Sudan University OF Science and technology

College of graduate studies

Performance Evaluation of WiMAX Femtocell

تقويم الاداء لخلية الوايماكس الصغيرة جداً

A thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of science in Electronics (Communications)

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بسم الله الرحمن الرحيم

قال تعالى:

﴿ وَيَسْأَلُونَكَ عَنِ الرُّوحِ قُلِ الرُّوحُ مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّنَ

الْعِلْمِ إِلاَّ قَلِيلاً ﴾

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And special thanks for

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for its great staff and laboratories that play a backbone in my research.

Dedication

I dedicate my research to my whole family, to my

father who has never left my heart and thought.

To the dearest of them all the great women who filled

me with love, strength and power, my mother.

and for my lovely sisters

To my faithful brothers and sisters

who gave me support.

To all my dear friends, who have always been there for

me in good and bad moments.

To all the people who have a special space in my life.

Abstract

Worldwide Interoperability for Microwave Access (WIMAX) , is considered today the most interesting opportunity able to provide coverage distance of almost 50 Km and data throughput to 70 MbPs and to complete wired network architecture enquiry a flexible and cheap solution for the last mile.

WiMAX is suffers from poor indoor coverage and the high cost of deploying base station. We can solve this problems by using Femtocell , it is very small cell or home access point (Femto 10^{-15})

Femtocells provide better in-premise coverage and reduce macro network deployment costs. While operators are benefited by low backhaul cost, and low power, backward compatible and scalable deployment, the end users enjoy better in-premise coverage, low service usage costs, and a better access to new and innovative applications. In this research a study and analysis of WiMAX network is done by using simulation written in MATLAB. In which the used of Femtocell resulted in improvement in the signal to interference ratio by 63% .and throughput increase by 47%. And also bit rate increased by 10% to 25% the increased of bit rate mean increased in spectral efficiency by 40% .and that the value of time delay decreased in Femtocell case applied by 9% .due to the above recorded enhancement in the performance parameters recommendations are made in assaying and Appling Femtocell for WiMAX network that are to be a technology to solve poor indoor coverage problem.

المستخلص

البيئة التشغيلية العالمية لنقاط الوصول (وايماكس) تعتبر اليوم اعظم فرصة لتقديم مساحة تغطية حوالي 50 كيلومتر و انتاجية تصل حتى 70 ميقابايت لكل ثانية . كما انها تقدم حلول رخيصة و مرنة لاكمال الشبكة السلكية في الامبال الاخيرة . و ككل الشبكات التي تعمل في الترددات العالية تعاني شبكة الوايماكس من ضعف التغطية الداخلية و ارتفاع تكلفة التشغيل. خلية الفيمتو يمكن ان تكون حل لكل مشاكل الوايماكس اذ تقدم خلية الفيمتو تغطية افضل للاماكن المغلقة و تخفض تكاليف تشغيل الوايماكس حيث يستفيد المخدم في خفض تكلفة التشغيل و تخفيض الطاقة المستهلكة و يتمتع المستخدم بتغطية افضل . في هذا البحث تمت دراسة شبكة الوايماكس و خلية الفيمتو و محاكاتها باستخدام برنامج الماتلاب و عند تحليل النتائج وجد ان تم تحسين الاشارة و كفاءة الخدمة بنسبة 10-25% لمعدل ارسال البيانات ,كما زادت الانتاجية بنسبة 47% و نقص التاخير بنسبة 9% مما ادى الى تحسين الخدمة بشكل كبير

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LIST OF SYMBOLS

Pt	Transmitted Power
Pr	Received Power
D	Distance From The Base Station
N	Number Of The Other Base Station
$N_{\circ}$:	Noise (Total Noise)
T	Attenuation Factor
L	Path Loss
$\frac{s}{i}$	Signal To Interference Ratio
Th	Throughput
Bw	Bandwidth
mf	Modulation Factor
BR	Bit Rate
Se	Spectral Efficiency
De	Delay
dt	Data
Dt_r	Data Rate

ABBREVIATIONS

AES	Advanced Encryption Standard
CDMA	Code Division Multiple Access
CPE	Customer Premise Equipment
DES	Data Encryption Standard
DSL	Digital Subscriber Line
EAP	Extensible Authentication Protocol
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FMC	Fixed–mobile convergence
GPS	Global Positioning System
GSM	Global System for Mobile communication
IEEE	Institute Of Electrical and Electronics Engineers
LAN	Local Area Network
LOS	Line Of Sight
LTE	Long Term Evolution
MAC	Media Access Control
MAN	Metropolitan Area Network
MNO	mobile network operator
NLOS	None Line Of Sight

NTP	Network Time Protocol
OFDM	Orthogonal Frequency Division Multiplexing
PC	Personal Computer
QOS	Quality Of Service
SIR	Signal To Interference Ratio
TDD	Time Division Duplex
VOIP	Voice Over IP
WCDMA	Wideband Code Division Multiple Access
WEP	Wireless Equivalent Privacy
Wi-Fi	Wireless Fidelity
WIMAX	Worldwide Interoperability For Microwave Access

CHAPTER ONE
INTRODUCTION

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1.1 Preface

WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard designed to provide 30 to 40 megabit-per-second data rates,[1] with the 2011 update providing up to 1 Gbit/s[1] for fixed stations. The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard. The forum describes WiMAX as "a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL".[2]

WiMAX refers to interoperable implementations of the IEEE 802.16 family of wireless-networks standards ratified by the WiMAX Forum. (Similarly, Wi-Fi refers to interoperable implementations of the IEEE 802.11 Wireless LAN standards certified by the Wi-Fi Alliance.) WiMAX Forum certification allows vendors to sell fixed or mobile products as WiMAX certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile.[3]

The original IEEE 802.16 standard (now called "Fixed WiMAX") was published in 2001. WiMAX adopted some of its technology from WiBro, a service marketed in Korea.[3] Mobile WiMAX (originally based on 802.16e-2005) is the revision that was deployed in many countries, and is the basis for future revisions such as 802.16m-2011.[4]

1.2 Problem Statement

With the rollout of WiMAX networks, operators are realizing that, like all other high frequency band access network, WiMAX network also suffers from poor indoor coverage and the high cost of deploying base stations. Though WiMAX can operate in any frequency range below 66GHz, WiMAX forum has published 2.3 GHz, 2.5 GHz and 3.5 GHz frequency ranges for WiMAX network. Hence, WiMAX networks are bound to suffer from poor indoor coverage and high costs of macro network deployment.

1.3 Proposed Solution

Femtocells or home access point can solve the problem of indoor coverage. WiMAX Femtocells provide better in-premise coverage and reduce macro network deployment costs. While operators are benefited by low backhaul cost, and low power, backward compatible and scalable deployment, the end users enjoy better in-premise coverage, low service usage costs, and a better access to new and innovative applications.

1.4 Aims And Objectives

The aim of this research is to evaluate the WiMAX network performance for better indoor coverage by implementing two scenarios using Matlab application, the first illustrates the WiMAX without the usage of Femtocells and the second by using Femtocells solve the WiMAX problem for user in poor indoor coverage.

1.5 Specific Objectives

The specific objectives of this research include the following steps:

1- To design and simulate WiMAX network to analyses the effectiveness of the proposed working scenarios.
2- In addition the network performance test will cover the Latency, SNR to BER, Throughput and Capacity.

1.6 Methodology

The methodology used in research process has been to start with a literature survey of the problem, analyses related problems and thereafter formulate a mathematical model of the problem. Then key performance parameters (metrics) has been defined and used to measure the improvement of the performance before and after applying the enhancement techniques. After that the proposed solutions are further simulated over a MATLAB platform, System parameters are input in the simulator and the output has then been processed in MATLAB. The result graph from the simulation illustrates the amount of the improvement in each parameter. Then the enhancements has been recorded and used in writing this thesis.(More details in Chapter Three and Chapter Four).

1.7 Thesis Outlines

The thesis is divided into five chapters; Chapter one is an introduction facilitates briefly the purpose of this project. Chapter two is a literature review that gives a brief review of WiMAX and Femtocell network structure. Chapter three discussed the calculation of the parameters.

Chapter four present a detailed discussion of the simulation results. Chapter five provides conclusion and recommendations.

discussion of the simulation results in chapter five the conclusion and recommendation is included.

CHAPTER TWO

LITREATURE REVIEW

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LITREATURE REVIEW

In this project deep investigation on WiMAX structure and study will be illustrated with a general overview of the WiMAX characteristics, performance along with the advantages and disadvantages.

2.1 Overview of WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. The technology is specified by the Institute of Electrical and Electronics Engineer, as the IEEE 802.16 standard [5].

Figure (2.1) is a diagram of a WiMAX network that illustrates the most typical WiMAX-based architecture, which includes a base station mounted on a building and shall be responsible for communicating on a point to multi-point basis with subscriber stations located in business offices, homes, and even automobiles [6]

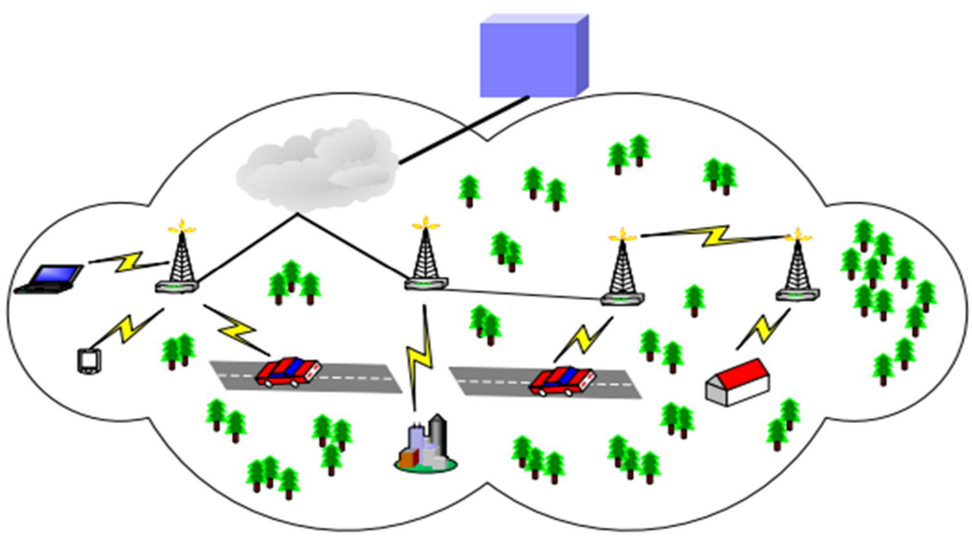


Figure (2-1) Wimax network architecture

2.1.1 Uses of WiMAX

The bandwidth and range of WiMAX make it suitable for the following potential applications

- Providing a wireless alternative to cable and DSL for "last mile" broadband access.
- Providing data and telecommunications services.
- Providing a source of Internet connectivity as part of a business continuity plan[4].

2.1.2 WiMAX Infrastructure

Typically, a WiMAX system consists of two components :

- A WiMAX Base Station: Base station consists of indoor electronics and a WiMAX tower shown in figure(2.2). Typically, a base station can cover up to 10 km radius (Theoretically, a base station can cover up to 50 kilo meter radius or 30 miles, however practical considerations limit it to about 10 km or 6 miles). Any wireless node within the coverage area would be able to access the Internet.[8]

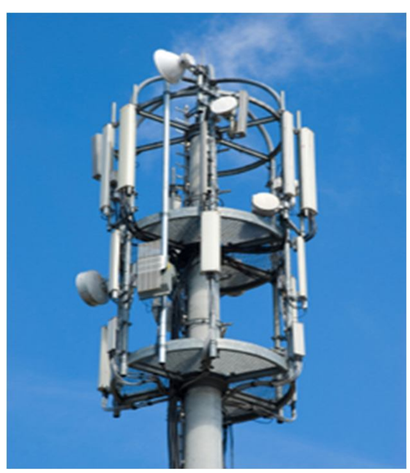


Figure (2.2) WiMAX tower

- A WiMAX receiver - The receiver and antenna - shown in figure (2.3) could be a stand-alone box or a PC card that sits in your laptop or computer. Access to WiMAX base station is similar to accessing a Wireless Access Point in a WiFi network, but the coverage is more.

Several base stations can be connected with one another by use of high-speed backhaul microwave links. This would allow for roaming by a WiMAX subscriber from one base station to another base station area, similar to roaming enabled by Cellular phone companies.

Figure (2.3) Wimax receiver

Several topology and backhauling options are supported on the WiMAX base stations: wireline backhauling (typically over Ethernet), microwave Point-to-Point connection, as well as WiMAX backhaul. With the latter option, the base station has the capability to backhaul itself. This can be achieved by reserving part of the bandwidth normally used for the end-user traffic and using it for backhauling purposes.[9]

2.2 WiMAX Specifications

WiMAX is expected to do more for Metropolitan Area Networks (MANs) and what Wi-Fi has done for local area networks (LANs). WiMAX is not projected to replace Wi-Fi, but to complement it by connecting Wi-Fi networks to each other or the Internet through high-speed wireless links.

You can therefore use WiMAX technology to extend the power and range of Wi-Fi and cellular networks. However, in developing countries, WiMAX may become the only wireless technology because Wi-Fi and cellular have not penetrated areas that can be reached with WiMAX technology[10].

2.2.1 WiMAX Range

The wide range of the WiMAX technology depends on the height of the antennas, if they are installed at the suitable position from where there is no barrier between the transmitter and receiver, and then we can get better range and service from it.

WiMAX can therefore support 30 to 50 kilometers distance with Line-of-Sight (LOS) links. As far as Non-line-of-sight (NLOS) links WiMAX can support the broad range from 3 to 10 kilometers using advanced modulation algorithm that can overcome many interfering objects that Wi-Fi systems cannot pass through [11].

2.2.2 WiMAX Data Rates

The technology used for WiMAX is Orthogonal Frequency Division Multiplexing (OFDM), it is not more efficient than the technology commonly used for 3G that is Wideband Code Division Multiple Access (WCDMA). However OFDM is coupled with a high channel bandwidth, that allows greater data rates. So, on average, for an equivalent spectrum allocation, users will see similar data rates. In specific simulations, where there are few users, it is possible that WiMAX will provide a higher data rate than 3G. [12], Refer to Figure (2-4).

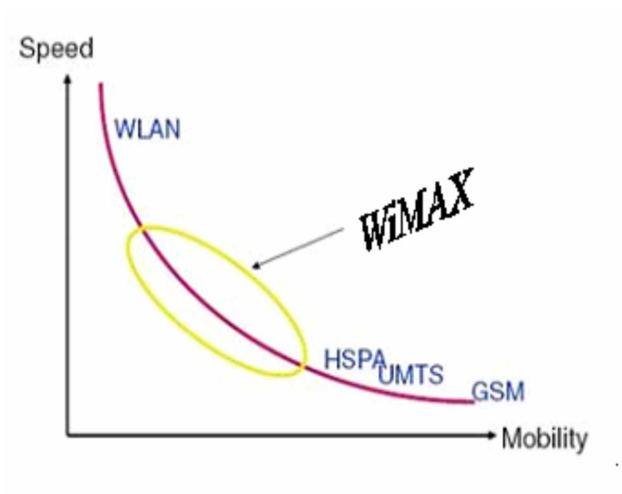


Figure (2-4) Wimax data rate speed vs mobility

2.2.3 WiMAX Cost

The network costs of WiMAX will be likely to be higher than for 3G because of the reduced range and hence the necessity to build more cells. The subscriber subsidy costs may be lower if WiMAX is built into processor chips, although this may not apply if users wish to have WiMAX handsets[13].

2.2.4 WiMax Quality Of Service (QOS) :

Excellent Quality Of service management appears from variety of WiMAX features. Just as on a Wi-Fi network, WiMAX users share a data and QoS can degrade as more users are added to the network.

Using the QoS features of WiMAX service providers can guarantee certain users specific bandwidth amounts by limiting the bandwidth consumption of other users [14].

2.3 WiMAX Design

The design of the WiMAX is ideal for challenges related with earlier versions of wired and wireless access networks. At the same time the backhaul connects the WiMAX system to the network, it is not an integrated part of WiMAX system.

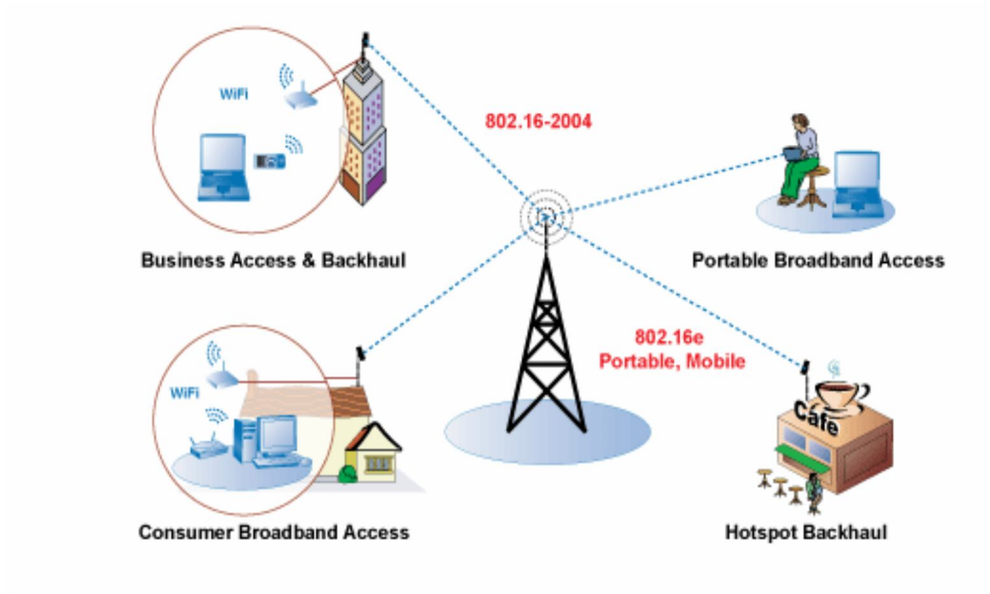
Normally a WiMAX network consists of two parts, a WiMAX Base Station (BS) and a WiMAX receiver also referred as Customer Premise Equipment (CPE) [15].

2.3.1 Backhaul Connection

Backhaul is actually a connection system from the Access Point (AP) back to the provider and to the connection from the provider to the network. A backhaul can set out any technology and media provided; it connects the system to the backbone. In most of the WiMAX deployments circumstances, it is also possible to connect several base stations with one another by use of high speed backhaul microware links. This would also allow for roaming by a WiMAX subscriber from one base station coverage area to another, similar to roaming enabled by cellular phone [16].

2.3.2 A WiMAX Receiver and transmitter

A WiMAX receiver, which is also referred as Customer Premise Equipment (CPE), may have a separate antenna or could be a stand-alone box. Access to a WiMAX base station is similar to accessing a wireless access point (AP) in a Wi-Fi network, but the coverage is more. So far oneof the biggest restrictions to the widespread acceptance of WiMAX has been the cost of CPE. This is not only the cost of CPE itself, but also that of installation. A WiMAX base station comprises of internal devices and a WiMAX tower. A base station can normally cover the area of about 50 kilometers or 30 miles radius, but some other environmental issues bound the limits of WiMAX range to 10 km or 6 miles. Any wireless user within the coverage area would be able to access the WiMAX services Figure (2-5). The WiMAX base stations would use the media access control layer defines in the standard and would allocate uplink and downlink bandwidth to subscribers according to their requirements on real time basis[17].



Figure(2-5) WiMAX Usage Scenarios

2.4 WiMAX Families

The WiMAX family of standards concentrates on two types of usage models a fixed usage model and a mobile usage model. The basic element that differentiates these systems is the ground speed at which the systems are designed to manage. Based on mobility, wireless access systems are designed to operate on the move without any disruption of service; wireless access can be divided into three classes; stationary, pedestrian and vehicular.

A mobile wireless access system is one that can address the vehicular class, whereas the fixed serves the stationary and pedestrian classes. This raises a question about the nomadic wireless access system, which is referred to as a system that works as a fixed wireless access system but can change its location [18].

2.4.1 Fixed WiMAX

Service and consumer usage of WiMAX for fixed access is expected to reflect that of fixed wire-line service, with many of the standards-based requirements being confined to the air interface. Because communications takes place via wireless links from Customer Premise Equipment (CPE) to a remote Non Line-of-sight (NLOS) base station, requirements for link security are greater than those needed for a wire-line service. The security mechanisms within the IEEE 802.16 standards are sufficient for fixed access service. [19]

Another challenge for the fixed access air interface is the need to set up high performance radio links capable of data rates comparable to wired broadband service, using equipment that can be self installed indoors by users, as is the case for Digital Subscriber Line (DSL) and cable modems. IEEE 802.16 standards provide advanced physical (PHY) layer techniques to achieve link margins capable of supporting high throughput in NLOS environments [20].

2.4.2 Mobile WiMAX

The 802.16a extension, refined in January 2003, uses a lower frequency of 2 to 11GHz, enabling NLOS connections. The latest 802.16e task group is capitalizing on the new capabilities provid by working on developing a specification to enable mobile WiMAX clients. These clients will be able to hand off betweenWiMAX base stations, enabling users to roam between service areas [21].

2.5 Advantage of WiMAX

2.5.1 More Flexibility And Security

Unlike WLAN, WiMAX provides a media access control (MAC) layer that uses a grant-request mechanism to authorize the exchange of data. This feature allows better exploitation of the radio resources, in particular with smart antennas, and independent management of the traffic of every user[22].

WiMAX proposes the full range of security features to ensure secured data exchange

- terminal authentication by exchanging certificates to prevent rogue devices,
- user authentication using the Extensible Authentication Protocol (EAP).
- data encryption using the Data Encryption Standard (DES) or Advanced Encryption Standard (AES), both much more robust than the Wireless Equivalent Privacy (WEP) initially used by WLAN. Furthermore, each service is encryptedwith its own security association and private keys [23].

2.5.2 WiMAX Is A Very Efficient Radio Solution

WiMAX must be able to provide a reliable service over long distances to customers using indoor terminals or PC cards (like today's WLAN cards). These requirements, with limited transmit power to comply with health requirements, will limit the link budget. Sub channeling in uplink and smart antennas at the base station has to overcome these constraints. The WiMAX system relies on a new radio physical (PHY) layer and appropriate MAC layer to support all demands driven by the target applications. The PHY layer modulation is based on OFDMA, in combination with a centralized MAC layer for optimized resource allocation and support of QoS for different types of services (VoIP, real-time and non real-time services and best effort). The OFDMA PHY layer is well adapted to the NLOS propagation environment in the (2 – 11) GHz frequency range. It is inherently robust when it comes to handling the significant delay spread caused by the typical NLOS reflections. Together with adaptive modulation, which is applied to each subscriber individually according to the radio channel capability, OFDMA can provide a high spectral efficiency of about 3 - 4 bit/s/Hz. However, in contrast to single carrier modulation, the OFDMA signal has an increased peak average ratio and increased frequency accuracy requirements. Therefore, selection of appropriate power amplifiers and frequency recovery concepts are crucial. WiMAX provides flexibility in terms of channelization, carrier frequency, and duplex mode (TDD and FDD) to meet a variety of requirements for available spectrum resources and targeted services[24].

2.6 Femtocell

In the telecommunications, a Femtocell is a small, low-power cellular base station, typically designed for use in a home or small business. A broader term which is more widespread in the industry is small cell, with Femtocell as a subset. It connects to the service provider's network via broadband (such as DSL or cable) figure (2.6); current designs typically support two to four active mobile phones in a residential setting, and eight to 16 active mobile phones in enterprise settings. A Femtocell allows service providers to extend service coverage indoors or at the cell edge, especially where access would otherwise be limited or unavailable. Although much attention is focused on WCDMA, the concept is applicable to all standards, including GSM, CDMA2000, TD-SCDMA, WiMAX and LTE solutions.[25]

Use of Femtocells benefits both the mobile operator and the consumer. For a mobile operator, the attractions of a Femtocell are improvements to both coverage, especially indoors, and capacity. Coverage is improved because Femtocells can fill in the gaps and eliminate loss of signal through buildings. Capacity is improved by a reduction in the number of phones attempting to use the main network cells and by the off-load of traffic through the user's network (via the internet) to the operator's infrastructure. Instead of using the operator's private network (microwave links, etc.), the internet is used.

Consumers benefit from improved coverage since they have a base-station inside their building. As a result the mobile phone (user equipment) achieves the same or higher data rates using less power, thus battery life is longer. They may also get better voice quality. The carrier may also offer more attractive tariffs, e.g., discounted calls from home.[26]

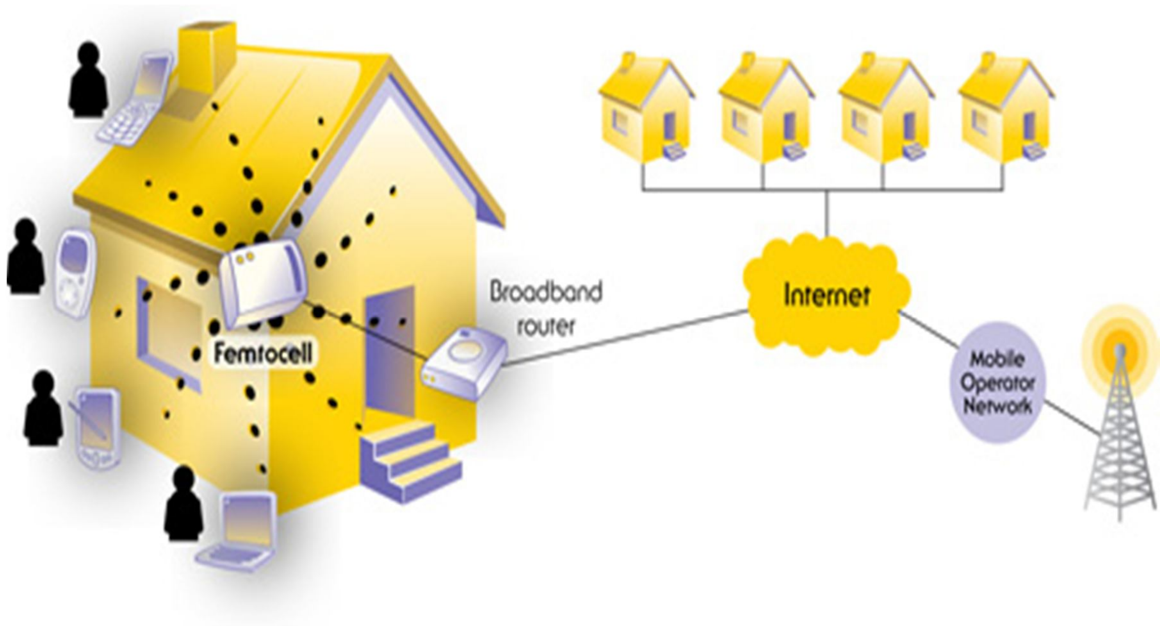


Figure (2.6) Typical femtocell network

Femtocells are an alternative way to deliver the benefits of Fixed–mobile convergence (FMC). The distinction is that most FMC architectures require a new (dual-mode) handset which works with existing unlicensed spectrum home/enterprise wireless access points, while a Femtocell-based deployment will work with existing handsets but requires installation of a new access point that uses licensed spectrum.

Many operators have launched Femtocell service, including Vodafone, SFR, AT&T, Sprint Nextel, Verizon, Zain, Mobile TeleSystems, and Orange.[27]

In 3GPP terminology, a Home Node B (HNB) is a 3G Femtocell. A Home eNode B (HeNB) is an LTEFemtocell.

Typically the range of a standard base station may be up to 35 kilometres (22 mi), a microcell is less than two kilometers wide, a picocell is 200 meters or less, and a Femtocell is in the order of 10 meters,[1] although AT&T calls its product, with a range of 40 feet (12 m), a "microcell".[2] AT&T uses "AT&T 3G MicroCell" as a trade mark and not necessarily the "microcell" technology, however.[27][28]

2.6.1 Operating mode

Femtocell is sold by a mobile network operator (MNO) to its residential or enterprise customers. A Femtocell is typically the size of a residential gateway or smaller, and connects to the user's broadband line. Integrated Femtocell (which includes both a DSL router and Femtocell) also exist. Once plugged in, the Femtocell connects to the MNO's mobile network, and provides extra coverage. From a user's perspective, it is plug and play, there is no specific installation or technical knowledge required—anyone can install a Femtocell at home.

In most cases, The user must then declare which mobile phone numbers are allowed to connect to his Femtocell, usually via a web interface provided by the MNO.[29] This needs to be done only once. When these mobile phones arrive under coverage of the Femtocell, they switch over from the macro cell (outdoor) to the Femtocell automatically. Most MNOs provide a way for the user to know this has happened, for example by having a different network name appear on the mobile phone. All communications will then automatically go through the Femtocell. When the user leaves the Femtocell coverage (whether in a call or not) area, his phone hands over seamlessly to the macro network. Femtocell requires specific hardware, so existing Wi-Fi or DSL routers cannot be upgraded to a Femtocell.

Once installed in a specific location, most Femtocell have protection mechanisms so that a location change will be reported to the MNO. Whether the MNO allows Femtocell to operate in a different location depends on the MNO's policy. International location change of a Femtocell is not permitted because the Femtocell transmits licensed frequencies which belong to different network operators in different countries.

2.6.2 Benefits for users

The main benefits for an end-user are the following:

- "5 bar" coverage when there is no existing signal or poor coverage
- Higher mobile data capacity, which is important if the end-user makes use of mobile data on his mobile phone (may not be relevant to a large number of subscribers who instead use Wi-Fi where Femtocell is located) [30]
- Depending on the pricing policy of the MNO, special tariffs at home can be applied for calls placed under Femtocell coverage
- For enterprise users, having femtos instead of DECT ("cordless" home) phones enables them to have a single phone, so a single contact list, etc.
- Improved battery life for mobile devices due to reduced transmitter-receiver distance.

Femtocell can be used to give coverage in rural areas.

2.6.3 Standardized architectures

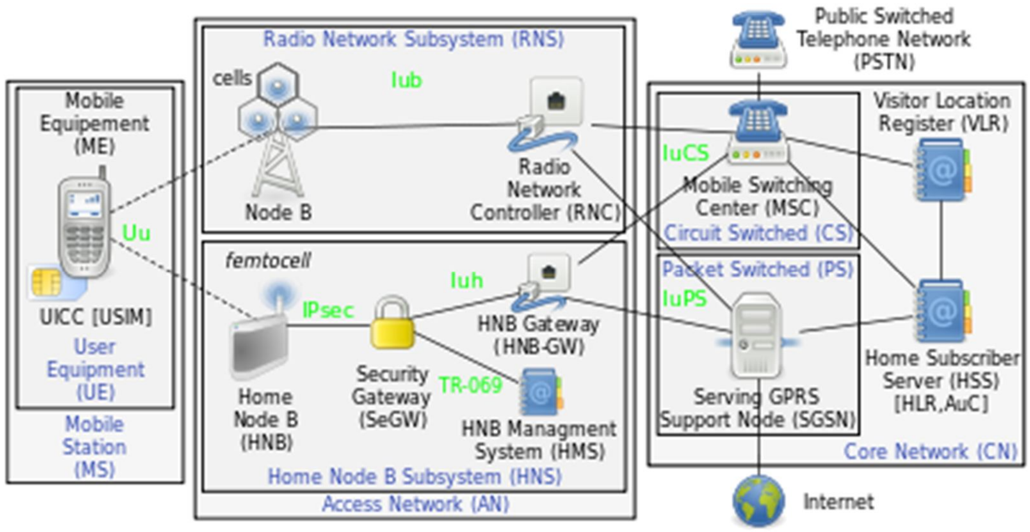


Figure (2.7) Simplified version of traditional Node B and Home Node B (3G Femtocell) in 3G architecture

The standards bodies have published formal specifications for Femtocells for the most popular technologies, namely WCDMA, CDMA2000, LTE and WiMAX. These all broadly conform to architecture with three major elements:

1. The Femtocell access points themselves, which embody greater network functionality than found in macrocell base stations, such as the radio resource control functions. This allows much greater autonomy within the Femtocell, enabling self-configuration and self-optimization. Femtocells are connected using broadband IP, such as DSL or cable modems, to the network operator’s core switching centers.
2. The Femtocell gateway, comprising a security gateway that terminates large numbers of encrypted IP data connections from

hundreds of thousands of Femtocells, and a signaling gateway which aggregates and validates the signaling traffic, authenticates each Femtocell and interfaces with the mobile network core switches using standard protocols.

3. The management and operational system which allows software updates and diagnostic checks to be administered. These typically use the same TR-069 management protocol published by the Broadband Forum and also used for administration of residential modems.

The key interface in these architectures is that between the Femtocell access points and the Femtocell gateway. Standardization enables a wider choice of Femtocell products to be used with any gateway, increasing competitive pressure and driving costs down.

2.6.4 Quality of service

When using an Ethernet or ADSL home backhaul connection, an Access Point Base Station must either share the backhaul bandwidth with other services, such as Internet browsing, gaming consoles, set-top boxes and triple-play equipment in general, or alternatively directly replace these functions within an integrated unit. In shared-bandwidth approaches, which are the majority of designs currently being developed, the effect on quality of service may be an issue.[31]

The uptake of Femtocell services will depend on the reliability and quality of both the cellular operator's network and the third-party broadband connection, and the broadband connection's subscriber understanding the concept of bandwidth utilization by different applications a subscriber may use. When things go wrong, subscribers will turn to cellular operators for support even if the root cause of the problem lies with the broadband connection to the home or workplace. Hence, the effects of any third-party ISP broadband network issues or traffic management policies need to be very closely monitored and the ramifications quickly communicated to subscribers.

A key issue recently identified is active traffic shaping by many ISPs on the underlying transport protocol IPSec. UK-based Femtocell benchmarking company Epitiro have published white papers about these IP-focused QoS issues.[32]

2.6.5 Spectrum accuracy of Femtocell

To meet Federal Communications Commission (FCC) / Of comspectrum mask requirements, Femtocells must generate the radio frequency signal with a high degree of precision. To do this over a long period of time is a major technical challenge. The solution to this problem is to use an external, accurate signal to constantly calibrate the oscillator to ensure it maintains its accuracy. This is not simple (broadband backhaul introduces issues of network jitter/wander and recovered clock accuracy), but technologies such as the IEEE 1588 time synchronization standard may address the issue. Also, Network Time Protocol (NTP) is being pursued by some developers as a possible solution to provide frequency stability. Conventional (Macrocell) base stations often use GPS timing for synchronization and this could be used,[18] although there are concerns on cost and the difficulty of ensuring good GPS coverage.

Standards bodies have recognized the challenge of this and the implications on device cost. For example, 3GPP has relaxed the 50ppb parts per billion precision to 100ppb for indoor base stations in Release 6 and a further loosening to 250ppb for Home Node B in Release 8.

2.6.6 Security of Femtocell

At 2013 Black Hat hacker conference in Las Vegas, NV, a pair of security researchers detailed their ability to use a Verizon Femtocell to secretly intercept the voice calls, data, and SMS text messages of any handset that connects to the device.

During a demonstration of their exploit, they showed how they could begin recording audio from a cell phone even before the call began. The recording included both sides of the conversation. They also demonstrated how it could trick Apple's iMessage – which encrypts texts sent over its network using SSL, rendering them unreadable to snoopers, including the NSA – into defaulting to SMS, allowing the Femtocell to intercept the messages.

They also demonstrated it was possible to "clone" a cell phone that runs on a CDMA network by remotely collecting its device ID number through the Femtocell, in spite of added security measures to prevent against cloning of CDMA phones.[33]

2.7 Releated work

2.7.1 Adaptive Coverage Adjustment for Femtocell Management in a Residential Scenario

Femtocell is an emerging technology for expanding cell coverage and increasing data rate, and its users deploy in their own premises by themselves. Therefore, Femto base stations cannot go through manual cell planning procedure as the mobile communication base stations do. Femto base station sets its parameters, such as transmit power or pilot power, considering the surrounding radio environment. Due to its automated cell planning and parameter setting, leakage of the power to the outside of a house can occur and lead to highly increased number of unwanted handover events of Macrocell users, which will finally lead to

higher call drop probability. In this paper, we propose a coverage self-optimizing scheme to decrease the call drop probability in a real residential scenario. Our proposed scheme prevents unwanted handovers and comprehensive simulation results show that it improves performance of network in terms of handover and call drop probability.

Since Femtocells are not manually deployed by operators, they require auto configuration abilities for self provisioning of their power and cell size. Moreover, service providers are not capable of controlling all Femtocells manually throughout their operation. Therefore self-optimization is required for Femtocells to operate well with Macrocells and other Femtocells. We proposed a more efficient mechanism of controlling the pilot power of the Femtocell to decrease Macrocell user's handover probability due to leakage of Femtocell power. Our proposed algorithm uses the distance of an active Femtocell UE to control the pilot power. This leads to a significant reduction of the handover probability as well as the call drop probability compared with conventional power controlling schemes[22].

2.7.2. Femto Cells: Current Status and Future Directions

This is a survey paper on the recently developed and rapidly evolving field of Femtocells. Quite often, it is noticed that cell-phone signals are strongly attenuated, when indoors, leading to call dropping or poor call quality. Femtocells are mini base stations that are deployed in users' homes so that the user can directly connect to the cellular network through the Femtocell instead of the outdoor Macrocell, thereby increasing call quality. In the later stages of the paper, we also discuss the integration of the Femtocell into the 3G architecture, as well as the various interference issues that the Femtocell faces.

As conclusion The promising Femtocell is being tested extensively by mobile operators around the world. However, there are still some issues that need to be worked on for Femtocells to be implemented as fault-free devices. In the years to come, Femtocells may also be able to operate efficiently using EDGE [5] standards. A number of hardware evolutions are required before high usability and quality of service standards are achieved. This may take a few years to achieve. Mobile operators must continue partnering with internet service providers, so as to make the Femtocell a reasonable means of improving cellular communication indoors. There is still sufficient capacity available in the macro network, so there is still no immediate need of Femtocells to help alleviate the pressure on Macrocells. However, Femtocells can be of immense help in rural areas where the distances between homes and the nearest Macrocell, could be many miles. The development of Femtocells can also help speed up the evolution of Universal Mobile Access[23].

CHAPTER THREE

RESEARCH METHODOLOGY

CHAPTER THREE

Research Methodology

The Femtocell is a small base station with a small service area. It's transmitting power and antenna size is small compared to the WiMAX Base Station It is designed to serve fewer than 10 users. The Femto Gateway validates all encrypted IP connections from hundreds of Femtocells. It connected with WiMAX via broadband (DSL)

3.1 Signal To Interference Ratio

The interest was in characterization of the signal to interference ratio (SIR) distribution on the downlink of a cellular system . This performance parameter is crucial for signal quality and channel quality evaluation. The whole SIR distribution is needed for performance [34]. The SIR can be calculated by equation 3.1

$$\frac{S}{I} = \frac{ptd^{-t}}{\sum_{i=1}^{N} ptd^{-t} + N_{\circ}} \qquad \textbf{(3.1)}$$

Where:

pt : transmitted power (in watt)

d: distance between the base station and the user (in Km)

$N_{\circ}$: The noise (in watt)

t: attenuation factor (ranging 2 to 4)

N: number of the other transmitting base stations

The pervious equation 3.1 does not take into other radio propagation effects such as the shadowing or multipath fading. Mean value of the effects are zero , therefore , the average received power depends only on the distance d , attenuation factor t and the transmitted power pt.

This is not the real case so the previous equation has been modified to be close realistic cases, the exponential path loss has been added, and the modified equation (3.2) is:

$$\frac{S}{I} = \frac{ptd^{-I}}{\sum_{i=1}^{N} ptd^{-I} + N_{\circ}} \quad (3.2)$$

Where:

I : 10*log10*(pt/pr)

Pr : pt – t

There are other parameters can improve the system performance such as:

3.2 Throughputs

Throughput is amount of useful data that user receives. The throughput depends on the channel conditions and modulation schemes, both are related to the interference ratio. The choice of digital modulation scheme will significantly affect the characteristic, performance and resulting physical realization of a communication system. There is no universal 'best' choice of scheme. But depending on the physical characteristic of the channel required different levels of modulation. Table (3.1) shows the different modulation schemes according to the channel quality identifier index. Equation 3.3 Is used to calculate throughput

$$\textbf{Th= Bw * mf} \qquad (3.3)$$

Where :

Th: throughput (Mbps)

Bw:Bandwidth (MHz)

mf: modulation factor (factor determine the suitable modulation scheme according to channel quality)

Table 3.1: present the modulation factor value for each modulation scheme depending on the SIR [34]

CQI index	Modulation	Spectral efficiency (bps\Hz)	Reference SINR (db)
1	QPSK	0.1523	-6.7
2	QPSK	0.2344	-3.61175
3	QPSK	0.3770	-2.19725
4	QPSK	0.6016	-1.30903
5	QPSK	0.8770	-0.59925
6	QPSK	1.1758	-0.20417
7	16-QAM	1.4766	-0.05223
8	16-QAM	1.9141	-0.01548
9	16-QAM	2.4063	-0.00398
10	64-QAM	2.7305	-0.00054
11	64-QAM	3.3223	-0.00012

12	64-QAM	3.9023	-2E-05
13	64-QAM	4.5234	-3.2E-06
14	64-QAM	5.1152	-4.2E-07
15	64-QAM	5.5547	-3.6E-08

3.3 Theoretical Maximum Bit Rate

Bit rate describes the rate at which bits are transferred from one location to another. It measures how much data transmitted in a given amount of time. Bit rate is commonly measured in bits per second (bps) or (kbps) or (Mpbs)

The maximum theoretical bit rate is the maximum amount of bit to be transmitted theoretically , it can be calculated by equation (3.4)

$$\mathbf{BR = Bw * log2*(1 + \frac{s}{i})} \quad \mathbf{(3.4)}$$

Where:

BR: bit rate (Mbps)

Bw: Bandwidth (MHz)

$\frac{s}{i}$: signal to interference ratio (dB)

3.4 Spectral Efficiency

the spectral efficiency is the ratio of amount of communications achieved per the amount of spectrum space used. A radio system operates at a particular frequency at a given location , and at a particular time.

Some resources are not used all of the time, they will not cause or receive interference when they are not being used which cause inefficient usage of the spectrum .therefore there is a time factor associated with the radio system [35]. Spectrum efficiency can be calculated by equation (3.5)

$$\mathbf{Se} = \frac{\boldsymbol{BR}}{\boldsymbol{BW}} \qquad \textbf{(3.5)}$$

Where:

Se: spectral efficiency (bit/Hz/sec)

$\boldsymbol{BR}$: bit rate (Mbps)

$\boldsymbol{BW}$: bandwidth (MHz)

3.5 Transmission Delay

The delay is very important parameter, it measures the time needed to receive the data, and it’s related to the amount of data to be transmitted and the used data rate. It can be calculated by equation (3.6)

$$\mathbf{De} = \frac{\mathbf{dt}}{\mathbf{dt\_r}} \qquad \textbf{(3.6)}$$

Where

De: transmission delay (ms)

dt: amount of data (Kbit)

dt_r : data rate (Mbps)

3.6 Simulation Development

A Matlab code has been developed to simulate the performance of the system by calculating the performance metrics. The source code is enclosed in appendix.

The idea of the code is to set variable value for each of (power transmitted, noise , bandwidth , distance) in a limited range based on the wimax advanced specifications, constant available band width and the number of users is assumed.

The first equation is the SIR. It has been calculated from the values of transmitted power (watt), distance (Km) separating the user from the base station and the path loss exponential by equation 3.2 the result is then converted from ratio to (db)

Then use the SIR values (as ratio) to test the throughput conditions to calculate the accumulated throughput calculated by equation 3.3

After that the theoretical maximum bit rate has been calculated using equation 3.4 .and the spectral efficiency has been calculated using equation 3.5. then the transmission delay has been calculated in equation 3.6

All the equations were implemented in both case macrocell and Femtocell and compare between those parameters in both cases and clarify the improvement

3.7 Simulation output

Afterward running the MATLAB code and processing the input system parameters, the resulted graphs represent the variation in each parameters, thereafter the amount of improvement has been calculated.

CHAPTER FOUR

RESULTS AND DISCUSSION

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter evaluation of Femtocell through a simulation written in MATLAB with the simulation parameters shown in table 4.1

The scenario contains Macrocell and Femtocell site. A MATLAB code has been developed to present the variation of the performance parameters which has been calculated from the equations as clarified in Chapter Three . After calculations the resulted values plotted to compare the system performance in Macrocell case and Femtocell case. Afterword the amount of the improvement has been calculated.

Table 4.1: simulation parameters[36]

No.	Parameter	Value
1	Simulation time	20 seconds
2	Available bandwidth	20 MHz
3	No. of Users	100 users
4	Attenuation	1.4553e+03
5	Distance	0.18Km
6	Transmission power	1.029671474965957e+02
7	Power Ratio	0.332675171227804

The following section represents the simulation results (figures) and a detailed discussion for each figure (the amount of increment , decrement and the reason of the or decrement)

4.1 Signals to Interference And Noise Ratio Comparison

Figure (4.1) represents the signal to interference and noise ratio before and after adding Femtocells the X axis represent the simulation time in ms and the Y axis represents the signal to interference noise ratio in db. The signal to interference and noise ratio has been improved by 63% in case of Femtocell, and this improvement was occurred due to the amplification and noise reduction of the signal from macrocell to the end users through femtocell.

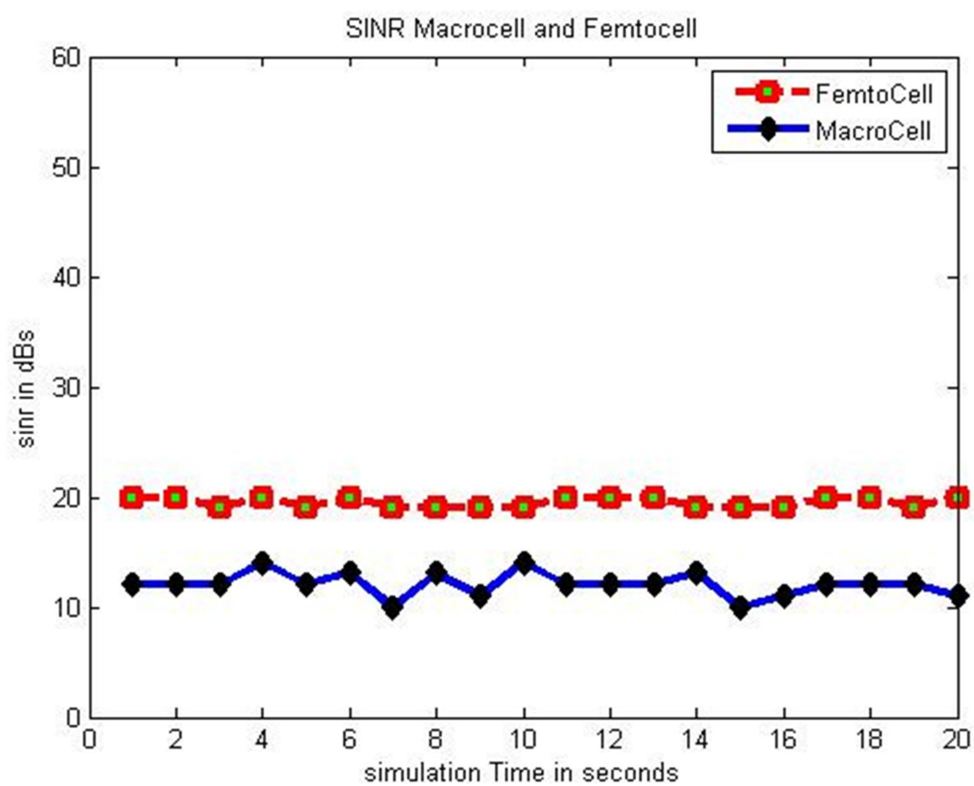


Figure (4.1) Signal to Interference Noise Ratio (db) before and after adding Femtocells

4.2 Accumulated Throughput Comparison

Figure 4.2 illustrates the accumulated throughput before and after Femtocells the X axis represent the simulation time in ms and the Y axis represents Accumulated Throughput in Kbit/sec. The accumulated throughput has been improved by 47%. and this improvement was occurred due to the amplification of the femtocell to the signal and the ability to establish new communication channel that increases the throughput of the system.

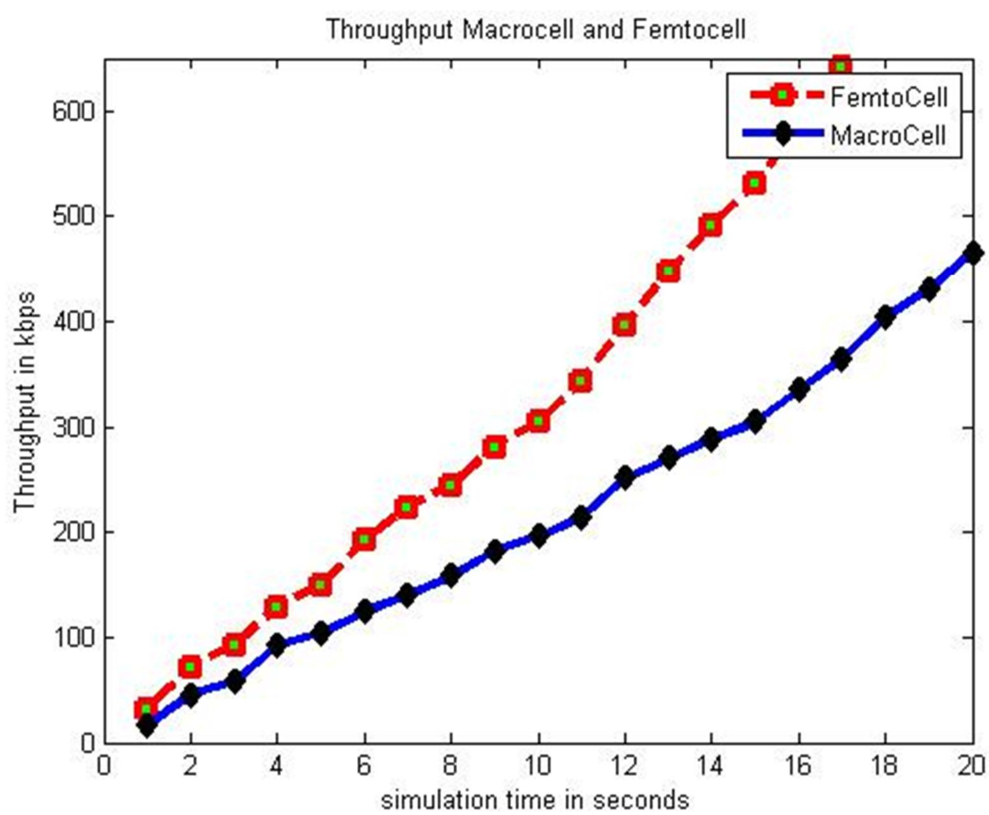


Figure (4.2) Accumulated throughput before and after Femtocells

4.3 Bit Rate Comparison

Figure 4.3clarifies the compression in term of theoretical maximum bit rate before and after adding Femtocells the X axis represent the simulation time in ms and the Y axis represents the Data Rate in Mbit/sec. As recorded from the figure of theoretical maximum bit rate has been improved by 10% to 25%. The amount of improvement in theoretical maximum bit rate is caused by the improvement in the (SIR) due to the direct proportion bet between the signal to interference ratio and the theoretical maximum bit rate.

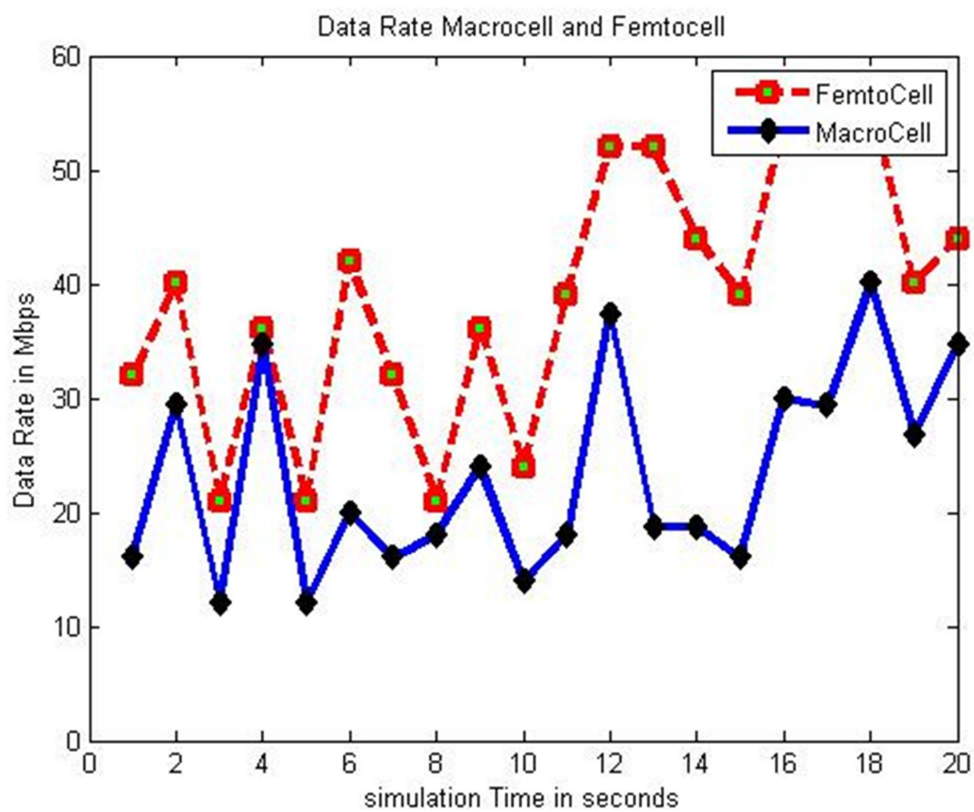


Figure (4.3) Bit Rate before and after Femtocells

4.4 Spectral Efficiency

Figure 4.4 shows the compression of the spectral efficiency before and after Femtocells the X axis represent the simulation time in ms and the Y axis represents the Spectral Efficiency in db. It's very clear that the spectral efficiency has been improved by 40% The value of spectral efficiency depends on amount of bite rate and the bandwidth . when the bit rate increases the spectral will increase too.

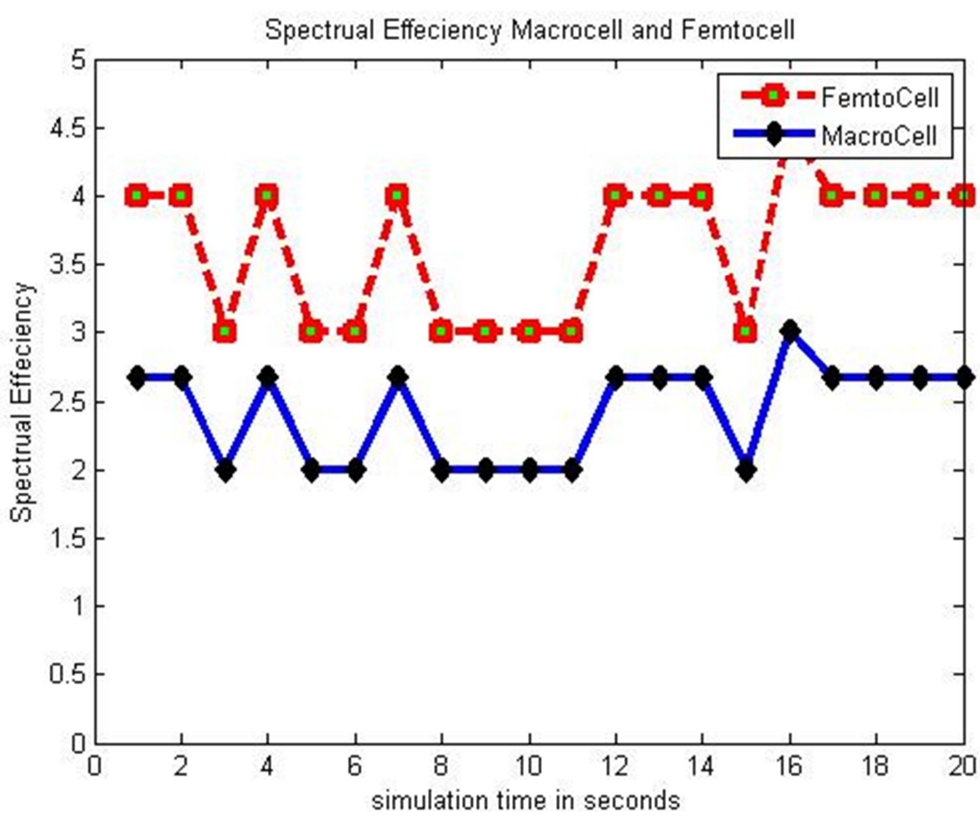


Figure (4.4) Spectral Efficiency before and after adding Femtocells

4.5 Transmission Delay Comparison

Figure 4.5 shows the variation of transmission delay before and after adding Femtocells the X axis represent the simulation time in ms and the Y axis represents the Transmission Delay in Seconds. it's clear that the value of time delay decreased in femtocell case applied by 9% there is a reverse proportional between the transmission delay and the throughput which depends on the signal to interference ratio when it increases the throughput increases lead to decrement the transmission delay

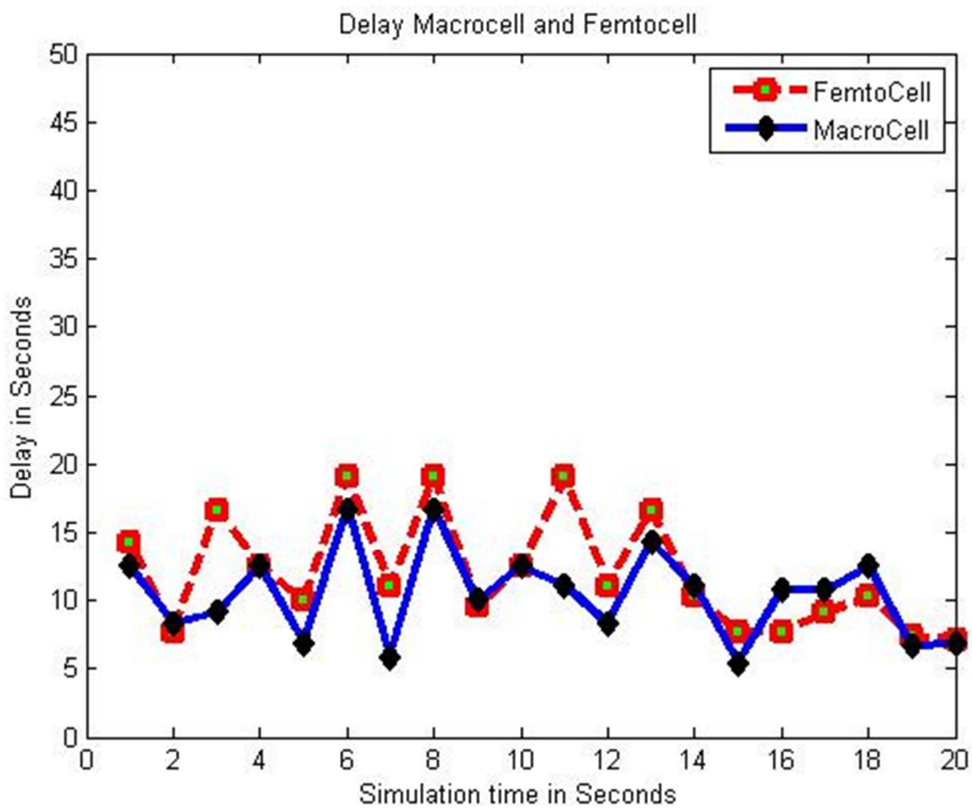


Figure (4.5) transmission Delay before and after adding Femtocells

4.6 Bandwidth Comparison

Figure 4.6 represent the bandwidth before and after adding Femtocells the X axis represent the simulation time in ms and the Y axis represents the Bandwidth in MHz. show the variation of Bandwidth in macrocell and femtocell . it's clear that the value of Bandwidth increased in femtocell case applied by 11.3 % and this improvement was occurred due to the new communication channel that is provided by the femtocell increases the bandwidth of the system.

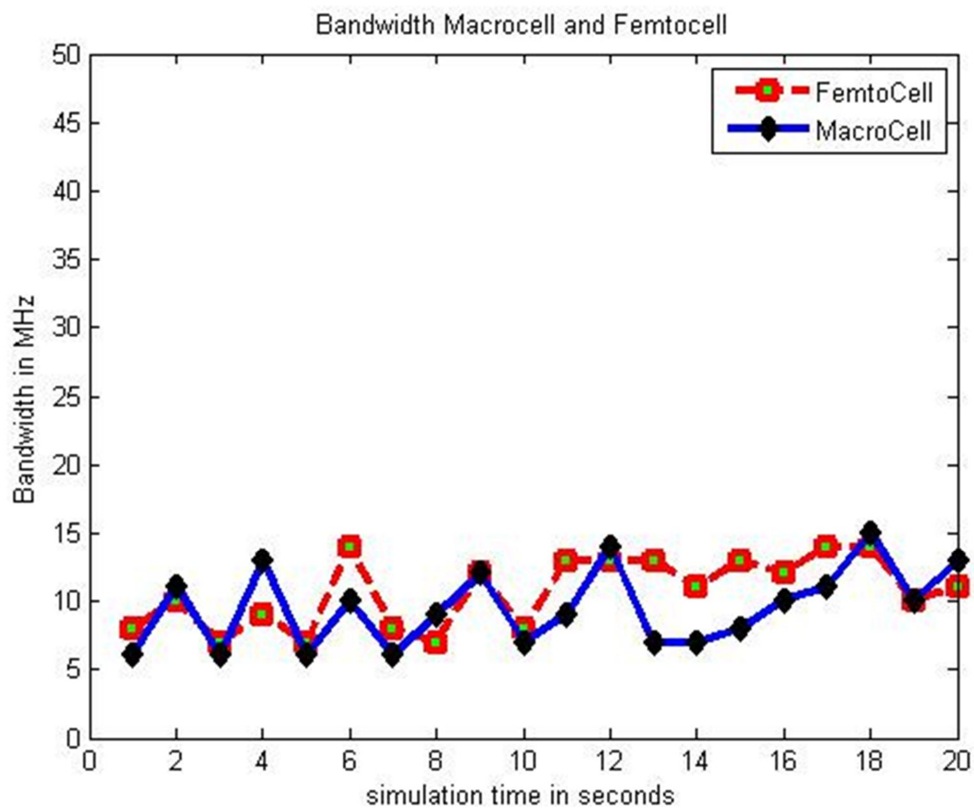


Figure (4.6) Bandwidth before and after adding Femtocells

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

WiMAX network is a Telecommunications technology that provides wireless transmission of data using a variety of transmission modes, from point-to-multipoint links to portable and fully mobile internet access. But it has problem including the indoor coverage, High cost of macro network stations Deployment. In this research Femtocell deployment has been studied in WiMAX

after investigating the WiMAX network and Repeaters used between two ends in an ordinary network that is used to connect between two WiMAX stations to cover distance increases the cost and it became not secure and it will be difficult to manage and maintain it the usage of Femtocells or home access point was found it is the solution to solve the problem of indoor coverage. WiMAX Femtocells provide better in-premise coverage and reduce macro network deployment costs. While operators are benefited by low backhaul cost, and low power, backward compatible and scalable deployment, the end users enjoy better in-premise coverage, low service usage costs, and a better access to new and innovative applications.

It was found that the signal to interference ratio has been improved by 63% in case of femtocell . as a resulte a much better signal to interference ratio is obtained in femtocell case and the accumulated throughput while adding the Femtocells is higher than using macrocell by 47% while the theoretical maximum bit rate has been 10% to 25% the amount of improvement in theoretical maximum bit is caused by improvement in the SINR due to the direct proportion between the signal to interference ratio and the theoretical maximum bit rate . and it's very clear that the spectral efficiency has been 40% The value of spectral efficiency depends on amount of bite rate and the bandwidth . when the bit rate increases the spectral will increase to.

Also it's clear that the value of time delay decreased in femtocell case applied by 9% there is a reverse proportional between the transmission delay and the throughput which depends on the signal to interference ratio when it increases the throughput increases lead to decrement the transmission delay while it's clear that the value of Bandwidth increased in femtocell case applied by 11.3 % there .

5.2 Recommendations

This project discusses Femtocell of WiMAX to improve the WiMAX deployment. For the future work the suggestions are made that to:

- Make the scenario more complicated and to be more realistic by adding propagations affects parameters.
- use multiple Femtocells in order to evaluate the system interference and noise ratio; moreover the simulation can be done through advanced simulating tools and applications such as Network simulator 2 and OPNET modular.
- Increase the number of users on the simulation using random generating procedures and add the mobility factor to the simulation.

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35. 37.

APPENDICES

```
close all;

clear all;

clc;

for n=1:10

time(1,n)=10*n;

available_bw(1,n)=20;


num_of_users(1,n)=10*n;

power_transmitted(1,n)=10^((20+1*rand(1))/10);


power_ratio(1,n)=(0.15)+(0.20)*rand(1);

side_lobes_power(1,n)=power_ratio(1,n).*power_transmitted(1,n);


attenuation(1,n)=10^((3+2*rand(1)/10));


power_received(1,n)=power_transmitted(1,n)-attenuation(1,n);


noise(1,n)=0.001+0.009*rand(1);

distance(1,n)=1+2*rand(1);



loss_ratio(1,n)=(power_transmitted(1,n)/power_received(1,n));
```

```
path_loss_db(1,n)=10*log10(loss_ratio(1,n));

path_loss_ratio(1,n)=10^(path_loss_db(1,n)/10);

serve_product(1,n)=side_lobes_power(1,n).*(distance(1,n).^-
path_loss_ratio(1,n));

summation(1,n)=sum(serve_product);


unwrap_product(1,n)=power_transmitted(1,n).*(distance(1,n).^-
path_loss_ratio(1,n));


femto_serve(1,n)=side_lobes_power(1,n).*(distance(1,1).^-
path_loss_ratio(1,n));


sir_1_ratio(1,n)=((unwrap_product(1,n))./((summation(1,n))+noise(1,n)));


ee(1,n)=100;


ww(1,n)=ee(1,n).*sir_1_ratio(1,n);


sir_1(1,n)=10*log10(ww(1,n));


sir_2(1,n)=10*log10((unwrap_product(1,n).*100)./(femto_serve(1,n))+nois
e(1,1));
```

```
bite_rate_1(1,n)=available_bw(1,n)*log2(1+sir_1(1,n));


bite_rate_2(1,n)=available_bw(1,n)*log2(1+sir_2(1,n));


if sir_1(1,n)>-6.7&&sir_1(1,n)<5.9
   throughput_1(1,n)=0
end
if sir_1(1,n)>5.9&&sir_1(1,n)<11.7
   throughput_1(1,n)=2*available_bw(1,n);
end


if sir_1(1,n)>11.7&&sir_1(1,n)<22.7
   throughput_1(1,n)=4*available_bw(1,n);
end


if sir_1(1,n)>22.7
   throughput_1(1,n)=6*available_bw(1,n);
end


if n==1
   accumulated_throughput_1(1,n)=throughput_1(1,n);
elseif n~=1
```

```
    accumulated_throughput_1(1,n)=accumulated_throughput_1(1,n-
1)+throughput_1(1,n)
else
   accumulated_throughput_1(1,n)=0
end
 if sir_2(1,n)>-6.7&&sir_2(1,n)<5.9
   throughput_2(1,n)=0
end
if sir_2(1,n)>5.9&&sir_2(1,n)<11.7
   throughput_2(1,n)=2*available_bw(1,n)
end

if sir_2(1,n)>11.7&&sir_2(1,n)<22.7
   throughput_2(1,n)=4*available_bw(1,n)
end
if sir_2(1,n)>22.7
   throughput_2(1,n)=6*available_bw(1,n)
end
if n==1
   accumulated_throughput_2(1,n)=throughput_2(1,n)
elseif n~=1
```

```
    accumulated_throughput_2(1,n)=accumulated_throughput_2(1,n-
1)+throughput_2(1,n)
else
   accumulated_throughput_2(1,n)=0
end
spectral_eff_1(1,n)=real(bite_rate_1(1,n)./available_bw(1,n))
spectral_eff_2(1,n)=real(bite_rate_2(1,n)./available_bw(1,n))



data(1,n)=20+100*rand(1)
delay_macro(1,n)=(data(1,n)./throughput_1(1,n))
delay_femto(1,n)=(data(1,n)./throughput_2(1,n))



end



comlextfunc2009(sir_1,sir_2,delay_macro,delay_femto,accumulated_throu
ghput_1,accumulated_throughput_2,spectral_eff_1,spectral_eff_2,bite_rat
e_1,bite_rate_2);
```