**Sudan University of Science and Technology**

**College of Engineering**

**Electronics Engineering**


# Performance Evaluation of VoIP over WiMAX

*A Research Submitted in partial Fulfillment for the Requirement of the Degree of B.Sc.(Honors)in Electronics Engineering*


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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

{الله نور السماوات والارض مثل نوره كمشكاة فيها مصباح المصباح في زجاجة الزجاجة كأنها كوكب دري يوقد من شجرة مباركة زيتونة لا شرقية ولا غربية يكاد زيتها يضيء ولو لم تمسسه نار نور على نور يهدي الله لنوره من يشاء ويضرب الله الأمثال للناس والله بكل شيء عليم}

سورة النور الاية(35)

# DEDICATION

Years of my life I started it with just one step and one day at a time and here I am now looking at the results of my efforts, journey of years where my goals were set and my dream was to achieve them one day and today I stand before with it accomplished.

To my angel, to the true meaning of love and compassion, who her love and prayers was the reason to my success, to my precious love my beloved mother.

To the person I proudly carry his name, who taught me to give without waiting for thanks or gratitude, which his words will always remain as my guiding stars in this life, to my dear father.

To my soul mates and my best friends in this life, who accompanied me step by step in my journey and stand by me against everything and helped me to stand where I am now, my brothers and sisters.

To whom I learned with them the true meaning of friendship and loyalty, which I found and knew I shouldn’t let go of them, to whom I shared the pain and the joy of the journey and helped me to stronger to my friends.

To who guided me the whole way with his knowledge and mind, to the person whom helped me through this and was generous with their time and advices, to my respect teachers.

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# Abstract

This project is to study, analyze, plan, design, simulate and evaluate performance of Voice over Internet Protocol through WiMAX network using Opnet software program to detect the acceptable number of nodes which provide less than over packet loss, jitter delay and end to end delay.The object is reduce time delay and data loss and evaluate parameters to achieved good quality of service. Design environment of simulation on Opnet software program and testing each scenario change number of nodes according to packet loss, jitter delay and end to end delay.

# المستخلص

هذا المشروع هو دراسة و تحليل و تخطيط و تصميم و محاكاة و تقييم أداء الصوت عبر بروتوكول الانترنت خلال شبكة وايماكس باستخدام برنامج الاوبنت لكشف عدد المستحدمين الذي يقدم اقل فقد بيانات وتاخير في زمن الوصول والزمن الكلي والهدف من المشروع تق ليل فقد البيانات و زمن الوصول وتمت محاكاة بيئة المشروع في برنامج الاوبنت واختبار عدد من السيناريوهات في تغيير عدد المستخدمين لدراسة التغير في فقد البيانات والتاخير في زمن الوصول والزمن الكلي.

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# LIST OF FIUGERS

## LIST OF ABBREVIATION

| | |
|---|---|
| 3G | Third Generation. |
| AAA | Authentication, Authorization and Accounting Server. |
| ASN | Access Service Network. |
| ASN-GW | Access Service Network Gateway. |
| ATM | Automatic Teller Machine. |
| BT | Base Transceiver Station. |
| CID | Connection Identifier. |
| CSMA/CA | Collection Senses Multiple Accesses With Collision Avoidance. |
| CSN | Connectivity Service Network. |
| CPE | Customer Premises Equipment. |
| DHCP | Dynamic Host Control Protocol. |
| FTP | File Transmission Protocol. |
| GK | Gate Keeper. |
| HA | Home Agent. |
| HTTP | Hypertext Transfer Protocol. |

| | |
|---|---|
| IEEE | Institute of Electrical and Electronics Engineers. |
| ITU | International Telecommunications Union. |
| ITU-T | Telecommunication Standardization Sector of the International Telecommunications Union. |
| IP | Internet Protocol. |
| LOS | Line Of Sight. |
| MAC | Medium Access Control. |
| MS | Mobile Station. |
| MOS | Mean Opinion Score. |
| MG | Media Gateway. |
| MGC | Media Gateway Controller. |
| MSDU | MAC Service Data Units. |
| MPDU | Moderately Priced Dwelling Unit. |
| QoS | Quality of Service. |
| NLOS | Non Line Of Sight. |
| PHY | Physical Layer. |
| PMP | Point to Multipoint. |
| PKMv2 | Privacy Key Management Version Two. |
| PSTN | Public Switched Telephone Network. |
| RF | Radio Frequency. |
| PBX | Private Branch Exchange. |
| RTP | Real Time Protocol. |
| SFID | Service Flow Identifier. |

| | |
|---|---|
| SIP | Session Initiation Protocol. |
| SMTP | Simple Mail Transfer Protocol. |
| SS | Subscriber Station. |
| TDM | Time Division Multiplexing. |
| UDP | User Datagram Protocol. |
| VoIP | Voice over Internet Protocol. |
| VoFi | Voice over Wireless Fidelity. |
| VOBB | Voice over Broadband. |
| WI-IF | Wireless Fidelity. |
| WiMAX | Worldwide Interoperability for Microwave Access. |
| WMANs | Wireless Metropolitan Area Networks. |
| WMF | WiMAX Forum Network Architecture. |

# Chapter One

# Introduction

# Chapter one

# Introduction

## 1.1 Preface

The history of WiMAX starts back in the 1990s with the realization that there would be a significant increase in data traffic over telecommunications networks. With wired telecommunications networks being very expensive, especially I outlying areas and not installed in many countries, wire-less methods were investigated.

WiMAX history started with these investigations into what was termed the last mile connectivity - methods of delivering high speed data to a large number of users who may have no existing wired connection[1].

The clearly indicates the need of a communication technology which should be cheap, with no specific time limits, give features and is easily accessible everywhere. The combination of Voice over IP (VoIP) over wireless combination is one of those Solutions which can fulfill most of the above requirements[5].

Packet loss describes an error condition in which data packets appear to be transmitted correctly at one end of a connection, but never arrive at the other. This might be because:

- Network conditions are poor and the packet became damaged in transmit.
- The packet was deliberately dropped at a router because of internet

## 1.2 Problem statement

Packet loss, jitter and end to end delay effective indirect on coverage area by effect on number of nodes that provide acceptable value of delay and loss .

## 1.3Proposed solutions

Evaluation performance of the network system according to change of number of nodes to determine the suitable value of number nodes based on standard packet loss, jitter and end to end delay .

## 1.4Objective

The aim of the project is evaluation performance of VoIP over WiMAX to achieve this objective:

1. Reduce the data loss.
2. Low cost.
3. High security.
4. Reduce delay.
5. Good QoS.

## 1.5 Methodology

Design of the software program using Opnet software program to simulate and perform packet loss, jitter and end to end delay for WiMAX network and evaluate the performance of the system to reduce the loss and delay.

## 1.6 Research Outlines

The project consists of four chapters, the rest chapters are:

Chapter one:

Provide background over view, problem definition, objective, methodology and chapters over view.

Chapter two:

Consider about WiMAX definition, architecture, components, types and applications.additonal VoIP definition, QoS parameters .

Chapter three:

Physical model, mathematical model, computer model,

Opnet simulation, result and result analysis.

Chapter four:

Conclusion and recommendations .

# Chapter Two

# Literature Review

# Chapter two

# Literature review

## 2.1 WiMAX Concept

WiMAX is short for Worldwide Interoperability for Microwave Access. It is a metropolitan wireless standard created by the companies Intel and Alvarion in 2002 and ratified by the IEEE (Institute of Electrical and Electronics Engineers) under the name IEEE-802.16. More precisely, WiMAX is the commercial designation that the WiMAX forum gives to devices which conform to the IEEE 802.16 standard, in order to ensure a high level of interoperability among them.[8]

## 2.2 Goals of WiMAX

The goal of WiMAX is to provide high-speed Internet access in a coverage range several kilometers in radius. In theory, WiMAX provides for speeds around 70 Mbps with a range of 50 kilometers. The WiMAX standard has the advantage of allowing wireless connections between a base transceiver station (BTS) and thousands of subscribers without requiring that they be in a direct line of sight (LOS) with that station. This technology is called NLOS for non-line-of-sight. In reality, WiMAX can only bypass small obstructions like trees or a hou.se and cannot cross hills or large buildings. When obstructions are present, actual throughput might be under 20 Mbps.[11]

## 2.3 Types of WiMAX

The revisions of the IEEE 802.16 standard fall into two categories:

- Fixed WiMAX, also called IEEE 802.16-2004, provides for a fixed-line connection with an antenna mounted on a rooftop, like a TV antenna. Fixed WiMAX operates in the 2.5 GHz and 3.5 GHz frequency bands, which require a license, as well as the license-free 5.8 GHz band.[12]
- Mobile WiMAX, also called IEEE 802.16e, allows mobile client machines to be connected to the Internet. Mobile WiMAX opens the doors to mobile phone use over IP, and even high-speed mobile services.

## 2.4 Applications of WiMAX

One of WiMAX's potential uses is to cover the so-called "last mile" (or "last kilometer) area, meaning providing high-speed Internet access to areas which normal wired technologies do not cover (such as DSL, cable, or dedicated T1 lines).

Another possibility involves using WiMAX as a backhaul between two local wireless networks, such as those using the Wi-Fi standard. WiMAX will ultimately enable two different hotspots to be linked to create a mesh network

## 2.5 WiMAX and Quality of Service

The WiMAX standard natively supports Quality of Service (often called *QoS* for short), the ability to ensure that a service works when used. In practice, WiMAX lets bandwidth be reserved for a given purpose. Some applications cannot work properly when bottlenecks occur. This is the case for Voice over IP (VoIP), as spoken communication is ineffective when gaps a second long are introduced.

## 2.6 WiMAX Standards

| Standard | Frequency | Status | Range |
|---|---|---|---|
| IEEE std 802.16 | Defines wireless metropolitan area networks (WMANs) on frequency bands higher than 10 GHz. | October 2002 | Obsolete |
| IEEE std 802.16a | Defines wireless metropolitan area networks on frequency bands from 2 to 11 GHz inclusive. | October 9, 2003 | Obsolete |
| IEEE 802.16b | Defines wireless metropolitan area networks on frequency bands from 10 to 60 GHz inclusive. | | Merged with 802.16a (Obsolete) |
| IEEE std 802.16c | Defines options (profiles) for wireless metropolitan area networks in unlicensed | | July 2003 |

| | | | |
|---|---|---|---|
| | frequency bands. | | |
| IEEE 802.16d (IEEE std 802.16-2004) | Revision incorporating the 802.16, 802.16a, and 802.16c standards. | October 1st, 2004 | Active |
| IEEE std 802.16e | Allows wireless metropolitan area networks to be used by mobile clients. | | not ratified |
| IEEE std 802.16f | Allows wireless mesh networks to be used. | | not ratified |

## 2.7 Optimal Modem Placement

It is important to note that WiMAX signals are emitted through radio waves and careful indoor placement can significantly boost indoor coverage.

As such, WiMAX Operators should educate users on where and how to place their indoor modem. Firstly, by simply placing the indoor modem.firstly the window that faces the nearest base station can improve the Antenna performance dramatically. This is because radio wave penetration loss for glass (6dB) is much lower than the penetration loss for concrete walls (13dB or more).

Secondly, placing the modem near the window as opposed to a distance away from the window yields better Throughputs as a result of improved indoor coverage. From observation and trial runs conducted, Green packet estimates a throughput reduction of 20-40% when the modem is placed 10m away from the window (and deeper into the room).

However, this finding is subjective and may vary in different countries, depending on distance from base station and RF
Environments.[9]

## 2.8 VoIP Components

Before committing to a commercial VoIP plan or business, a couple of things must be considered. VoIP equipment can be introduced gradually or at full capacity and with any number of specialized equipment to transport and control voice communication over IP. Call agents such as Gate keeper (GK), Media Gateway Controller (MGC), SIP Server, and Soft Switch (SS) can perform translation between ITU E.164 telephone numbers and IP network addresses. Further, call agents can receive and generate signaling messages to the appropriate destination, control and subscribe screening to validate access, control access to network resources, provide bandwidth management, and record call performance and account. Below are specific devices and equipment used by commercial VoIP provider:

- Media Gateway (MG) is a device under the control of a Call agent that converts media between circuit and IP networks. Specifically, MGs encode and decode media signals, perform packetisation and depacketisation to and from IPs, control echo, play announcements and tones, and account for jitter. In other words, MGs will increase the clarity of a call.
- Real Time Protocol (RTP) is used as the IP transport protocol and is run on an UDP. RTP provides time stamps, loss detection, delivery monitoring, and content identification to implement reliability and flow control.

- SIP is a mechanism to initiate, terminate, and modify sessions in an IP network. It uses client and server architecture to enable personal mobility by tracking down and delivering calls to an endpoint. Although it does not relay details of the session, it is lightweight, text-based and reuses the construct of other internet protocols such as HTTP and SMTP.

## 2.9 Voice over Internet Protocol (VoIP) concept

Voice over Internet Protocol (VoIP) is a methodology and group of technologies for the delivery of voice communications and multimedia sessions as packets (10 bytes of compressed voice or 320bytes of uncompressed )over Internet Protocol (IP) networks, such as the Internet. Other terms commonly associated with VoIP are *IP* telephony, Internet telephony, voice over broadband (VoBB), broadband telephony, IP communications, and broadband phone service.

The term Internet telephony specifically refers to the provisioning of communications services (voice, fax, SMS, voice-messaging) over the public Internet, rather than via the public switched telephone network (PSTN). The steps and principles involved in originating VoIP telephone calls are similar to traditional digital telephony, and involve signaling, channel setup, digitization of the analog voice signals, and encoding. Instead of being transmitted over a circuit-switched network, however, the digital information is packetized and transmission occurs as Internet Protocol (IP) packets over a packet-switched network. Such transmission entails careful considerations about resource management different from time-division multiplexing (TDM) networks.

Early providers of voice over IP services offered business models and technical solutions that mirrored the architecture of the legacy telephone network. Second generation providers, such as Skype, have built closed networks for private user bases, offering the benefit of free calls and convenience, while potentially charging for access to other communication networks, such as the PSTN. This has limited the freedom of users to mix-and-match third-party hardware and software. Third generation providers, such as Google Talk have adopted the concept of federated VoIP – which is a departure from the architecture of the legacy networks. These solutions typically allow dynamic interconnection between users on any two domains on the Internet when a user wishes to place a call.

VoIP is available on many smart phones, personal computers, and on Internet access devices. Calls and SMS text messages may be sent over 3G or Wi-Fi.[2]

## 2.10 Protocols

Voice over IP has been implemented in various ways using both proprietary protocols, as well as protocols based on open standards. Examples of the VoIP protocols are:

- H.323
- Media Gateway Control Protocol (MGCP)
- Session Initiation Protocol (SIP)
- Media Gateway Control or H.248 (Megaco)
- Real-time Transport Protocol (RTP)
- Real-time Transport Control Protocol (RTCP)

- Secure Real-time Transport Protocol (SRTP)
- Session Description Protocol (SDP)
- Inter-Asterisk exchange (IAX)
- Jingle XMPP VoIP extensions
- Skype protocol

The H.323 protocol was one of the first VoIP protocols that found widespread implementation for long-distance traffic, as well as local area network services. However, since the development of newer, less complex protocols such as MGCP and SIP, H.323 deployments are increasingly limited to carrying existing long-haul network traffic. In particular, the Session Initiation Protocol (SIP) has gained widespread VoIP market penetration.

These protocols can be used by special-purpose software, such as Jitsi, or integrated into a web page (web-based VoIP), like Google Talk.

## 2.11 Consumer market

A major development that started in 2004 was the introduction of mass-market VoIP services that utilize existing broadband Internet access, by which subscribers place and receive telephone calls in much the same manner as they would via the public switched telephone network (PSTN). Full-service VoIP phone companies provide inbound and outbound service with direct inbound dialing. Many offer unlimited domestic calling for a flat monthly subscription fee. This sometimes includes international calls to certain countries. Phone calls between subscribers of the same provider are usually free when flat-fee service is not available. A VoIP phone is necessary to connect to a VoIP service provider. This can be implemented in several ways:

- Dedicated VoIP phones connect directly to the IP network using technologies such as wired Ethernet or wireless Wi-Fi. They are typically designed in the style of traditional digital business telephones.
- An analog telephone adapter is a device that connects to the network and implements the electronics and firmware to operate a conventional analog telephone attached through a modular phone jack. Some residential Internet gateways and cable modems have this function built in.
- A soft phone is application software installed on a networked computer that is equipped with a microphone and speaker, or headset. The application typically presents a dial pad and display field to the user to operate the application by mouse clicks or keyboard input.

## 2.12 Quality of service

Communication on the IP network is perceived less reliable in contrast to the circuit-switched public telephone network, as it does not provide a network-based mechanism to ensure that data packets are not lost, and are delivered in sequential order. It is a best-effort network without fundamental Quality of Service (QoS) guarantees. Therefore, VoIP implementations may face problems with end to end delay, packet loss and jitter.

- Jitter is variations in delay of packet delivery and maximum acceptable value is 40ms .
- End to end delay is the time taken for a packet to be transmitted across a network from source to destination which should be less than 125ms .
- Packet loss is description of error condition on packets data that droop when too much traffic or poor network and 5% is the maximum suitable standard .

## 2.13 WiMAX MAC layer basics and operation

A MAC layer or Media Access Control data communication protocol sub-layer may also be known as a Medium Access Control layer.

A MAC layer is a sub-layer of the Data Link Layer. This is defined in the standard seven-layer OSI model as layer 2. The MAC layer provides addressing and channel access control mechanisms that make it possible for several terminals or network nodes to communicate within a multi-point network, typically a local area network (LAN) or metropolitan area network (MAN).

The WiMAX MAC has been designed and optimized to enable point to multipoint wireless applications and the WiMAX MAC layer provides an interface between the physical layer and the higher application layers within the stack.

The WiMAX MAC layer has to meet a number of requirements:

- Point to multipoint***:*** One of the main requirements for WiMAX is that it must be possible for a base station to communicate with a number of different outlying users, either fixed or mobile. To achieve this, the IEEE 802.16, WiMAX MAC layer is based on collision sense multiple accesses with collision avoidance, CSMA/CA to provide the point to multipoint, PMP capability.
- Connection orientated**.**
- Supports communication in all conditions***:*** The WiMAX MAC layer must be able to support a large number of users along with high data rates. As the traffic is packet data orientated it must be able to support both continuous and" bursty" traffic. Most data traffic is "bursty" in nature having short times of high data rates then remaining dormant for a short while.
- Efficient spectrum use***:*** The WiMAX MAC must be capable of supporting methods that enable very efficient use of the spectrum.
- Variety of QoS options***:*** To provide the support for different forms of traffic from voice data to Internet surfing, etc, a variety of different classes and forms of QoS support are needed. Support for QoS is a fundamental part of the WiMAX MAC-layer. The WiMAX MAC utilizes some of the concepts that are embedded in the DOCSIS cable modem standard.
- Multiple WiMAX / IEEE 802.16 physical layers***:*** With different variants, the WiMAX MAC layer must be able to provide support for the different PHYs.

The WiMAX MAC layer is primarily an adaptation layer between the physical layer and the upper layers within the overall stack.

One of the main tasks of the WiMAX MAC layer is to transfer data between the various layers.

- Transmission of data - reception of MAC Service Data Units, MSDUs from the layer above. It then aggregates and encapsulates them into MAC Protocol Data Units, MPDUs, before passing them to the physical layer, PHY for transmission.
- Reception of data - the WiMAX MAC layer takes MPDUs from the physical layer. It decapsulates and reorganizes them into MSDUs, and then passes them on to the upper-layer protocols.

For the different formats: IEEE 802.16-2004 and IEEE 802.16e-2005, the WiMAX MAC design includes a convergence sublayer. This is used to interface with a variety of higher-layer protocols, such as ATM, Ethernet, IP, TDM Voice, and other future protocols that may arise.

WiMAX defines a concept of a service flow and has an accompanying Service Flow Identifier, SFID. The service flow is a unidirectional flow of packets with a particular set of QoS parameters, and the identifier is used to identify the flow to enable operation.

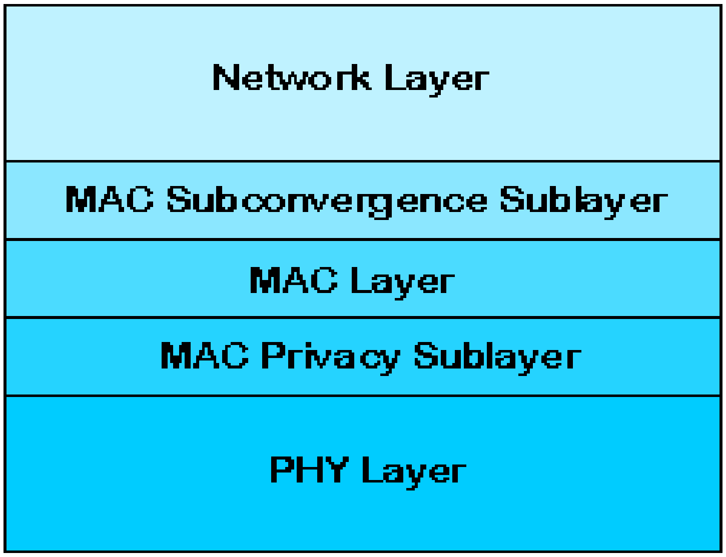



**Figure 2-1: WiMAX Protocol Stack**

There is an additional layer between the WiMAX MAC itself and the upper layers. This is called the Convergence Sublayer. For the upper protocol layers, the convergence sublayer acts as an interface to the WiMAX MAC. Currently the convergence sublayer only supports IP and Ethernet, although other protocols can be supported by encapsulating the data.

The WiMAX MAC layer provides for a flexible allocation of capacity to different users. It is possible to use variably sized MPDUs from different flows - these can be included into one data burst before being handed over to the PHY layer for transmission. Also, multiple small MSDUs can be aggregated into one larger MPDU. Conversely, one big MSDU can be fragmented into multiple small ones in order to further enhance system performance. This level of flexibility gives significant improvements in overall efficiency.

## 2.14 WIMAX MAC Connection Identifier

Before any data is transferred over a WiMAX link, the user equipment or mobile station and the base station must create a connection between the WiMAX MAC layers of the two stations. To achieve this, an identifier known as a Connection Identifier, CID is generated and assigned to each uplink / downlink connection. The CID serves as an intermediate address for the data packets transmitted over the WiMAX link.

There is another identifier used within the WiMAX MAC layer. Known as the Service Flow Identifier, SFID, this is assigned to unidirectional packet data traffic by the base station. It is worth noting that the base station WiMAX MAC layer also handles the mapping of the SFIDs to CIDs to provide the required quality of service.

The WiMAX MAC layer also incorporates a number of other features including power-management techniques and security features.

The WiMAX MAC layer has been developed to provide the functionality required for a point to multipoint system. The WiMAX MAC layer is also able to provide support for the different physical layers needed for the different flavors of WiMAX that are in use.

## 2.15 WiMAX network basics

The basic WiMAX standard does not define the WiMAX network for end to end connectivity. However the need for a standard WiMAX network architecture is realized and the WiMAX Forum Network Working Group have developed a standard for defining the WiMAX network architecture.

The standard now used is available from the WiMAX Forum as WiMAX Forum Network Architecture, document: WMF - T32-002-R010v04 and it is dated February**n** 03, 2009.

## 2.16WiMAX Network architecture

The WiMAX network architecture defines the system after the air interface to enable a full end to end network to be achieved.

In order that elements of network equipment can be used from different suppliers, it is necessary to define the WiMAX network architecture that is common to all WiMAX networks. In this way economies of scale can be gained along with robust networks that are able to perform reliably under all conditions.

The overall WiMAX network comprises a number of different entities that make up the different major areas described above. These include the following entities

- Subscriber Station, SS / Mobile Station, MS: The Subscriber station, SS may often be referred to as the Customer Premises Equipment, CPE. These take a variety of forms and these may be termed "indoor CPE" or "outdoor CPE" - the terminology is self-explanatory. The outdoor CPE has the advantage that it provides better performance as a result of the better position of the antenna, whereas the indoor CPE can be installed by the user. Mobile Stations may also be used. These are often in the form of a dongle for a laptop, etc.
- Base Station, BS: The base-station forms an essential element of the WiMAX network. It is responsible for providing the air interface to

the subscriber and mobile stations. It provides additional functionality in terms of 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.

- ASN Gateway, ASN-GW: The ASN gateway within the WiMAX network architecture typically acts as a layer 2 traffic aggregation point within the overall ASN.

  The ASN-GW may also provide additional functions that include: intra-ASN location management and paging, radio resource management and admission control, caching of subscriber profiles and encryption keys. The ASN-GW may also include the AAA client functionality (see below), establishment and management of mobility tunnel with base stations, QoS and policy enforcement, foreign agent functionality for mobile IP, and routing to the selected CSN.
- Home Agent, HA: The Home Agent within the WiMAX network is located within the CSN. With Mobile-IP forming a key element within WiMAX technology, the Home Agent works in conjunction with a "Foreign Agent", such as the ASN Gateway, to provide an efficient end-to-end Mobile IP solution. The Home Agent serves as an anchor point for subscribers, providing secure roaming with QOS capabilities.
- Authentication, Authorization and Accounting Server, AAA: As with any communications or wireless system requiring subscription

services, an Authentication, Authorization and Accounting server is used. This is included within the CSN.

## 2.17 WiMAX Security basic

An overview of the essential elements for WiMAX security including encryption and authentication and the ways they are implemented Like any system security is a key element within the overall WiMAX system. WiMAX security has to implement in a way that provides sufficient protection against intrusion and other forms of unauthorized access without hindering the overall operation.

Accordingly WiMAX security has been incorporated into the heart of the system to ensure that seamlessly integrated and provides an effective solution.

WiMAX security utilizes a number of advanced techniques including PKMv2 based authentication and over the air encryption. These considerable improve the level of security that is can be attained, but overall end-to-end security is still challenging and requires each network to adopt security within the overall network design and roll out as well as in the ways of working.

WiMAX security basics:

WiMAX uses Internet Protocol, IP as the core transport mechanism, and as a result, WiMAX security measures need to incorporate not only the traditional security requirements for a wireless telecommunications system, but also those relating to the use of IP systems.

In view of the need for a high level of WiMAX security, the IEEE 802.16 working groups incorporated security measures into the standard during the concept stages to counteract WiMAX security threats. WiMAX security has been embedded into the standard from the beginning rather than being added as an extra at a later stage. By adopting this approach, WiMAX security has been made more effective while being less intrusive to the user.

WiMAX security elements are included in the standard and fall under four main headings:

- Authentication of the user device
- Higher level user authentication
- Advanced over-the-air encryption
- Methods for securing the control and signaling within an IP scenario

Each of these WiMAX security areas has been addressed within standards, but even so, it is still necessary for the network operators to use good practice to ensure that security is not compromised. It is quite possible to circumvent the best security technology if the correct operating procedures are not in place.

## 2.18 WiMAX security measures

The WiMAX standard includes several security protection measures to address and overcome the various WiMAX security threats that are posed to the system. These include mutual device / user authentication techniques, a flexible key management tool, traffic encryption, and control and management message protection.

There are several key protocols and standards that are used as part of the overall WiMAX security strategy:

- PKMv2: This is the Privacy Key Management Protocol version 2. This is used as a key management protocol for the encrypted and authorized exchange of crypto keys for multicast and broadcast traffic.
- EAP: This is the Internet Engineering Task Force, Extensible Authentication Protocol. This protocol is used for device and user authentication.
- EAS: This is the Advanced Encryption Standard. This is used for encrypting the over the air traffic.

During the operation of the system, the various WiMAX security measures are brought in to play at the various required stages.

- WiMAX security authentication: Authentication is the ability of the network to ensure that the subscriber and subscriber devices are legitimate users and devices to be connected to the network.

  Network entry authorization uses EAP because it provides a flexible and scalable framework for authentication of the user and devices.
- WiMAX security encryption: The EAS encryption is used for encrypting over the air traffic. The WiMAX security approach utilizes uses Counter Mode with Cipher Block Chaining Message, CCM, and authentication code. With AES CCM, the sender generates a unique value per packet and sends this value to the receiver. This prevents man-in-the-middle attacks because they would have

difficulty in substituting the traffic. An additional measure introduces the use of Traffic Encryption State machine which uses a periodic key refresh mechanism to provide for the continued transition of keys.

WiMAX security is able to bring into play a number of security mechanisms to ensure a high level of security. Although no security measures can be deemed to be one hundred percent safe, the WiMAX security measures provide a very high level of security. Provided that the operator processes and procedures are also secure, the overall level of WiMAX security should be sufficiently high for most applications.

# Chapter Three

# Methodology and Simulation

# Chapter Three

# Methodology and Simulation

## 3.1 Physical Model

The design of a WiMAX network has been done using Opnet software program in a campus with area 30 x 30 Km with one cell and number of nodes between ( 20 , 40 and 60 ) With one profile VOIP , with cell radius equal 20 Km and consist of one voice server , one Profile and application configuration , the power transmitted which was taken in our consideration equal 0.5 Watt for the base station and subscriber antenna , with simulation time equal 10 minute .

## 3.2 Mathematical Model

The formula for estimating jitter is:

$$J(i)=J(i-1)+(|D(i-1,i)|-J(i-1)/16 \quad (3.1)$$

For estimating packet loss using:

$$\text{Packet loss}= ((\text{send packet}-\text{received packet})/\text{send packet})*100 \quad (3.2)$$

The end to end equation is:

$$d=N[d\ trans+d\ prop+d\ proc+d\ queue] \quad (3.3)$$

d trans=transmission delay .

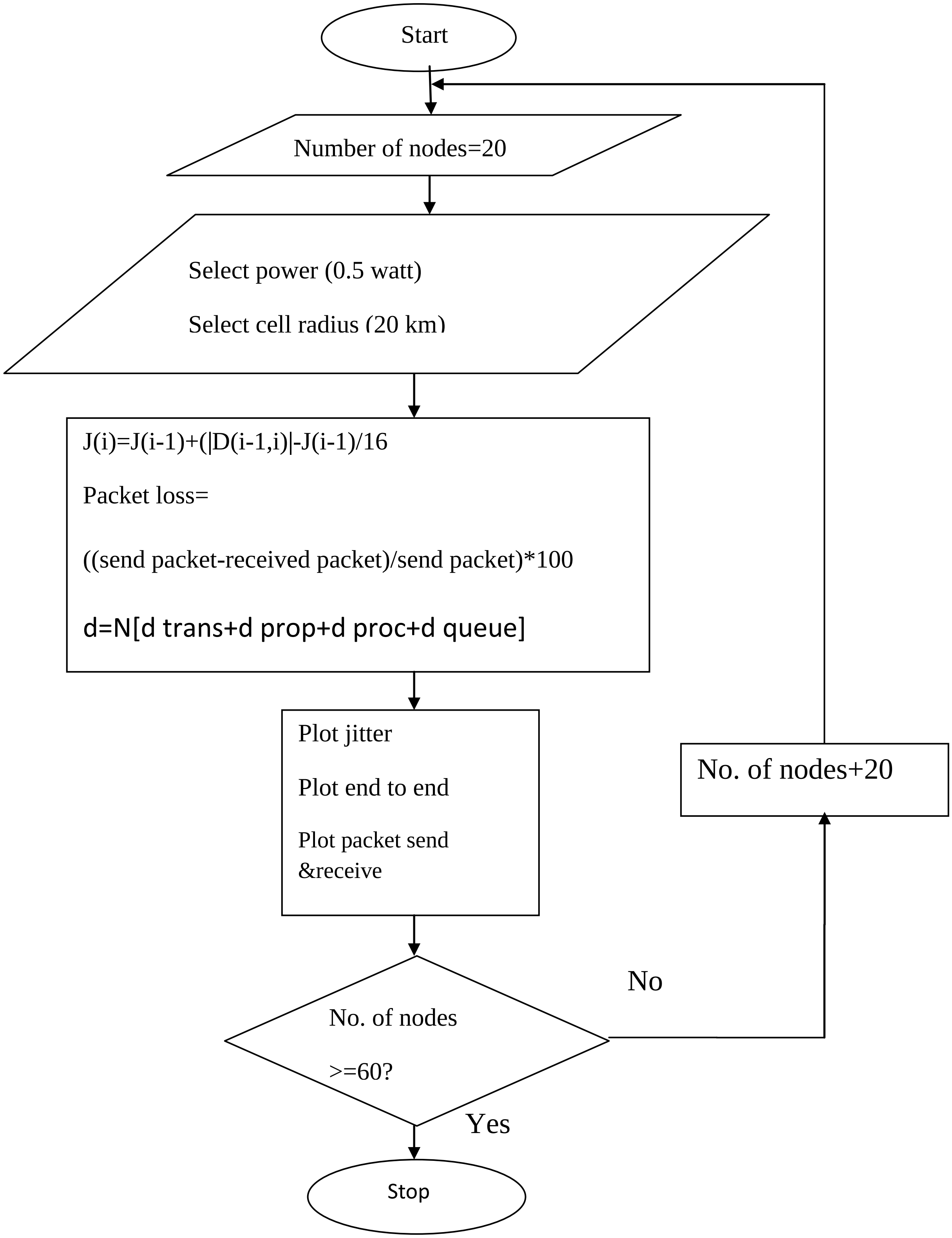
d prop=propagation delay .

d proc=processing delay .

d queuing delay.

N=number of links(number of routers+1) .

## 3.4 Computer Model



## 3.4 Simulation Environment

The parameters which were taken into our consideration were:-

Table 3-1: Parameters.

| Parameters | Value |
|---|---|
| Power Transmitted | 0.5 Watt |
| Number Of Cells | 1 Cell |
| Cell Radius | 20 Km |
| Area Of The Network | 30 x 30 Km |
| Number of Nodes | 20,40and60 |
| Simulation Time | 10 min |
| Application Profile | VOIP |

## 3.5 Simulation Block Diagram

The simulator environment, descriptive analysis and mathematical model are designed using Opnet software program as shown in figure below:

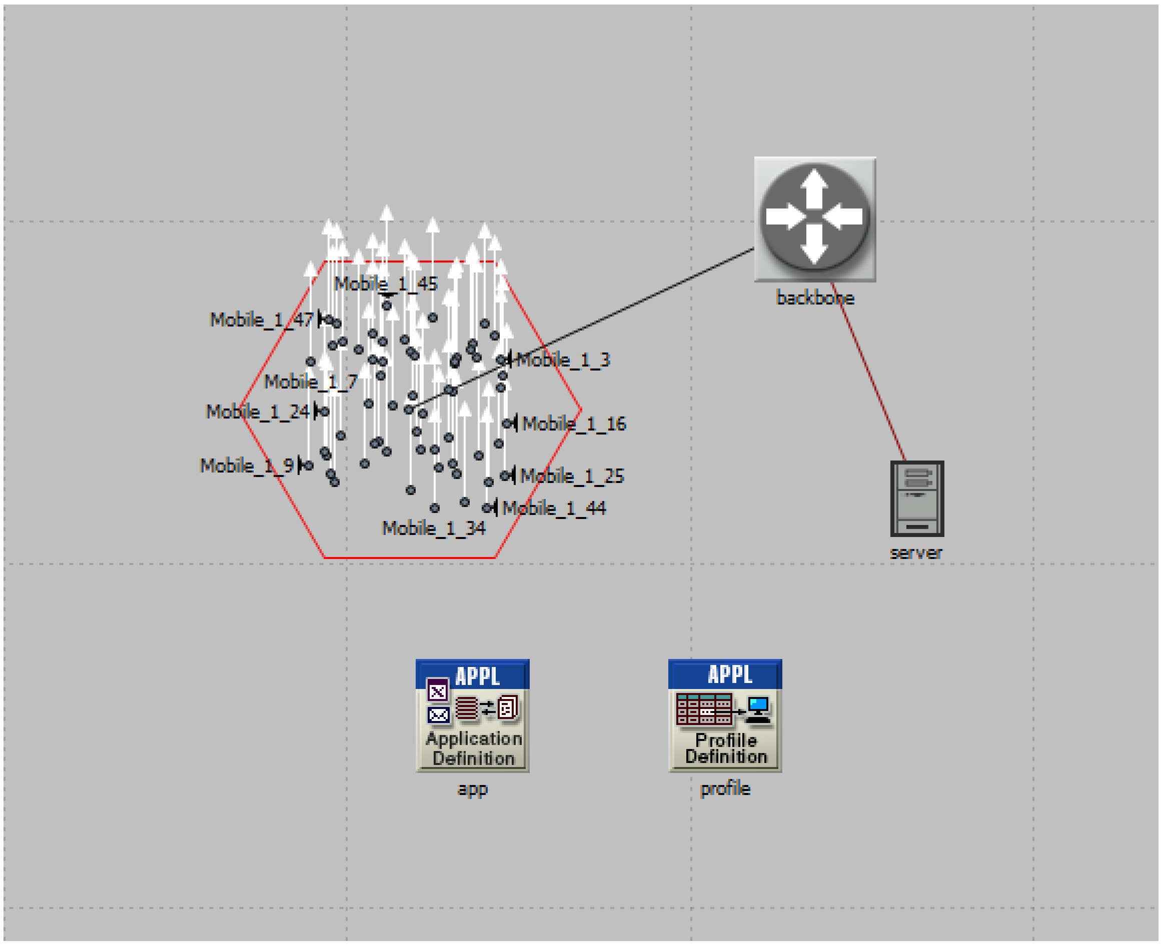



Figure 3-1: WiMAX network with 60 clients.

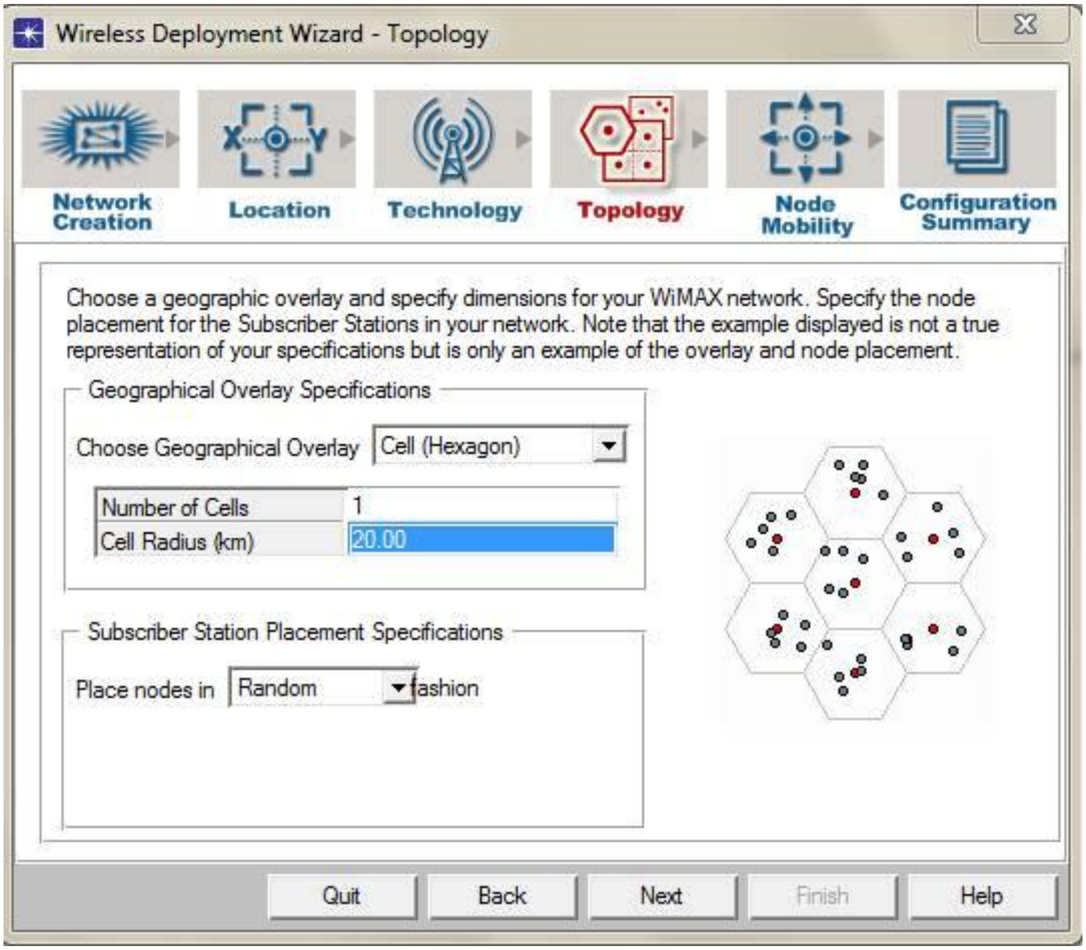



Figure 3-2:Opent Cell

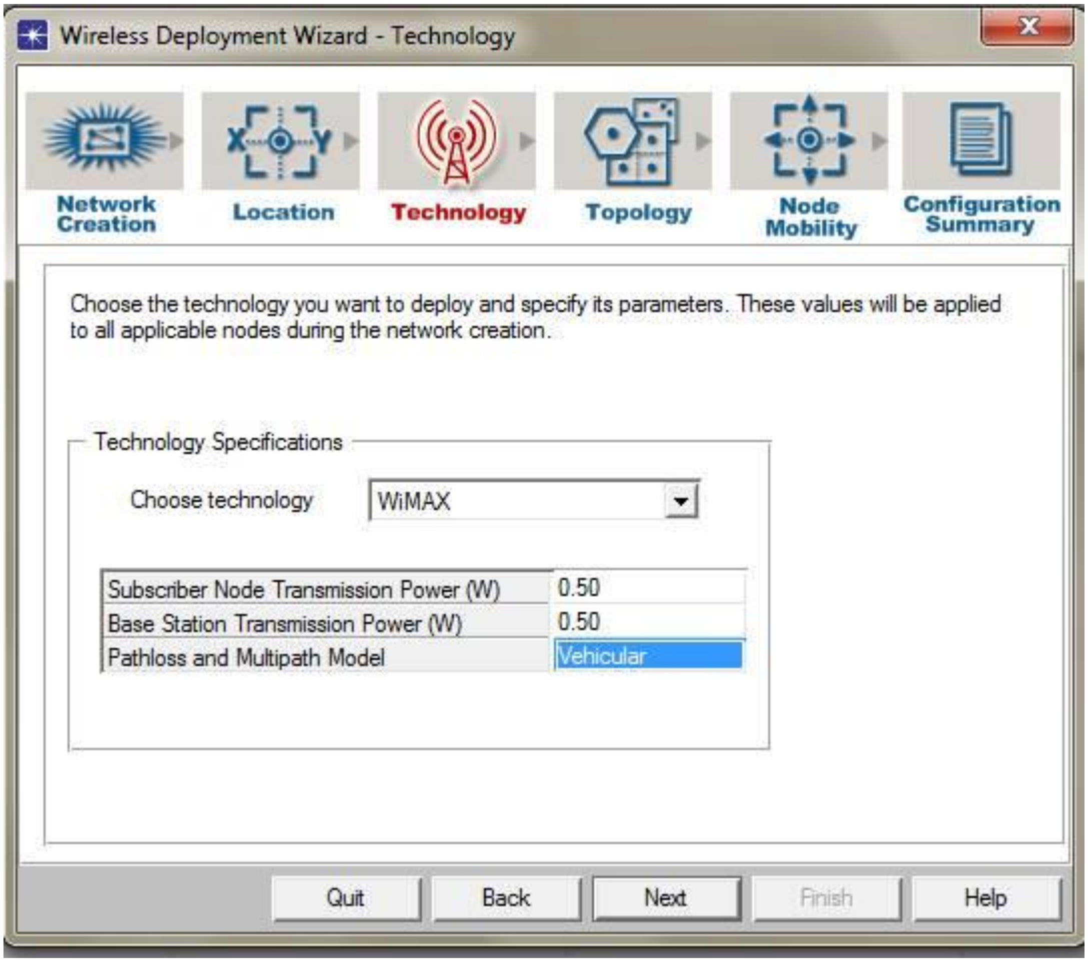



Figure 3-3: Opnet WiMAX

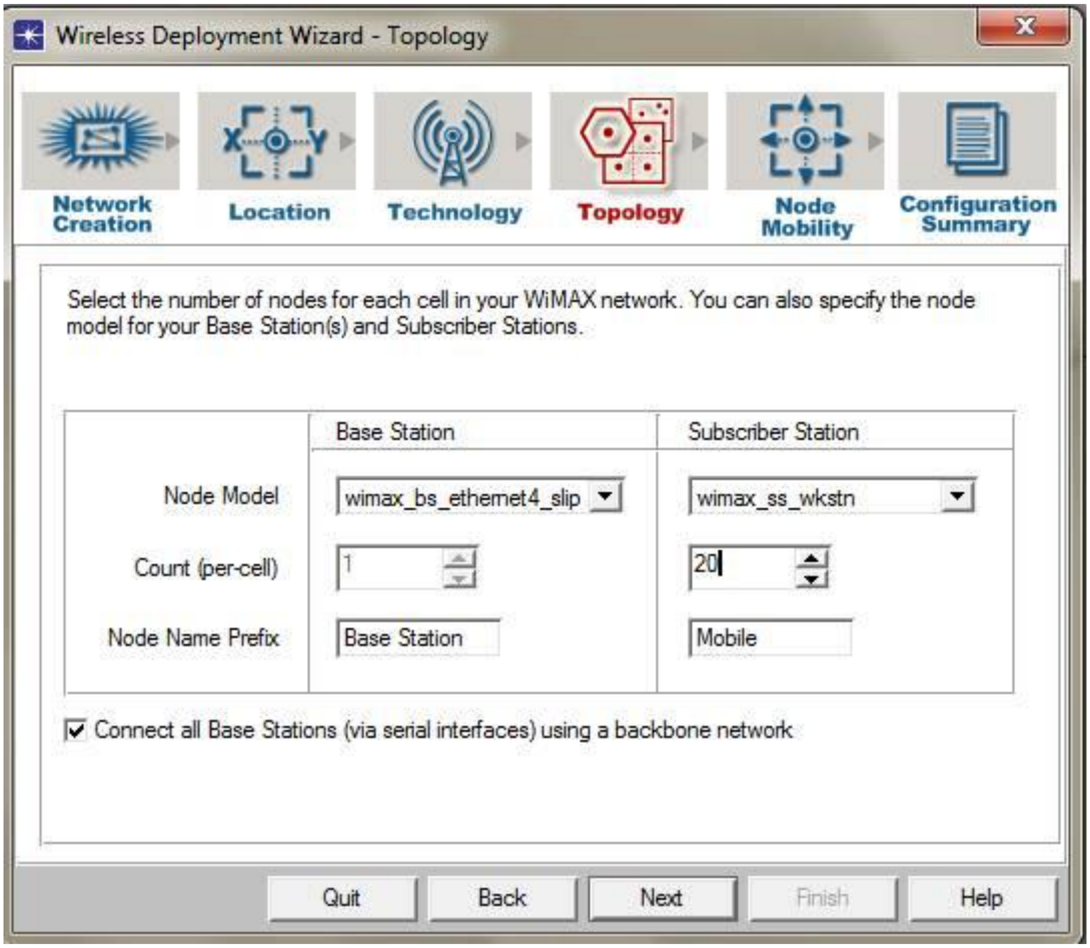



Figure 3-4: Opnet Model

## 3.6 Results

After the running of the simulator block diagram using Opnet software program we get the following results:

Table 3-2: jitter result

| No of nodes | Cell radius(km) | power transmit(watt) | Jitter(ms) |
|---|---|---|---|
| 20 | 20 | 0.5 | 2.2 |
| 40 | 20 | 0.5 | 2.5 |
| 60 | 20 | 0.5 | 935 |

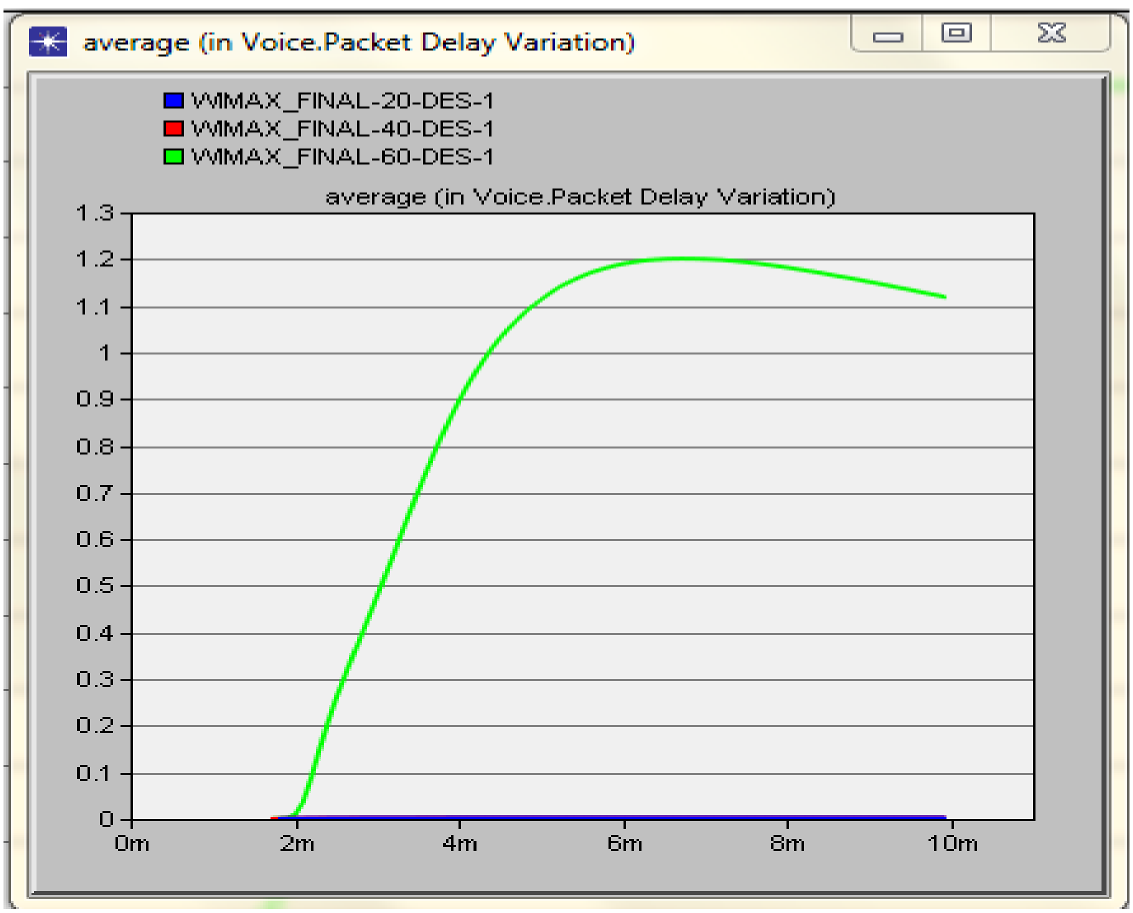


Figure 3-5: Jitter result

The upper figure present the result of jitter in which the number of nodes is changing , in 20 and 40 clients  the values of  delay are small and there are no mean between them but in 60 clients have huge amount of delay and the value is over the maximum stander  of the jitter .

Table 3-3: End to end delay

| No of nodes | Cell radius(km) | Power transmit(watt) | End to end delay(ms) |
|---|---|---|---|
| 20 | 20 | 0.5 | 107 |
| 40 | 20 | 0.5 | 113 |
| 60 | 20 | 0.5 | 1700 |

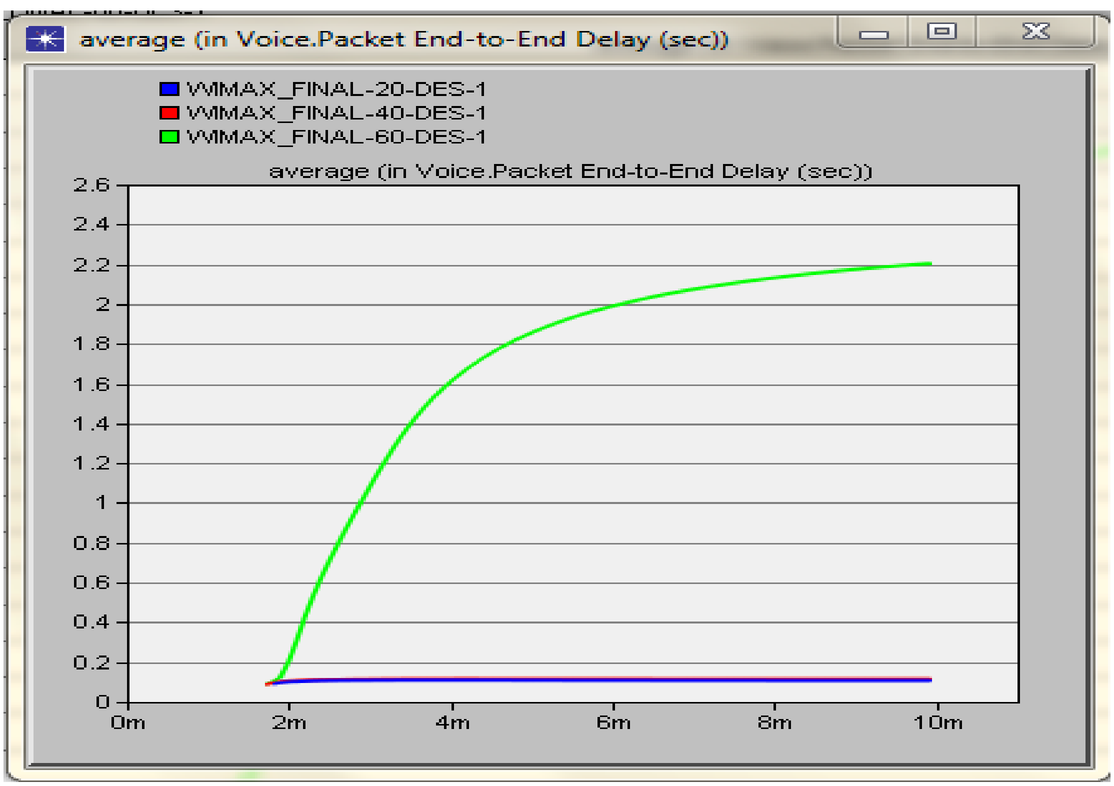



Figure 3-6: End to end delay

The upper figure present the result of end to end delay in which the number of nodes are changing , in 20 and 40 clients the values of delay are small and there are no mean differences between them , but in 60 clients have huge amount of delay and the values are over the maximum stander of the end to end delay .

Table 3-4: packet loss result

| No of nodes | Cell radius(km) | Power transmit(watt) | Packet loss (%) |
|---|---|---|---|
| 20 | 20 | 0.5 | 0.3 |
| 40 | 20 | 0.5 | 0.3 |
| 60 | 20 | 0.5 | 6 |

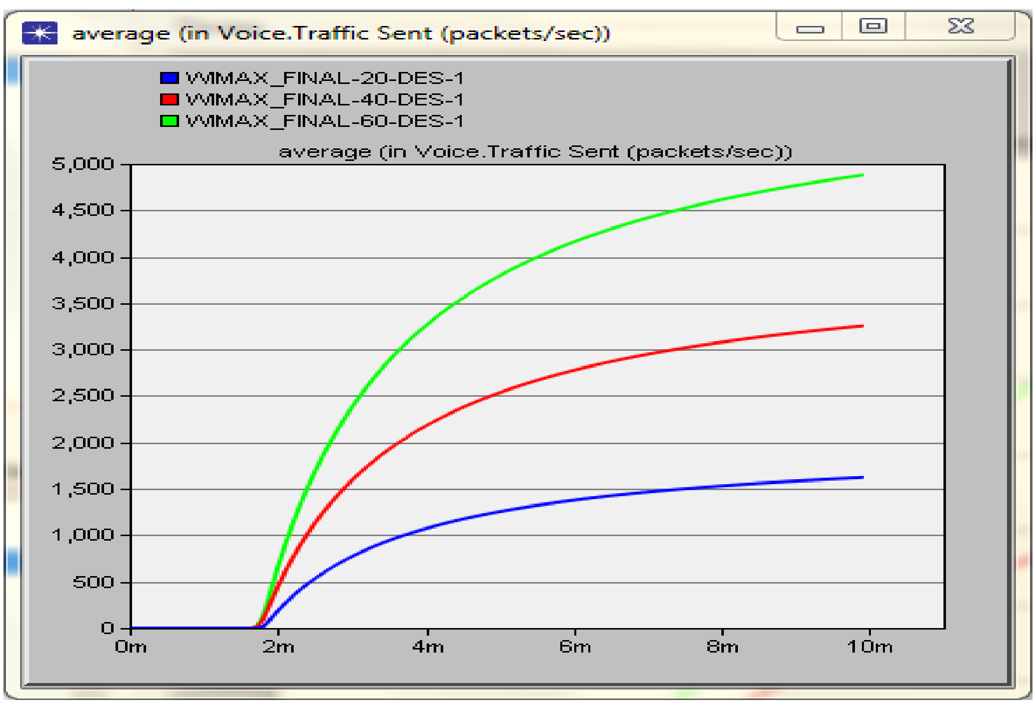



Figure 3-7: packet send

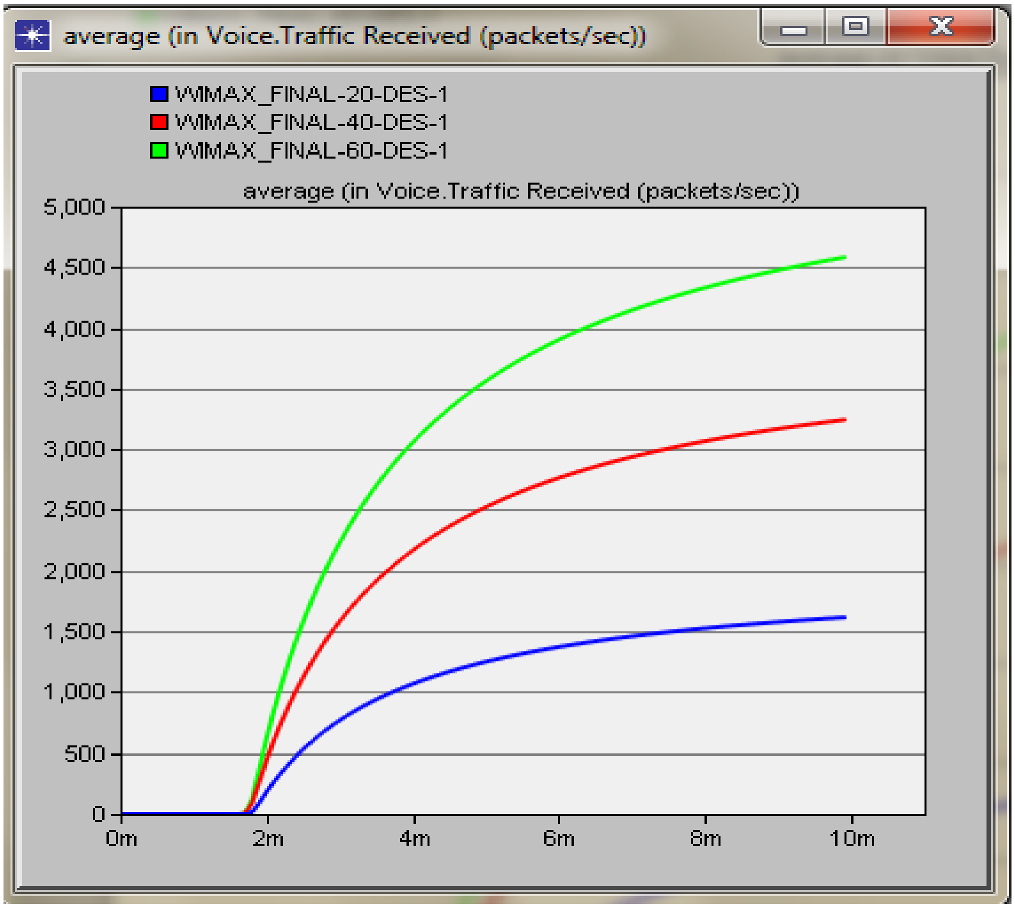



Figure 3-8: packet received

The upper figures present the result of the packet loss in which the number of nodes are changing, in 20 and 40 Clints the values of packet loss are small and there are no mean differences between them, but in 60 Clints have huge amount of loss and the values are over the maximum stander of packet loss.

**Result analysis:**

- As the number of nodes increased the value of jitter delay increased.
- As the number of nodes increased the value of end to end delay increased.
- As the number of nodes increased the value of packet loss increased
- The acceptable maximum value take as standard background to all result and compare it with viewed value as shown and determine the rejected value of nodes 60 nodes.

# Chapter Four

# Conclusion and Recommendations

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## 4.1Conclusion

The study, analysis, plan, design of the software program to simulate and perform For WiMAX Network and evaluate the performance of the system using Opnet software program.

the parameter which were taken into consideration were : jitter delay , end to end delay ,packet loss and number of nodes with one profile (VoIP) .

After the execution of the simulator the results were obtained in term of tables and graphs. From the results we observed the following:

As the number of nodes received 60 clients the jitter delay, end to end delay and packet loss will exceeds the acceptable standard value.

## 4.2Recommendations

From the results obtained we suggest the following recommendation for future work:

- Not increase the number of nodes without back to references standard value.
- To increase the simulation time for further inspection.
- To ensure in regular time the system work well and parameters not change.

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