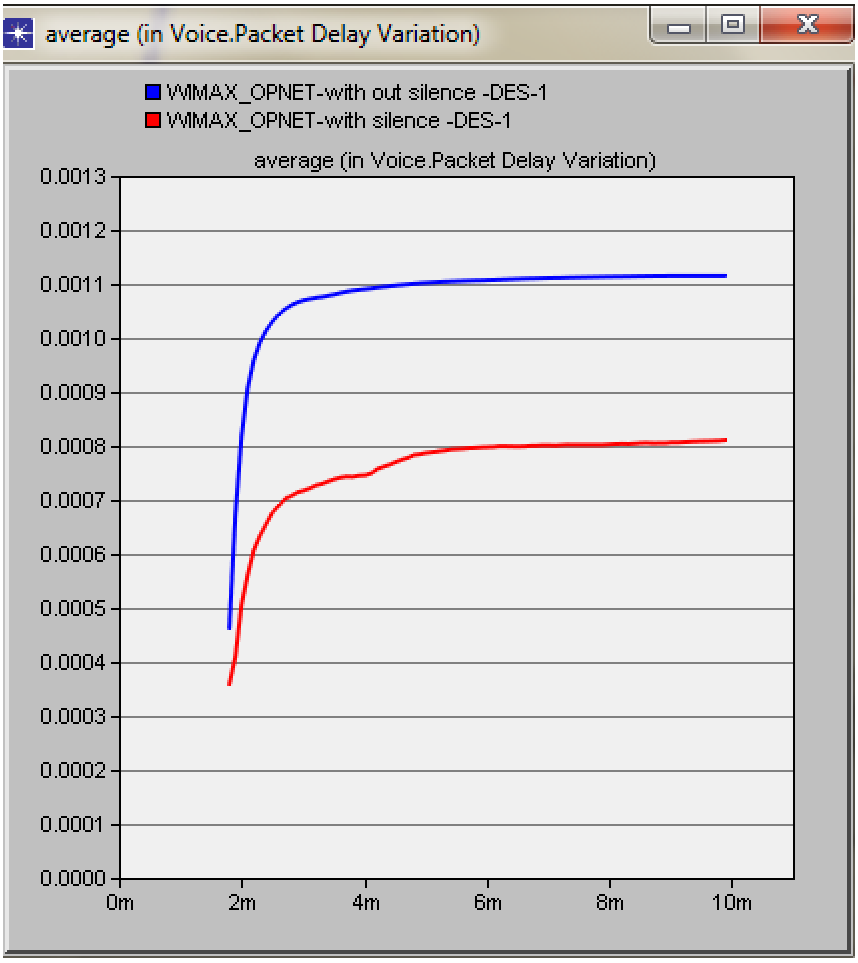


Figure 4-2: WiMAX average packet delay variation

4.1.3 Average Packet End to End Delay

VOIP experienced a packet end to end delay as shown in figure 4-3. As the number of packets increase the congestion increase. The congestion affects the packet delay. When using Silence suppression it decrease the number of packets which results in a lower packet end to end delay of **0.0919sec**. When not using silence suppression it produced a higher packet end to end delay of **0.0980 sec.**

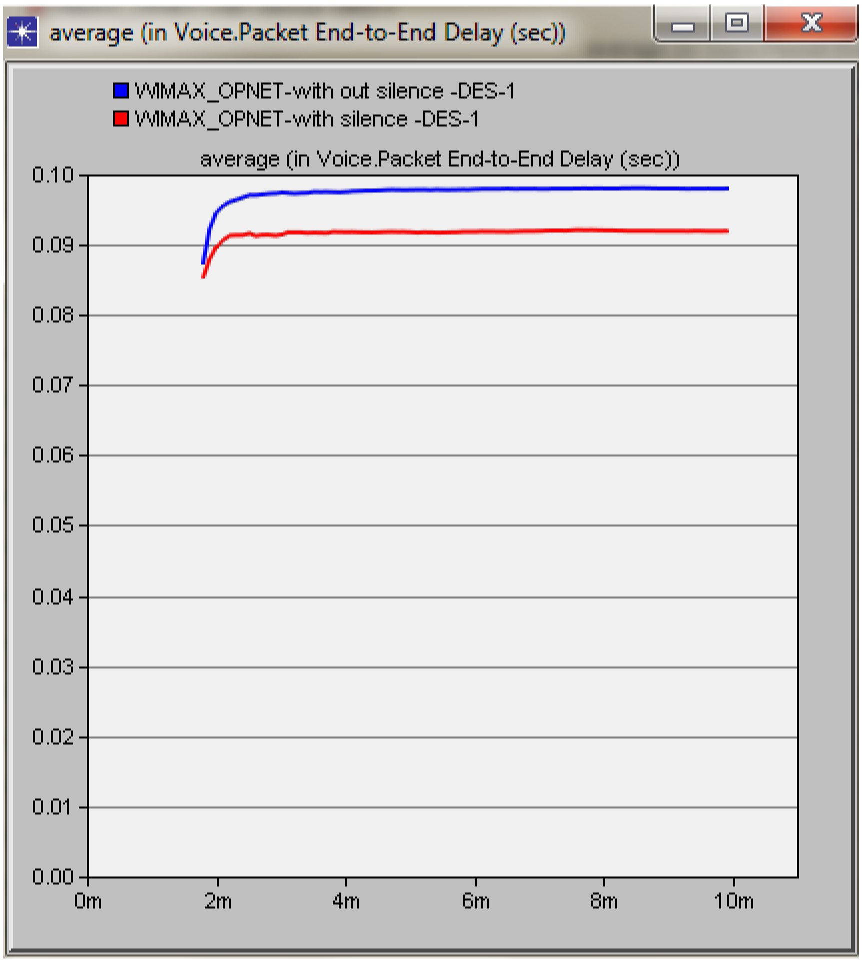


Figure 4-3: WiMAX packet end to end delay

4.2 WLAN Topology

4.2.1 Average MOS

Figure 4-4 shows the mean opinion score (MOS) obtained by the WLAN. As mentioned before MOS value is affected by number of packets dropped .without using silence suppression. It shows that the voice quality produced is unacceptable as it have scored a MOS value of **1.13** which implies a high packet drop and unacceptable quality of voice. Silence suppression has to be introduced and the improved MOS is **3.07**.

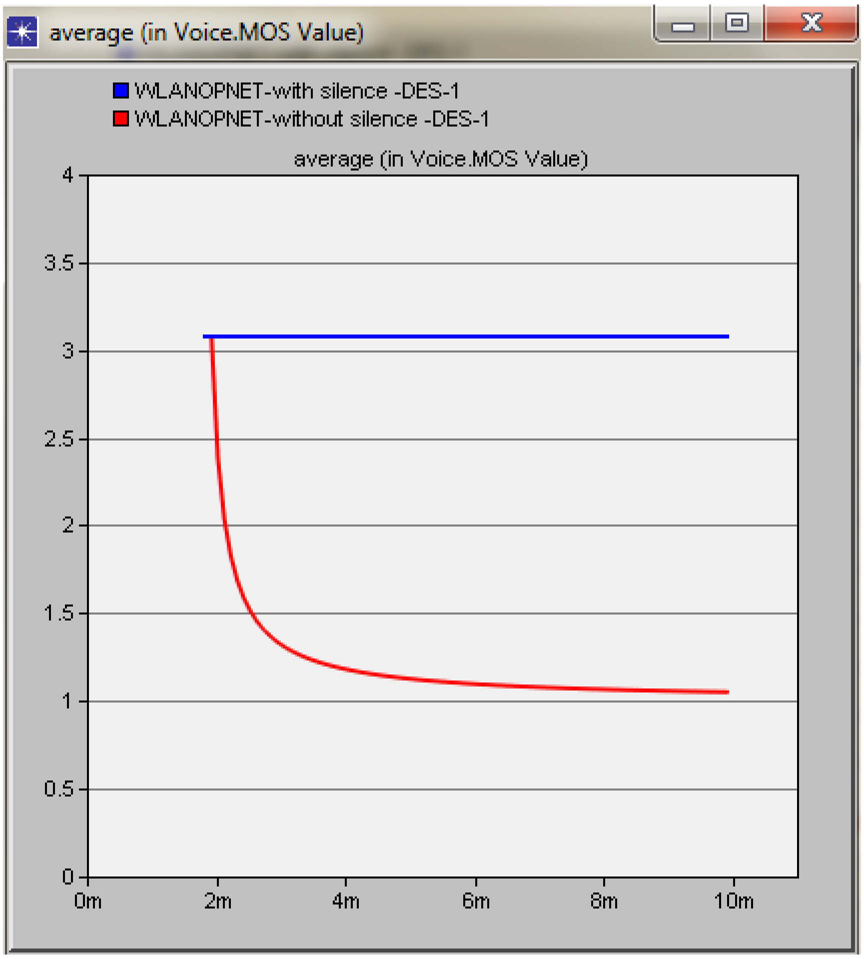


Figure 4-4: WLAN average MOS value

4.2.2 Average packet delay variation

In figure 4-5 the average jitter varies from higher value of **1.13 sec** when not using silence suppression to a very small value when silence suppression is used **0.00000042**.

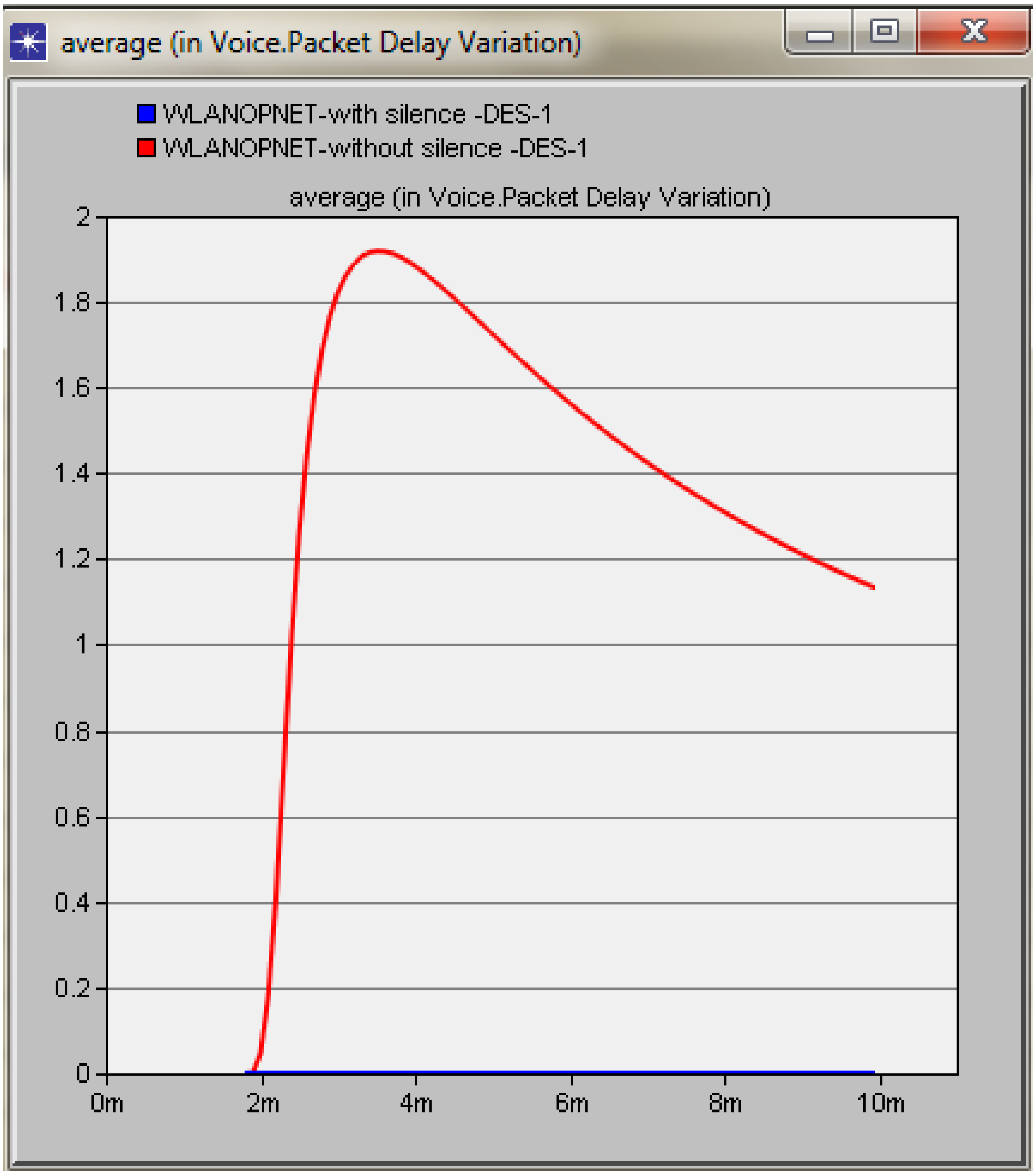


Figure 4-5: WLAN average packet delay variation

4.2.3 Average Packet End to End Delay

Average VOIP packet end to end delay is shown in figure 4-6, without silence suppression high end to end delay of **4.45 sec** is experienced. Because WLAN 802.11b provides a data rate of 11 Mbps and the Access points are overloaded with voice traffic this results in a bottleneck situation in the Access Points which results in packet drop any packet loss is interpreted as delay. With silence suppression lower end to end delay is produced and is considerably less of **0.061 sec.**

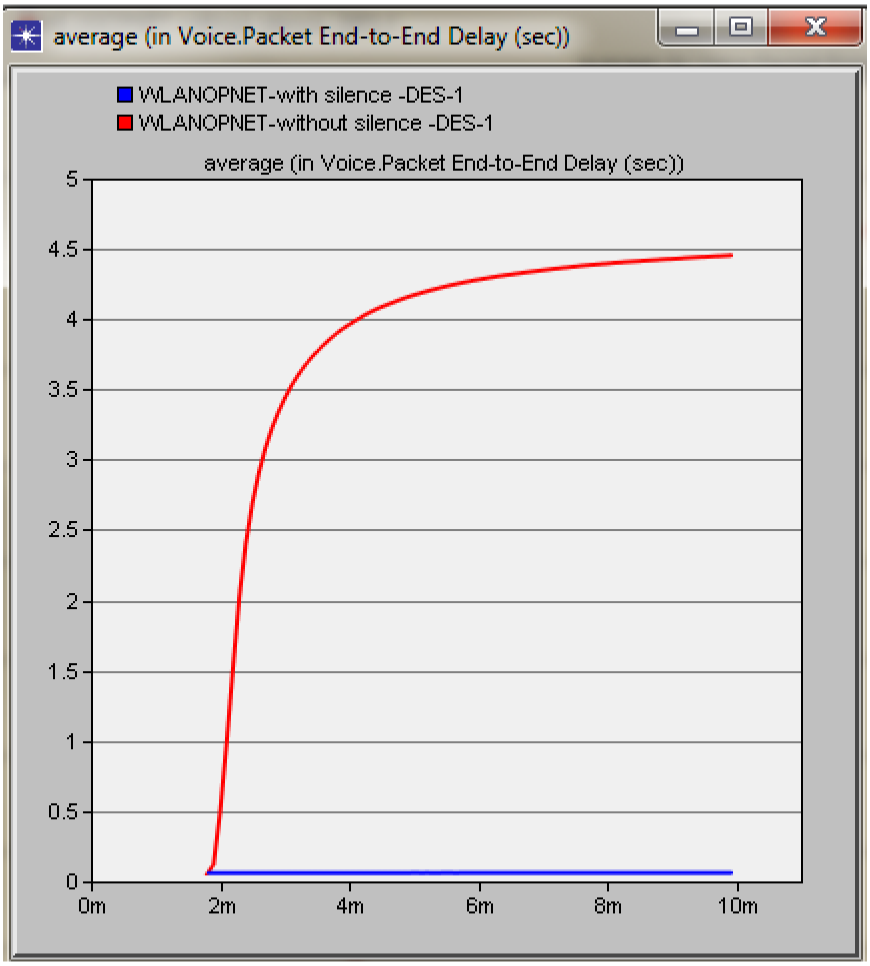


Figure 4-6: WLAN packet end to end delay

4.3 WLAN-WIMAX Integrated

4.3.1 Average MOS

As presented in the figure 4-7 below the MOS value without silence suppression achieved is **1.31** which doesn't provide a good VOIP Quality. With silence being suppressed in the communication period MOS improved to reach value of **4.0** implying that the network can provide acceptable quality of voice. And this is because the load on the network is released.

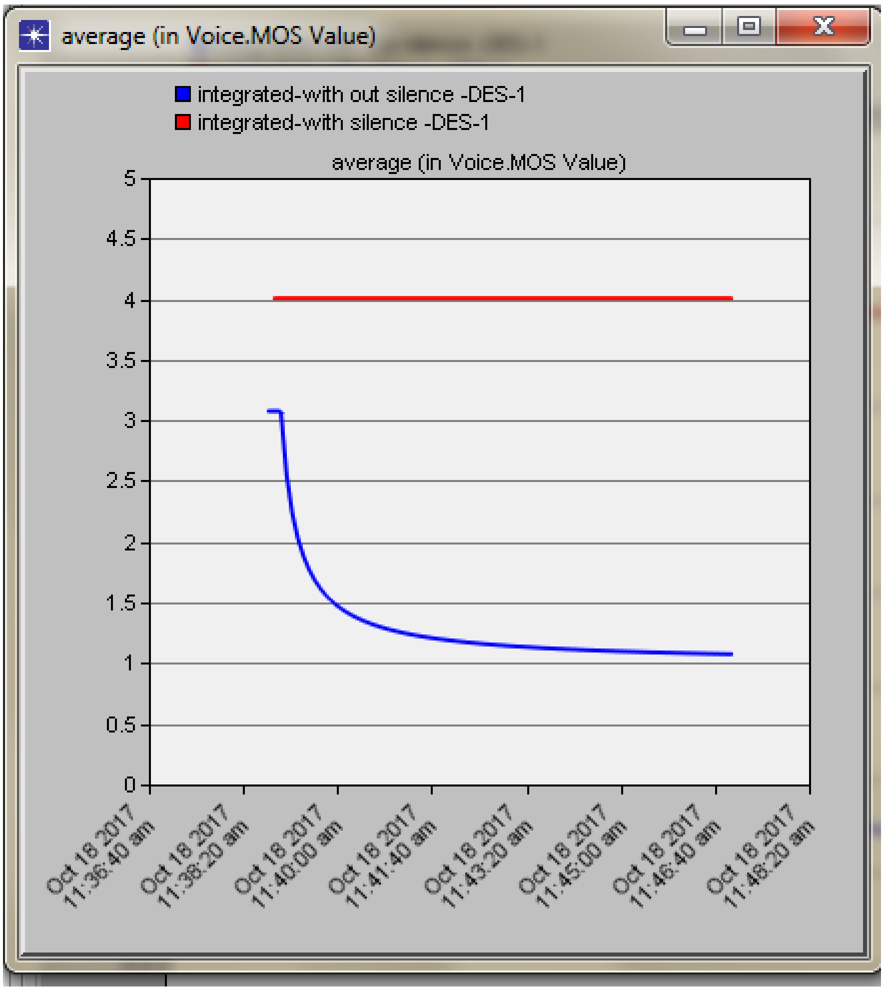


Figure 4-7: integrated network average MOS value

4.3.2 Average Packet delay Variation

The average packet delay variation produced is very small for the two cases. Its **0.0000010 sec** without silence suppression and **0.00000038 sec** when silence is suppressed. With voice activity detection enabled. It detects the silence period and prevents the paketisation of the background noise during the silence period.

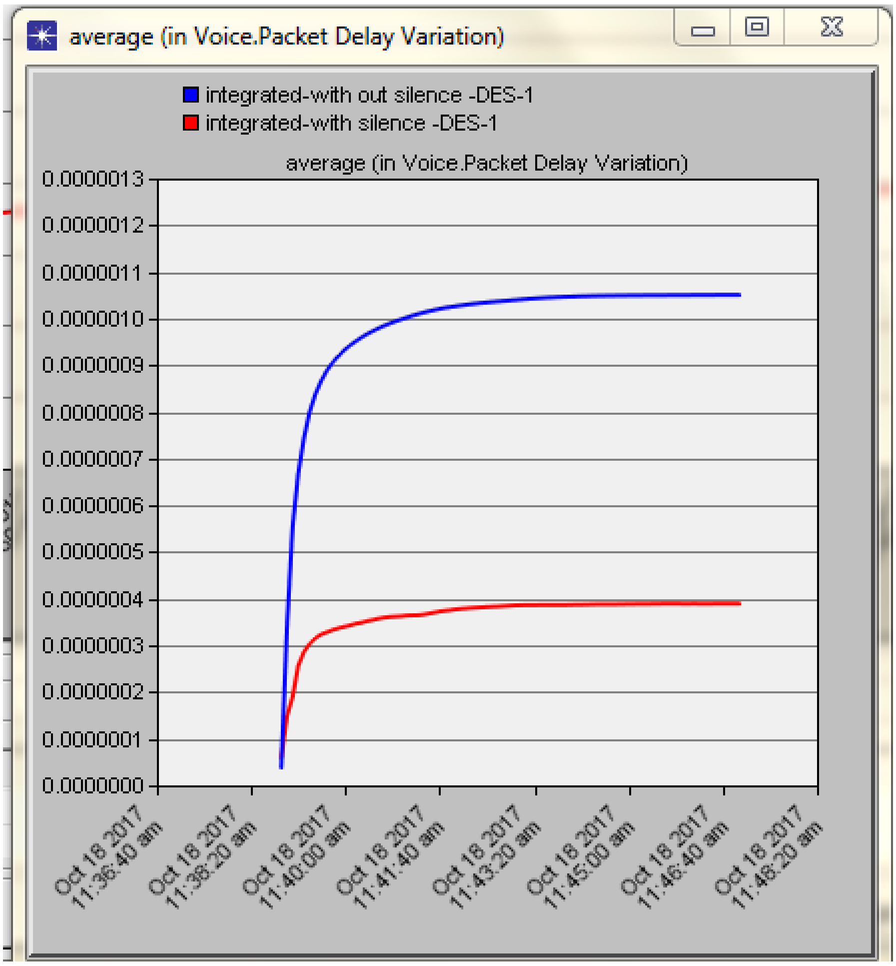


Figure 4-8: Integrated network average packet delay variation

4.3.3 Average Packet End to End Delay

The packet end-to-end delay for the WLAN-WiMAX integrated network is shown in figure 4-9. VOIP traffic experienced acceptable end to end delay; delay produced is **0.0621 sec** when silence suppression is not applied. And **0.0610 sec** when using it. Silence suppression basically identifies the silence period in the communication period by sensing the amplitude and stops packetizing the voice when silence happens. This decreases the number of packets in the network thereby releasing the network load.

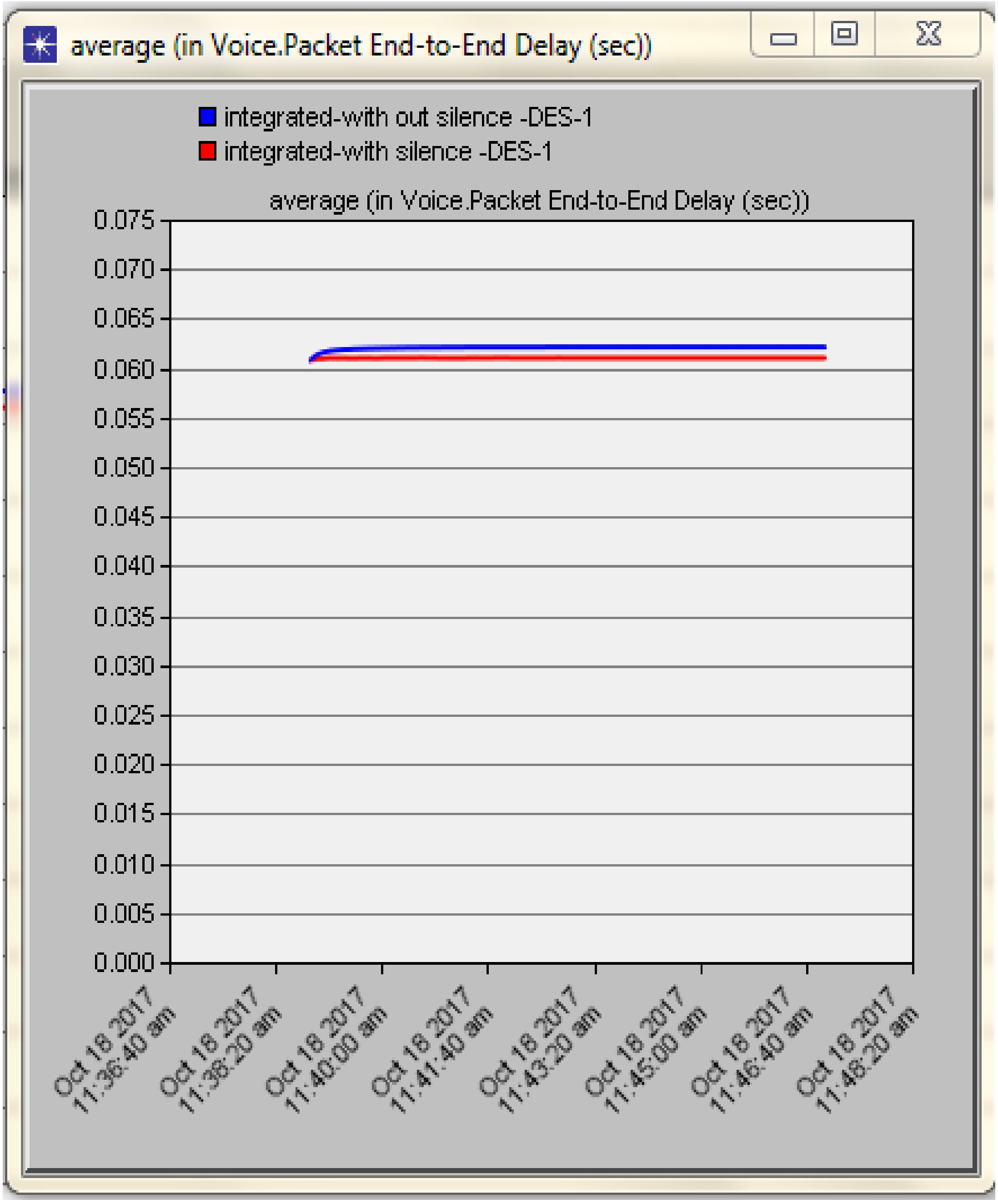


Figure 4-9: Integrated network average end to end delay

4.4 comparative analyses

The variation of jitter for the three networks for voice over IP is shown in figure 4-10. Perceived voice quality is considered to be good if the jitter is zero. As, shown in the figure, the average voice jitter is almost 0 for WiMAX implying good quality of voice in comparison to WLAN which has the highest jitter reaching **1.135 sec** . The integrated network shows a good jitter of **0.000001 sec** indicating a good performance.

As shown in figure 4-11 .With silence suppression average jitter is almost zero in both WLAN and WLAN-WIMAX integrated network while WiMAX has the highest value and shows increase from the other two.

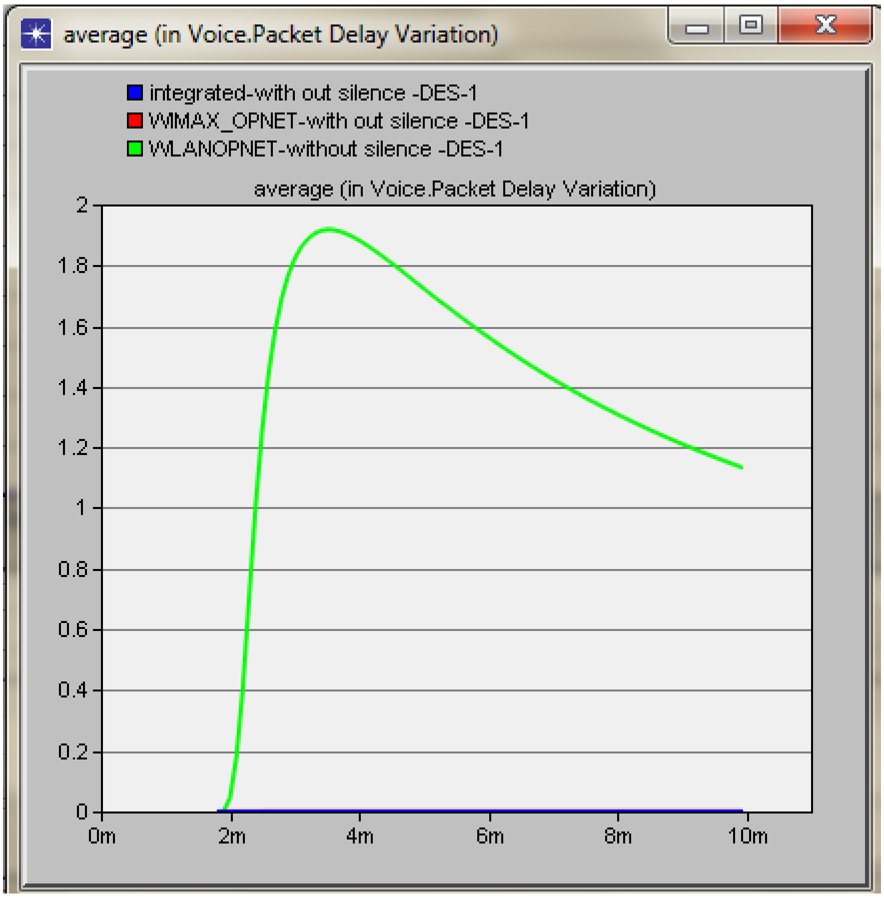


Figure 4-10: average packet delay without silence suppression

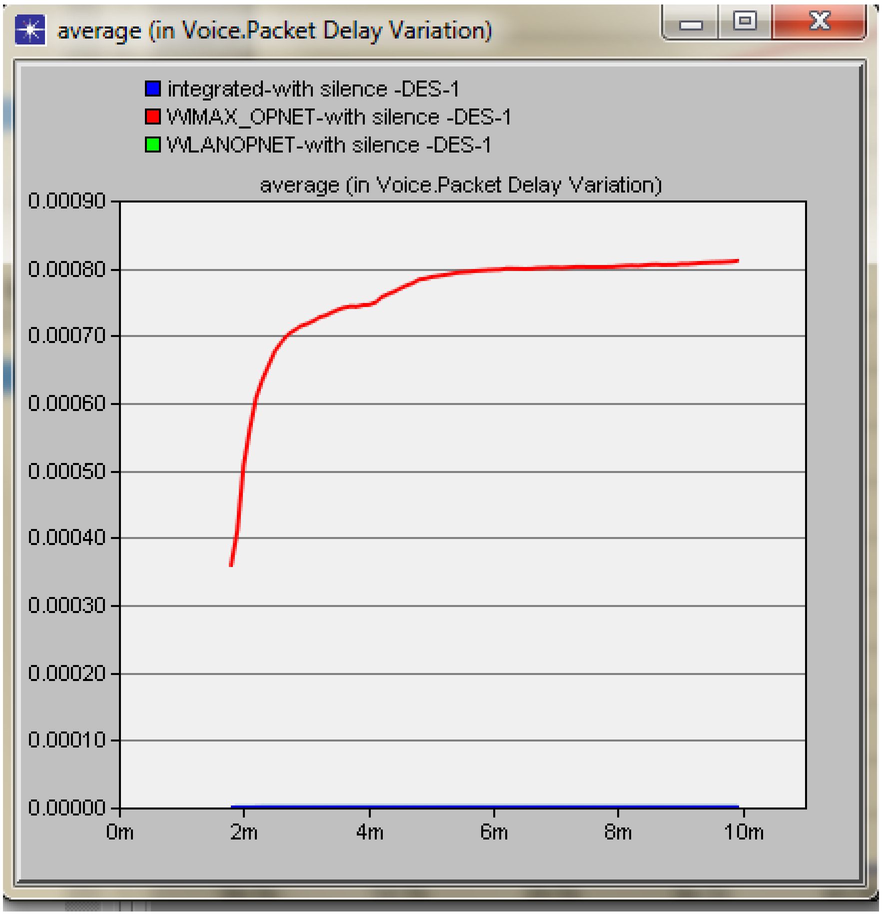


Figure 4-11: average packet delay with silence suppression

As shown in figure 4-12, the MOS value obtained for WiMAX is above **3.** For WLAN is almost **1** and for the integrated network it's about **1.31.** The result with silence suppression is totally different. As shown in Figure 4-13, integrated WLAN-WiMAX shows better performance among the three networks with a MOS value of **4** and improved WLAN MOS value about **3.07,** this is because with the silence suppression the number of packets in the network decreases thereby releasing the congestion in the WLAN network. This decreases the amount of packet dropped and thereby increases the MOS value.

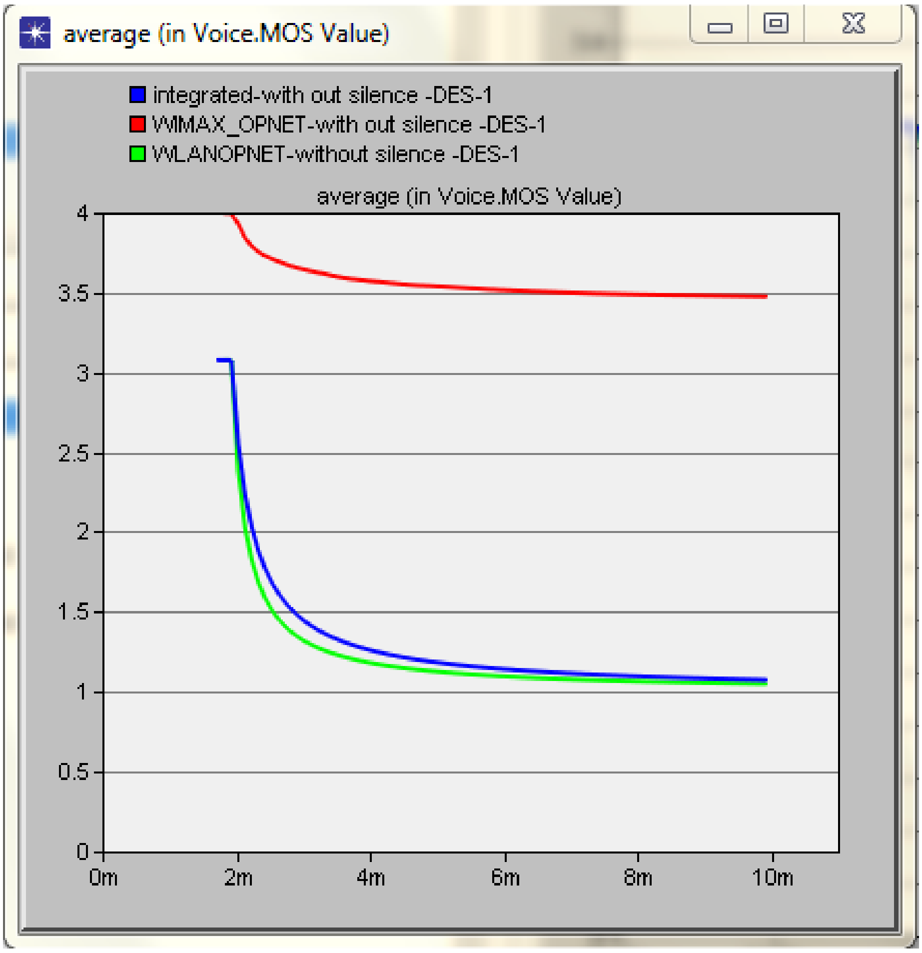


Figure 4-12 : average MOS value without silence supprsion

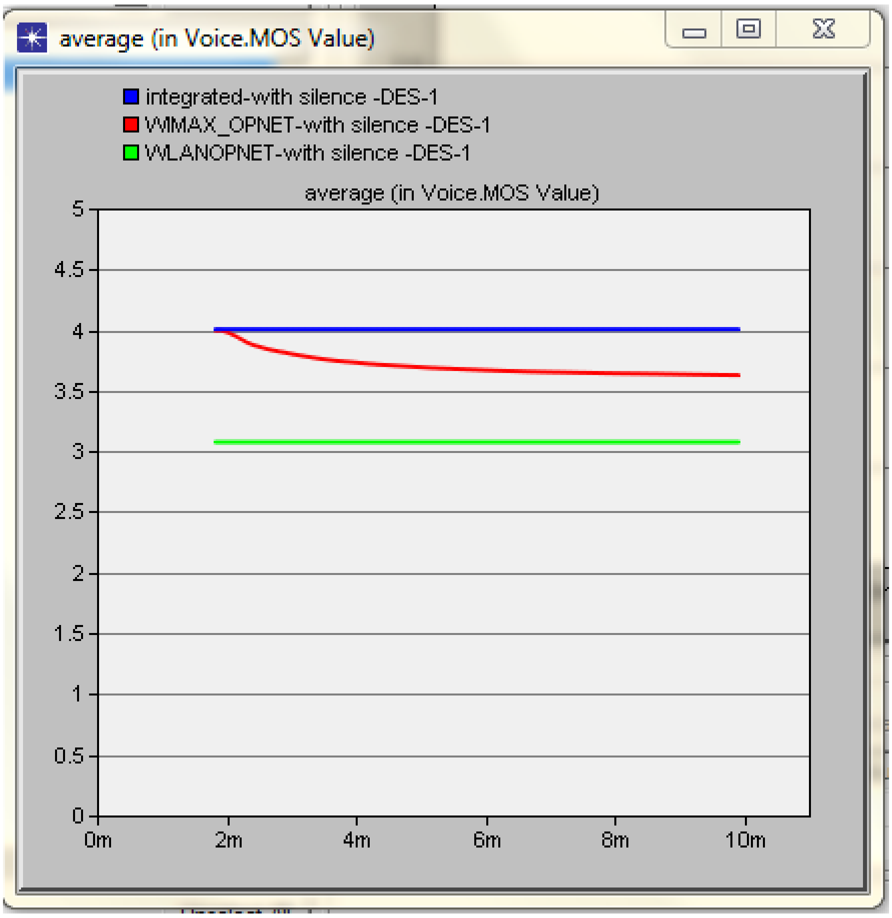


Figure 4-13 :average MOS value with silence supprssion

As shown in Figure 4-14, the packet end to end delay for voice without silence suppression is less than **0.5** seconds for WiMAX and for the integrated network . where as for WLAN it is very high reaching **4.45 sec** . This is because the silence periods is also packetised and send thereby creating huge bandwidth requirement and congestion in the WLAN network. The integrated network shows a packet end to end delay less than the WLAN and WiMAX network as the capacity of the network has got enhanced due to the integration thereby resulting in less congestion. On the other hand as shown in Figure 4-15, the packet end-to-end delay with silence suppression shows that WiMAX has a packet end-to-end delay more than WLAN and the integrated network has the same almost as that of WLAN network This is because with silence suppression the number of packets to be send decreases thereby releasing the congestion in the networks.

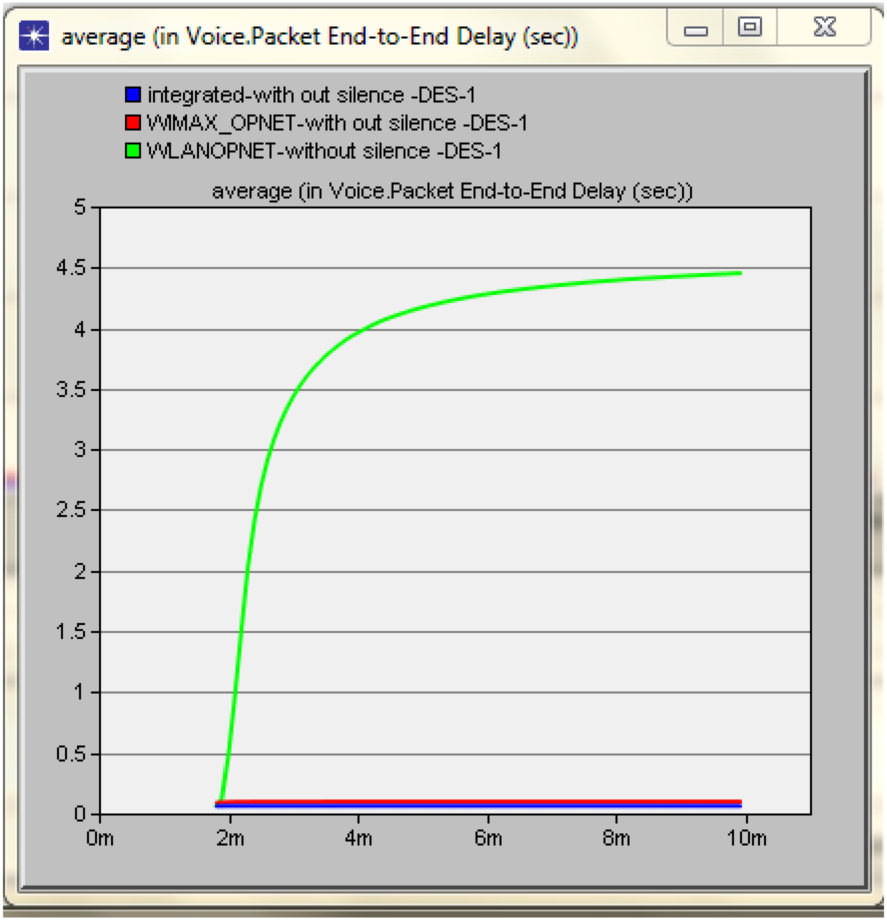
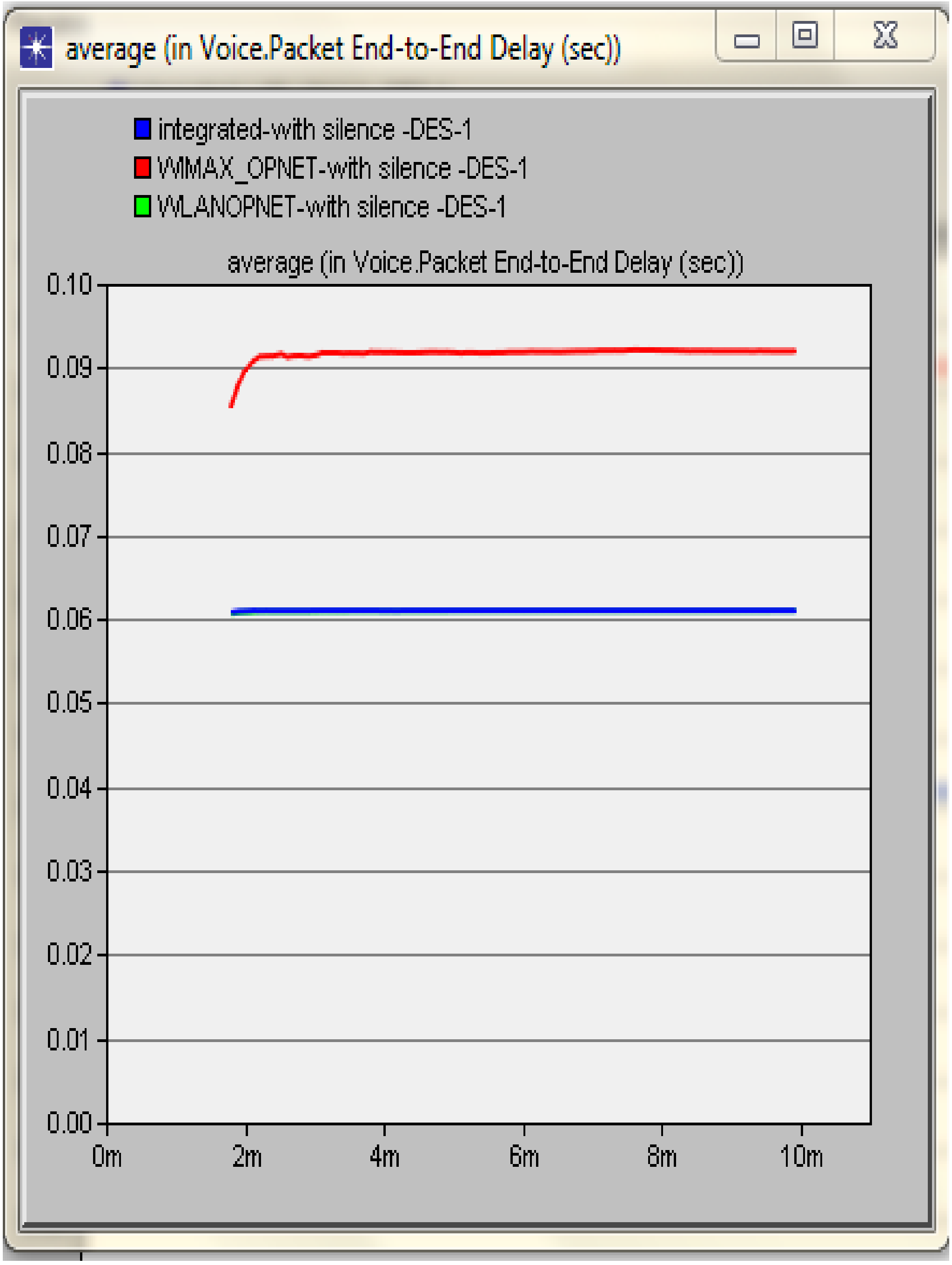


Figure 4-14: average packet end to end delay without silence suppression



Figurer 4-15: average packet end to end delay with silence suppression

Chapter five

Conclusion and future work

5.1 Conclusion

In this project OPNET 14.5 simulation tool is used to study and analyze VOIP application performance over WiMAX(IEEE 802.16) network, WLAN(IEEE802.11b) network and also on a WLAN-WiMAX integrated network . Different network performance metric including voice packet end to end delay, packet delay variation (jitter) and mean opinion score (MOS) value are used to determine quality of voice over IP (VOIP) calls generated in the network.

We studied the performance of VOIP application under two different cases. When silences is suppressed in the network and without silence suppression. These two approaches are done to the three topologies and the effect of the silence suppression on VOIP is defined.

The results of the project simulation reveal that WiMAX network perform better in term of jitter, MOS and end to end delay than WLAN (IEEE802.11) for VOIP application when silence suppression is not considered. With silence suppression come in the picture WLAN provide a better voice quality than WiMAX. On the other hand the integrated network performs almost like WLAN when silence suppression is not used. When silence is suppressed it performs much better than other two.

5.2 Future Work

This project worked on the performance of WLAN 802.11 and WiMAX 802.16 networks for voice application. It can be extended to use other applications like video conferencing, file transfer protocol or HTTP.

The integrated network is deployed using WiMAX (IEEE802.16) and WLAN (IEEE802.11b), these part can be extended by using LTE instead of WiMAX and analyze the performance of the network. Another work can be done is to use IEEE802.11a which provide high data rate of 54Mpbs or another improved IEEE802.011 standard instead of IEEE802.11b.

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