

Palestine Polytechnic University



College of Engineering & Technology

Electrical and Computer Engineering Department

Project name

**Possibility of Applying Green Communication in Palestinian
Cellular Networks**

Project Team

Omar Maraqa

Saif Najmeddin

Yaqoub Sharabati

Project Supervisor

Dr. Murad Abusubaih

Hebron - Palestine

Abstract

Energy efficient networks are becoming a hot research field. The networking community is increasingly devoting its attention to the identification of approaches to save energy in the networks of today. However, the networks of tomorrow will require built-in energy efficiency capabilities; so that the new network designs should take into account the energy efficiency issue.

Green Communication is one of the newest ideas in the communication fields. It includes any techniques that reduce energy consumption in communication devices. The ICT (Information and Communication Technologies) is responsible for approximately 2% to 10% from the total power consumption in the world where the cellular communications is the largest consumer. One of these techniques to obtain energy efficiency is based on the activation of network resources on demand, thus avoiding power on all the resources that are designed to serve users during peak traffic periods.

This project tries to characterize the amount of energy that can be saved by reducing the number of active cells during low traffic periods. When some cells are switched off, radio coverage and service provisioning handled by other active cells, so as to guarantee that service is available over the whole area. In addition, we will check the possibility of applying this idea through a real case study of the existing networks in Palestine {JAWWAL & WATANIYA}.

In our project, we consider three cases which are one operator network, two operators networks. Our results have shown a remarkable energy savings, up to 33.3% from the total power consumption.

Dedication

To those who give of themselves

So that others may live

To our Families for their patience

To our Colleagues for their support and encouragement

To our Supervisor Dr. Murad Abusubaih

Acknowledgments

All praise to Allah the ultimate guide and the cherisher who gave us the courage and the ability to do such work with a satisfying degree of perfection.

We would like to thank Dr. Murad Abusubaih, for his support, outstanding guidance and encouragement throughout our senior project.

We would like to thank our family, especially our parents, for their encouragement, patience and assistance over the years. We are forever indebted to our parents, who have always kept us in their prayers.

Table of Contents

Title Page	I
Abstract	II
Dedication	III
Acknowledgments	IV
Table of content	V
List of Tables	VIII
List of Figures	IX
Chapter 1: Overview	1
1.1 Introduction	2
1.2 The origin of Green Communication idea	4
1.3 Project Objectives	4
1.4 Problem Statement	4
1.5 Related Works	5
1.6 Needed Tools	6
1.7 Project Risks	7
1.8 Report Organization	8
1.9 Project Schedule	9
Chapter 2: Theoretical Background	10
2.1 Introduction to GSM	11
2.2 GSM Network Overview	12
2.3 GSM Interfaces	23

2.4 GSM carrier frequencies	24
2.5 GSM Channels	26
2.6 Handoff	27
2.7 Power Control	29
2.8 Traffic Engineering	30
2.9 Current trend in green cellular communication	35
2.10 UMTS Network	37
2.11 OPNET Modeler	49
Chapter 3: Simulation Design	55
3.1 Introduction	56
3.2 Typical traffic profile	56
3.3 Wataniya Network	57
3.4 Jawwal Network	59
3.5 The Combined Network	60
3.6 Project Design in OPNET Modeler	61
Chapter 4: Experiments & Results	71
4.1 Introduction	72
4.2 One Network Experiments	72
4.3 Two Network Experiments	80
4.3.1 Roaming-To-One	80
4.3.2 Roaming-To-All	84

Chapter 5: Aggregated Results and Future Work	92
5.1 One Operator	93
5.2 Two Operators	95
5.2.1 Roaming-To-One	95
5.2.2 Roaming-To-All	96
5.3 Conclusions	98
5.4 Future Work	98
References	99

List of Tables

Table (1.1) Project Schedule	9
Table (2.1) the standard frequency and data bandwidth for GSM network	11
Table (2.2): GSM frequency bands	25
Table (2.3): Erlang B	34
Table (2.4): Main WCDMA parameters	40
Table (3.1): Wataniya cells power	58
Table (3.2): Jawwal cells power	60
Table (3.3): Number of user in low traffic period for Wednesday in each BTS	68
Table (3.4): Number of user in low traffic period for Friday in each BTS	68
Table (4.1): The number of the turned off hours in Friday for One operator case	78
Table (4.2): The number of the turned off hours in Wednesday for One operator	79
Table (4.3): The number of the turned off hours in Friday for Roaming-to-all	90
Table (4.4): number of the turned off hours in Wednesday for Roaming-to-all	91
Table (5.1): The power saving in the one network case	94
Table (5.2): The power saving in roaming to one case	96
Table (5.3): The power saving in roaming to all case	97
Table (5.4): The project cases complexity	97

List of Figures

Figure (1.1) Green Communication fields	3
Figure (1.2) three levels of abstraction plus the code in the process model	7
Figure (2.1) GSM Architecture	12
Figure (2.2) BSS Architecture	13
Figure (2.3) types of subscriber in air interface	14
Figure (2.4) BTS power consumption distribution	17
Figure (2.5) power consumption in the BTS	17
Figure (2.6) GSM Interfaces	23
Figure (2.7) The GSM burst structure	26
Figure (2.8) Handoff Concept	28
Figure (2.9) Soft and Hard Handoff	29
Figure (2.10) the typical power consumption in Vodafone European mobile	35
Figure (2.11) BTS power consumption over the three access techniques in 3G	36
Figure (2.12): UMTS cell structure	37
Figure (2.13): Multiple access technologies	38
Figure (2.14) Principle of spread-spectrum multiple access	39
Figure (2.15): UMTS architecture	42
Figure (2.16): UTRAN Network	43
Figure (2.17): screenshot of the network editor	50
Figure (2.18): node representation of UMTS workstation	51
Figure (2.19): State Transition Diagram of umts_gmm in UE GMM layer	52

Figure (2.20): OPNET UMTS architecture representation	53
Figure (3.1) typical traffic profile over 24 hours	56
Figure (3.2): Wataniya BTSs locations	57
Figure (3.3): Wataniya traffic profile	57
Figure (3.4): Jawwal BTSs locations	59
Figure (3.5): Jawwal traffic profile	59
Figure (3.6): Jawwal and Wataniya BTSs distribution	61
Figure (3.7): Power addition for Wataniya network	62
Figure (3.8): Power addition for Jawwal network	62
Figure (3.9): Traffic addition in OPNET modeler	63
Figure (3.10): Application selection in OPNET	63
Figure (3.11): SGSN Identifier	64
Figure (3.12): SGSN Identifier for each UE	64
Figure (3.13): Path loss selection (HATA)	65
Figure (3.14): Path loss selection (CCIR)	65
Figure (3.15): the deployment of the Wataniya network	69
Figure (3.16): deployment of Jawwal network	69
Figure (3.17): Jawwal and Wataniya networks deployments	70
Figure (4.1): Wataniya Network Operator	72
Figure (4.2): The received SNR at 12 AM and 1 AM for Wednesday	73
Figure (4.3): The received SNR at 2 AM and 3 AM for Wednesday	74

Figure (4.4): The received SNR at 4 AM and 5 AM for Wednesday	74
Figure (4.5): The received SNR at 6 AM and 7 AM for Wednesday	75
Figure (4.6): The received SNR at 12 AM and 1 AM for Friday	75
Figure (4.7): The received SNR at 2 AM and 3 AM for Friday	76
Figure (4.8): The received SNR at 4AM and 5 AM for Friday	76
Figure (4.9): The received SNR at 6 AM and 7 AM for Friday	77
Figure (4.10): The received SNR at 8 AM and 9 AM for Friday	77
Figure (4.11): The Two Provider Network	80
Figure (4.12): The received SNR for three samples in the two one case	81
Figure (4.13): The two networks BTSs pairs	84
Figure (4.14): The received SNR at 12 AM and 1 AM “Two networks”	85
Figure (4.15): The received SNR at 2 AM and 3 AM “Two networks”	86
Figure (4.16): The received SNR at 4 AM and 5 AM “Two networks”	86
Figure (4.17): The received SNR at 6 AM and 7 AM “Two networks”	87
Figure (4.18): The received SNR at 12 AM and 1 AM “Two networks”	87
Figure (4.19): The received SNR at 2 AM and 3 AM “Two networks”	88
Figure (4.20): The received SNR at 4 AM and 5 AM “Two networks”	88
Figure (4.21): The received SNR at 6 AM and 7 AM “Two networks”	89
Figure (4.22): The received SNR at 8 AM and 9 AM “Two networks”	89
Figure (5.1) SNR values for the mobiles between nodeB3 and nodeB4	93
Figure (5.2): number of user in the low traffic with average SNR for Wednesday	94

Figure (5.3): number of user in the low traffic with the average SNR for Friday	94
Figure (5.4): Received SNR for different mobiles in roaming to one case	95
Figure (5.5): the aggregated results for the "Roaming to All" case in Wednesday	96
Figure (5.6): the aggregated results for the "Roaming to All" case in Friday	97

Chapter

1

Overview

1.1 Introduction

1.2 The Origin of Green Communication Idea

1.3 Project Objectives

1.4 Problem Statement

1.5 Related Works

1.6 Needed Tools

1.7 Project Risks

1.8 Report Organization

1.9 Project Schedule

1.1 Introduction:

The number of cellular network subscribers worldwide has recently surpassed the staggering number of 4 billion, with an average of more than 6 subscriptions every 10 people [1]. Every year, 120,000 new base stations are deployed servicing 400 million new mobile subscribers around the world [7]. This huge numbers of wireless terminals, together with the access network equipment necessary to serve them, consume an enormous amount of energy. Therefore network operators are paying huge energy bills. This situation, coupled with increasing energy costs, has generated a great interest of telecommunication network operators for energy saving approaches. This caught the interest of networking researchers, and has stimulated the birth of an innovative research line, often called “Green Communication”.

Green Communication is a broad concept, includes any techniques that reduce the energy consumption in communication. One of these techniques focus on the energy consumption from base stations of cellular network and how to optimize the energy saving.

Cellular operators have focused technological developments primarily on meeting capacity and Quality-of-service demands of the consumer as well as addressing the insatiable appetite for increased broadband data. However, the recent dramatic increase in energy costs and greater awareness of the cellular industry’s impact on the environment, create new urgency on improving power efficiency in communications.

Energy consumption has become a key issue, from both environmental and economic side, ICT(Information and Communication Technologies) alone is responsible of a percentage which varies between 2% and 10% of the world power consumption[3], placing the energy usage of cellular networks in perspective. Typical base station antenna and its supporting equipment use a total of 35 MWh per year [7]. Base stations are responsible for about 80% of energy consumed by a cellular network [2]. Therefore, it is required to focus on base stations reduce its power consumption.

Possibility of Applying Green Communication in Palestinian Cellular Networks

Addressing the issue of Green Communications has benefits to many stakeholders including the industry, academic researchers and government agencies. The cellular industry can realize cost savings and lower their impact to the environment, government agencies realize fulfillment of administrative goals for energy savings as well as development of standards and metrics, while researchers can push the boundaries of current technologies and theories in material science, distributed computing and system engineering.

Research in this field also has great collaboration with developments in a Smart Grid given the significant impact that cellular base stations have on power usage. Coordinated power control of cellular equipment and dynamic load balancing within the greater power grid can lead to transformational improvements in both communications and the energy systems.

This chapter provides a general overview. It starts with the first ideas of Green Communication, some definitions and a brief review of related works in this field.

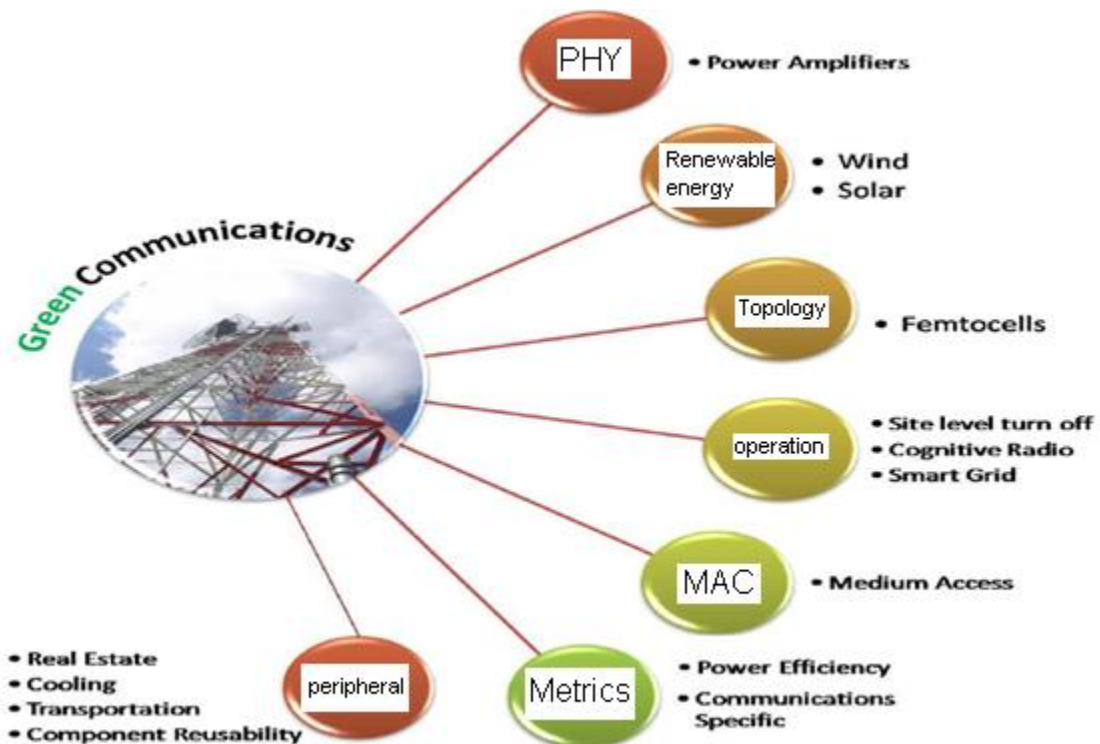


Figure (1.1) Green Communication fields [7]

1.2 The origin of Green Communication idea:

Energy efficiency has traditionally been an issue tackled by hardware designers and equipment manufacturers. The first area of networking that paid attention to energy consumption was represented by sensor networks, where the peculiarity of the network nodes made energy quite a significant element of the network design space. The first work that submitted for green communication concept talks about reducing the power consumption of wired network links and network devices considered in [4].

In the last two years, the attention of the energy issues in networking has been rise drastically. Some specific meetings were organized to discuss this problem. Also large numbers of papers were published in this field.

1.3 Project Objectives:

This project, tries to achieve the following objectives:

- Simulation of green communication idea using the OPNET modeler.
- Trying to characterize the amount of energy that can be saved by reducing the number of active cells during low traffic periods.
- Study the possibility of applying the green communication idea in Palestine within the networks operated by Jawwal and Wataniya. Based on real traffic traces and Network topologies.

1.4 Problem Statement:

This project studies energy saving in Cellular network, and simulate real case scenario using OPNET modeler in one GSM operator and between two operators to develop simple real case study to implement it in the field.

1.5 Related Works:

This section includes a simple review of what have been written about green communication idea. It is a new study field in the world. There are many researchers' concern about this subject especially between 2008 and 2011. This idea include energy efficient strategies in many networks, like wireless sensor network (WSN), wireless local area networks (WLAN) and in cellular access network include 2G,3G and in future 4G.

Before preceding the literature review, it is important to say that all papers in this field encourage new cooperative attitudes between the operators with appropriate incentives, or even enforced by regulation authorities. Because the real need for saving the huge energy consumption in networks that increases day after day.

In [1], Marson et.al evaluates the amount of energy that can be saved by using two networks in high traffic conditions, by switching off one of the two during the periods when traffic is low insurance the same quality of service that can be obtained using two operator networks. This idea is so efficient because the cellular operator designs his own networks according to peak traffic, the network provide redundant resources when traffic is low. The result of the paper is a save of (25%-30%) of the power consumption by implement the switching off pattern on two operator, the energy saving will increase remarkable if we implement it on more than two operators.

The authors of [2] provide simple analytical models that study the energy-aware management of cellular access networks, trying to characterize the amount of energy that can be saved by reducing the number of active cells during the periods when they are not necessary because traffic is low. The paper assumes two simplifying assumptions on the network which are: traffic is uniform across cells, and when a cell is switched off coverage can be filled by its neighbors. The paper encourages the cellular network operators to devised approaches to dynamically manage the resources in their networks, so as to obtain very large energy savings. The authors suggested several extensions and refinements of the results as a future work. First, doing more precise consideration of the effects of cell switch-off on the radio coverage, considering the technological aspects, such as cell breathing and antenna tilting. Second, the effect of different traffic patterns in neighboring cells should be investigated. Third, a most interesting aspect which is the possibility of choosing among several energy levels for cells.

Possibility of Applying Green Communication in Palestinian Cellular Networks

The authors of [3] show the dynamic planning of UMTS network. Switch off some UMTS cells and Node B's in urban areas during low-traffic periods, while still guaranteeing quality of service (QoS) constraints in terms of blocking probability. The authors conclude that in some scenarios, it is possible to reduce power consumption of the network for 50%.

Two Significant papers [5],[6] make the first attempt for adoption resource on-demand (RoD) WLAN strategies that can reduce energy consumption of WLANs without effecting the performance of clients in the network. Reference [5] concerns about large-scale and high-density WLAN which can be reduced through on-demand powering of APs. Reference [6] improves an analytical model used for studying simple on-demand polices, in dense WLANs, select the appropriate number of active APs to avoid the wasting energy by underutilized APs .

1.6 Needed Tools:

The needed tool in this project is the OPNET modeler, because it is one of the most useful simulation tools for many networks.

The OPNET has many features like the following:

- Friendly graphical user interface (GUI).
- Object-oriented modeling.
- Integrated data analysis tool.
- More scalable and efficient simulation engine.
- Hundreds of protocol and vendor device models.
- Flexibility to develop detailed custom models.

The OPNET modeler has primarily three levels of abstraction

- Network Model (highest level)
 - ✓ Entire network, e.g., the entire Internet
- Node Model
 - ✓ Individual devices, e.g., computers, routers, servers, ...
- Process Model (lowest level)

1.8 Report Organization:

This report is divided into four chapters, each one concern in a specific part as follow:

- **Chapter 1: Overview**

This chapter presents introduction, related work, project objectives and the needed technology for our work in green communication.

- **Chapter 2: Theoretical Background**

In this chapter we will include details about the required background, material, technology, needed for the project. Such as introduction to the GSM network, current trend in green communication, overview for UMTS network and short description about UMTS models in OPNET modeler.

- **Chapter 3: Simulation Design**

Because we do not have any hardware design in the project we will build a UMTS network with GSM attributes that we will apply our scenarios on it.

- **Chapter 4: Experiments & Analysis**

It includes the project experiments, the simulation for each case on the OPNET Modeler, and the saved power calculations.

- **Chapter 5: Aggregated Results & Future Work**

This chapter contains the results, conclusion and future work and some recommendation for those who want to continue on our work.

1.9 Project Schedule:

The project schedule will be divided into the following tasks:

Task 1: Preparing the Project:

The aim of this task is to clarify the idea of the project, and to identify its scope, followed by information collection, reading of the related works.

Task 2: Study of the principles:

During this task, the study of the GSM, UMTS will be performed.

Task 3: The project requirements analysis:

In this task, choose the simulation tool (OPNET modeler) and studying it deeply.

Task 4: Project Simulation:

We choose the different scenarios of the project, determined the main parameters, begin simulate the project experiments, take the results and analyze it.

Task 5: Documentation and writing

Documentation of the project findings and writing of its document will begin from the first phase to the last one.

	Week																															
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
T1	█	█	█	█																												
T2			█	█	█	█	█	█																								
T3																																
T4																																
T5																																

Table (1.1) project schedule

Chapter

2

Theoretical Background

2.1 Introduction to GSM

2.2 GSM Network Overview

2.3 GSM Interfaces

2.4 GSM carrier frequencies

2.5 GSM Channels

2.6 Handoff

2.7 Power Control

2.8 Traffic Engineering

2.9 Current trend in Green cellular Communication

2.10 UMTS Network

2.11 OPNET Modeler

2.1 Introduction to GSM:

The first generation of Cellular telephony was designed for voice communication using analog signals. Advanced Mobile Phone System (AMPS) is one of the leading analog cellular systems. It uses FDMA to separate channels in a link.

Global System for Mobile Communication (GSM) is a second generation cellular standard that was developed to solve fragmentation problems of the first cellular systems. It provides higher quality mobile voice communication as compare to first generation, the main motive for designing the second generation is to digitized voice. GSM was introduced into European market in 1991, till now there are more than 1.7 billion users of GSM all over the world. GSM originally used two cellular bands: 890-915 MHz from subscriber to base station (uplink) and 935-960 MHz from base station to subscriber (downlink).

In GSM each network component is design to communicate over an interface specified by the GSM standards. This provides flexibility and enables a system operator to utilize system components from different manufacturers.

Early, one powerful transmitter located at the highest spot in an area would broadcast in a radius of up to 50 kilometers. The cellular concept structured the mobile telephone network in a different way. Instead of using one powerful transmitter many low power transmitters were placed throughout a coverage area.

In GSM, Subscribers located within the radio range can access wireless connection which is provided by the cellular radio system. Large numbers of mobile users are bound to use limited frequency spectrum to communicate each other. The techniques FDMA, TDMA, CDMA provide a two-way communication it means users can able to transmit and receive signal at same time which is known as full duplex.

Standard	GSM
Frequency wavelength	900 MHz, 1800 MHz, 1900 MHz
Data bandwidth	9.6 kbps

Table (2.1) the standard frequency and data bandwidth for GSM network

2.3 GSM Network Overview:

Each network component is designed to communicate over an interface specified by the GSM standards. This provides flexibility and enables a system operate to utilize system components from different manufacturers. Main GSM network components:

- Mobile station (MS)
- Base station system (BSS)
- Network switching system (NSS)
- Operation and Maintenance system (OMC)

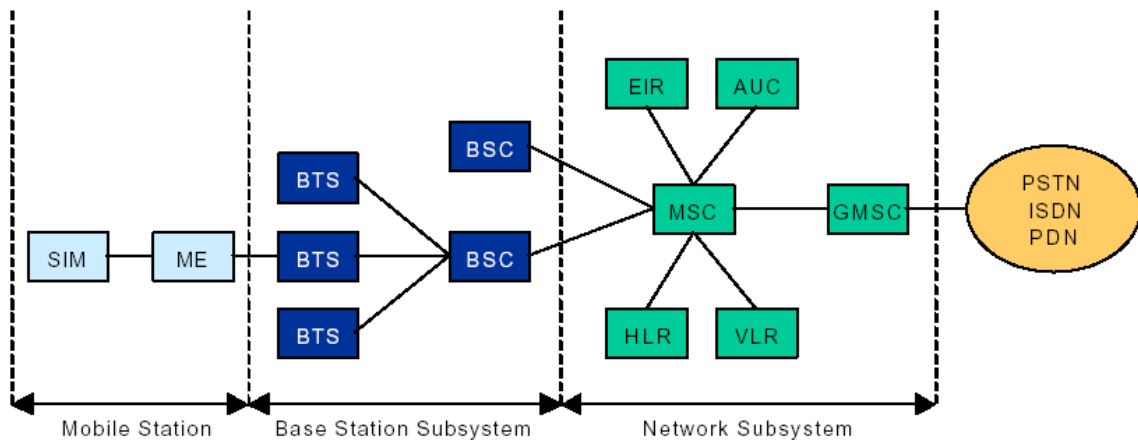


Figure (2.1) GSM Architecture

2.2.1 Mobile Station (MS):

The Mobile Station is based on combination of main two essential components, mobile Equipment (ME) and an electronic smart card called Subscriber identity Module (SIM).

Mobile equipment is used by the subscriber when it needs to access to the network. Subscriber can use any mobile phone from different manufacturer companies. Because each mobile has an identity number totally associated with it, unique for that particular device and permanently stored in it. This identity number is called International mobile equipment identity (IMEI).

The SIM is a card which plugs into the mobile equipment. This card identifies the Subscriber and also give information to the user regarding the service that subscriber received.

The SIM card contains several pieces of information these are listed below:

1- International mobile subscriber identity (IMSI): the mobile subscriber is identified by this number. During initialization this number is transmitted over the air.

2- Temporary mobile subscriber identity (TMSI): this number is used to prevent any intruder or unauthorized user to monitor the radio interface. This number also provides a protection which is periodically changed by the system management.

3- Location area identity (LAI): is the local area identity used for identifying the authentication of a subscriber card.

4- Mobile station international standard data network (MSISDN): this is number which is assigned to the subscriber with country code as well as national code.

2.2.2 Base Station Subsystem (BSS):

It is the equipment found at the cell site. The BSS provides the link between the mobile equipment and the mobile services switching center. The BSS communicates with the mobile station over the digital air interface and with the mobile services switching center (MSC) with 2 Mbit PCM links.

The BSS consists of three major hardware components:

1- Base Transceiver Station (BTS):

BTS provides the air interface connection with the Mobile and the Network, it has limited amount of functionality; this reduce the amount of traffic which needs to pass between the BTS and BSC and so makes it fast. Each BTS cabinet will provide between 3 and 5 RF (Radio Frequency) carriers which in turn will provide between 24 and 40 simultaneous calls.

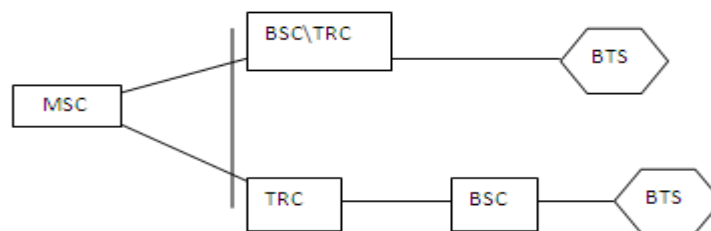


Figure (2.2) BSS Architecture

Possibility of Applying Green Communication in Palestinian Cellular Networks

The BTS houses the radio transceivers that define a cell and handles the radio link protocols with the MS. In a large urban area, a large number of BTSs may be deployed.

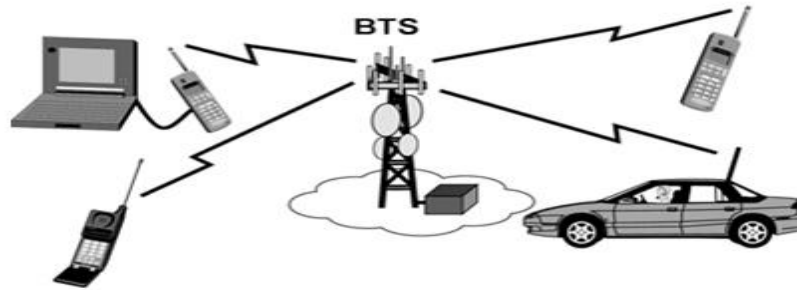


Figure (2.3): types of subscriber in air interface [12]

The BTS corresponds to the transceivers and antennas used in each cell of the network. A BTS is usually placed in the center of a cell. Its transmitting power defines the size of a cell. Each BTS has between 1 and 16 transceivers, depending on the density of users in the cell. Each BTS serves a single cell.

It also includes the following functions:

- Encoding, encrypting, multiplexing, modulating and feeding the RF signals to the antenna.
- Transcoding and rate adaptation
- Time and frequency synchronizing
- Voice through full- or half-rate services
- Decoding, decrypting, and equalizing received signals
- Random access detection
- Uplink channel measurements

❖ Components of the BTS:

Shelter: This is the housing in which all installations hardware, configuration and termination is done. It usually is 10*10 ft with provision for two air-condition unit & a feeder window.

Mast/Tower: The importance of the tower on the BTS is to have a clear Line of Sight for the PDH/SDH radio and give room for easy radiation of radio signals by the sectorial antenna. The height of the tower is dependent on the topography of the land in focus but the standard recommended height is between 35-40m approximately.

Sectorial Antenna: It's a broadband antenna capable of multiplexing dual frequency bands for transmission. This antenna radiates at an angle of 120°. For a total coverage, three sectorial antennas are used on a tower to cover 360° circumference. It also has a radiation distance of about 35km if concentrating on capacity building for urban areas & 121km when emphasizing on coverage.

PDH/SDH Microwave: Plesio synchronous Digital Hierarchy (PDH) & Synchronous Digital Hierarchy (SDH) are microwaves commonly used on the Base Station System. Point to Point (p2p) & Point to Multipoint transmission. The PDH microwave has a capacity of 16 E1 making it the mostly used for BTS transmission since it gives room for upgrade and it is very efficient in terms of radio transmission to the BSC on the Abis interface. SDH on the other hand has a capacity of 75 E1. It's used basically on the Hub stations for transmission to the BSC on the Ater interface i.e. if you have the BSC & Transcoder Controller (TRC) on a single node. It has a transmission length of about 50km.

Waveguides: As a result of skin effect, waveguides were invented to eliminate or minimize loss of electro-magnetic signals passing through cables in the course of transmission. This black armored like cables have connectors at their tips to fit into the duplexers via feeder window on the shelter.

Radio Base Station (RBS): Radio Base Stations (RBS) handles the modulation of speech signals. The Transceiver Unit does basically base band speech processing, Abis interface signaling processing, RF signal amplification, modulation & demodulation. Frequency

Possibility of Applying Green Communication in Palestinian Cellular Networks

assignment is done on the TRU and the transceiver units are multiplexed in the combiner unit i.e. Combiner & Distribution Unit (CDU). The combiner unit does the filtering of signals from 33.8kbps to 16kbps before its being sent to the PDH from Abis interface. Since the GSM system uses the TDMA technology, several speech signals can be conveyed on frequency. Each physical channel has 8 time slot under this technology. Every logic channel can connect via the slots. Ericsson has several versions but prominent are the RBS 2200 and RBS 2100 versions. RBS 2216 version has six TRU slots for both GSM 900 & 1800 frequencies. It has dummy slots for upgrade purpose The RBS provides interface to mobile station on the air interface also it interfaces the BSC on the Abis interface on the Distribution Switch Unit (DXU).

Rectifier: The RBS works on a 48V d.c Alternating to direct current conversion is maintained by the rectifier and its output fed into the site voltage regulator. Four 12V d.c batteries are used as backup on the rectifier. The RBS takes its power directly from the rectifier.

Transmission Rack: Otherwise known as TX cabinet, it holds the PDH/SDH radio & contains the connectors on which the alarm, TX/RX installations are done.

Trunking: The trunk consists of a ladder and a bus like rail on which all installation cables/waveguides run.

Duplexers: The duplexer does de-multiplexing function between the sectorial antennas and the RBS. The sectorial antenna has a dual frequency input. Waveguides connects the input of these frequencies then de-multiplexes. The duplexers have two input and four outputs. Each output connects to each 1800 TRU card on the RBS. A pair of the output on the duplexer for 900 connects to a TRU card.

Data Distribution Frame: The Data Distribution Frame (DDF) or krone box acts as the interface between the Distribution Switch Unit (DSU) and the radio. It's just a connector where all E1 connections & DXU connection is terminated.

Possibility of Applying Green Communication in Palestinian Cellular Networks

- ❖ **BTS Power Consumption:** A typical base station site has a number of contributors to its total power consumption as illustrated in the following graph:

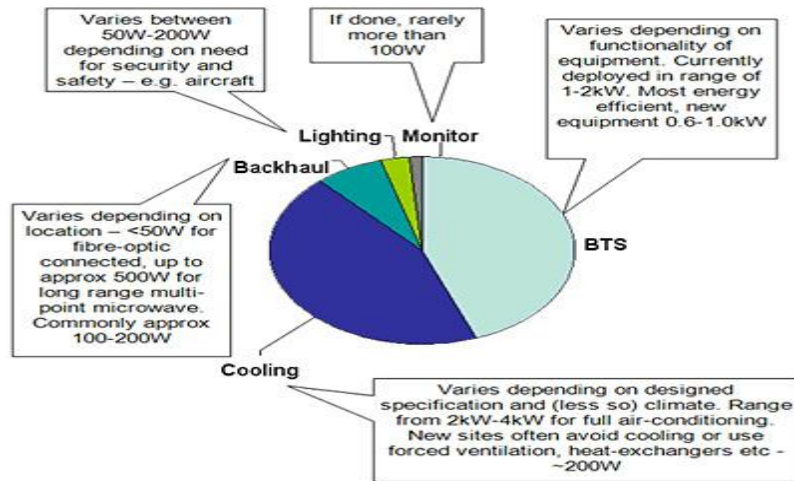


Figure (2.4): BTS power consumption distribution [13]

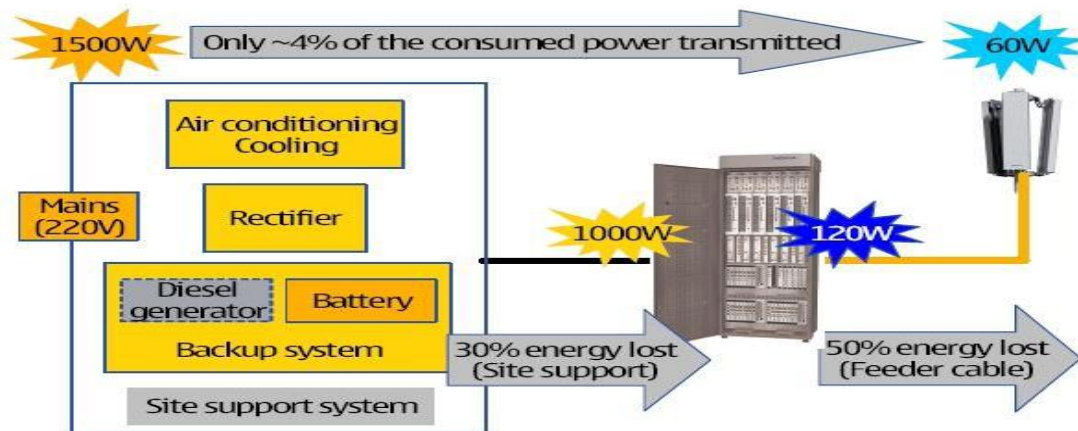


Figure (2.5) power consumption in the BTS [2]

2-Base Station Controller (BSC):

The BSC provides control for the BSS. One BSC may control approximately 40 BTS.

Any information required by the BTS for operation will be received via the BSC. Also any information required about the BTS (by the OMC for example) will be obtained by the BSC. The BSC switching matrix allows the BSC to perform “handover” between radio channels on separate BTS, under its control, without involving the MSC.

3-Transcoder (XCDR)

The Transcoder (XCDR) is required to convert the speech or data output from 64Kbps into the form specified by SMG specifications for the transmission over the air interface, that is between the BSS (Base Station Subsystem) and MS (Mobile Station).

The 64kbps pulse code modulation (PCM) circuits from the MSC, if it is transmitted on the air interface without modification would occupy an excessive amount of bandwidth. The required bandwidth is therefore reduced by processing the 64kbps circuits so that the amount of information required in transmit digitized voice falls to 13kbps. The transcoder may be located with the MSC, BSC or BTS. If it is located at the MSC the 13kbps channels will be transmitted by the BSS by “bit stuffing” them to data transfer rate of 16kbps and then fitting four of them into each 64kbps terrestrial circuits. Thus each 30 channel 2Mb/s PCM link can carry 120 GSM specified channels, with obvious cost savings from the system operator.

2.2.3 The Network Switching System (NSS):

The main switching function of the GSM network includes the network switching system. The main function of NSS is to store the data of required subscriber and all kind of mobility management (database).

The components of NSS are listed below:

- Mobile Switching Center - (MSC)
- Home Location Register - (HLR)
- Visitor Location Register - (VLR)
- Equipment Identity Register-(EIR)
- Authentication Center - (AUC)
- Interworking Function - (IWF)
- Echo Cancellor - (EC)

1-Mobile Switching Center (MSC):

The mobile switching center (MSC) is a part of a GSM network that is equivalent of an exchange in a fixed network, plus everything extra needed to handle mobile stations.

Basically MSC major jobs are location, registration, handovers, authentication and routing of calls to move from one MS to another.

The MSC controls the switching and handoffs between cells, providing commands to each BS which is near for dropping the current call from old BS and arrange the new one. In order to make it sure that current call should active as much as possible. Voice channel is given to handoff calls over new calls. Mobile switching center organize the process of creating new calls. MSC will initiate the call by using a reserve control channel to make request. The MSC has to then grant the request, after which a pair of voice channels are assigned for the calls.

2-Home Location Register (HLR):

The network consists of more than one HLR and the data is easily accessible for all required MSCs and the VLRs in the network. HLR is the responsible to store a whole data and contains the master database of the total numbers of subscriber to a GSM PLMN (public land mobile network). Subscriber has option to access either from the IMSI or the MSISDN number.

The parameters stored in the HLR are listed below:

- Subscriber ID (IMSI and MSISDN)
- Current subscriber VLR (current location)
- Supplementary services subscribed to
- Subscriber status (register/unregistered)
- Authentication key and AUC functionality
- Temporary mobile subscriber identity (TMSI)
- Mobile Subscriber Roaming Number (MSRN)

3-Visitor Location Register (VLR):

The main function of VLR is to store data temporary of the subscriber only as long as the user is active in the region which is covered by the VLR. The data which is stored at the HLR is taken by the temporary data storage VLR. The VLR provides a local database for the subscriber wherever he is physically located within a PLMN; this may or may not be the home system.

The additional data stored in the VLR is listed below:

- Mobile status (busy/free/no answer etc.)
- Location Area Identities (LAI)
- Temporary Mobile Subscriber Identities
- Mobile Station Roaming Number

5-Equipment Identity Register (EIR):

The EIR contains a centralized database for validating the International Mobile Equipment Identity (IMEI). This database is remotely accessed by the MSC in the network. The EIR database consists of lists IMEIs (or arrange of IMEIs) organized as follows:

WHITE LIST contains those IMEIS which assigned to valid mobile equipment.

BLACK LIST contains IMEIs of mobiles which have been accepted stolen.

GRAY LIST any Mobile Equipment that appears on the gray list will be allowed to function but will trigger an alert to the network operator.

6-Authentication Center (AuC):

The AuC is a processor system it performs the “authentication” function. It will normally be co-located with the Home location register (HLR) as it will required to continuously access and update as necessary, the system subscriber record.

The Authentication process will usually take place each time the subscriber “initializes” on the system.

Possibility of Applying Green Communication in Palestinian Cellular Networks

In the authentication process secure data stored on the SIM card is manipulated and compared with data held in the HLR database. This data is entered into the SIM and the system database (HLR) at the time the SIM card is issued.

7-Interworking Function (IWF):

GSM system is to enable to make connection with the various types of private and public networks which transfer or receive all the data currently available. This main function is provided by the Interworking Function (IWF).

The basic featured of IWF are given below:

- Rate Conversion
- Protocol Adaption

Some system require more IWF capability than others, this depend upon the network to which it is connected.

8-Echo Canceller:

An Echo Canceller is used on the PSTN side of the MSC for all voice circuits. Echo control is required at the switch because the GSM inherent system delay can cause an unacceptable echo condition even on short distance PSTN circuit connection.

During a normal PSTN land to land call, no echo is apparent because the delay is too short and the user is unable to distinguish between the echo and the normal telephone. However, with the GSM round trip delay added and without EC (Echo Canceller), the effect would be very irritating to the MS subscriber, disrupting speech and concentration.

The standard EC will provide cancellation of up to 68millisecond on the “trail circuit” (the tail circuit is the connection between the output of EC and the land phone).

2.2.4 Operation and Maintenance System (OMC):

The operation and maintenance sub-system provides a capability to manage the GSM network remotely. This area of the GSM network is not currently tightly specified by the SMG specifications. It is left to the network operator to decide what capabilities they wish it to have.

The operation and maintenance system comprises of two parts:

Possibility of Applying Green Communication in Palestinian Cellular Networks

- Network Management Center- NMC
- Operation and Maintenance Center- OMC

1-Network Management Center (NMC):

The network management center offers the ability to provide hierarchical regionalized network management of complete GSM system. It is responsible for operation and Maintenance is the network level supported by the OMCs which are responsible for regional network management. The NMC therefore singles logical facility at the top of the network management hierarchy.

The NMC has a high level view of the network as serried of network nodes and interconnecting Communication facilities. The OMC, on the other hand is used to filter information from the network equipment for forwarding to the NMC thus allowing it to focus on issues requiring national coordination. The NMC also can coordinate issues regarding interconnect to the other networks.

❖ Functionality of the NMC

- Monitor trunk routes between nodes on the network
- Monitor high level Alarms
- Passes on knowledge from one OMC region to another to improve problem solving strategies.
- Monitor OMC regions and provides assistance to OMC staff
- Enables long term planning for the entire network

2-Operations and Maintenance Center (OMC)

The OMC provides a central point from which to control and monitor the other network entities (i.e. base stations, switches, database, etc.) as well as monitor the quality of service being provided by the network as a whole.

At the present equipment manufacturer have their own OMCs which are not compatible in every aspect with those of other manufacturers. This is particularly the case between Radio base station equipment suppliers, where in some cases the OMC is a separate item and digital switching equipment supplier, where in OMC is an integral, but functionally separate, part of the hardware.

Possibility of Applying Green Communication in Palestinian Cellular Networks

These are two types of OMC:

- OMC (R)- OMC assigned specially to the base station system
- OMC (S)- OMC assigned specially to the Network switching system

❖ Function of OMC

The OMC should support the following function.

- Event/ Alarm Management
- Fault Management
- Performance Management
- Configuration Management
- Security Management

2.3 GSM Interfaces:

The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Transceiver Station (**BTS**) and the Base Station Controller (**BSC**) communicate across the standardized A-bis interface. The **BSC** communicates with the **MSC** across the A interface.

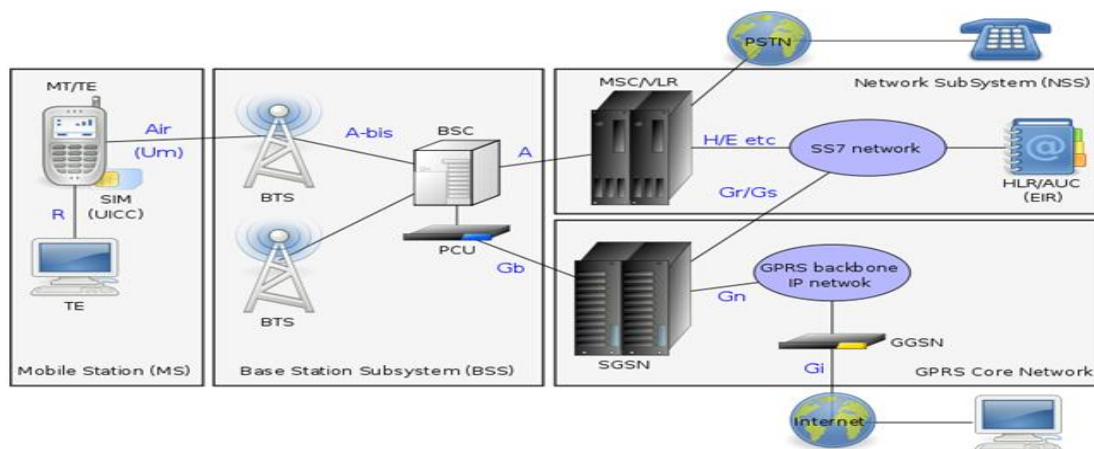


Figure (2.6): GSM Interfaces

2.4 GSM carrier frequencies:

GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G). Most 2G GSM networks operate in the 900 MHz or 1800 MHz bands. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead. In rare cases the 400 and 450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems. Most 3G networks in Europe operate in the 2100 MHz frequency band. Regardless of the frequency selected by an operator, it is divided into timeslots for individual phones to use. This allows eight full-rate or sixteen half-rate speech channels per radio frequency. These eight radio timeslots (or eight burst periods) are grouped into a TDMA frame. Half rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833kbit/s and the frame duration is 4.615 ms.

The transmission power in the handset is limited to a maximum of 2watts in GSM850/900 and 1 watt in GSM1800/1900.

The frequency band is divided into 124 pairs of frequency duplex channels with 200 KHz carrier spacing. For a given distance, less power is required to transmit signal over a lower frequency.

To save MS power, uplink frequencies in mobile systems are always the lower band of frequencies. Discontinuous transmission is used in GSM to save the power consumption of the MS. With this function, MS turns the transmitter ON only while voice is present. When there is no voice input, the transmitter is turned OFF. GSM also supports discontinuous reception where the MS only needs to listen to its sub-channel for paging.

Possibility of Applying Green Communication in Palestinian Cellular Networks

Channel number	Downlink (MHz)	Uplink (MHz)	Band	System
Dynamic	390.2–399.8	380.2–389.8	380	T-GSM-380
Dynamic	420.2–429.8	410.2–419.8	410	T-GSM-410
259–293	460.4–467.6	450.4–457.6	450	GSM-450
306–340	488.8–496.0	478.8–486.0	480	GSM-480
Dynamic	728.0–746.0	698.0–716.0	710	GSM-710
438–511	777.0–792.0	747.0–762.0	750	GSM-750
Dynamic	851.0–866.0	806.0–821.0	810	T-GSM-810
128–251	869.0–894.0	824.0–849.0	850	GSM-850
1–124	935.2–959.8	890.2–914.8	900	P-GSM-900
975–1023, 0-124	925.0–930.0	880.0–890.0	900	E-GSM-900
955–1023, 0-124	921.0–959.8	876.0–914.8	900	R-GSM-900
Dynamic	915.4–921.0	870.4–876.0	900	T-GSM-900
512–885	1805.2–1879.8	1710.2–1784.8	1800	DCS-1800
512–810	1930.0–1990.0	1850.0–1910.0	1900	PCS-1900

Table (2.2): GSM frequency band [11]

The length of a GSM frame in a frequency channel is 4.615 msec. The frame is divided into 8 bursts (time slots) of length 0.577 msec. The time slots in the uplink are derived from the downlink by a delay of three time slots. This arrangement prevents an MS from transmitting and receiving at the same time. However, due to propagation delays, especially when the MS is far away from the BTS, the three-time-slot delay cannot be accurately maintained. The solution is to compute the timing advance value so that the exact shift between downlink and uplink seen by the MS is three time slots minus the timing advance value. This timing advance value is calculated by the BSS based on the bursts received from the MS and is signaled to the MS twice per second to inform the MS of the appropriate timing value.

The GSM burst structure is illustrated in the figure 2.2, every burst contains 148 bits (0.546 msec) followed by 0.031 msec guard time (8.25 bits). The burst begins with 3 head bits and ends with 3 tail bits, all of which are logical zeros. Two groups of data bits are separated by an equalizer training sequence of 26 bits. Each data group consists of 57 information bits and one flag that indicate whether the information bits are for user speech/data or signaling.

Possibility of Applying Green Communication in Palestinian Cellular Networks

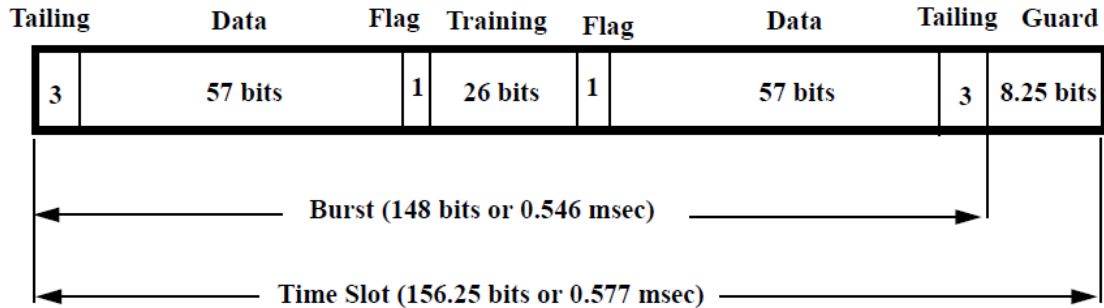


Figure (2.7): The GSM burst structure [9]

2.5 GSM Channels:

Two types of logical channels are defined:

- The traffic channels (**TCHs**): TCHs are intended to carry user information (speech or data), are defined in two types:
 1. Full rate TCH (**TCH/F**) provides transmission speed of 13 Kb/s for speech or 9.6, 4.8 or 2.4 Kb/s for data. Enhanced Full Rate (**EFR**) speech coders have been implemented to improve the speech quality of a TCH/F.
 2. Half rate TCH (**TCH/H**) allows transmission of 5.6 Kb/s speech or 4.8 or 2.4 Kb/s data.
- The control channels (**CCHs**): The CCHs are intended to carry signaling information, are defined in three types:
 1. Common control channels (**CCCHs**): Common Control Channels support common procedures required to establish a dedicated link with the network. Typical channels include the **RACH** (Random Access Channel) which used by the MSs for initial access to the network, **PCH** (Paging Channel) that used to alert the mobile station of an incoming call , and **AGCH** (Access Grant Channel) that used by the network to indicate radio link allocation upon prime access of an MS.
 2. Broadcast channels (BCCCHs): Continually broadcasts, on the downlink, information including base station identity, frequency allocations and frequency hopping sequences.

Possibility of Applying Green Communication in Palestinian Cellular Networks

3. Dedicated control channels (DCCHs): are supported in GSM for dedicated use by a specific MS.

a. The standalone dedicated control channel (**SDCCH**) is used only for signaling and for short messages.

b. The slow associated control channel (**SACCH**) is associated with either a TCH or an SDCCH. The SACCH is used for non-urgent procedures, mainly the transmission of power and time alignment control information over the downlink and measurement reports from the MS over the uplink. A TCH is always allocated with a control channel SACCH to transport both user information and signaling data in parallel.

c. The fast associated control channel (**FACCH**) is used for time critical signaling such as call establishing progress, authentication of subscriber, or handoff. The FACCH makes use of the TCH during a call. Thus, there is a loss of user data because the FACCH "steals" the bandwidth of the TCH.

d. The cell broadcast channel (**CBCH**) only carries the short message service cell broadcast messages, which uses the same time slot as the SDCCH.

The CBCH is used in downlink only. SDCCH, SACCH and FACCH are used in both downlink and uplink.

2.6 Hand Off

Allocation of radio and fixed links are temporary during the ongoing call and it is known as handover or handoff. The technique is used when a user is move from cell to other cell a long distance without terminating the ongoing call. The implementation and capacity required for handover form and one of essential functions of the MSC.

Four types of handover that involves transfers an ongoing call in the GSM system.

- Base stations controller (BSCs) directly belonging to the same Mobile service Switching center (MSC).
- Base transceiver stations of different location under the control of different BSCs.
- Different channels belonging to the same BTS.

Possibility of Applying Green Communication in Palestinian Cellular Networks

➤ Base station controller (BSC) control the cells called (base transceiver stations).

MSCs using first two types to manage all handover requested calls and it is known as external handover. Last two types are controlled by single Base Station in order to save the bandwidth and these types are known as internal handovers.

Handovers can be initiated by either the mobile or the MSC (as a means of traffic load balancing). The mobile always scans the broadcast control channels approximately 16 neighboring cells, during its inactive timeslots and categorically select the six best candidates for possible handover and it totally based on received signal strength.

After completing this process the message is forwarded to BSC and MSC, at least once per second and finally it is used by the handover algorithm.

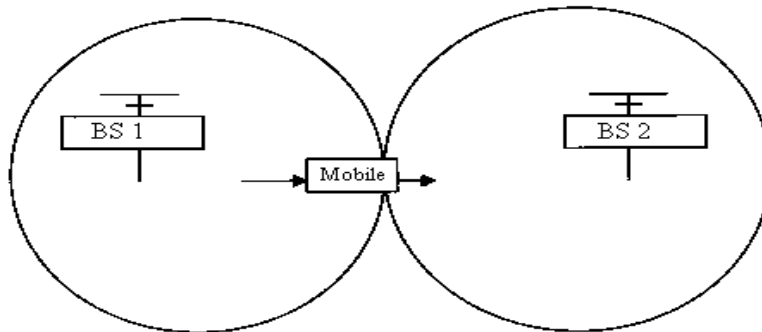


Figure (2.8) Handoff Concept [15]

1- Hard Hand off

Signal strength of ongoing call exceeds of the current cell. The mobile is constructed to switch to a new frequency band that is within the allocation of new cell. The channel in the source cell is released then the channel in the target cell is engaged. It is also known as break-before-make.

2- Soft Hand off

In modern wireless system, when a mobile moves into a different cell while a conversation is in progress. Soft hand-off occur only change of base station but no change in actual channel when MSC transfer the ongoing call to a base station.

In GSM there is concept of Mobile Assisted Hand-Off (MAHO). The power levels of all base stations which are situated in certain area are measured continually by mobile station and report

Possibility of Applying Green Communication in Palestinian Cellular Networks

to the serving base station. The power level of BS of neighboring cell increase than the current cell as far as certain time or level is concerned and then hand-off begins. It is also known as break-before-make.

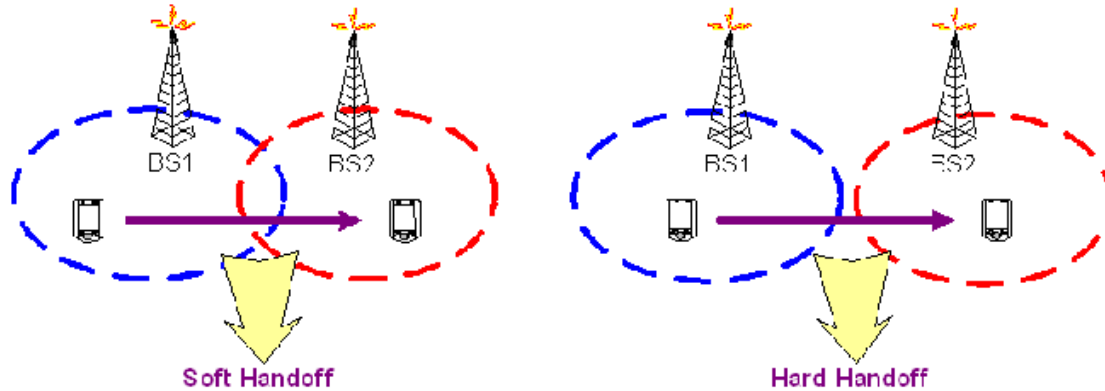


Figure (2.9) Soft and Hard Handoff [14]

2.7 Power Control:

There are five classes of GSM mobile stations, defined according to their peak transmitter power, rated at 20,8,5,2 and 0.8 watts.

To minimize co-channel interference and to conserve power. Both the mobiles and the Base Transceiver Stations operate at the lowest power level that will maintain an acceptable signal quality. Power levels can be stepped up or down in steps of 2 dB from the peak power for the class down to a minimum of 13 dBm (20milliwatts).

The mobile station measures the signal strength or signal quality based on the bit error ratio and sends the information to the Base Station Controller. This ultimately decides if and when the power level should be changed. Power control should be handled carefully, since there is the possibility of instability. This arises from having mobiles in co-channel cells alternating increase their power in response to increased co-channel interference caused by the other mobile increasing its power. [9]

2.8 Traffic Engineering:

2.8.1 Trunking Theory:

The concept of trucking allows a large number of users to share the relatively small number of channels in a cell by providing access to each other, on demand, from a pool of available channels [16]. Single channel is assigned to an every subscriber for an ongoing call and when call is disconnected the channel which is allocated to a user is move back to pool of the available channel.

“Trunking exploits the statistical behavior of user so that fixed number of channels may accommodate a large, random number of channels that need to be allocated for hundreds of users [16]”. There is trade-off between the number of available channels and the likelihood of a particular user finding that no channels are available during the peak calling time [16].

The traffic intensity offered by each user is equal to the call request rate multiplied by the holding time. That is, each user generates a traffic intensity of A_u Erlangs (traffic load unit) given by:

$$A_u = \lambda * H$$

Where λ is the average number of call requests per unit time and H is the average duration of a call. For a system containing U subscriber and an unspecified number of channels, the total offered traffic intensity A , is given as:

$$A = U * A_u$$

Furthermore, in a C channel trunked system, if the traffic is equally distributed among the channels, then the traffic intensity per channel, A_c , is given as:

$$A_c = U * A_u / C$$

2.8.2 Types of Trunked Systems

There are two types of trunked systems which are commonly used:

1-Blocked Calls Cleared

It provides the easy way to access the service by user and it will automatically inform user for accessing the available channel in short time. If channels are not available user is not able to access and its request is blocked but user can send a request for accessing again. It selects the random users for call request.

2-Blocked Calls Delayed

This kind of trunking provides a queue for holding calls which are already blocked and waits an ongoing call until the availability of channel.

2.8.3 Grade of Service (GOS)

It measures the strength of a subscriber when it tries to access a trunked system during the heavy traffic on system as well as measure the time duration. The busy hour is based upon customer demand at the busiest hour during a week, month or year. Basically grade of service is a standard to define a performance level of a trunked system that how much it is capable to allow user for access the available channel in the system.

When user attempts to make a telephone call, the routing equipment handling the call has to determine whether to accept the call, or reject the call entirely. Rejected calls occur as a result of heavy traffic loads (congestion) on the system and can result in the call either being delayed or lost. If a call is delayed, the user simply has to wait for the traffic decrease, however if a call is lost then it is removed from the system.

Grade of service is the used to measure the quality of an ongoing call when a subscriber sends a request. In a loss system, the grade of service is described as the proportion of calls that are lost due to congestion in the busy hour.

The exact way to measure the grade of service is to divide all loss calls number with offered calls.

Possibility of Applying Green Communication in Palestinian Cellular Networks

The other way to measure the grade of service is to utilize the different parts of the network. When a call is routed from one end to another; it will pass through several exchanges. If the Grade of Service is calculated based on the number of calls rejected by the final circuit group, then the grade of service is determined by the final circuit group blocking criteria. If the Grade of Service is calculated is determined by the exchange-to-exchange blocking criteria.

Grade of service is also known as blocking probability and this blocking probability occurs during communication between mobile and station. During a radio transmission low blocking probability is possible but it doesn't effect on system performance.

$$\frac{A^C/C!}{\sum_{K=0}^C A^k/K!}$$

Where C is the number of trunked channels which are offered by a trunked radio system, and A is the total offered traffic. While it is possible to model trunked systems with finite users, the resulting expressions are much more complicated than the Erlang B result, and the added complexity is not warranted for typical trunked systems which have users that outnumber available channels by orders of magnitude. Furthermore, the Erlang B formula provides a conservative estimate of the GOS, as the finite user results always predict a smaller likelihood of blocking.

2.8.4 Traffic Analysis

Cell planning starts with traffic coverage analysis. The analysis produces information about the geographical area, expected capacity (traffic load). The collected data types are:

- Pool traffic channels
- Capacity
- Cost
- Grade of Service (GOS)
- Coverage
- Available frequencies
- Speech quality
- System growth capability

Possibility of Applying Green Communication in Palestinian Cellular Networks

The cell planning depends on the traffic demand, i.e. total strength of subscribers is engaged with the network and how much traffic they generate. The Erlang (E) can be calculated with the following formula:

$$A = n \times T / 3600 \text{ Erlang}$$

Here, A represents the total traffic available for subscribers, n gives the estimate number of calls per hour and T is an average call time per second.

The number of subscribers and the Grade of Service (GOS) has to be known for calculating number of cells. Capacity of networks depends on the total numbers of subscribers, available frequencies, cell pattern, GOS, and traffic per subscriber, if we know the exact figure of all above data then we can able to calculate the total strength of capacity like how much frequency is allocated to each cell by a network operator, available traffic channel allocated by the pool system, i.e. If 14 TCH are allocated by a pool with a 2% GOS the total traffic intensity per cell will be 8.2 Erlangs (see Erlang B table). The total numbers cells in one area can be calculated by dividing the total numbers subscribers with the subscribers of one cell.

Possibility of Applying Green Communication in Palestinian Cellular Networks

Number of channels C	Capacity (Erlang) for GOS									
	0.007	0.008	0.009	0.01	0.02	0.03	0.05	0.1	0.2	0.4
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598
14	6.9811	7.1155	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541
17	9.2119	9.3714	9.5171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074

Table (2.3): Erlang B Table [16]

Possibility of Applying Green Communication in Palestinian Cellular Networks

For cellular circuit groups 2% GOS is acceptable. It means that two subscriber of the circuit group out of a hundred with encounter a call refusal during busy hour at the end of planning period. If GOS is 5% then one call in 20 will be blocked during the busiest hour the overloaded traffic on the cell.

Suppose call is established between user and cell via MSC. Assuming a continuous connection and data rate transfer rate at 30 kbit/s, and then call will terminated after 50 minutes so the total offered traffic intensity will be 0.833. Here offered traffic intensity depends on the holding time. If MSC receives 240 calls/hr and the average time of terminating calls is 5 minutes so the outgoing offered traffic intensity of MSC to subscribers will be 20 Erlangs. Total 20 hours of circuit talk time is required for every hour of elapsed time. An average of voice circuit busy at any time is 20. (20 channels are continuously for 20 hours).

2.9 Current trend in Green cellular communication:

This section talks about the other Green Communication ways for saving energy in cellular network other than turn off the base stations in low traffic periods.

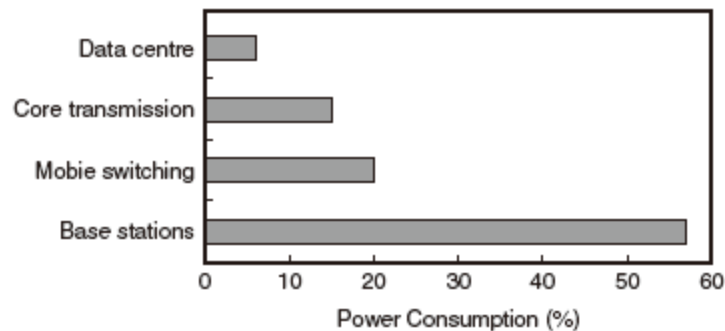


Figure (2.10) the typical power consumption in Vodafone European mobile [8].

More than 50% of the energy consumption is directly attribute to BTS'S and approximately 40% to core side. Thus base stations and core are the prime target for energy savings.

Because the green communication concept are recently acknowledged, only the 3G long term evolution (LTE) and high speed packet access (HSPA) networks are concerned with this idea.

Possibility of Applying Green Communication in Palestinian Cellular Networks

During the 3G evolution the power consumption has dramatically decreased from early 3G wideband code division multiple access (W-CDMA) base stations, to modern 3G high speed packet access (HSPA) and 3G LTE base stations. This clarified in figure (2.11).

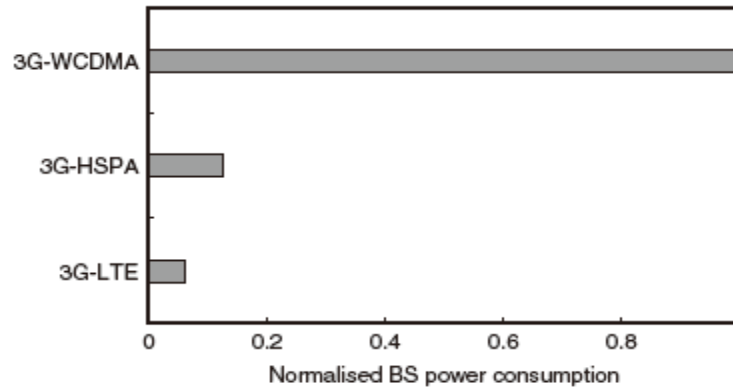


Figure (2.11) BTS power consumption over the three access techniques in 3G

The traditional base stations are required air-conditioned cooling unit, which themselves consume a significant portion of energy. Even the non-air conditioning-based design consumed much energy. Modern 3G LTE base stations are naturally air cooled and in most cases does not use cooling fans. On the other hand, the designers of the 3G LTE base stations used special radio frequency amplifiers and reduce the processing in the base station to minimum, using digital integrated circuit. These base stations have energy consumption around 50% lower than the traditional design.

In the core side, the energy saving considered in 3G LTE network too. The 3G LTE networks are full IP-based architecture so it has low power, low cost server equipment. Beside the data center equipment's such as proxy servers improve a sleep mode technique that reduces number of active communication links during low traffic periods.

The 3G LTE use multi input multi output (MIMO), beamforming, resource allocation and packet scheduling techniques to enhance the spectral efficiency and reduce the required transmitted energy per bit. LTE use the path loss model, cell size and shadowing conditions. The strategic use of these parameters can reduce the power wasted due to channel conditions.

Another concept is home base station (femto-BS) which enhances the in-building coverage without requiring excessive transmits power like the conventional BS. [8]

2.10 UMTS Network

2.10.1 Introduction

The third generation mobile communication system UMTS (Universal Mobile telecommunications System) is successor of GSM (Global System for Mobile Communications). UMTS networks can be divided in two parts. One part that is responsible for the circuit switched services (CS-domain) and one part that manages packet switched services. The CS-domain manages voice calls and on the other hand the PS-domain is responsible for data connections like connections from a mobile device (called user equipment (UE) in UMTS) to the internet.

2.10.2 Hierarchical Cell Structure

UMTS is designed to provide global access and world-wide roaming. To support this URAN (UMTS Radio Access Network) will be build in different hierarchical levels.

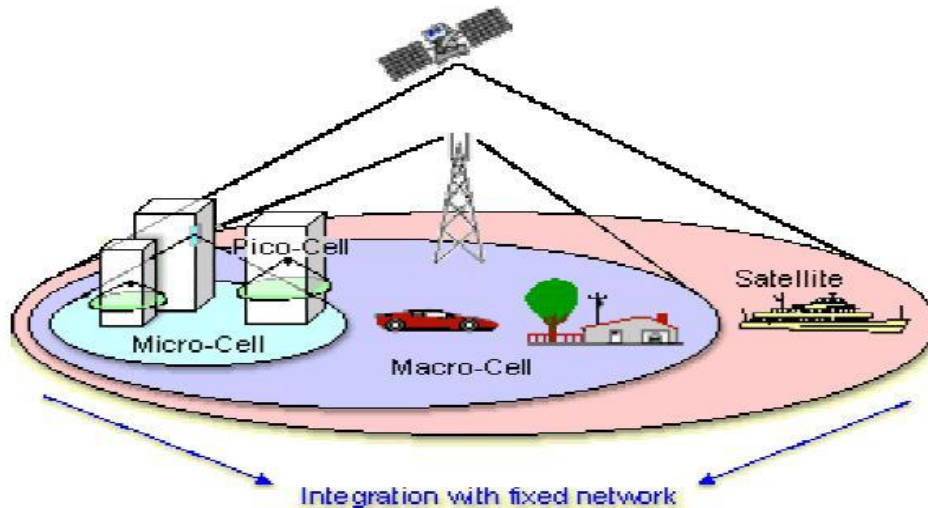


Figure (2.12): UMTS cell structure

Higher levels cover larger geographical areas. Lower levels cover only little areas but they can handle a higher density of devices that want to access the network in these little areas. They also provide faster wireless links to the network than larger levels. The whole system is connected and integrated with PTSN (Public Telephone Switched Network) and PDN (Public Data Network) like internet etc. [17]. The following levels are planned:

Possibility of Applying Green Communication in Palestinian Cellular Networks

- **Satellite System:** This covers the whole planet. Even on seas and in uninhabited regions access to the network is possible via satellites.
- **UTRAN (UMTS Terrestrial Radio Access Network):** The UTRAN infrastructure is terrestrial and consists also of different levels and cells:
 - ❖ **Macro layer:** These cells cover large areas with regions where only few devices access the network.
 - ❖ **Micro layer:** In regions with a high density of devices that want access to the network, like bigger cities, micro cells are used. They cover only quite little areas to provide enough capacity for all devices in this area.
 - ❖ **Pico layer:** A Pico cell is normally located in bigger buildings to provide fast and good access to the network. For example hot spots are made out of Pico cells in buildings.

2.10.3 Multiple Accesses

A mobile communication network is a multi-user system, in which a large number of users share a common physical resource to transmit and receive information. Multiple access capability is one of the fundamental components.

The spectral spreading of the transmitted signal gives the feasibility of multiple accesses to CDMA systems [18].

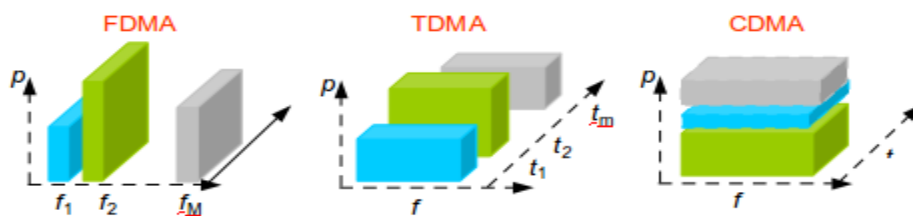


Figure (2.13): Multiple access technologies

Figure (2.13) shows three different multiple access technologies: TDMA, FDMA and CDMA. In FDMA, (Frequency Division Multiple Access), signals for different users are transmitted in different channels each with a different modulating frequency; in TDMA, (Time Division Multiple Access), signals for different users are transmitted in different time slots. With these two technologies, the maximum number of users who can share the physical channels

Possibility of Applying Green Communication in Palestinian Cellular Networks

simultaneously is fixed. However, in CDMA, signals for different users are transmitted in the same frequency band at the same time. Each user's signal acts as interference to other user's signals and hence the capacity of the CDMA system is related closely to the interference level: there is no fixed maximum number, so the term soft capacity is used. Figure (2.14) shows an example of how 3 users can have simultaneous access in a CDMA system.

At the receiver, user 2 de-spreads its information signal back to the narrow band signal, but nobody else's. This is because that the cross-correlations between the code of the desired user and the codes of other users are small: coherent detection will only put the power of the desired signal and a small part of the signal from other users into the information bandwidth.

The processing gain, together with the wideband nature of the process, gives benefits to CDMA systems, such as high spectral efficiency and soft capacity.

However, all these benefits require the use of tight power control and soft handover to avoid one user's signal cloaking the communication of others.

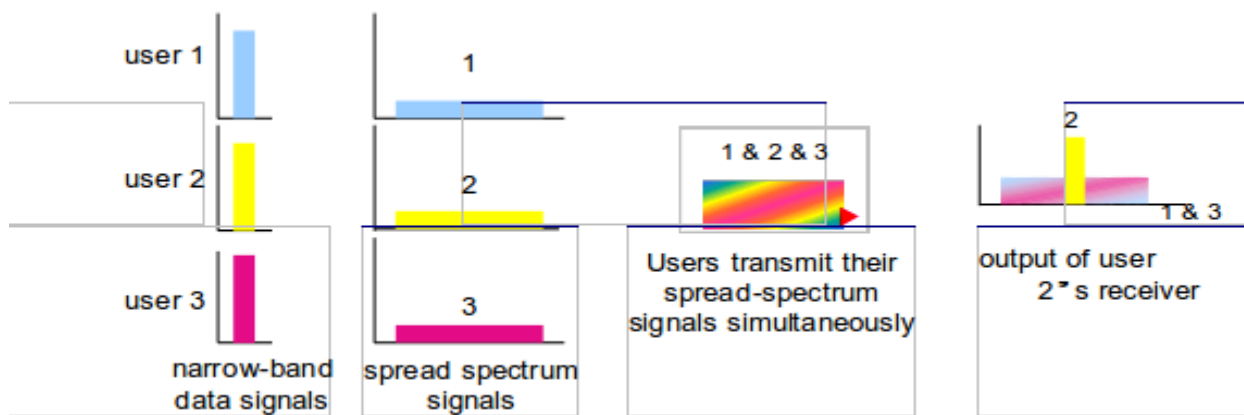


Figure (2.14) Principle of spread-spectrum multiple access

2.10.3.1 WCDMA

Wideband-CDMA (WCDMA) has been adopted by UMTS as the multiple access technology and it is also referred to as UMTS terrestrial radio access (UTRA) [19]. This section introduces the principles of the WCDMA air interface. Special attention is drawn to those features by which WCDMA differs from GSM.

Multiple access method	DS-CDMA
Duplexing method	FDD/TDD
Base station synchronization	Asynchronous operation
Chip rate	3.84 Mcps
Frame length	10 ms
Service multiplexing	Multiple services with different quality of service requirements multiplexed on one connection
Multi rate concept	Variable spreading factor and multimode
Detection	Coherent using pilot symbols or common pilot
Multiuser detection, smart antennas	Supported by the standard, optional in the implementation

Table (2.4): Main WCDMA parameters

Table (2.4) summarizes the main parameters related to the WCDMA air interface. Some of the items that characterize WCDMA are:

WCDMA is a wideband CDMA system. User information bits are spread over a wide bandwidth (5 MHz) by multiplying with spreading codes before transmission and are recovered by decoding in the receiver.

The chip rate of 3.84 Mchip/s used leads to a carrier bandwidth of approximately 5 MHz. In GSM, carrier bandwidth is only 200 kHz. Even in narrowband CDMA systems, such as IS-95, the carrier bandwidth is only 1.25 MHz.

The inherently wide carrier bandwidth of WCDMA supports high user data rates and also has certain performance benefits, such as increased multipath diversity .

WCDMA supports highly variable user data rates; in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. Each user is allocated frames of 10 ms

Possibility of Applying Green Communication in Palestinian Cellular Networks

duration, during which the user data rate is kept constant. However, the data capacity among the users can change from frame to frame.

WCDMA supports two basic modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In FDD mode, separate 5MHz carriers are used for the uplink and downlink respectively, whereas in TDD only one 5 MHz is time-shared between uplink and downlink.

WCDMA supports the operation of asynchronous base stations. Unlike the synchronous IS-95 system, there is no need for a global time reference, such as a GPS, so making deployment of indoor and micro base stations easier.

WCDMA employs coherent detection on uplink and downlink based on the use of pilot signals or common pilot. In IS-95 coherent detection is only used on the downlink. The use of coherent detection on uplink will result in an overall increase of coverage and capacity on the uplink. This makes the downlink more likely to be the bottleneck of the whole system.

The WCDMA air interface has been crafted in such a way that advanced CDMA receiver concepts, such as multiuser detection and smart adaptive antennas, can be deployed by the network operator as a system option to increase capacity and/or coverage. In most second generation systems no provision has been made for such concepts.

WCDMA is designed to be deployed in conjunction with GSM. Therefore, handovers between GSM and WCDMA are supported.

2.10.4 UMTS Architecture

The UMTS network can be divided into three parts:

- 1. User Equipment (UE):** The UE connects to the UTRAN via wireless radio link to one or more cells. Unlike in GSM it is possible to have a link to many cells at the same time.
- 2. UMTS Terrestrial Radio Access Network (UTRAN):** The UTRAN consists of NodeB's (BTS in GSM) that are connected to Radio Network Controllers (RNCs – BSC in GSM). The RNCs are connected to each other and to the core networks via ATM.
- 3. Core Network (CN):** The core network is connected to other networks like PTSN (Public Telephone Switched Network), Internet, other mobile networks etc. It is

Possibility of Applying Green Communication in Palestinian Cellular Networks

responsible for routing, authentication, location tracking, etc. The core networks are divided into two domains, the circuit switched (CS) and the packet switched (PS) domain. This work will further focus on the PS- domain.

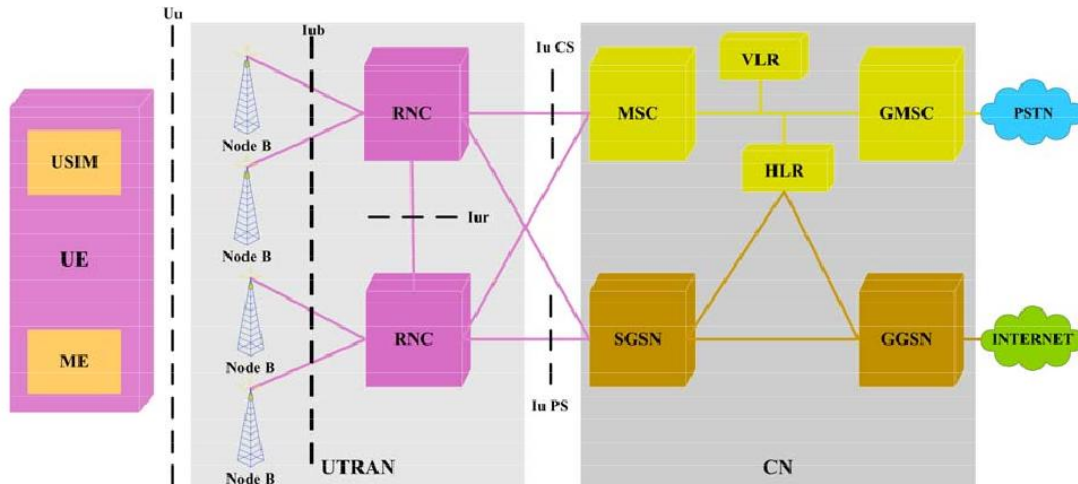


Figure (2.15): UMTS architecture

2.10.4.1 User Equipment (UE)

UE is a synonym for device here. For example an UE may be a mobile phone, a personal digital assistant (PDA) or a notebook. UE connects via the radio interface UE based on the W-CDMA technology to the UTRAN. A device can be connected to more than one cell simultaneously. The UE consists of two parts:

- ❖ **Mobile Equipment:** That is the hardware device itself. The device alone cannot use any UMTS services.
- ❖ **USIM-Card:** All necessary data for authentication and getting access to the UMTS network to use services is stored on an USIM-Card (UMTS Subscriber Identity Module-Card). This card is equivalent to the SIM-Card in GSM. The USIM-Card is issued by the common carrier and is unlike GSM SIM-Cards able to save some MB of personal data. GSM SIM-Cards only have between 8kB and 32kB of memory.

2.10.4.2 UMTS Terrestrial Radio Access Network (UTRAN)

Among other things the UTRAN is responsible for the radio resource management. This includes the responsibility for power control, support for the different handover types and also controlling and managing handovers.

Possibility of Applying Green Communication in Palestinian Cellular Networks

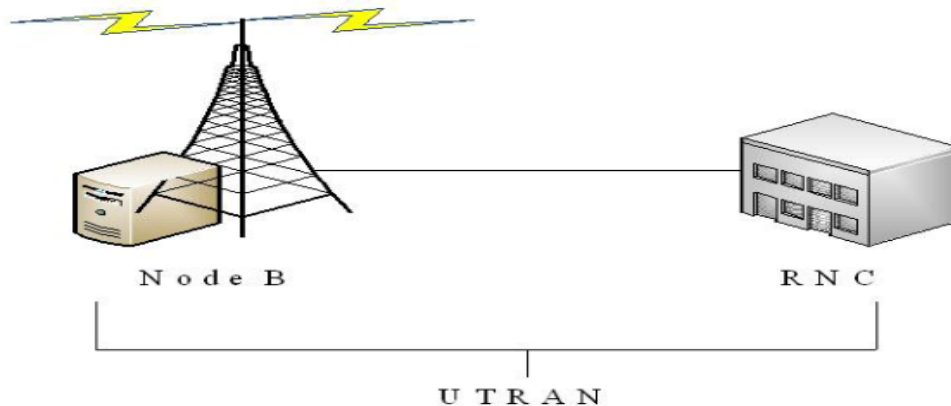


Figure (2.16): UTRAN Network

The UTRAN consists of NodeB's and RNCs:

- **Radio Network Controller (RNC)** In the radio access network the RNC is the main node between the mobile equipment and the radio access network a number of the protocols are applied in the radio network controller through the Iur interface with the other RNC's of the core network. The function of the RNC is same as the function of the BSc in the GSM network. The radio resource management is controlled in more than one Node-B by the RNC. The following are tasks of the RNC:
 - ✓ Through the radio interface it performs all the data transmission tasks.
 - ✓ The radio resources are managed by this entity.
 - ✓ The connection and the replacement of the radio bearers.
 - ✓ The admission of the call control through the Call admission control.
 - ✓ The allocation of the code is also the duty of this entity.
 - ✓ The control of power.
 - ✓ Helps in handovers and the scheduling of the packet.
 - ✓ The relocation of the SRNS and the conversion of the protocol.
 - ✓ The data coming from other networks are ciphered in the RNC's.

There are three types of RNC's:

- ❖ **Serving RNC:** This RNC serves the user equipment because the user equipment is connected to this RNC. That is why this RNC is called as the serving RNC.
- ❖ **Controlling RNC:** It works with reference to the Node – B.
- ❖ **Drift RNC:** It works in the process of handover.

Possibility of Applying Green Communication in Palestinian Cellular Networks

- **NodeB:** Its functions are similar to the BTS in the GSM network. The Node-B's are also called as the radio network controller. The following are functions of the Node-B.
 - ✓ Many cells are managed by the Node-B.
 - ✓ The tasks which are attached to the radio interface is manage in the Node-B.
 - ✓ The data splitting and the combination is also the duty of this entity.
 - ✓ It helps in the process of handovers too.

Node-B's has three types which include the following

- UTRA-TDD Node B
- UTRA-FDD Node B
- Dual Node B

Most of the NodeBs manages three cells. Groups of NodeBs are connected with the Iub interface to one RNC via an ATM network. The RNC, a Node B is connected to, is called Controlling RNC (CRNC) (of this Node B). One RNC with all connected NodeBs is called Radio Network Subsystem (RNS).

A NodeB operates at physical and network layer and passes the data to the CRNC. It also measures the quality and power of the radio links to the UEs and reports it to the CRNC. The CRNC can react on basis of this information, for example to reduce or increase the power of the radio signal at the Node B and/or UE. The RNC also assigns a W- CDMA code for the radio link between UE and Node B so that the data from the specific UE can be extracted from the whole data sent by all UEs and NodeBs around . It is also responsible for handovers between different RNS, radio resource control, etc. To provide a soft handover the RNCs are connected to each other with the Iur interface via an ATM network. They are also connected to the CN via the Iu-CS interface for circuit switched services and via the Iu-PS interface for packet switched services.

2.10.4.3 Core Network (CN)

The core network is divided into two parts. One for circuit switched services (CS- domain) and one for packet switched services (PS-domain). The CS-domain contains the following parts:

Possibility of Applying Green Communication in Palestinian Cellular Networks

- **Mobile Switching Center (MSC):** The MSC is a switching node that routes data of CS-services within and out of the own network via the Gateway Mobile Switching Centre (GMSC). A MSC manages many RNCs that are connected via the Iu-CS interface. The MSC is also connected to different databases for example to the Home Location Register (HLR) and manages the mobility for the CS-services. Depending on the size of the network there is normally more than one MSC in an UMTS network.
- **Gateway Mobile Switching Center (GMSC):** The GMSC is connected to the MSC and interconnects the own UMTS network to other CS-switched networks like PTSN (Public Telephone Switched Network) or ISDN (Integrated Services Digital Network). In an UMTS network can be more than one GMSC.
- **Visitor Location Register (VLR):** One VLR is normally assigned to every MSC. The VLR saves temporarily security, authentication and identification data of all participants that are currently managed by the MSC. Some of the data are copied from the Home Location Register (HLR, see below).
- **Transcoder Rate Adapter Unit (TRAU):** The TRAU is a gateway between the RNC and the MSC that is responsible for the conversion of the format (Adaptive Multi Rate (AMR) to Pulse Code Modulation 30 (PCM30) and vice versa) of speech data. This is necessary because UTRAN and CN use different formats. In an UMTS network can be more than one TRAU.

The PS-domain consists of the following parts:

- **Serving GPRS Support Node (SGSN):** The SGSN in the PS-domain is similar to the MSC in the CS- domain. It routes data of PS- services in the own UMTS networks and outside via the Gateway GPRS Support Node (GGSN). It also manages many RNCs that are connected via the Iu-PS interface and is connected to databases like the Home Location Register (HLR, see below). The SGSN is also responsible for authentication and mobility management. Depending on the size there is normally more than one SGSN in an UMTS network.
- **Gateway GPRS Support Node (GGSN):** The GGSN again is very similar to the GMSC in the CS-domain. It interconnects the UMTS Network with other PS networks like the Internet or X.25 networks and is connected to the SGSN. In an UMTS network there can be more than one GGSN. There are also some elements that are used by both domains.

Possibility of Applying Green Communication in Palestinian Cellular Networks

One important component of them is the following:

- **Home Location Register (HLR)/Authentication Center (AuC):** The HLR/AuC is a database that saves data of participants that rarely change like security and encryption information, phone number, services that a user is allowed to access by contract etc.

2.10.4.3.1 Interfaces of UMTS

The following are the different interfaces in the UMTS.

- **Lub Interface:** The RNC and the Node-B's are connected through the Lub interface. There are many functionalities of this interface which include the management of the information system, the validation of the message on the user side, management of the traffic on different channels like in control and the dedicated channel and timings and the management of the link status.
- **Lur Interface:** Two RNC's are connected to the interface known as Lur interface. The functionalities of this interface include management of the traffic in different channels like dedicated and common transport channel.
- **Uu Interface:** The RNC and the mobile equipment through the NodeB's are connected to this interface. The main functionalities of this interface include paging and the management of the security, MAC/RLC reconfiguration and configuration and the handling of priority and the selection of the TFC.
- **Iu Interface:** The core network and the RNC's are connected through the Iu interface. The main functionalities of the Iu Interface include establishment of the radio access bearers, its maintenance and the replacement is also the responsibility of this interface.
- **Iu-CS:** The RNC's connected to the circuit switched domain of the core network through this interface.
- **Iu-PS:** The RNC's connected to the packet switched domain of the core network through this interface.

2.10.5 UMTS Features and some functionality

2.10.5.1 Power Control

Power control normalizes the transmission power of the mobile equipment and the RNC. It is very important to cope with the fading and the path loss. Greater capacity is gain by the regulation of the power transmission. To beaten the near far effects the received power equalization is very important. Also to minimize the interference level and the noise in the cell power control is very important. There are three power control mechanisms used in the WCDMA.

- **Closed Loop Power Control:** From the mobile equipment the RNC measures the uplink signal and sends a command to the user's equipment. The down link signal is monitor by the mobile equipment and the data is forwarded to the RNC. To accommodate the near far problem in uplink this algorithm is used. The main function of the closed loop power control is that the power equalization at the users equipment all time.
- **Open Loop Power Control:** This mechanism is the property of the user's equipment for arranging a required power for the required receiver. The mobile equipment measures the pilot signal from the base station and sets the power of the signal according to the power of the receiver signal.
- **Inner Loop Power Control:** This power control is also called as the closed loop power control. The power received is kept constant in fading channel due to this power control. The near far terminal problem is reduced due to this power control mechanism.
- **Outer Loop Power Control:** This type of the power control is related to the long term fluctuations of the channels. This type of power control is also called as the slow closed loop power control.

2.10.5.2 Cell Breathing

Cell breathing phenomenon gets higher from power control. The cell size varies because it depends upon the traffic load. This is the exchange between coverage and capacity. Good quality can be gained though from a long distance from base station when there is low load in the cell means number of users will be less in the cell. On the other hand, when the number of users in the cell is high, the large number of subscribers generates a high interference level and subscribers have to get closer to the base station to achieve good quality. If the number of users is higher in the cell then to get the good quality the users should get closer to the base station and in case of more users, far away from base station there will involve more interference.

2.10.5.3 Channel Type Switching

In order to maximize the total traffic throughput, different types of channels are used to transmit the data in WCDMA. To move the subscribers between the two channels like between common channels and dedicated channels, depending upon the information that subscribers need to transmit, Channel type switching functionality will be used.

The two most basic ones are:

- **Dedicated Channels:** When there is enough information for transmission, for example downloading, voice conversation then dedicated channel is used. It efficiently utilizes the radio resources because it provides supports for power control and soft handover.
- **Common Channels:** The common channel, in contrast, is smaller quantity spectrums efficient. As many subscribers can share the same resource, the common channel reduces the delays. This is one of the advantages of common channel. Thus for the transfer of limited information common channel is a preferable channel.
- **Admission Control:** To avoid system overload and for providing planned coverage, Admission control functionality is used. This functionality is used because in WCDMA there is very clear exchange between coverage and capacity. When a new subscriber looks access to the network, the admission control functionality estimates the network load on the base of newly coming load, then subscriber is either allowed to enter in the network or being blocked. According to the services of subscriber's demand the operator can expand the network usage within a set of network quality levels.

2.10.5.4 Congestion Control

Overload may also occur even in case of using efficient admission control. The main cause of this is due to the movement of subscribers from one area to another one. In case of overload four different actions can be taken.

- To resolve the overload issue congestion control becomes activated and it decreases the bit rate of non-real time applications.
- If overload issue is not fully solved by reducing bit rate then inter or intra frequency handover becomes active by congestion control, which moves some of the subscribers to the less loaded frequencies.
- Some subscribers are being handover to GSM
- The action of discontinue is taken to keep the quality of the remaining connections.

2.10.5.5 Synchronization

For accurate synchronization of base stations, when WCDMA system was standardized, should not depend on external systems and this is the basic requirement for synchronization. This has achieved by a method, where the handset, when needed, measures the synchronization of offset between the different cells and then reports this to the network. Moreover, there is also another option for the use of an external source, for example GPS, for node synchronization, i.e. to always give the top solution for both asynchronous and synchronous nodes are supported.

2.11 OPNET Modeler

OPNET Modeler provides a graphical user interface, which enables modeling and simulating networks. The modeling environment consists of different hierarchical layers for developing communication structures. OPNET provides the flexibility to build very detailed customized models as well to perform general system analysis [20]. Systems are built up in an object oriented way, compiling the models automatically generates discrete event simulations in C language. After simulation it is possible to gather and analyze results with some of the built-in performance statistics features provided by this package.

2.11.1 Network Layer

The network layer enables to define the network topology on a logical or geographical map. It is possible to place network elements — called nodes — and interconnect them with different types of links; both fixed and radio links. Users having a radio link connection can be assigned trajectories to simulate their mobility. This being particularly useful in this context where it is necessary to be able to simulate mobile UMTS users and their effect on the network resources used.

In the network layer it is possible to nest sub networks to configure complex hierarchical networks. Imagine a pan-European network, consisting of different national networks, formed by interconnection of different ring networks, which can in turn be connected to LAN entities...

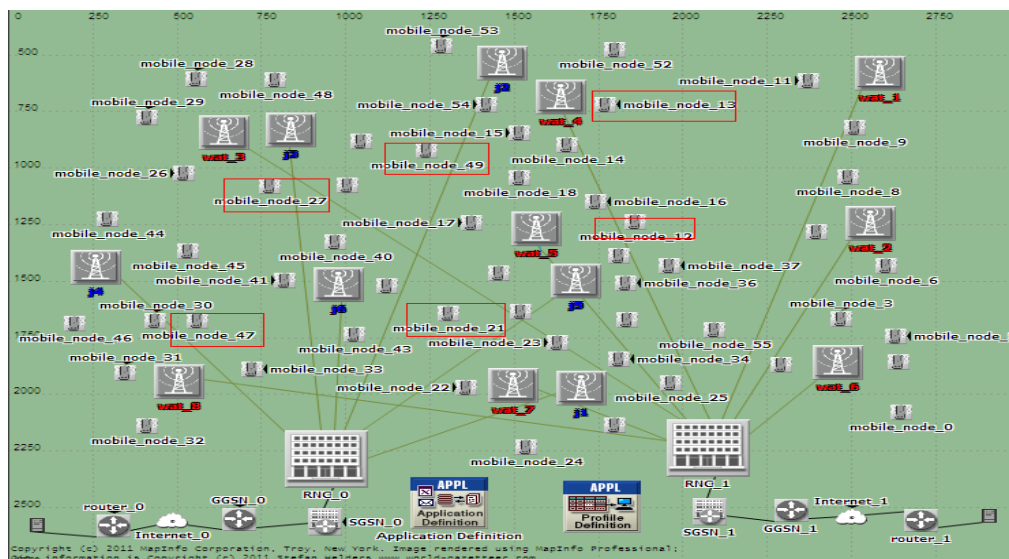


Figure (2.17): screenshot of the network editor

A network project can be built up using the network editor. OPNET contains an extensive library of node models of different technologies ranging from Ethernet, ATM, UMTS, wireless and IP networks as also equipment models of specific manufacturers as Cisco, 3Com and others.

2.11.2 Node Layer

The node layer provides functionality to build node — or network element — models to be used and interconnected on network level. In the node editor the nodes are built up out of processors, queues, transmitters and receivers. These building blocks called modules allow implementing node specific characteristics. Different modules are interconnected with packet streams, statistic wires or logical associations between them. Modules act as information sources and sinks or simply process the packets sent between them.

Figure (2.18) shows the node level implementation of a UMTS workstation (umts_wkstn_adv) as included in the OPNET UMTS model. Notice the presence of the full TCP/IP stack.

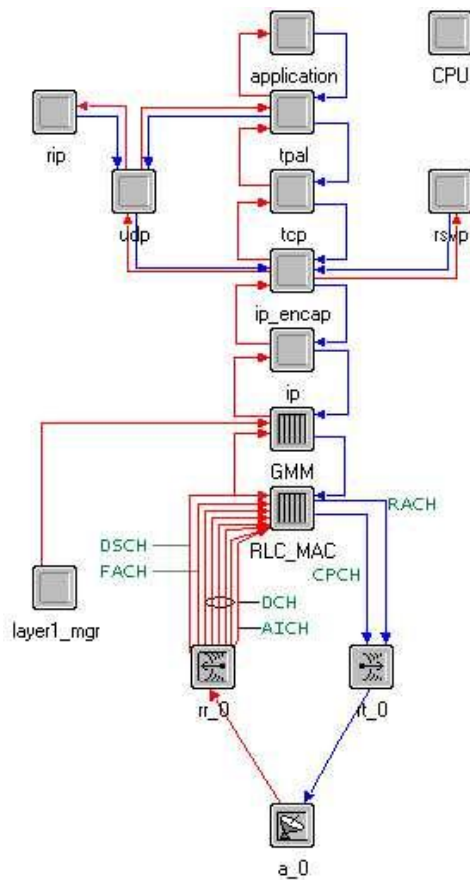


Figure (2.18): node representation of UMTS workstation

2.11.3 Process Layer

To further increase the level of detail used in the network model, the process layer makes it possible to program the different modules used in the node layer in order to implement specific protocols or desired behavior of the nodes. The processes carried out by the nodes are very similar to procedures commonly used in communication networks but it is also possible to include user specific functions by writing C++ code. The process editor makes use of a programming language called proto-C, which combines graphical State Transition Diagrams (STD) and C/C++ programming language. A STD consists of states with transitions between them. Both forced and unforced states exist. Whereas a system can wait in an unforced state, it has to leave the forced state immediately after executing the executives of that state. The state executives are actions to be performed right after entering — enter executives — or right before leaving state— exit executives. Whether a transition should be traversed or not is decided by the transition conditions. These statements expressed in C/C++ language respond to interrupts or combinations of state variables.

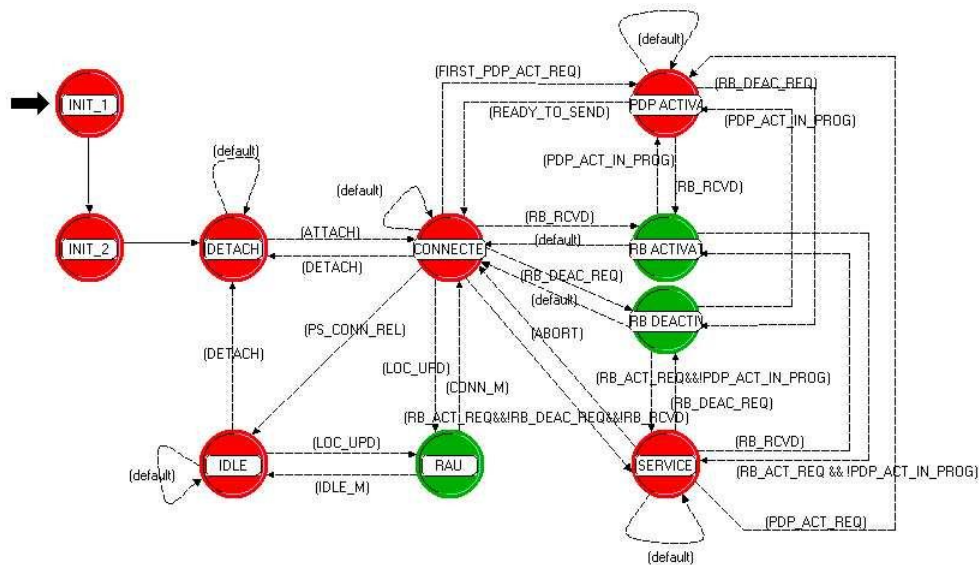


Figure (2.19): State Transition Diagram (STD) of umts_gmm process in UE GMM layer

2.11.4 OPNET UMTS Model

OPNET modeler offers specialized models that address the specific needs for modeling and simulating networks focused on a certain area of technology. One of those specialized models is the UMTS model based on the 3GPP specifications. This model follows closely the UE-UTRAN-CN system architecture as described in the previous chapter. The UE model offers functionality related to terminal equipment and mobile termination, responsible for terminating the radio link. The UTRAN part consists of models for the Node B and the RNC. The Core Network architecture is not fully implemented. The SGSN and the GGSN are implemented but the MSC/VLR and the HLR are currently not included in the UMTS model. The graphical representation of the architecture is shown on the picture below.

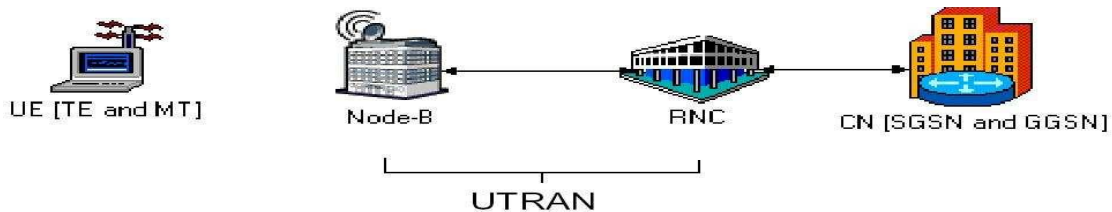


Figure (2.20): OPNET UMTS architecture representation

Below an overview of the features of the UMTS model as used for the modeling, will be given beside a discussion of the implementation of the different node models.

The UMTS specialized model supports a wide range of features resembling real network characteristics. Four different traffic classes have been defined: streaming, conversational, interactive and background. With each traffic class a QoS profile has been associated. This allows studying the effect of error or delay sensitive traffic in the system.

Also the following channels are supported in the model: DCH, DSCH and FACH&RACH. Hence also the Cell DCH and the Cell FACH state as mentioned in the previous chapter are supported. To simulate soft handovers it is essential to model users in the Cell DCH state as only dedicated transport channels support soft handovers. Additional features of the UMTS model are the supported mobility of users, power control and TCP/IP functionality. Although the UMTS model is much extended and reflects real networks to high detail it has significant limitations. One limitation is that only the UMTS FDD mode is supported. As initially pointed out not to

Possibility of Applying Green Communication in Palestinian Cellular Networks

evaluate the TDD mode this shortcoming is not limiting. Several other limitations are related to attaching procedures between the mobile device and the network. GMM idle mode and the GPRS detach procedure are not included. Also mobility of the mobile terminal prior to the attachment to the network is impossible.

Chapter

3

Simulation Design

3.1 Introduction

3.2 Typical Traffic Profile

3.3 Wataniya Network

3.4 Jawwal Network

3.5 The Combined Network

3.6 Project Design in OPNET Modeler

3.1 Introduction

The aim of this project is to simulate green communication concept, which may become possible when there is no congestion in the network.

This chapter presents the design of simulation experiments. In addition to that, it discusses the main parameters (transmitted power, Traffic profile, Quality of service) that will be considered in these experiments.

3.2 Typical Traffic Profile:

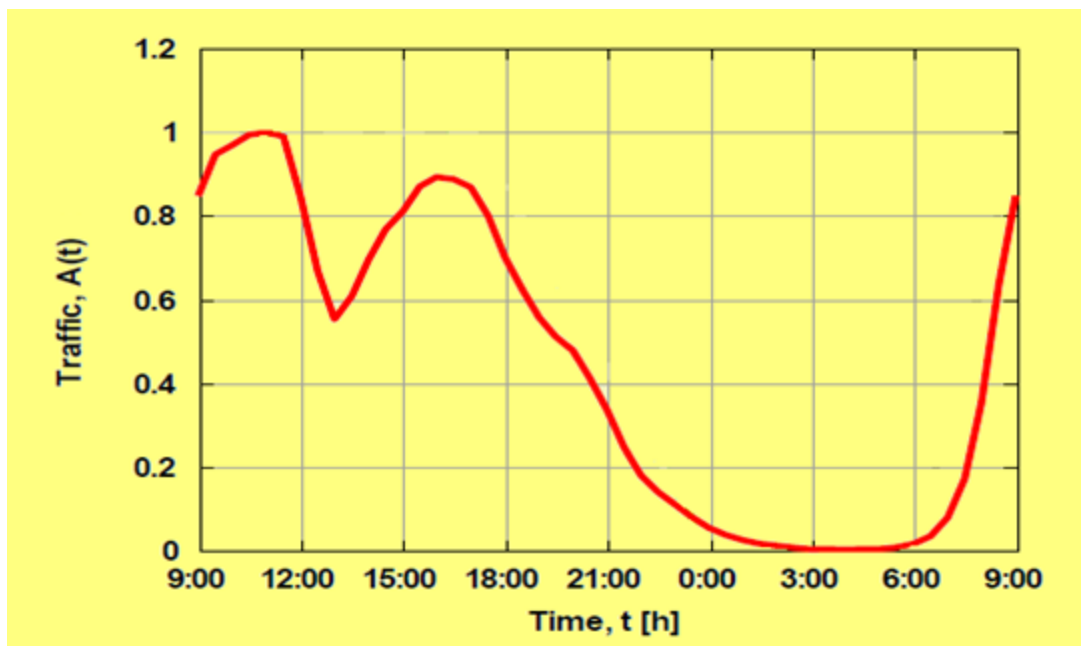


Figure (3.1): typical traffic profile over 24 hours [2]

In figure (3.1), the traffic profile has two peaks, one at 11AM when all the people are in their works, the other one at 4:00 PM when people (especially Employees) leave their works. So, the green communication idea (turn off some cells) may be not applicable during these periods. Therefore we need high capacity to carry all the traffic, but between 1:00AM to 7:00AM, the traffic is low because the majority of people are sleeping, so, cells consume energy without providing real services. Therefore, by applying the green communication idea during this period we can save the power in an efficient way.

3.3 Wataniya Network

3.3.1 BTSs locations

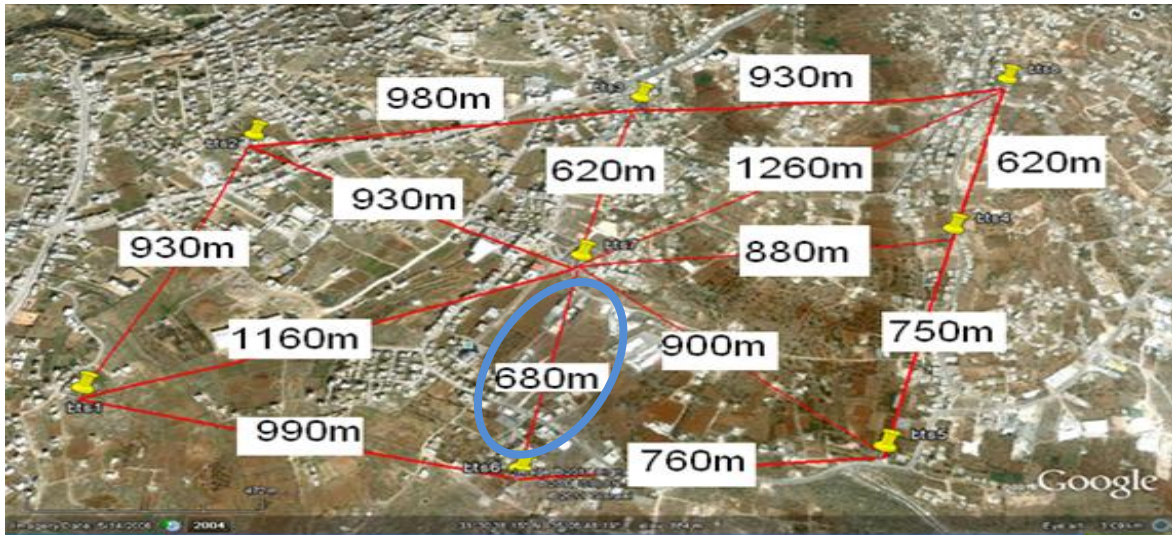


Figure (3.2): Wataniya BTSs locations

Figure (3.2) shows the location of the BTSs within PPU area and the spacing between them. We build Wataniya network on the OPNET depending on the distances appear on the last Figure. The blue circle on the map shows the PPU campus that we will concentrate our work on it.

3.3.2 Traffic Profile

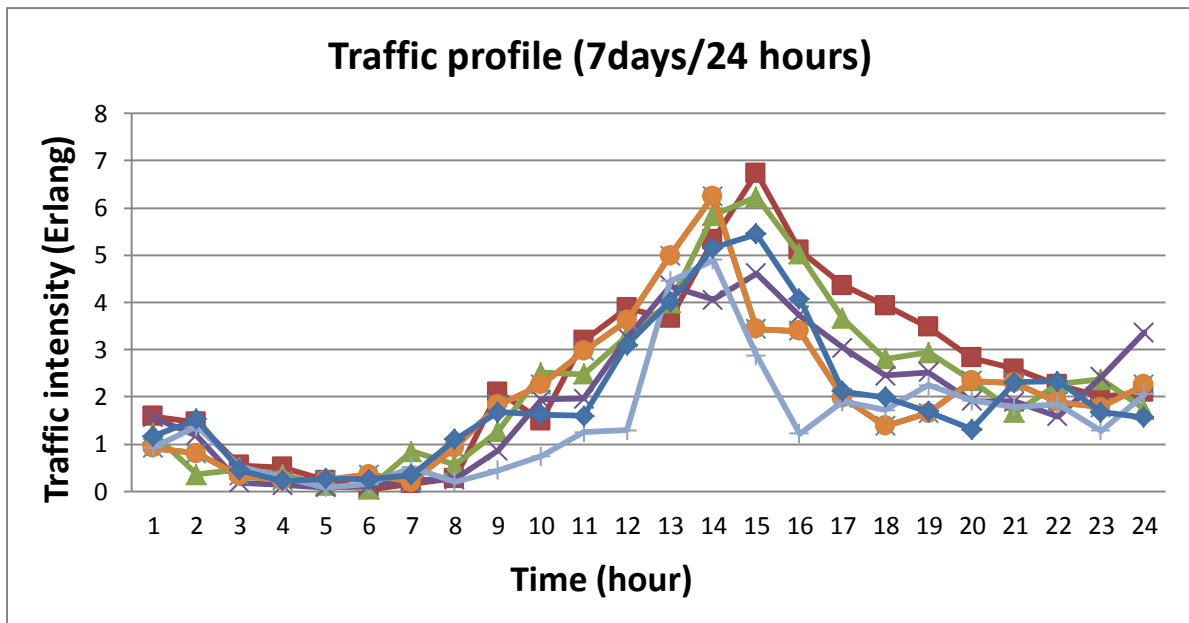


Figure (3.3): Wataniya traffic profile

Possibility of Applying Green Communication in Palestinian Cellular Networks

Figure (3.3) shows the traffic profile in the PPU area for 7 days over 24 hour for the Wataniya Company in the area mentioned in figure (3.2). From this figure, the peak hours are from 13:00 to 15:00 for all week days, and the low traffic period is between 2:00 and 8:00. So, we can apply the green communication idea during this period. On the OPNET modeler, we take this traffic profile into concern while doing one and two operators experiments, and then we simulate the network once without applying the idea of the project and other with applying it. After collecting the results from the modeler, we analyze them and then calculate the amount of power that can be saved. We also focus on the loss in the signal to noise ratio for the mobile that will handover to another cell when applying the idea.

The average daily traffic intensity (A_u) which equal ($\lambda * H$) is 25 mErlang/user (0.025 Erlang/user), where λ (the number of request per hour) =2 call\hour, and H (the average call duration) = 45 second. The accepted GoS (blocking rate) is 2%, but for the cells serving the PPU campus the congestion is 0% (GoS \ll 1%).

3.3.3 Cells power

This section contains the values of the power for the cells that serve the PPU campus.

Cell	Transceiver Output Power (dBm)	In Watt	EIRP (dBm)
H225B	43	19.952	54
H225C	41	12.589	52
H238A	41	12.589	52

Table (3.1): Wataniya cells power

Table (3.1) shows The Transceiver Output Power (dBm, watt), where $\text{dBm} = 10\log_{10}(\text{power in mW})$ and the Equivalent isotropically radiated power (EIRP) equals $\text{EIRP} = P_T - L_c + G_a$, where L_c is the cable losses in dB, G_a is the antenna gain expressed in dBi, which is related to a (theoretical) isotropic reference antenna.

We used the Transceiver Output Power in Watts for all cells of Wataniya network in the OPNET Modeler.

3.4 Jawwal Network

3.4.1 BTSs locations

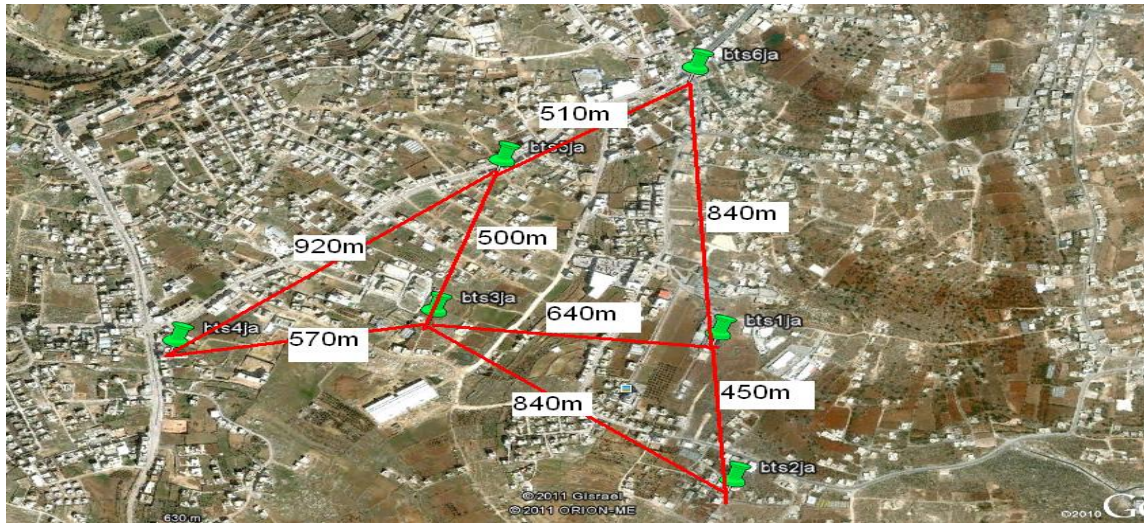


Figure (3.4): Jawwal BTSs locations

Figure (3.4) shows the distribution of Jawwal BTSs within PPU area and the spacing between them. The number of Jawwal BTSs {6 BTSs} which is less than the number of Wataniya by two BTSs for the same area. This refers to Jawwal Company uses the 900 MHz band and Wataniya Company uses the 1800 MHz band, so Wataniya needs more BTSs to cover the same area that Jawwal covers.

3.4.2 Traffic Profile

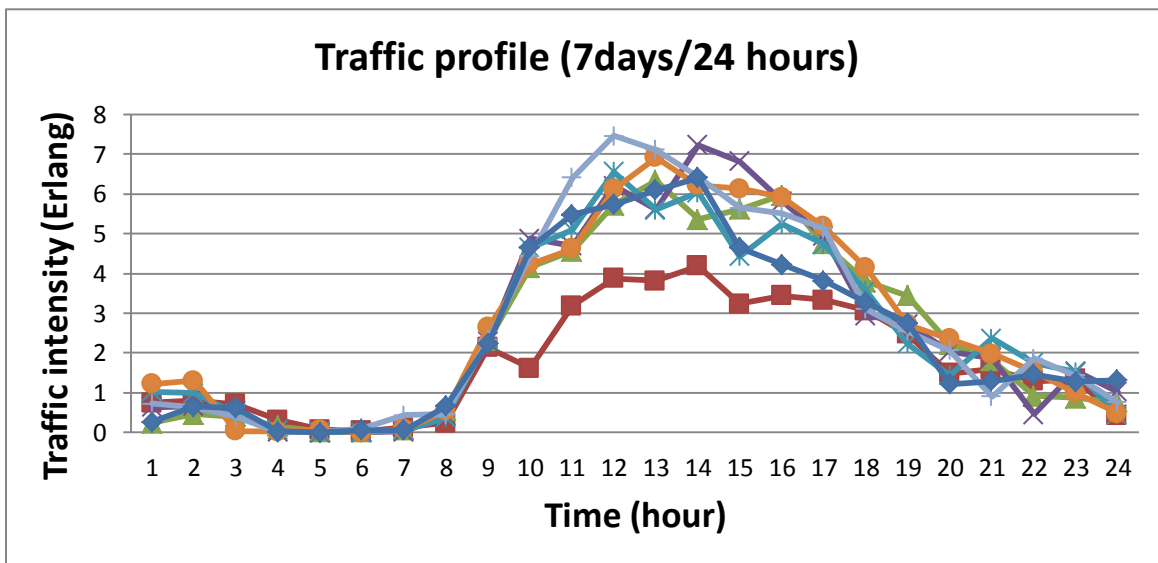


Figure (3.5): Jawwal traffic profile

Possibility of Applying Green Communication in Palestinian Cellular Networks

Figure (3.5) shows the traffic profile for the cells that serve the PPU campus for 7 days during 24 hour {not actual traffic profile}. This traffic profile has a peak from 12:00PM to 2:00PM, and in this period, applying of green communication idea is impossible because of the high load in the network. However, the low traffic period approximately 12:00AM to 08:00AM allows applying the idea -turning off some cells and switching its entire user to its neighboring cells- because there is no congestion in the network, and in this case the network doesn't operates in the full load as in the high traffic period.

3.4.3 Cells power

Cell ID	EIRP(dBm)	Transceiver(dBm)	watts
HEBR65A	47.24	36.24	4.207
HEBR65B	48.44	37.44	5.546
HEBR65C	55.44	44.44	27.797
HEBR11A	56.39	45.39	34.594
HEBR11B	56.39	45.39	34.594
HEBR25A	60.49	49.49	88.92
HEBR25B	60.49	49.49	88.92
HEBR25C	60.49	49.49	88.92
HEBR12A	47.99	36.99	5.0
HEBR12B	47.99	36.99	5.0
HEBR84A	54.24	43.24	21.08
HEBR84B	54.24	43.24	21.08
HEBR84C	53.6	42.6	18.197
HEBR64A	54.24	43.24	21.08
HEBR64B	57.5	46.5	44.668
HEBR64C	55.44	44.44	27.797

Table (3.2): Jawwal cells power

Table (3.2) shows the cell power in each cell for Jawwal operator within PPU campus. We used these values in the simulation of Jawwal network and in the combined network simulation on each cell.

3.5 The Combined Network

This section contains Jawwal and Wataniya networks as a group. We build the combined network in the OPNET Modeler like figure (3.6). We apply the traffic profile and the cell power for each network in its associated BTSs as mentioned above.

3.5.1 BTSs locations

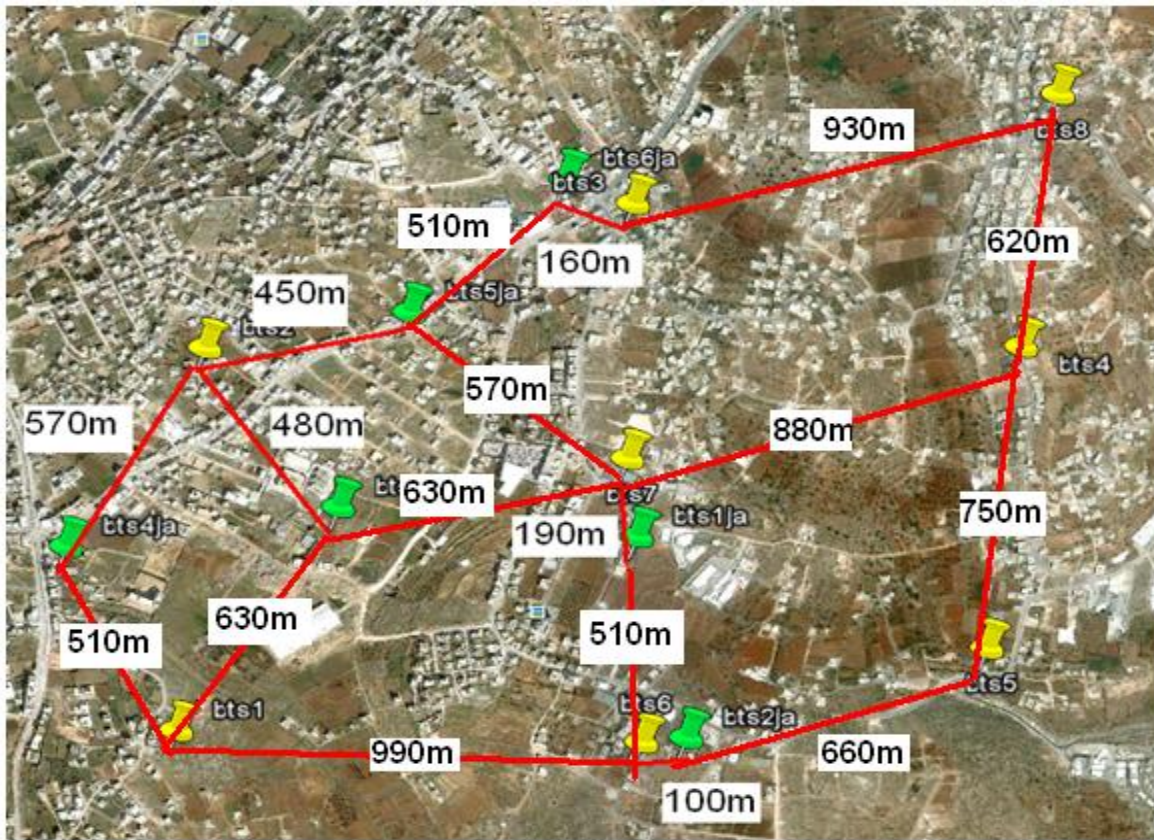


Figure (3.6): Jawwal and Wataniya BTSs distribution

Figure (3.6) shows the location of Jawwal and Wataniya BTSs and the spacing between them in the PPU area. The yellow color in the map indicates Wataniya BTSs while the green color indicates Jawwal BTS's. In the two operators scenario, we have two cases. The first one called "Roaming-To-One" in which all Wataniya or Jawwal BTSs will be turned off, and the Jawwal or Wataniya users will be served by one of the two networks. This saves the power for one network by 100% and assures the service for all users in both networks. The second one called "Roaming-To-All" which depends on turning off some cells from each operator. This resembles a collaborative scenario.

3.6 Project Design in OPNET Modeler:

This section presents the OPNET attributes used in the project, such as: the transmission power for the cells, creation of VOIP calls, the path loss used in the project and other parameters.

Before illustrating these design parameters, we should say that, the OPNET Modeler 14.5 that will be used for simulation experiments doesn't include a GSM model. Therefore, we build a UMTS network with GSM attributes.

3.6.1 OPNET Attributes

- **Power addition:** Figure (3.7) and figure (3.8) show how we configure the transmission power for each NodeB in each network, depending on the table (3.1) and (3.2) for Wataniya and Jawwal that are listed on the previous sections.

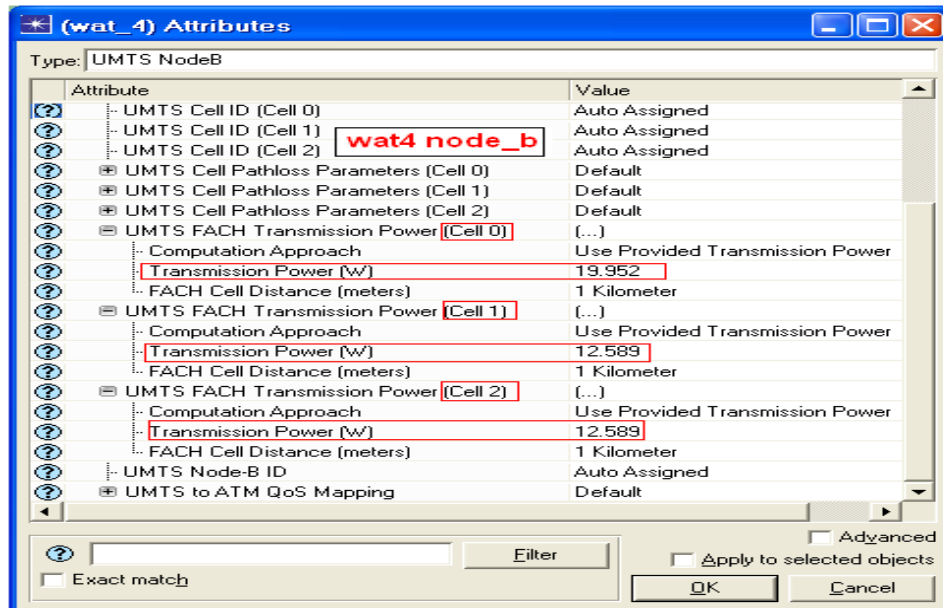


Figure (3.7): Power addition for Wataniya network

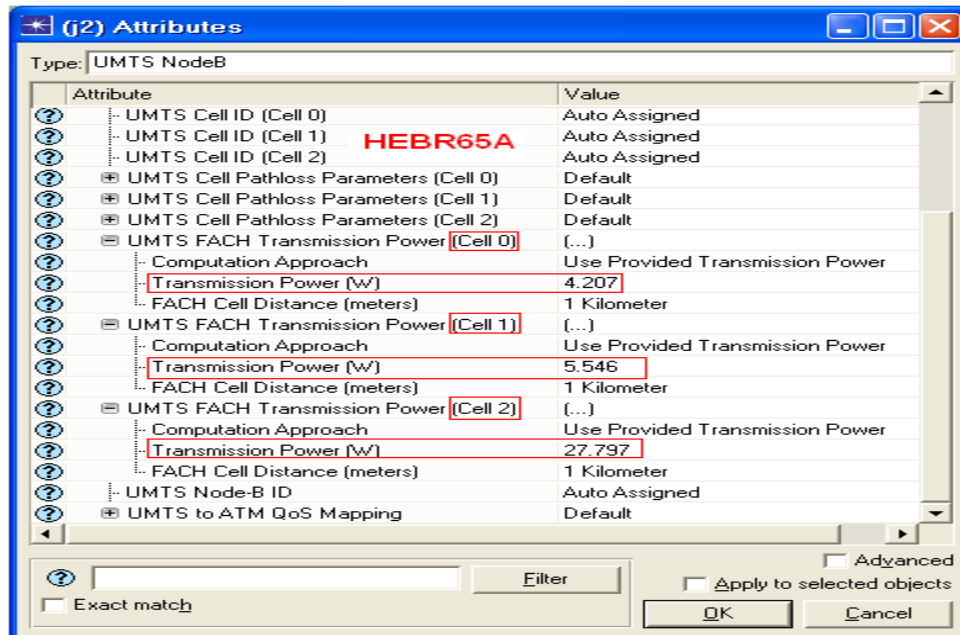
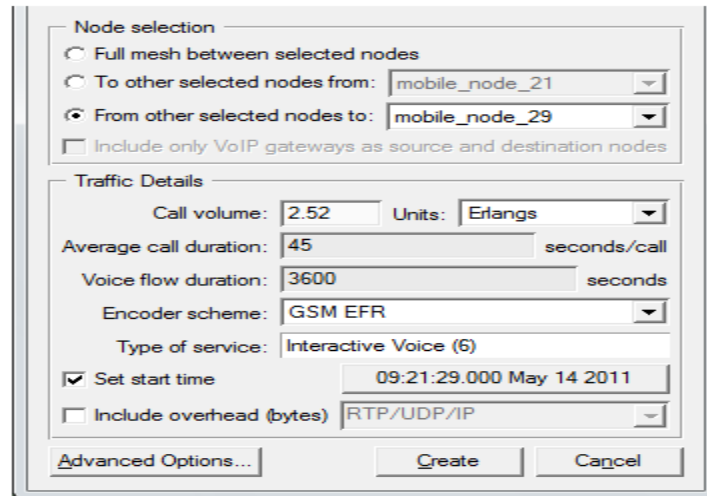


Figure (3.8): Power addition for Jawwal network

Possibility of Applying Green Communication in Palestinian Cellular Networks

- **Traffic creation:** Figure (3.9) shows the traffic configuration method in the OPNET modeler for both Wataniya and Jawwal networks. It also shows the values that we have from the Wataniya network. These values are call volume {Erlangs} for one hour, average call duration {H in second/call} which is 45 second/call, and encoder scheme is GSM FR which provides transmission speed of 13 Kb/s for speech or 9.6, 4.8 or 2.4Kb/s for data and provide eight user per channel.



Node selection

Full mesh between selected nodes

To other selected nodes from: mobile_node_21

From other selected nodes to: mobile_node_29

Include only VoIP gateways as source and destination nodes

Traffic Details

Call volume: 2.52 Units: Erlangs

Average call duration: 45 seconds/call

Voice flow duration: 3600 seconds

Encoder scheme: GSM EFR

Type of service: Interactive Voice (6)

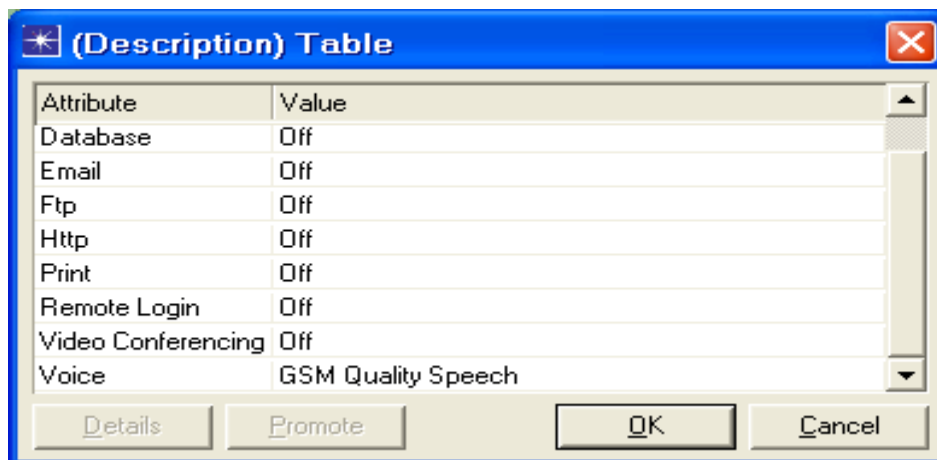
Set start time 09:21:29.000 May 14 2011

Include overhead (bytes) RTP/UDP/IP

Advanced Options... Create Cancel

Figure (3.9): Traffic addition in OPNET modeler

- **Application:** Figure (3.10) shows the applications table which is used to choose the service that we want in the simulation. In the project, we just need the voice service with the GSM quality speech.



(Description) Table

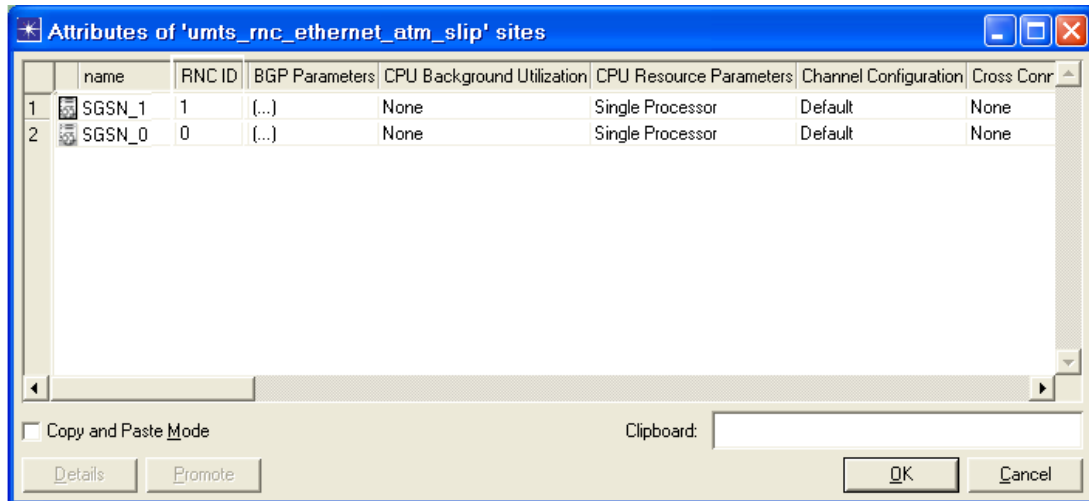
Attribute	Value
Database	Off
Email	Off
Ftp	Off
Http	Off
Print	Off
Remote Login	Off
Video Conferencing	Off
Voice	GSM Quality Speech

Details Promote OK Cancel

Figure (3.10): Application selection in OPNET

Possibility of Applying Green Communication in Palestinian Cellular Networks

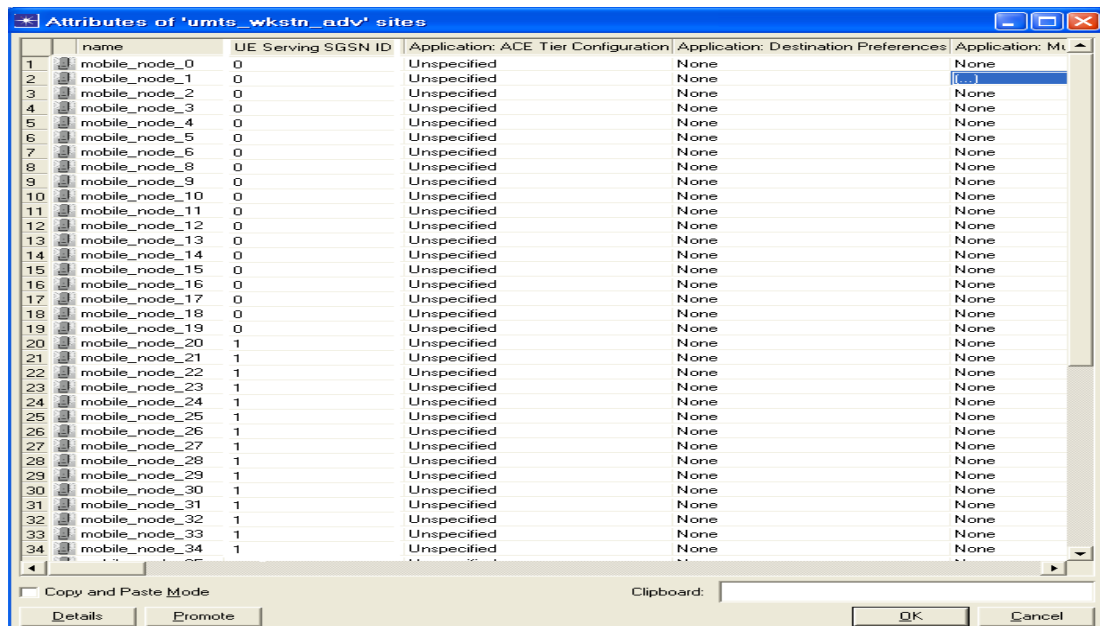
- **SGSN Identifier:** it is an identifier used to differentiate between the UEs with respect to their provider. In the two network simulation, it is important to differentiate between the UEs when we turn off one network, to assure that the UEs for the turned off network are associated with the remaining network. Figure (3.11) shows this identifier:



	name	RNC ID	BGP Parameters	CPU Background Utilization	CPU Resource Parameters	Channel Configuration	Cross Conn
1	SGSN_1	1	(...)	None	Single Processor	Default	None
2	SGSN_0	0	(...)	None	Single Processor	Default	None

Figure (3.11): SGSN Identifier

Figure (3.12) shows also the SGSN identifier for the UEs in the network. The UEs with SGSN ID (1) are associated with Wataniya provider, and UEs with SGSN ID (0) are associated with Jawwal provider.



	name	UE Serving SGSN ID	Application: ACE Tier Configuration	Application: Destination Preferences	Application: Mt
1	mobile_node_0	0	Unspecified	None	None
2	mobile_node_1	0	Unspecified	None	(...)
3	mobile_node_2	0	Unspecified	None	None
4	mobile_node_3	0	Unspecified	None	None
5	mobile_node_4	0	Unspecified	None	None
6	mobile_node_5	0	Unspecified	None	None
7	mobile_node_6	0	Unspecified	None	None
8	mobile_node_8	0	Unspecified	None	None
9	mobile_node_9	0	Unspecified	None	None
10	mobile_node_10	0	Unspecified	None	None
11	mobile_node_11	0	Unspecified	None	None
12	mobile_node_12	0	Unspecified	None	None
13	mobile_node_13	0	Unspecified	None	None
14	mobile_node_14	0	Unspecified	None	None
15	mobile_node_15	0	Unspecified	None	None
16	mobile_node_16	0	Unspecified	None	None
17	mobile_node_17	0	Unspecified	None	None
18	mobile_node_18	0	Unspecified	None	None
19	mobile_node_19	0	Unspecified	None	None
20	mobile_node_20	1	Unspecified	None	None
21	mobile_node_21	1	Unspecified	None	None
22	mobile_node_22	1	Unspecified	None	None
23	mobile_node_23	1	Unspecified	None	None
24	mobile_node_24	1	Unspecified	None	None
25	mobile_node_25	1	Unspecified	None	None
26	mobile_node_26	1	Unspecified	None	None
27	mobile_node_27	1	Unspecified	None	None
28	mobile_node_28	1	Unspecified	None	None
29	mobile_node_29	1	Unspecified	None	None
30	mobile_node_30	1	Unspecified	None	None
31	mobile_node_31	1	Unspecified	None	None
32	mobile_node_32	1	Unspecified	None	None
33	mobile_node_33	1	Unspecified	None	None
34	mobile_node_34	1	Unspecified	None	None

Figure (3.12): SGSN Identifier for each UE

Possibility of Applying Green Communication in Palestinian Cellular Networks

- **Path loss selection:** In any wireless network, it is necessary to take in the account the losses that are come from environment, the terrain, obstacles and the man made things such as buildings, cars, etc. Because of that, all the information that we have is for suburban area, so we assumed the path loss is Hata path loss model for the suburban area as in the Figure (3.13).

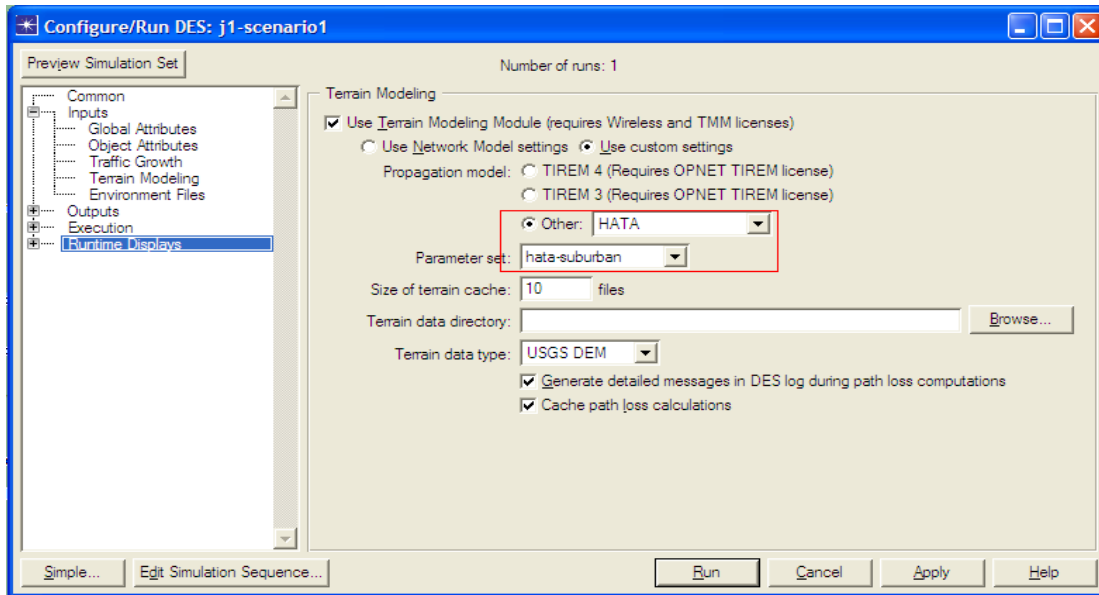


Figure (3.13): Path loss selection (HATA)

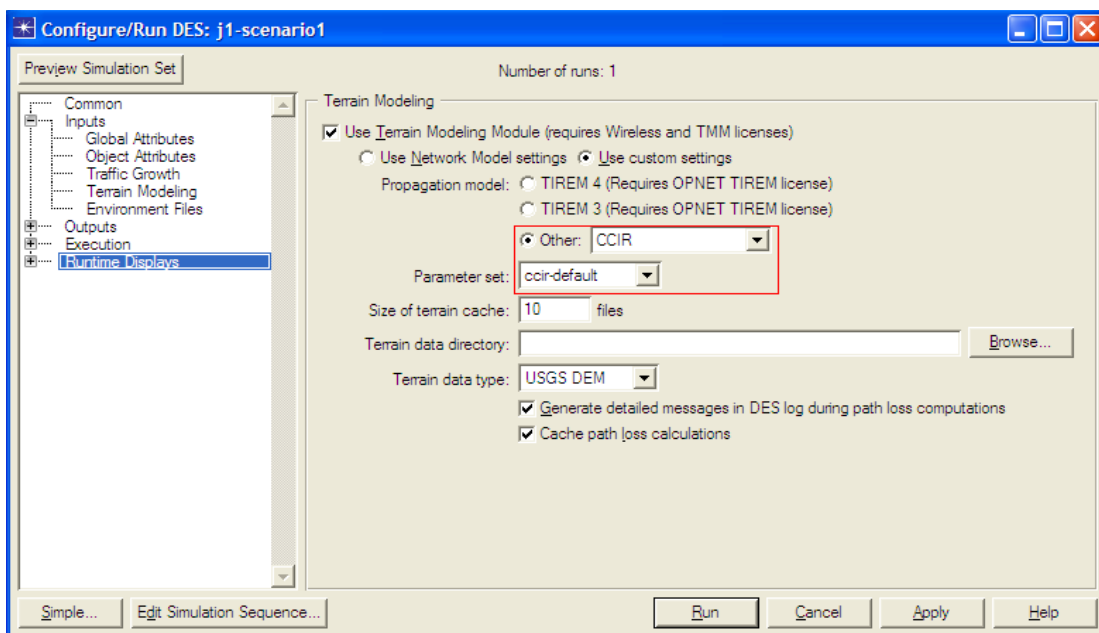


Figure (3.14): Path loss selection (CCIR)

Possibility of Applying Green Communication in Palestinian Cellular Networks

The OPNET modeler supports the following path loss model:

- 1. The Hata model** for Suburban Areas, also known as the Okumura-Hata model for being a developed version of the Okumura Model, is the most widely used model in radio frequency propagation for predicting the behavior of cellular transmissions in city outskirts and other rural areas. This model incorporates the graphical information from Okumura model and develops it further in order to suites the need. This model also has two more varieties for transmission in Urban Areas and Open Areas. Moreover, Hata Model predicts the total path loss along a link of terrestrial microwave. Also, it is a function of transmission frequency and the average path loss in urban area is the PCS extension from 1500 to 2000 MHz The distance between the mobile and base station can take values between 1 and 20 km, the receiver can have an antenna height of 1 to 10 m, and the transmitter can have an antenna height of 30 to 200 m.
- 2. CCIR Model:** It is an empirical formula for the combined effect of free space path loss and terrain induced path loss, and it was published by the CCIR (committee consultative international radio communication) which called now ITU-R. CCIR model is a model for medium-small city propagation conditions.
- 3. The indoor office environment** assumes typical floor structure, light internal walls and internal walls made of concrete and brick. The number of floor $n=4$ is an average for indoor office environment. If the distance between the mobile station and base station is above 1 km, a warning message will be given.
- 4. For outdoor to indoor and pedestrian environment,** a typical urban and suburban environment is assumed with 10.5 m between the mean building height and the mobile antenna height, 15 m between the mobile and the diffracting edges, and 80 m as the average separation between rows of buildings. The base station antenna height is assumed near mean rooftop level for this environment.
- 5. For vehicular environment,** a typical urban and suburban environment is assumed with 10.5 m between the mean building height and the mobile antenna height, 15 m between the mobile and the diffracting edges, and 80 m as the average separation between rows of buildings. The antenna height difference between the base station antenna and the mean building rooftop height can take values between 0 and 50 m.

Possibility of Applying Green Communication in Palestinian Cellular Networks

We compare between the received SNR from the mobile station side when the CCIR model or the Hata model are used. The two values do not differ much from each other. In the OPNET modeler, HATA has a suburban type which is suitable for our network comparing with other models, so we used the Hata path loss model in all simulations.

3.6.2 Traffic Profile

This section explains the method for changing the traffic in Erlangs into number of users. We find the number of users by dividing the average traffic intensity (A) on 0.025 {Au: the traffic intensity for each user}. We add this number into the simulation hour by hour in the one network case, and Roaming-to-All case, and then find the received SNR for each mobile from the surroundings cells; to decide which cell must be turned off. In the Roaming-to-One case, turning OFF one network and keep the other ON, there are no constraints for the number of users because the remaining network can serve its users and the turned off network users in the low traffic period.

Hour	Wednesday			average	# of users
	Cell0	Cell1	Cell2		
0	0.499	0.395	0.454	0.449333	17.973
1	0.375	0.414	0.328	0.372333	14.893
2	0.304	0.311	0.316	0.310333	12.413
3	0.242	0.299	0.302	0.281	11.24
4	0.184	0.196	0.206	0.195333	7.8133
5	0.398	0.435	0.326	0.386333	15.453
6	0.633	0.596	0.648	0.625667	25.027
7	0.722	0.775	0.704	0.733667	29.347

Table (3.3): Number of user in low traffic period for Wednesday in each BTS

The traffic profile is approximately the same for all the days except Friday. Therefore, we calculate the number of users for Wednesday and consider the remaining days the same as Wednesday. We consider that the low traffic period for these days between 00:00AM – 07:00AM.

Hour	Friday			Average	# of users
	Cell0	Cell1	Cell2		
0	0.375	0.43	0.105	0.30333	12.1333333
1	0.26	0.349	0.155	0.25467	10.1866667
2	0.146	0.22	0.195	0.187	7.48
3	0.121	0.243	0.176	0.18	7.2
4	0.179	0.198	0.214	0.197	7.88
5	0.226	0.31	0.292	0.276	11.04
6	0.185	0.122	0.154	0.15367	6.14666667
7	0.282	0.294	0.142	0.23933	9.57333333
8	0.415	0.306	0.204	0.30833	12.3333333
9	0.455	0.43	0.45	0.445	17.8

Table (3.4): Number of user in low traffic period for Friday in each BTS

It is notable from Table (3.4) that the traffic profile for Friday differs completely from the traffic profile for the remaining days, so that the number of hours in the low traffic is larger than those in the other days.

Possibility of Applying Green Communication in Palestinian Cellular Networks

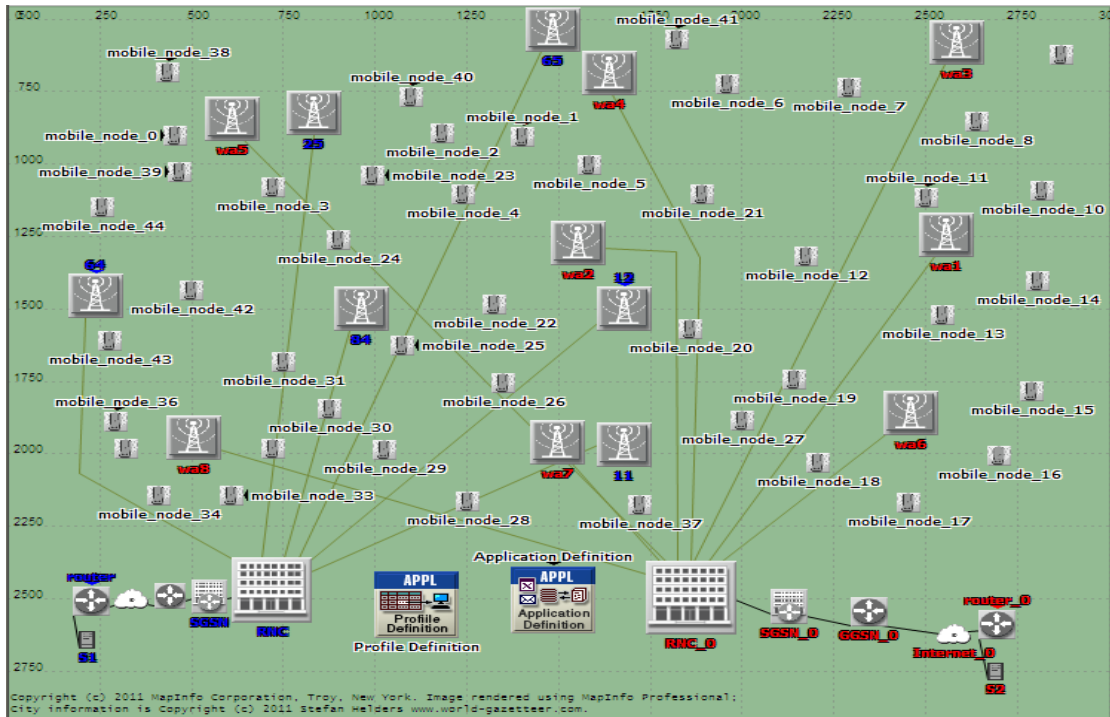


Figure (3.17): Jawwal and Wataniya networks deployments

Figure (3.17) shows the combined network deployment that contains the two operator networks depending on the map in section 3.4. The nodes with the red color are for Wataniya Company and the nodes with blue color are for Jawwal Company.

We build the networks depending on the map, the cells power and the traffic profile that are listed in sections 3.3 and 3.4.

Chapter

4

Experiments & Analysis

4.1 Introduction

4.2 One Network Experiments

4.2.1 Received SNR

4.2.2 Power saved calculation

4.3 Two Network Experiments

4.3.1 Roaming-To-One

4.3.1.1 Received SNR

4.3.1.2 Power saved calculation

4.4.2 Roaming-To-All

4.4.2.1 Received SNR

4.4.2.2 Power saved calculation

4.1 Introduction

This chapter illustrates the simulation methodologies and results obtained from the OPNET modeler. We have three cases; case for one operator and two cases for the two operators. In each case, we compared the SNR received at the mobile stations side before applying the project idea and after applying it. We compute the amount of power that can be saved when turning off some cells in the one network case, or turning off one network completely in the "Roaming-to-One" case, or turning off some cells from each operator and insuring the remaining cells of the two networks to serve the whole number of users in the "Roaming-to-All" case.

4.2 One Network Experiments

This section contains the simulation layout of the one network case. In this case, we turn OFF some cells and keep the others ON. We take NodeB3 and NodeB4 that appear in figure (4.1) as a **sample** from the whole work. This sample shows the way we decide which cells must be turned off according to the number of users that receive power under a threshold in each hour for Wednesday and Friday. We add users hour by hour according to the tables (3.3) and (3.4) in chapter 3.

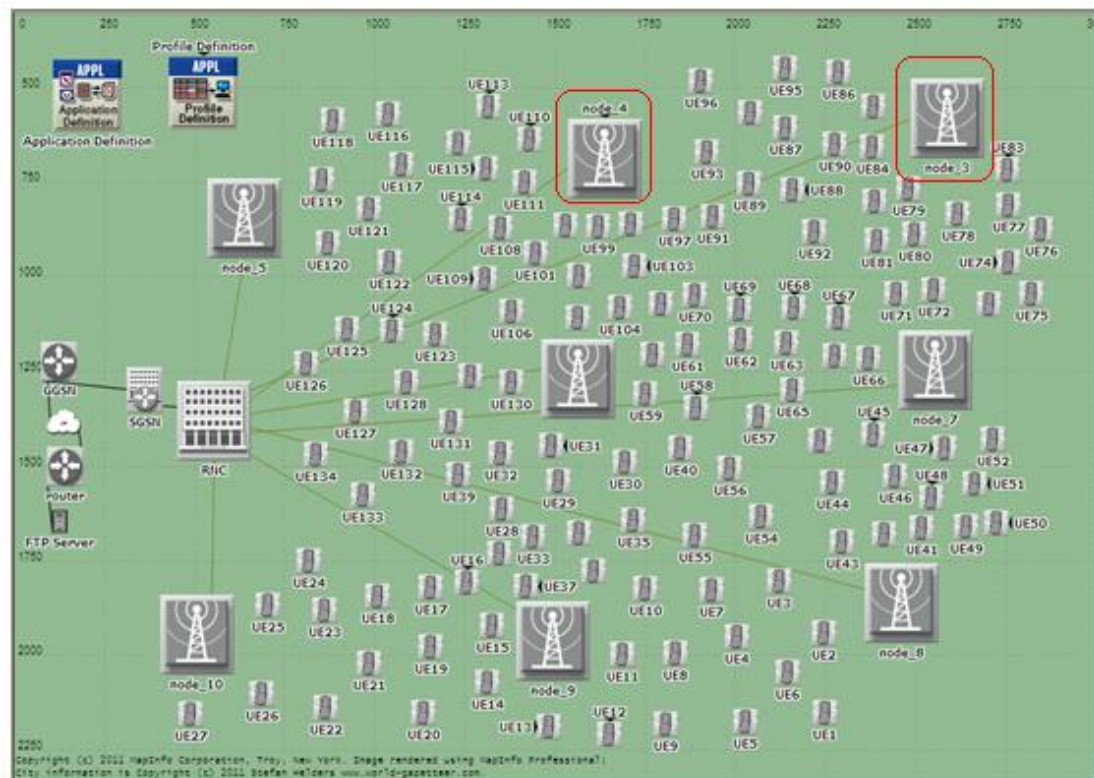


Figure (4.1): Wataniya network operator

We choose a threshold depending on the TEMS program that measures the received power from the NodeBs and classified it as the following:

- ❖ Excellent (**dark green**): from $\{-55\}$ dBm – $\{-70\}$ dBm, it is a good communication environment.
- ❖ Good (**light green**): From $\{-70\}$ dBm– $\{-80\}$ dBm, mobiles still make call setup with high QoS.
- ❖ Medium (**yellow**): From $\{-80\}$ dBm – $\{-90\}$ dBm, mobiles still make call setup but with acceptable QoS.
- ❖ Bad (**red**): From $\{-90\}$ dBm– $\{-104\}$ dBm, there is no ability to make call setup, and normally any mobile reaches this range will make a handoff to another cell.

Therefore we take the threshold on the **medium region** -80 dBm because the mobile that receives power in this range can make call setup but with acceptable QoS compared with the excellent and the good ranges.

4.2.1 Received SNR

In the one network case, we turn off some cells depending on the number of mobiles that receive power below -80 dBm, so that the cell that serves more mobiles with power less than the threshold -compared with the other neighbor cell- must be turned off. The next figures show which cell must be turned off in the low traffic period for Wednesday for NodeB3 (cell1) and NodeB4 (cell0).

- **Wednesday**

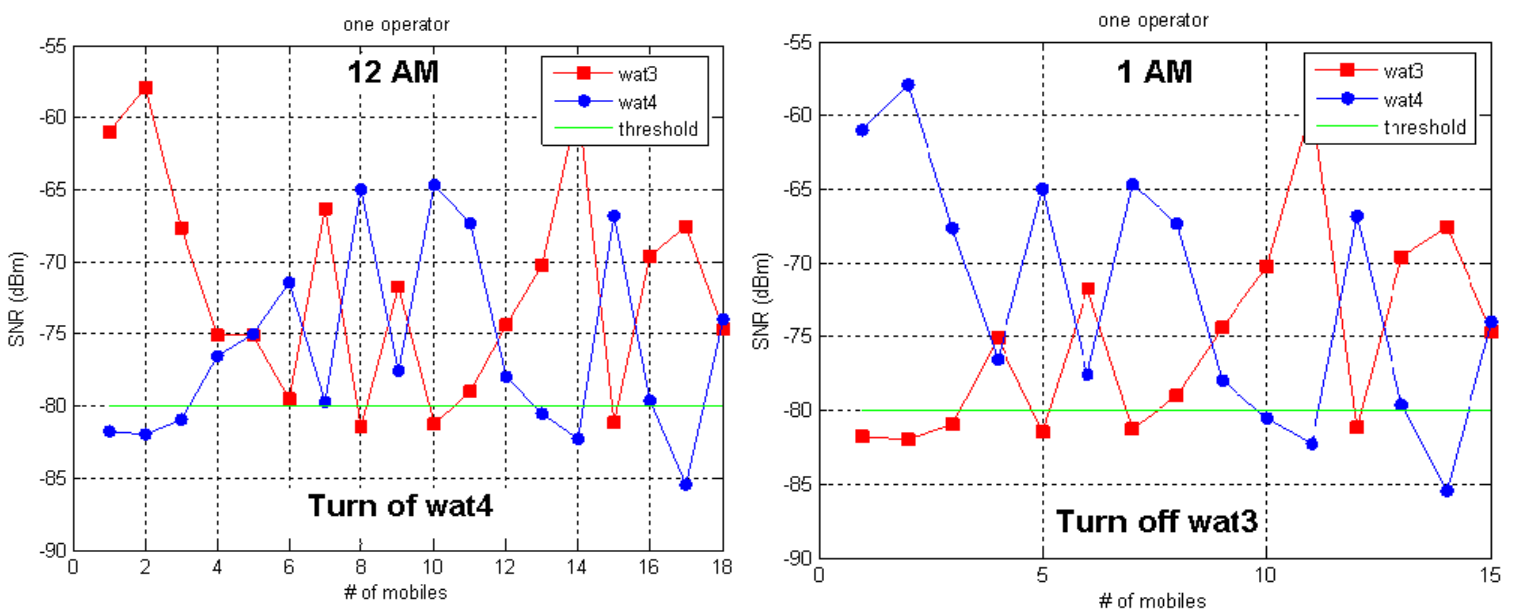


Figure (4.2): The received SNR at 12 AM and 1 AM for Wednesday

Possibility of Applying Green Communication in Palestinian Cellular Networks

From figure (4.2) at 12 AM, the number of mobiles that receive power under -80dBm for wat4 (cell0) is greater than wat3 (cell1) for the same number of mobiles at this hour. So, if wat4 (cell0) is turned off wat3 (cell1) is kept ON, the majority of mobiles will receive power above threshold and make calls with acceptable QoS, and the same method is used at 1 AM and other hours.

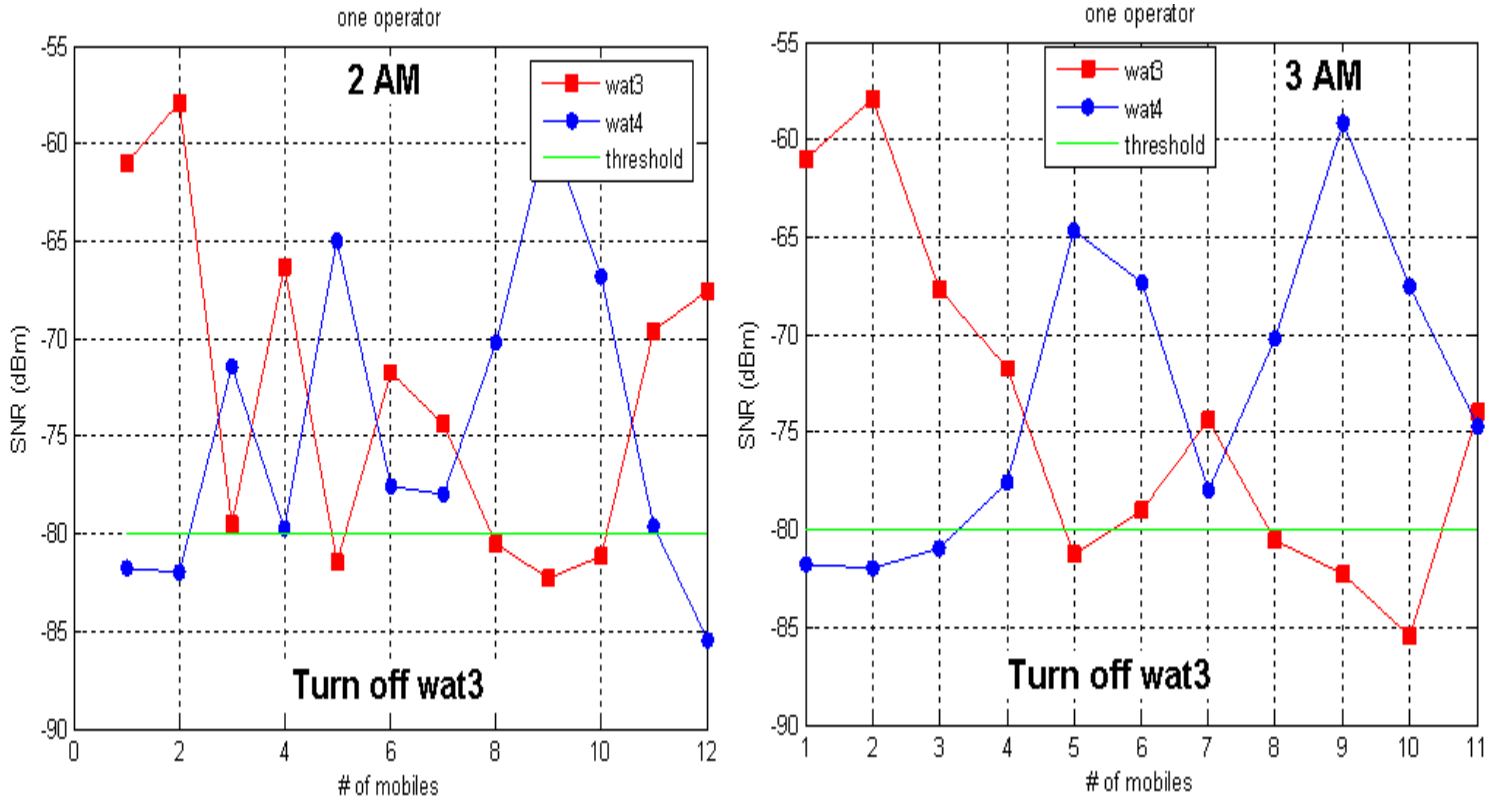


Figure (4.3): The received SNR at 2 AM and 3 AM for Wednesday

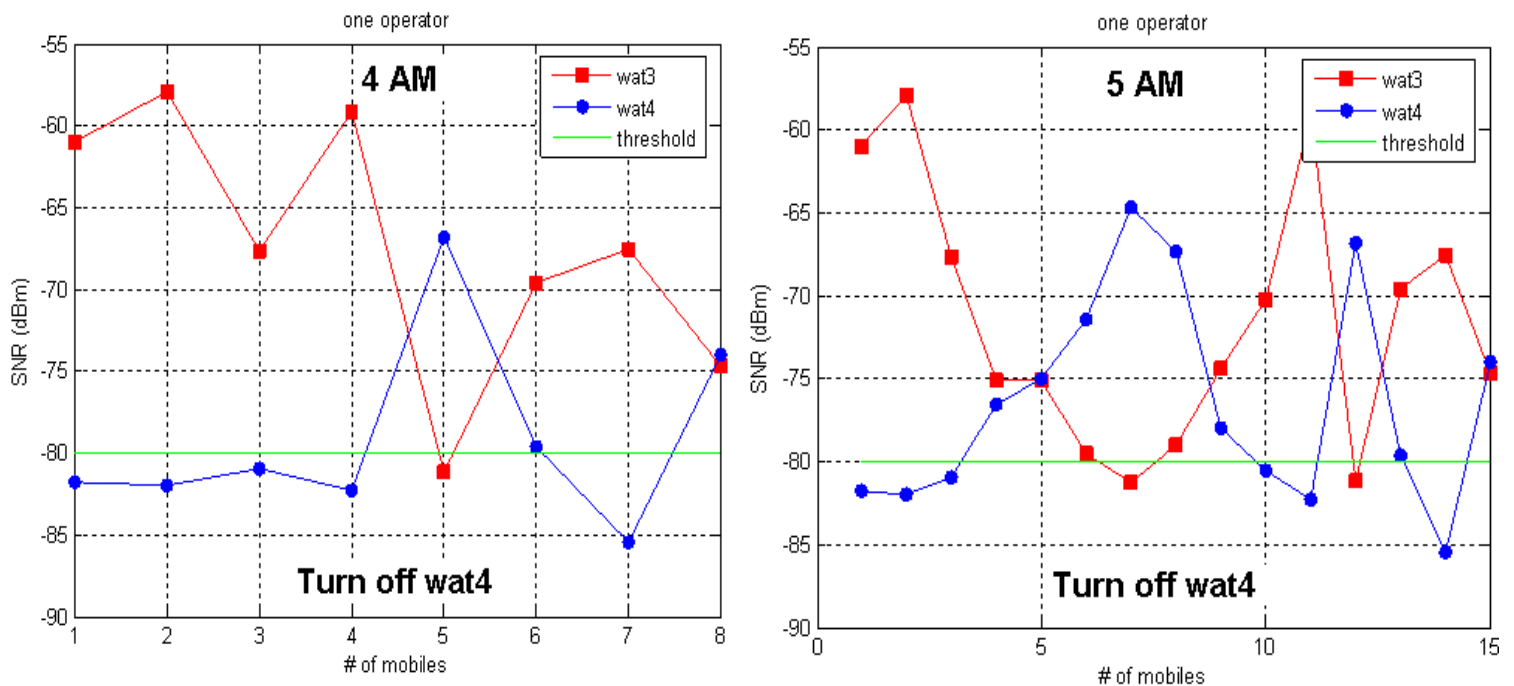


Figure (4.4): The received SNR at 4 AM and 5 AM for Wednesday

Possibility of Applying Green Communication in Palestinian Cellular Networks

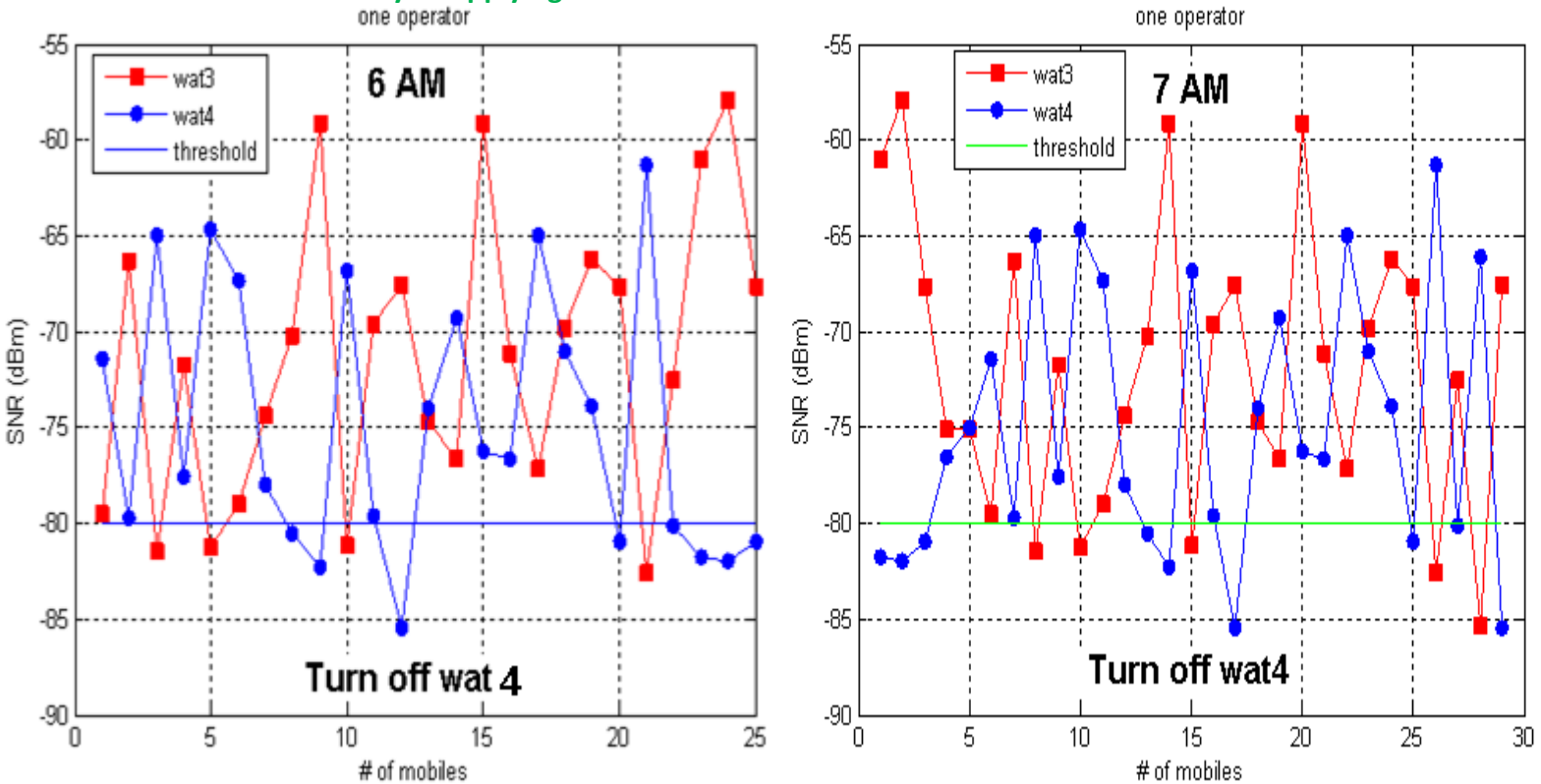


Figure (4.5): The received SNR at 6 AM and 7 AM for Wednesday

The rest of week days are as Wednesday expect Friday because on Friday the low traffic period which is greater than any day in the week.

- **Friday**

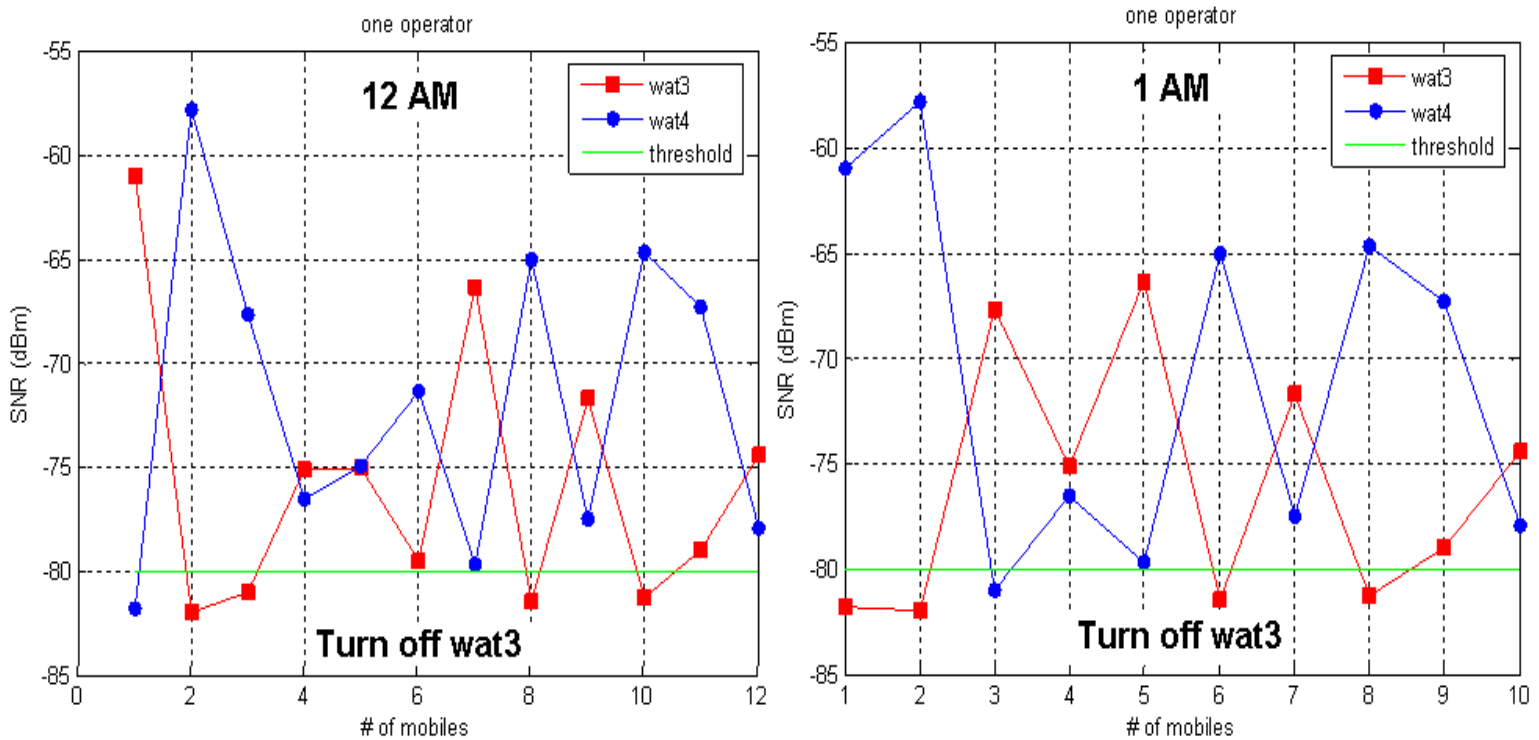


Figure (4.6): The received SNR at 12 AM and 1 AM for Friday

Possibility of Applying Green Communication in Palestinian Cellular Networks

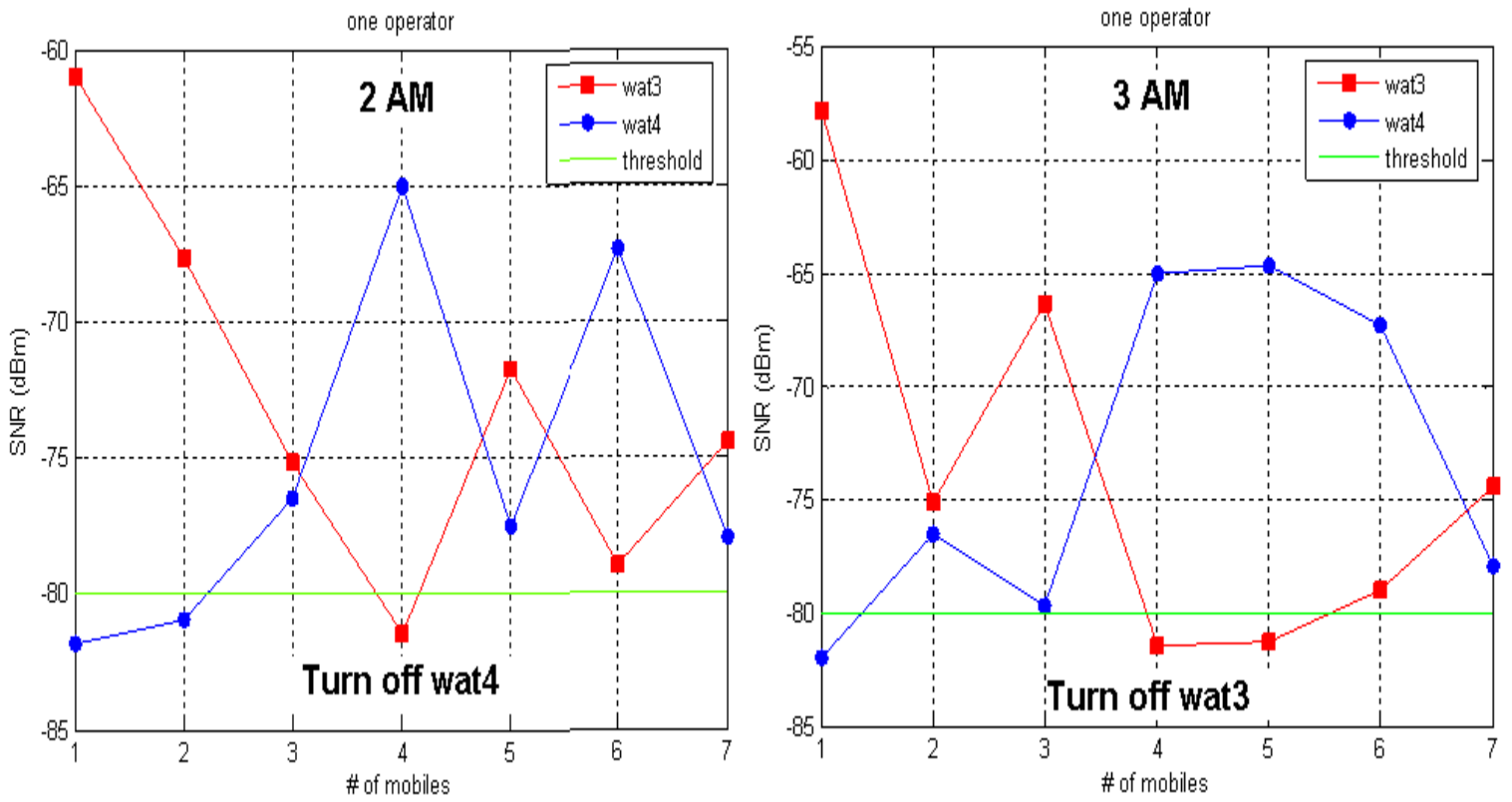


Figure (4.7): The received SNR at 2 AM and 3 AM for Friday

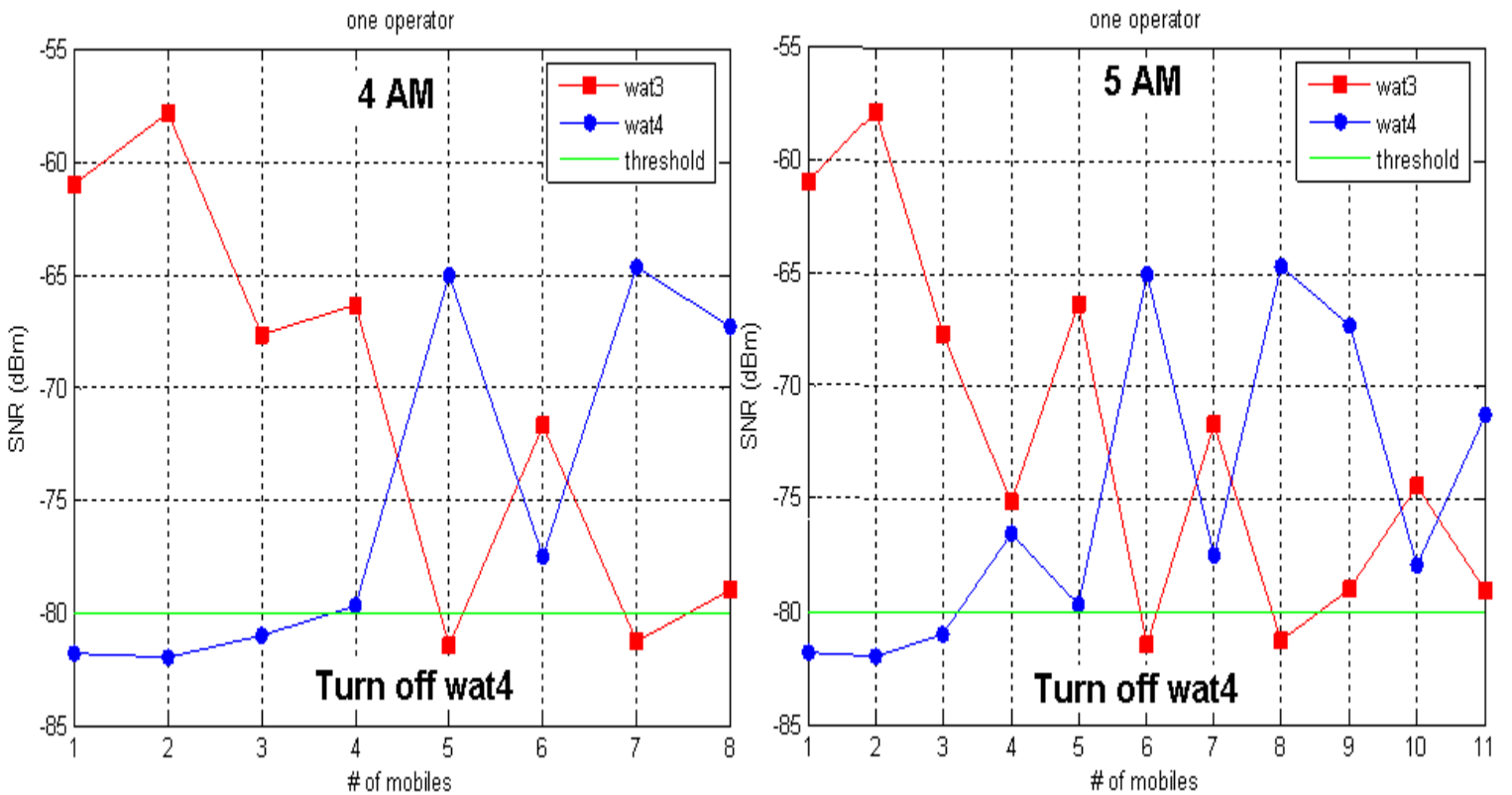


Figure (4.8): The received SNR at 4 AM and 5 AM for Friday

Possibility of Applying Green Communication in Palestinian Cellular Networks

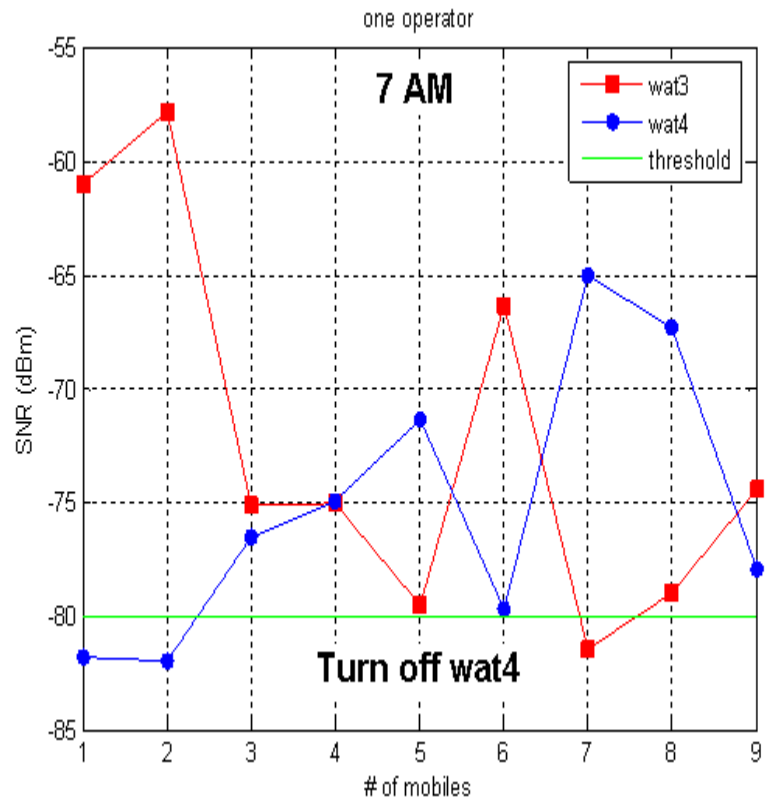
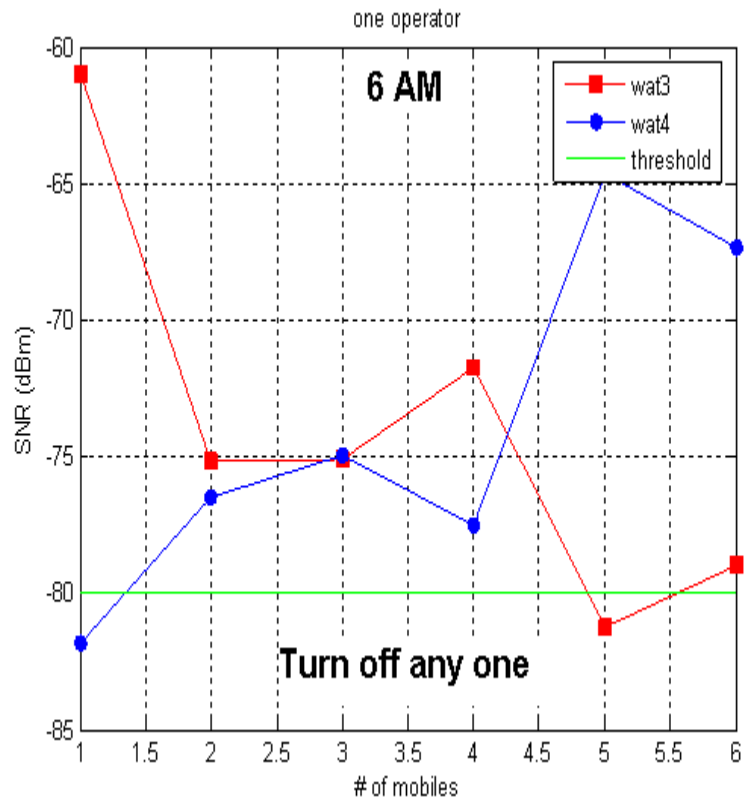


Figure (4.9): The received SNR at 6 AM and 7 AM for Friday

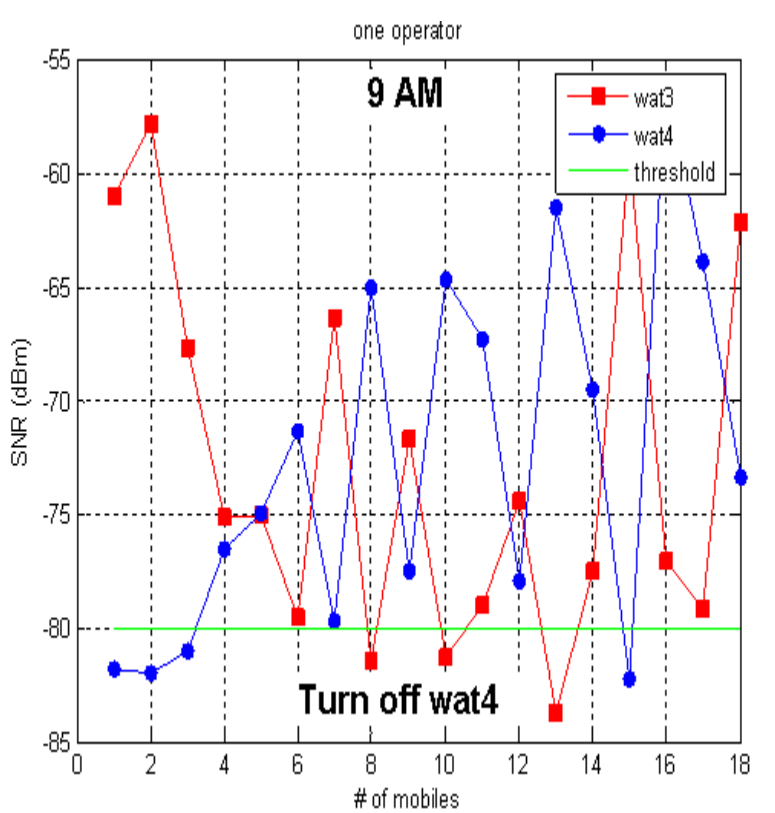
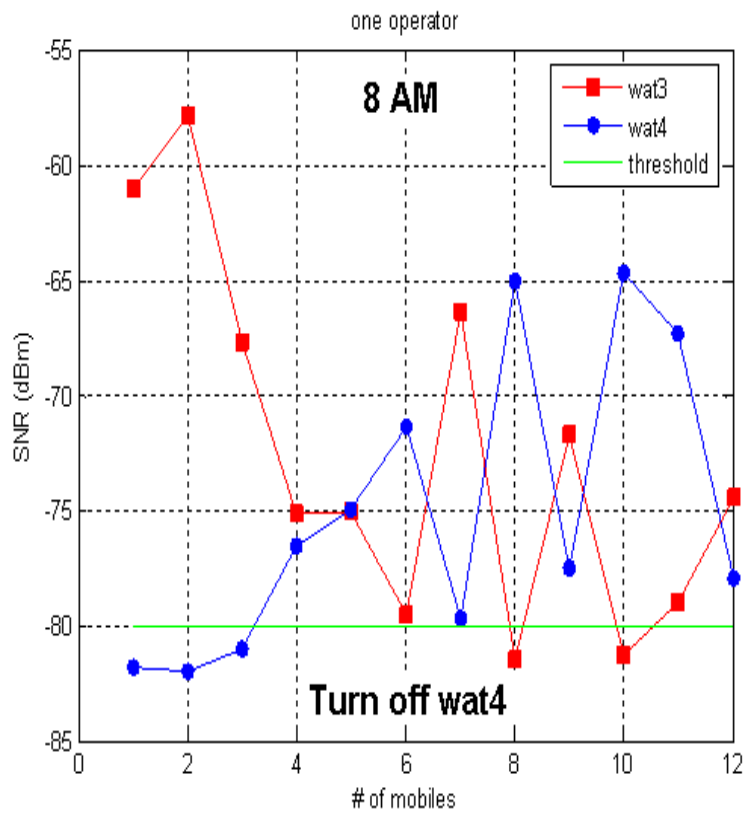


Figure (4.10): The received SNR at 8 AM and 9 AM for Friday

4.2.2 Power saved calculation

In the calculation of the saved power in the one network case, it is necessary to know the time that each cell in the network is turned OFF. Table (4.1) and table (4.2) show the number of hours at which each cell in the network is turned off.

Cells	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	Total(hour)
B3C0	X	x	X	X	X	x	x	x	X	x	X
B3C1	1	1	0	1	0	0	1	0	0	0	4
B3C2	1	0	0	1	1	0	0	0	1	1	5
B4C0	0	0	1	0	1	1	0	1	1	1	6
B4C1	0	0	1	1	0	1	1	0	0	0	4
B4C2	0	1	1	0	0	1	1	1	0	0	5
B5C0	1	1	0	0	1	0	0	1	1	1	6
B5C1	X	x	X	X	X	x	x	x	X	x	X
B5C2	0	0	0	0	0	0	0	0	0	0	0
B6C0	1	0	0	1	1	0	0	0	1	1	5
B6C1	0	0	0	0	0	0	0	0	0	0	0
B6C2	1	1	1	0	0	1	0	1	0	1	6
B7C0	0	1	1	0	0	1	1	1	0	0	5
B7C1	0	1	1	0	0	1	1	1	0	0	5
B7C2	0	0	0	1	1	0	1	0	1	0	4
B8C0	1	1	1	0	0	1	0	1	0	1	6
B8C1	1	1	1	0	0	1	0	1	0	1	6
B8C2	0	0	0	0	0	0	0	0	0	0	0
B9C0	0	0	0	1	1	0	1	0	1	0	4
B9C1	0	0	0	1	1	0	1	0	1	0	4
B9C2	0	0	0	0	0	0	0	0	0	0	0
B10C0	1	1	1	0	0	1	0	1	0	1	6
B10C1	X	x	X	X	X	x	x	x	X	x	X
B10C2	0	0	0	0	0	0	0	0	0	0	0
Total turn off for all cells in Friday											81

Table (4.1): The number of the turned off hours in Friday for One operator case

$$P_{res} = (P_{con} * T * C_{off} * D) = 0.69 * 81 * 1 = 55.89 \text{ KW}$$

$$\text{Cost} = P_{res} * S = 55.89 \text{ KW} * 0.59 = 33 \text{ NIS}$$

Without applying the idea the total power consumption will be:

$$P_{con} = 0.69 * 24 * 16 \text{ cells} * 1 = 256 \text{ KW}$$

So by applying the green communication idea we can save $55.89/256 = 21.1\%$ from the total power consumption.

Possibility of Applying Green Communication in Palestinian Cellular Networks

Cells	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	Total(hour)
B3C0	X	x	x	x	x	X	X	x	X
B3C1	1	1	0	1	0	0	1	0	3
B3C2	1	0	0	1	1	0	0	0	3
B4C0	0	0	1	0	1	1	0	1	5
B4C1	0	0	1	1	0	1	1	0	4
B4C2	0	1	1	0	0	1	1	1	5
B5C0	1	1	0	0	1	0	0	1	4
B5C1	X	x	x	x	x	X	X	x	X
B5C2	0	0	0	0	0	0	0	0	0
B6C0	1	0	0	1	1	0	0	0	3
B6C1	0	0	0	0	0	0	0	0	0
B6C2	1	1	1	0	0	1	0	1	5
B7C0	0	1	1	0	0	1	1	1	5
B7C1	0	1	1	0	0	1	1	1	5
B7C2	0	0	0	1	1	0	1	0	3
B8C0	1	1	1	0	0	1	0	1	5
B8C1	1	1	1	0	0	1	0	1	5
B8C2	0	0	0	0	0	0	0	0	0
B9C0	0	0	0	1	1	0	1	0	3
B9C1	0	0	0	1	1	0	1	0	3
B9C2	0	0	0	0	0	0	0	0	0
B10C0	1	1	1	0	0	1	0	1	5
B10C1	X	x	X	x	x	X	X	x	X
B10C2	0	0	0	0	0	0	0	0	0
Total turn off for all cells in Wednesday									66

Table (4.2): The number of the turned off hours in Wednesday

$$P_{res} = (P_{con} * T * C_{off} * D) = 0.69 * 66 * 6 = 273.24 \text{ KW}$$

$$\text{Cost} = P_{res} * S = 55.89 \text{ KW} * 0.59 = 161.21 \text{ NIS}$$

Without applying the idea, the total power consumption will be:

$$P_{con} = 0.69 * 24 * 16 \text{ cells} * 6 = 1590 \text{ KW}$$

So by applying the green communication idea we can save $273.24/1590 = 17.2\%$ from the total power consumption for the Wataniya network

$$\text{The total saved power in the week} = 273.24 + 55.89 = 329.13 \text{ KW}$$

$$\text{The total power consumption per week} = 1590 + 256 = 1846 \text{ KW}$$

$$\text{The percentage of saving per week} = 329.13 \text{ KW} / 1846 \text{ KW} = \underline{\underline{17.8\%}}$$

4.3 Two Network Experiments

4.3.1 Roaming-To-One

This section presents the simulation results of the two network scenario and some analysis for the results. We suppose one distribution of users in this scenario because both networks cover the same area. If one network was turned off, the other one can serve the users for the both wherever the mobile station exists. So, the turn off idea is distribution independent in this case. Figure (4.11) shows the two provider network and the distribution of users. As shown, it is notable that the samples are chosen from different locations to cover whole area.

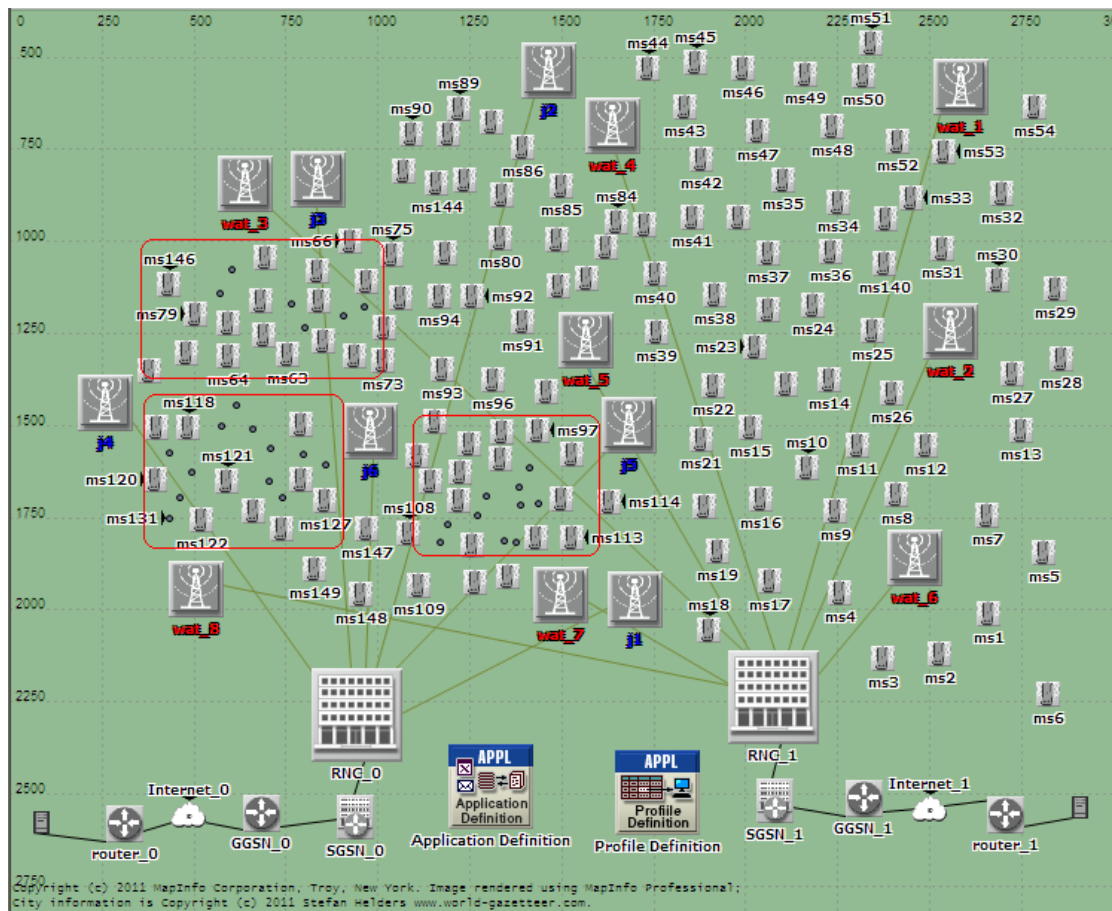


Figure (4.11): The Two Provider Network

4.3.1.1 Received SNR

This section contains the SNR received for the mobile stations that are in figure (4.11) before and after applying the green communication idea. We have three cases:

❖ **Case1: SNR decrease**

Figure (4.12) shows the received SNR after turning off Wataniya network. The received SNR when the mobile station roams to the Wataniya network is less than the received SNR from the Jawwal network in the third sample and this is the cost of the green communication idea regardless of the power that can be saved.

Possibility of Applying Green Communication in Palestinian Cellular Networks

❖ Case2: SNR increase

Figure (4.12) shows also the received power for another mobile station. We turn OFF Wataniya network, so this mobile roam to Wataniya operator. The new power received from the Wataniya network is more than the power received from Jawwal network. We can conclude that the power received not necessarily be less than the power before applying the idea.

❖ Case3: The Same SNR

In this case, the received power from Wataniya network and Jawwal network is the same.

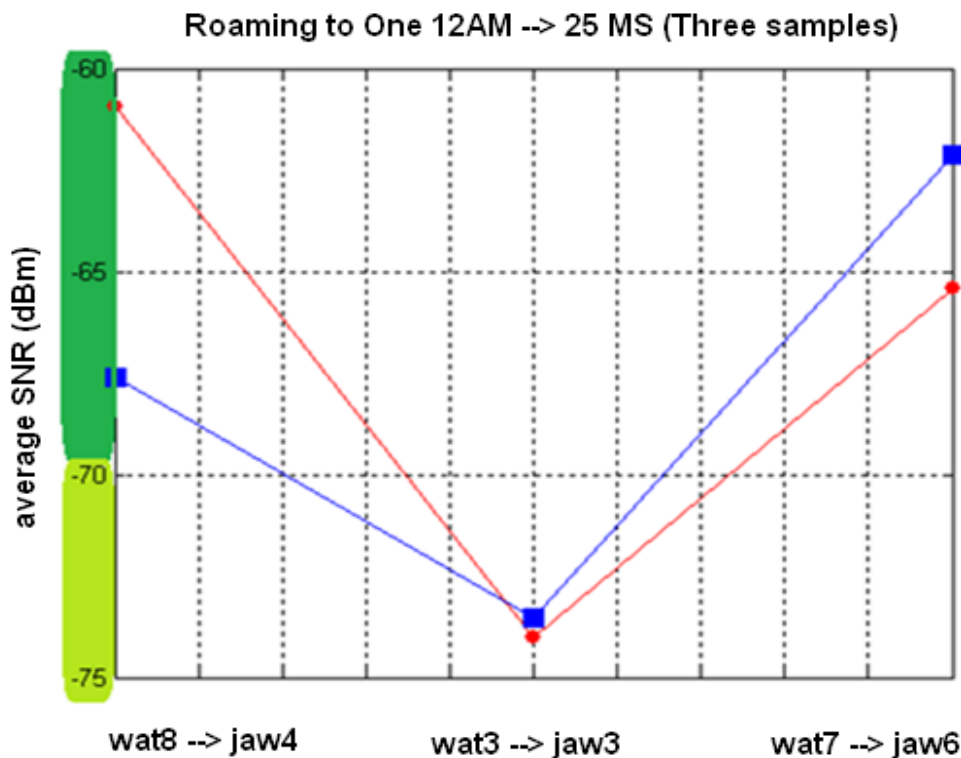


Figure (4.12): The received SNR for six samples in the two one case

We will get the same results if we turn off Jawwal network and keep Wataniya network to serve all user.

4.3.1.2 Power saved calculation:

In this project we are interested in two parameters: the received power in the mobile station, which is occasionally the cost for the green communication idea, and the amount of power that can be saved which is the core for this project. This section contains the calculation for the saved power in the two network cases. The next equation is used to calculate the reserved power.

Possibility of Applying Green Communication in Palestinian Cellular Networks

In general:

$$P_{res} = (P_{con} * T * C_{off} * D) (N-1)/N \text{ for } N > 1$$

Where:

P_{res} : The amount of power reservation in KW.

P_{con} : Power consumed from cell per hour in KW.

T: Time of cells turning-off in hours.

C_{off} : # of cells that turn off.

D: # of days that the cells turn off.

N: # of networks (operators).

$$\text{Cost} = P_{res} * S$$

Multiply by (N-1)/N to make balancing between networks in turn off operation.

Where:

S: cost of KW

In cases:

- In one week D= 7
- In one month D= 30
- In one year D=365

❖ If we keep jawwalnetwork ON for the PPU area, T= 8 hour and D=7.

$$P_{res} = (P_{con} * T * C_{off} * D) = (0.5KW*8 \text{ hour}*(6 \text{ BTSs}*3 \text{ cells/BTS})*7\text{days}) = 504 \text{ KW}$$

$$\text{Cost} = P_{res} * S = 504 \text{ KW}*0.59 \text{ NIS/KW}=297 \text{ NIS/week}$$

Without applying green communication idea the consumed power will be:

$$P_{con} = (0.5 \text{ KW}*24 \text{ hour}*(6 \text{ BTSs}*3 \text{ cells/BTS})*7 \text{ days}) = 1512 \text{ KW}$$

$$\text{Cost} = P_{res} * S = 1512 \text{ KW}*0.59\text{NIS/KW}=892 \text{ NIS/week}$$

So by applying the green communication we can reserve $297/892=33.3\%$ from electricity bills in the Jawwal operator.

❖ If we keep Wataniya network ON the amount of power that can be saved:

$$P_{res} = (P_{con} * T * C_{off} * D) = (0.69KW*8\text{hour}*(5\text{BTSs}*3\text{cells/BTS})*7\text{days}) = 579.6\text{KW}$$

$$\text{Cost} = P_{res} * S = 579.6 \text{ KW}*0.59 \text{ NIS/KW}=342 \text{ NIS/week}$$

Possibility of Applying Green Communication in Palestinian Cellular Networks

Without applying green communication idea the consumed power will be:

$$P_{con} = (0.69 \text{ KW} * 24 \text{ hour} * (5 \text{ BTSs} * 3 \text{ cells/BTS}) * 7 \text{ days}) = 1739 \text{ KW}$$

$$\text{Cost} = P_{res} * S = 1739 \text{ KW} * 0.59 \text{ NIS/KW} = 1026 \text{ NIS/week}$$

So by applying the green communication we can reserve $579.6/1739=33.3\%$ of the Wataniya network power.

- ❖ If D=30days 15 days Jawwal ON and 15 days Wataniya ON the power reservation as the following:

$$\begin{aligned} P_{res} (\text{Jawwal}) &= (P_{con} * T * C_{off} * D) (N-1)/N \\ &= (0.5 \text{ KW} * 8 \text{ hour} * (6 \text{ BTSs} * 3 \text{ cells/BTS}) * 30 \text{ days}) * 1/2 = 1080 \text{ KW} \end{aligned}$$

$$\begin{aligned} \text{Cost} &= P_{res} * S \\ &= 1080 \text{ KW} * 0.59 \text{ NIS/KW} = 637 \text{ NIS/month} \end{aligned}$$

$$\begin{aligned} P_{res} (\text{Wataniya}) &= (P_{con} * T * C_{off} * D) (N-1)/N \\ &= (0.69 \text{ KW} * 8 \text{ hour} * (5 \text{ BTSs} * 3 \text{ cells/BTS}) * 30 \text{ days}) * 1/2 = 1242 \text{ KW} \end{aligned}$$

$$\begin{aligned} \text{Cost} &= P_{res} * S \\ &= 1242 \text{ KW} * 0.59 \text{ NIS/KW} = 733 \text{ NIS/month} \end{aligned}$$

With apply the green communication idea we can reserve 33.3%

- ❖ If D=365 days the power reservation as the following:

$$\begin{aligned} P_{res} (\text{Jawwal}) &= (P_{con} * T * C_{off} * D) (N-1)/N \\ &= (0.5 \text{ KW} * 8 \text{ hour} * (6 \text{ BTSs} * 3 \text{ cells/BTS}) * 365 \text{ days}) * 1/2 = 13140 \text{ KW} \end{aligned}$$

$$\begin{aligned} \text{Cost} &= P_{res} * S \\ &= 1080 \text{ KW} * 0.59 \text{ NIS/KW} = 7752 \text{ NIS/year} \end{aligned}$$

$$\begin{aligned} P_{res} (\text{Wataniya}) &= (P_{con} * T * C_{off} * D) (N-1)/N \\ &= (0.69 \text{ KW} * 8 \text{ hour} * (5 \text{ BTSs} * 3 \text{ cells/BTS}) * 365 \text{ days}) * 1/2 = 15111 \text{ KW} \end{aligned}$$

$$\text{Cost} = P_{res} * S = 15111 \text{ KW} * 0.59 \text{ NIS/KW} = 8915 \text{ NIS/year}$$

We can save the same percentage if the green communication idea is applied **33.3%**.

It is notable that the amount of saved power in the Wataniya network is greater than that for Jawwal network, this refer to that number of Wataniya BTSs is greater than

Possibility of Applying Green Communication in Palestinian Cellular Networks

Jawwal BTSs number in the same area. So, the idea will be more efficient with respect to Wataniya Company if there is a cooperation between them.

4.3.2 Roaming-To-All:

This case differs from the “Roaming to One case” that in the previous case, in which we turned off one network completely and roam its users to the remaining network. In this case, we turn off some of the BTSs (cells) for the two networks depending on the received SNR on the mobiles.

In the simulation of this case, we performed **two steps**:

1. We turned off one BTS from each pair that appears in figure (4.6) for both networks because these BTSs are very close to each other. In this case, the mobiles receive high power from both. Therefore, one BTS is enough to serve all surrounding users.
2. Then we turn off the cells for both networks as in the One Network Case according to the traffic profile for each network.

We add twice the number of users in each hour because the remaining network must serve the whole users for both networks. In this case, there is an important point Jawwal network operates at 900 MHz and Wataniya network operates at 1800 MHz so Wataniyas capacity is less than Jawwal capacity. Therefore, the turned off percentage in Wataniya network is less than Jawwal percentage, but we ignore this point in the simulation of this case.

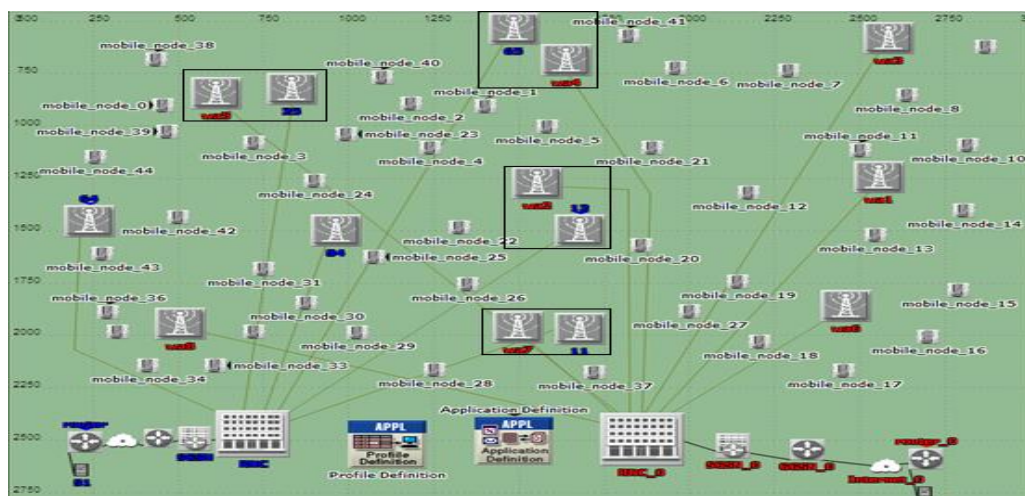


Figure (4.13): The two networks BTSs pairs

4.3.2.1 Received SNR

In this case, the determination of turned off cell from the two networks BTSs is accomplished depending on the number of mobiles that receive power under the threshold $\{-70 \text{ dBm}\}$, so that the cell that serves more mobiles with power less than the threshold must be turned off.

We choose this threshold depending on the TEMS levels because the remaining BTSs – for both networks - after turning off one BTS from each pair are much close to each other. Therefore, the revived power for each mobile from the two networks is high compared with the received power for the same mobile from its serving network.

The following figures show which cell must be turned of depending on the last criteria.

• **Wednesday**

roam to all

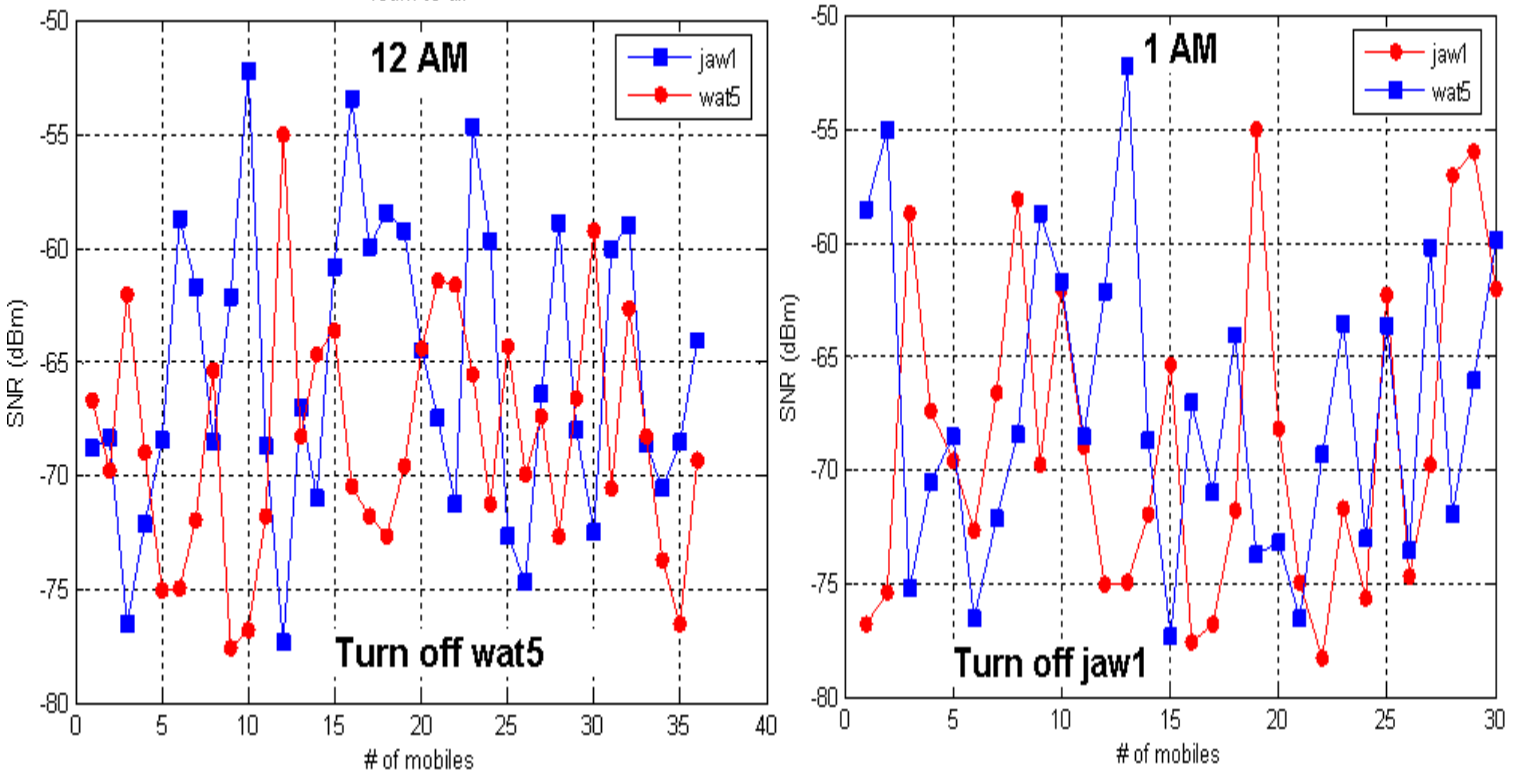


Figure (4.14): The received SNR at 12 AM and 1 AM "two networks"

From figure (4.14) at 12 AM the number of mobiles that receive power under threshold for wat5 (cell2) is greater than the power received for jaw1 (cell1); for the same mobiles at this hour. So, if wat5 (cell2) is turned off all mobiles will receive power above threshold and make calls with acceptable QoS, and the same method is

Possibility of Applying Green Communication in Palestinian Cellular Networks

used at 1 AM and the other hours. We can note also that there are mobiles receive less, above and the same power from the neighbors cell.

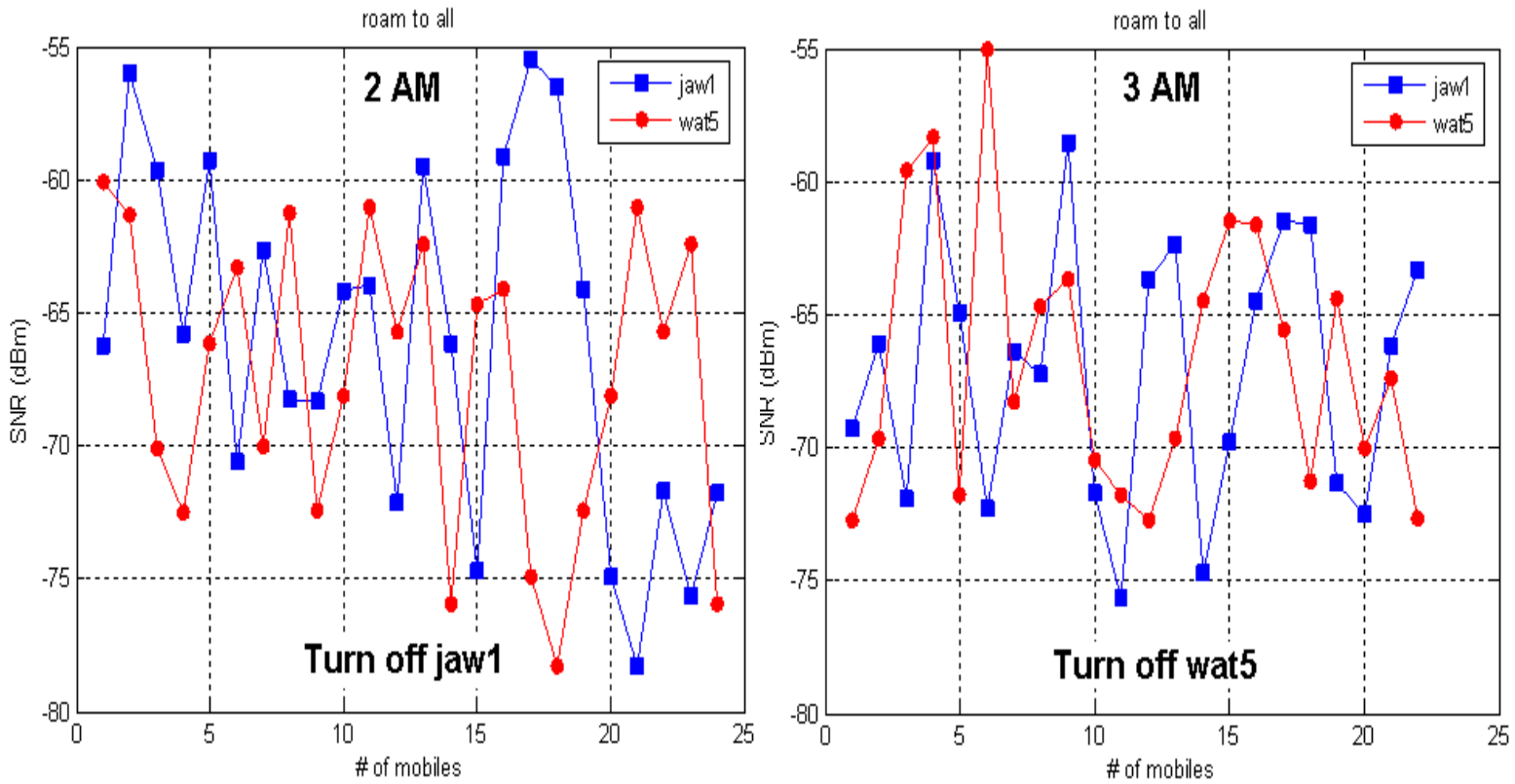


Figure (4.15): The received SNR at 2 AM and 3 AM "two networks"

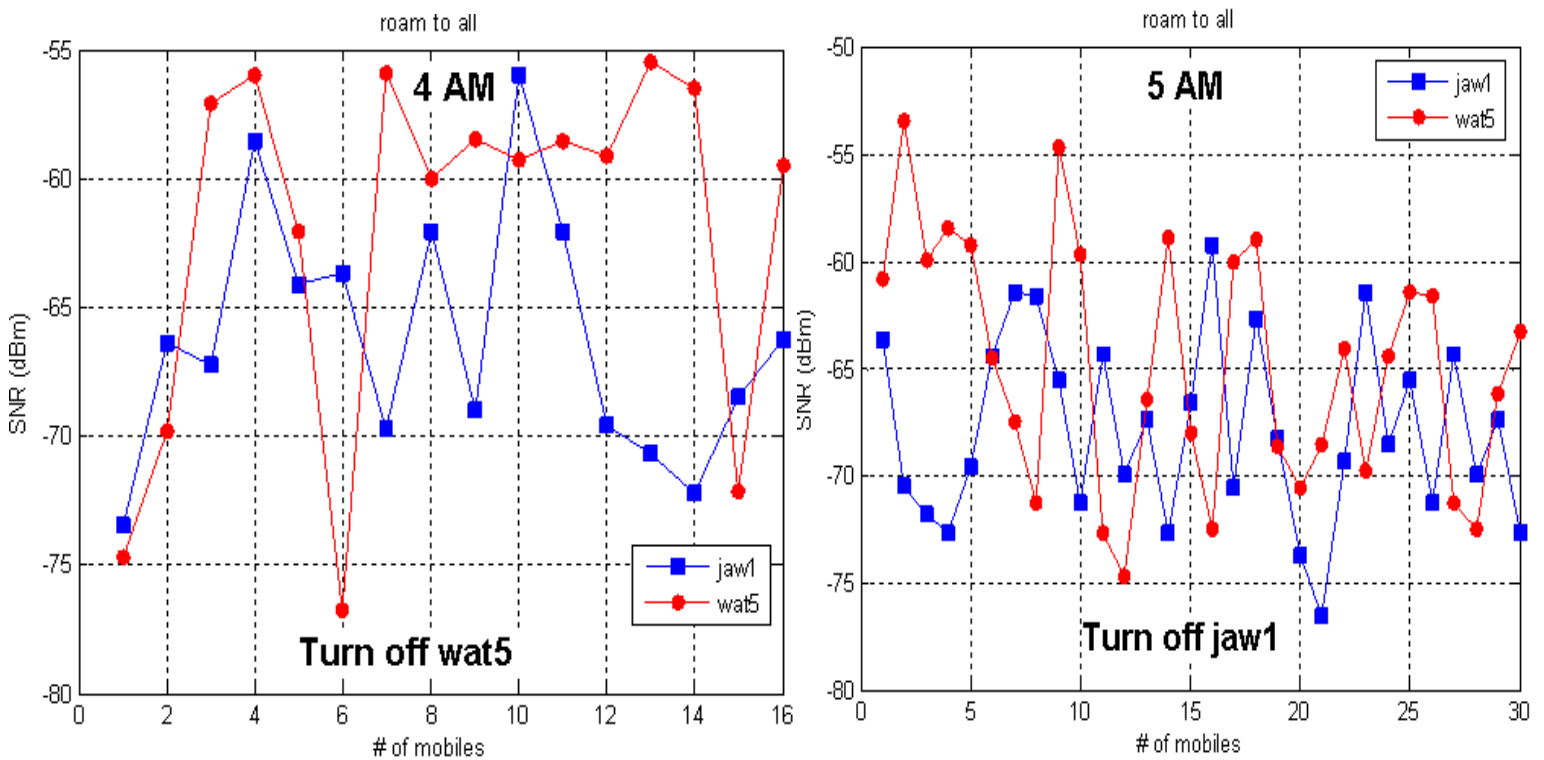


Figure (4.16): The received SNR at 4 AM and 5 AM "two networks"

Possibility of Applying Green Communication in Palestinian Cellular Networks

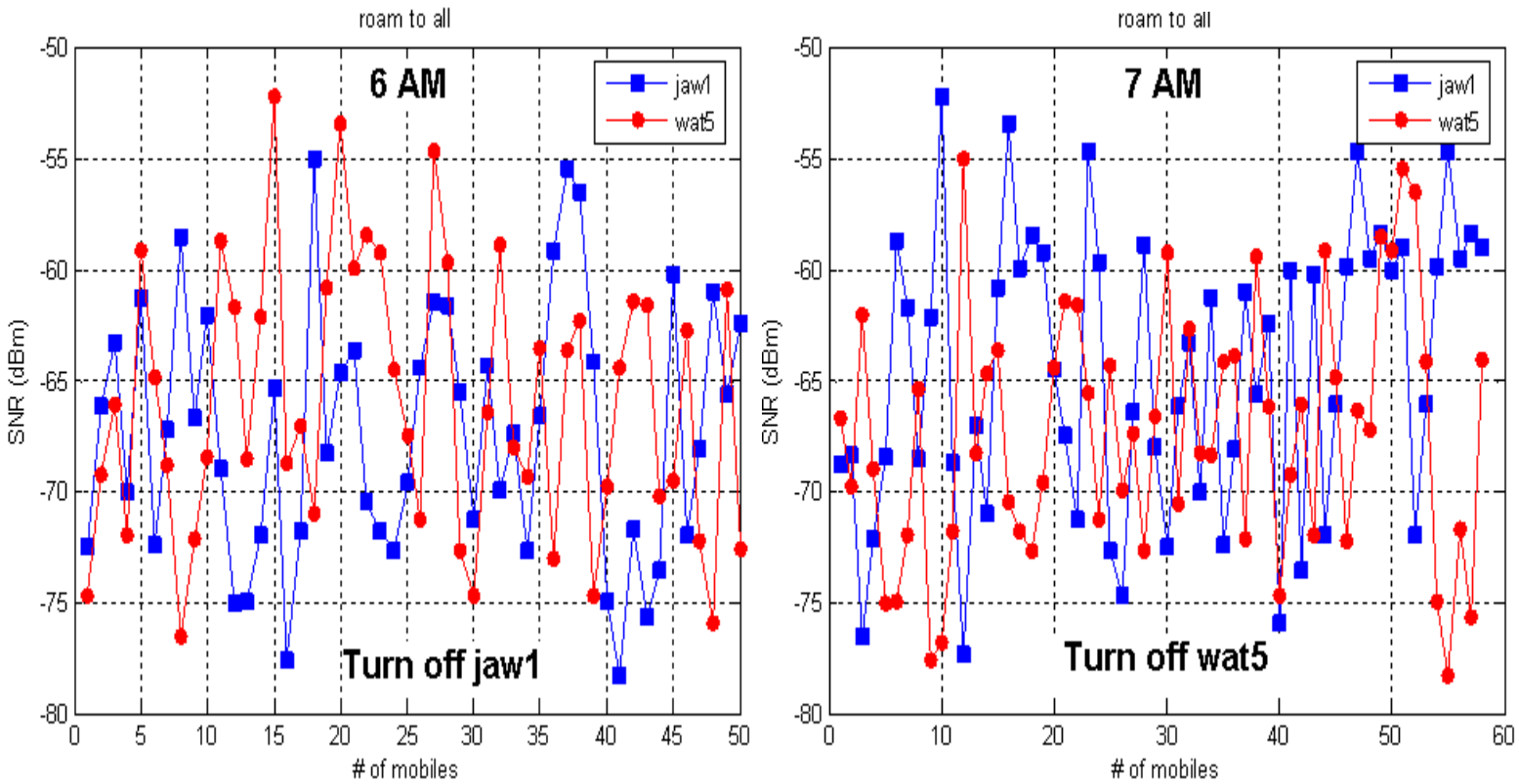


Figure (4.17): The received SNR at 6 AM and 7 AM "two networks"

- **Friday**

The rest of week days are as Wednesday expect Friday because on Friday the low traffic period which is greater than any day in the week.

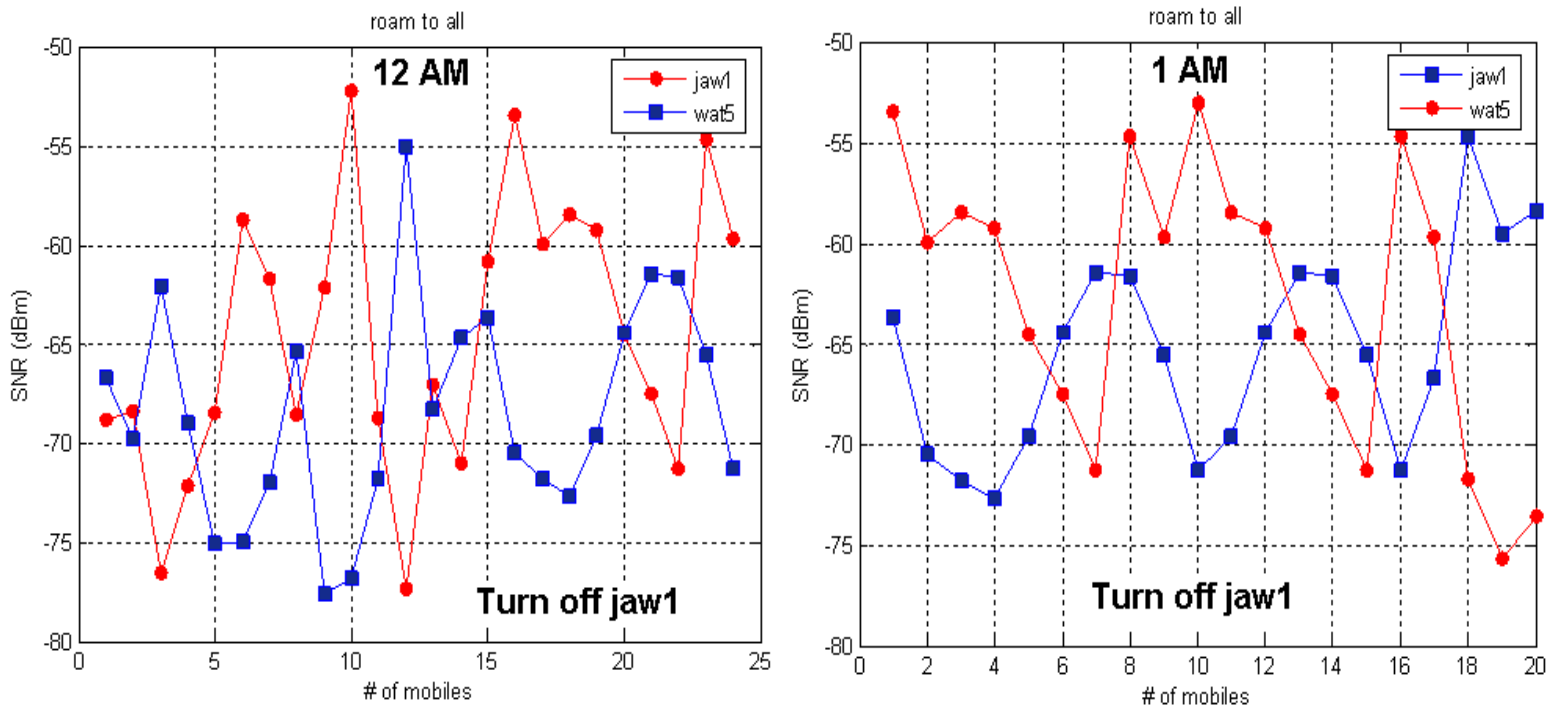


Figure (4.18): The received SNR at 12 AM and 1 AM "two networks"

Possibility of Applying Green Communication in Palestinian Cellular Networks

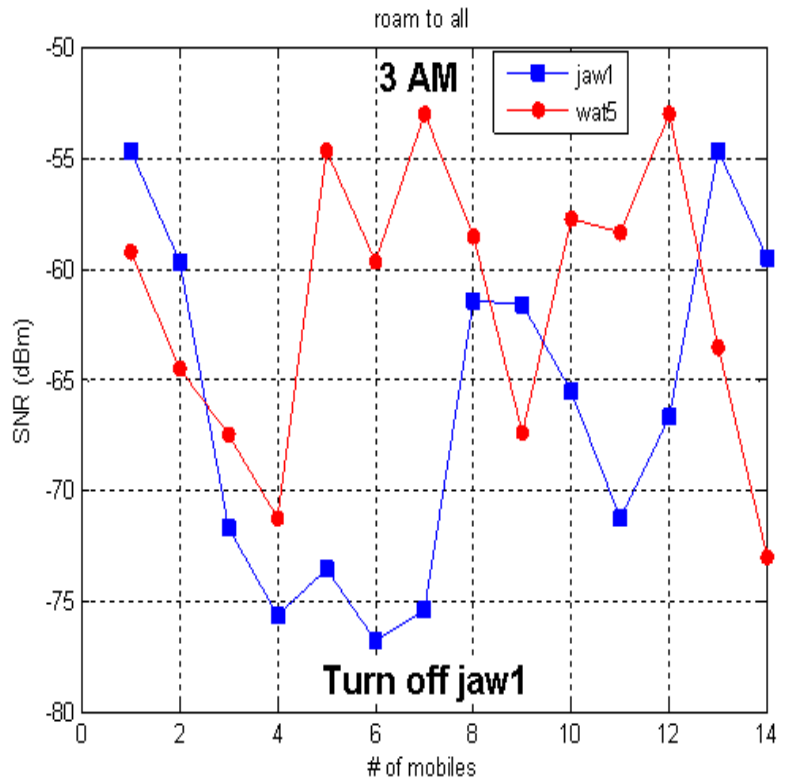
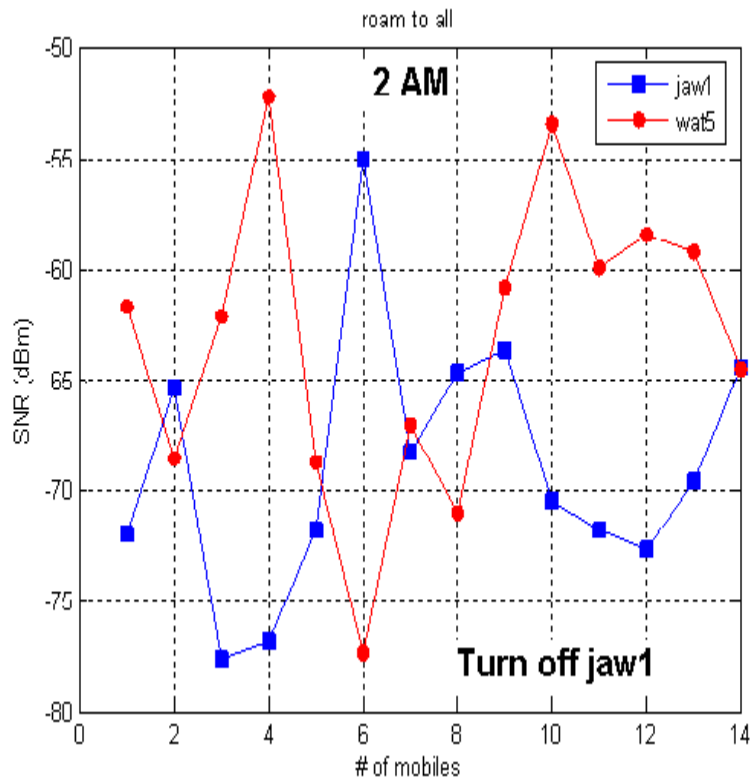


Figure (4.19): The received SNR at 2 AM and 3 AM "two networks"

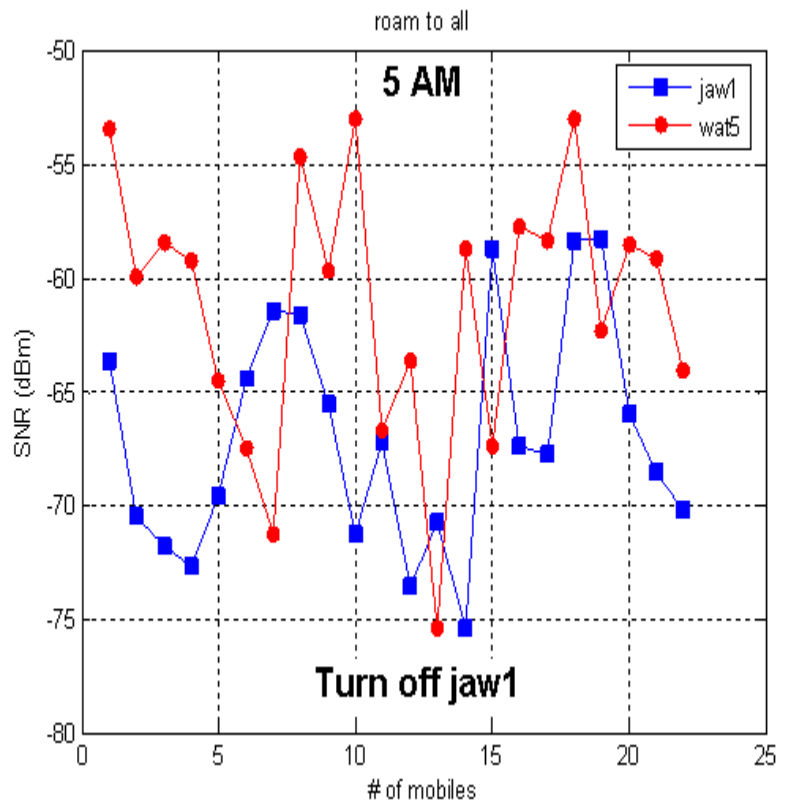
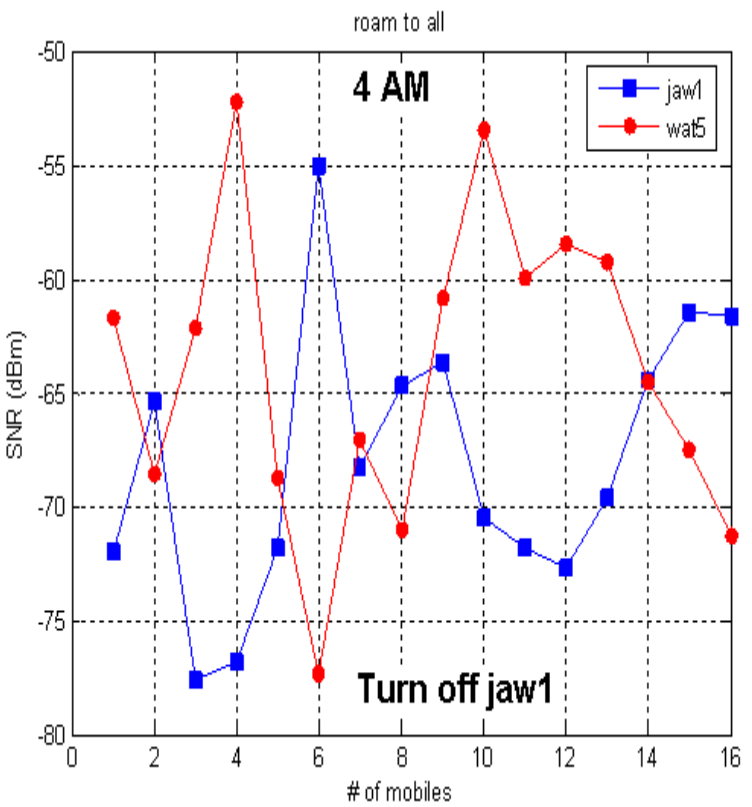


Figure (4.20): The received SNR at 4 AM and 5 AM "two networks"

Possibility of Applying Green Communication in Palestinian Cellular Networks

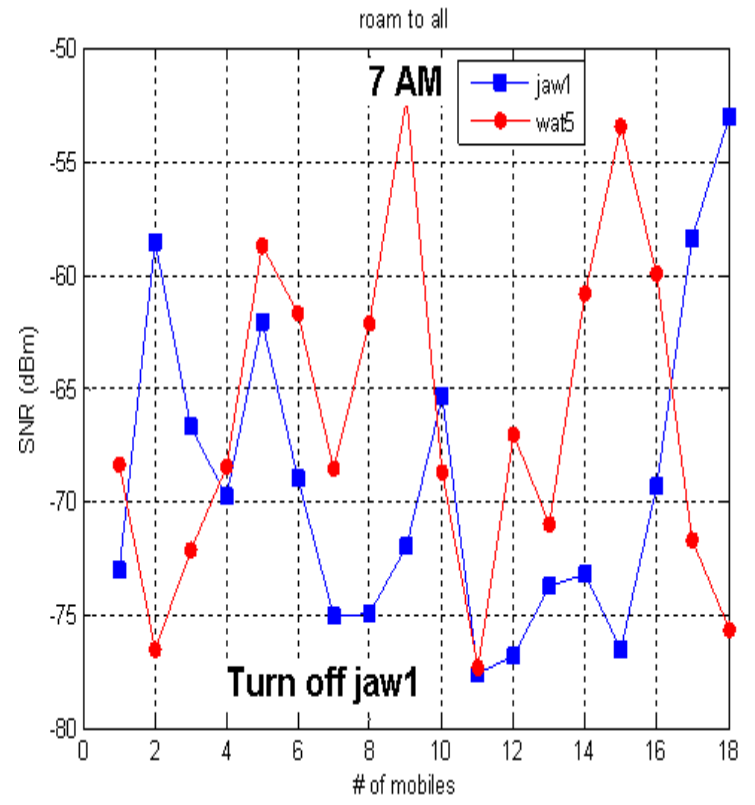
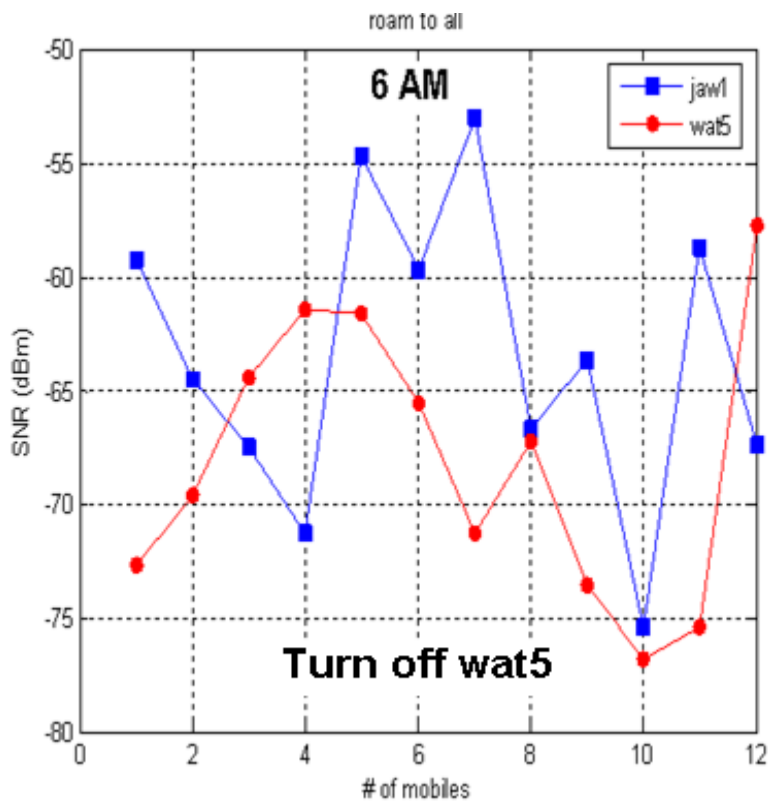


Figure (4.21): The received SNR at 6 AM and 7 AM "two networks"

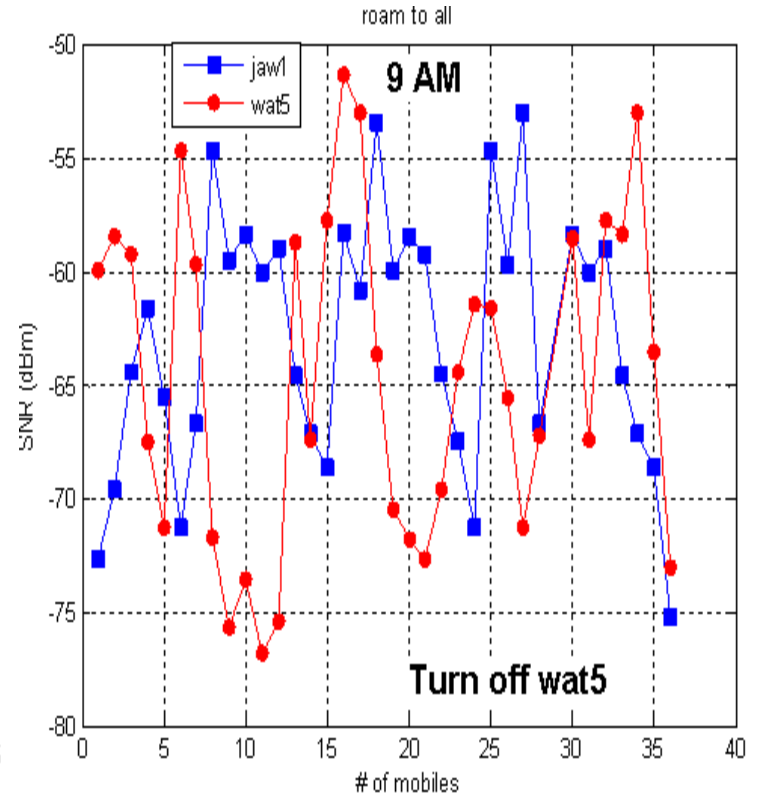
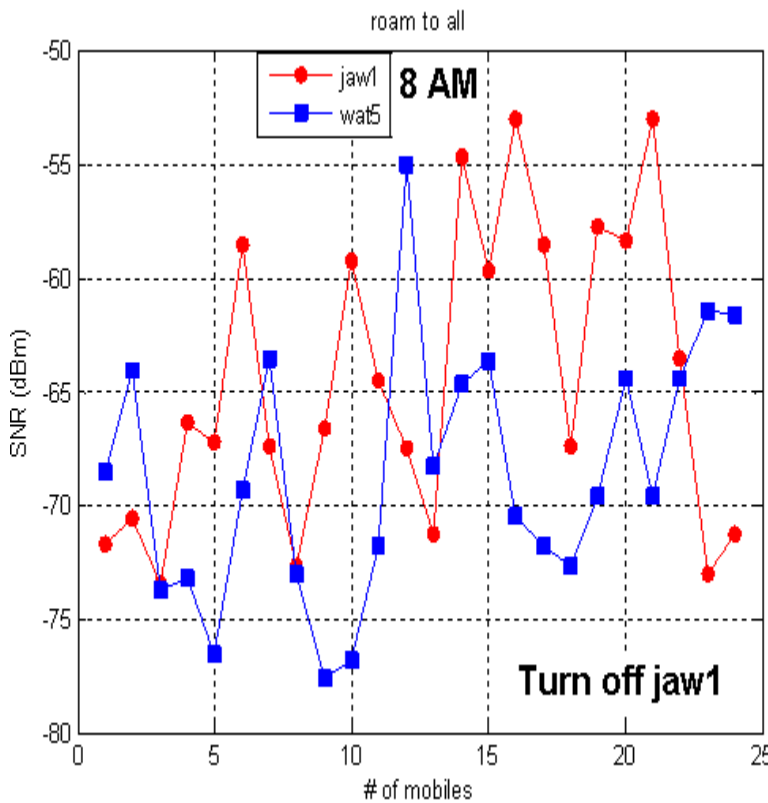


Figure (4.22): The received SNR at 8 AM and 9 AM "two networks"

4.3.2.2 Power saved calculation

Cells	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	Total(hour)
Wat5c2	1	1	0	0	0	0	1	0	1	0	4
Jaw1c1	0	0	1	1	1	1	0	1	0	1	6
Jaw6c0	0	0	1	0	1	0	0	1	0	0	3
Jaw4c0	0	1	1	0	1	0	1	0	1	0	5
Wat8c1	1	0	0	1	1	1	0	0	1	1	6
Wat5c1	1	1	0	1	0	1	1	0	1	1	7
Jaw6c1	1	0	0	1	0	1	0	1	0	1	5
Jaw4c2	0	1	1	0	0	0	1	1	0	0	4
Total turn off for all cells in Friday											40

Table (4.3): The number of the turned off hours in Friday for Roaming-to-all case

$$P_{res} \text{ (second step)} = (P_{con} * T * C_{off} * D) = 0.69 \text{ (KW/hour)} * 17 \text{ hour} * 1 \text{ day} = 11.73 \text{ KW (wataniya)}$$

$$P_{res} \text{ (first step)} = (P_{con} * T * C_{off} * D) = 0.69 * (2 \text{ BTS} * 3 \text{ cell}) * 10 * 1 = 41.4 \text{ KW}$$

$$\text{Total} = 41.4 \text{ KW} + 11.73 \text{ KW} = 53.13 \text{ KW (for Friday)}$$

Without applying the idea the total power consumption will be:

$$P_{con} = 0.69 * 24 * (5 \text{ BTS} * 3 \text{ cells}) * 1 = 248.4 \text{ KW (for Friday)}$$

So by applying the green communication idea we can save $53.13 / 248.4 = 21.38\%$ from the total power consumption in Wataniya network for Friday.

$$P_{res} \text{ (second step)} = (P_{con} * T * C_{off} * D) = 0.5 \text{ (KW/hour)} * 23 * 1 = 11.5 \text{ KW (Jawwal)}$$

$$P_{res} \text{ (first step)} = (P_{con} * T * C_{off} * D) = 0.5 * (2 \text{ BTS} * 3 \text{ cell}) * 10 * 1 = 30 \text{ KW}$$

$$\text{Total} = 30 \text{ KW} + 11.5 \text{ KW} = 41.5 \text{ KW (for Friday)}$$

Without applying the idea the total power consumption will be:

$$P_{con} = 0.5 * 24 * 18 \text{ cells} * 1 = 216 \text{ KW (for Friday)}$$

So by applying the green communication idea we can save $41.5 / 216 = 19.21\%$ from the total power consumption in Wataniya network for Friday.

From two:

$$P_{con} \text{ (total)} = 216 \text{ KW} + 248.4 \text{ KW} = 464.4 \text{ KW}$$

$$P_{res} \text{ (total)} = 53.13 \text{ KW} + 41.5 \text{ KW} = 94.63 \text{ KW}$$

$$\text{Ratio} = 94.63 / 464.4 = 20.37\% \text{ (for Friday)}$$

Possibility of Applying Green Communication in Palestinian Cellular Networks

Cells	12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	Total(hour)
Wat5c2	1	0	1	1	0	1	0	1	5
Jaw1c1	0	1	0	0	1	0	1	0	3
Jaw6c0	0	0	1	1	1	0	1	0	4
Jaw4c0	1	0	1	0	1	1	0	1	5
Wat8c1	0	1	1	0	1	1	1	1	6
Wat5c1	1	1	0	0	0	1	0	1	4
Jaw6c1	0	1	0	1	0	0	1	0	3
Jaw4c2	1	0	0	1	0	0	0	0	2
Total turn off for all cells in Wednesday									32

Table (4.4): The number of the turned off hours in Wednesday for Roaming-to-all case

$$P_{res} \text{ (second step)} = (P_{con} * T * C_{off} * D) = 0.69 * 15 \text{ hour} * 6 \text{ days} = 62.1 \text{ KW (Wataniya)}$$

$$P_{res} \text{ (first step)} = (P_{con} * T * C_{off} * D) = 0.69 * 6 \text{ cells} * 8 \text{ hour} * 6 \text{ days} = 198.72 \text{ KW}$$

$$\text{Total} = 62.1 \text{ KW} + 198.72 \text{ KW} = 260.82 \text{ KW (for Wednesday)}$$

Without applying the idea the total power consumption will be:

$$P_{con} = 0.69 * 24 \text{ hour} * 15 \text{ cells} * 6 \text{ days} = 1490.4 \text{ KW (for Wednesday)}$$

So by applying the green communication idea we can save $260.82 / 1490.4 = 17.5\%$ from the total power consumption in Wataniya network for Wednesday.

$$P_{res} \text{ (second step)} = (P_{con} * T * C_{off} * D) = 0.5 * 17 * 6 = 51 \text{ KW (jawwal)}$$

$$P_{res} \text{ (first step)} = (P_{con} * T * C_{off} * D) = 0.5 * 6 * 8 * 6 = 144 \text{ KW}$$

$$\text{Total} = 51 \text{ KW} + 144 \text{ KW} = 195 \text{ KW (for Wednesday)}$$

Without applying the idea the total power consumption will be:

$$P_{con} = 0.5 * 24 * 18 \text{ cells} * 6 = 1296 \text{ KW}$$

So by applying the green communication idea we can save $195 / 1296 = 15.04\%$ from the total power consumption in Wataniya network for Wednesday

From two:

$$P_{con} \text{ (total)} = 1296 \text{ KW} + 1490.4 \text{ KW} = 2786.4 \text{ KW}$$

$$P_{res} \text{ (total)} = 260.82 \text{ KW} + 195 \text{ KW} = 455.82 \text{ KW}$$

$$\text{Ratio} = 455.82 / 2786.4 = 16.35\%$$

$$\text{Total ratio} = (94.63 + 455.82) / (464.4 + 2786.4) = \underline{\underline{16.93\%}}$$

Chapter

5 Aggregated Results and Future Work

5.1 One Operator

5.2 Two Operators

5.2.1 Roaming-To-One

5.2.2 Roaming-To-All

5.3 Conclusions

5.4 Future Work

5.1 One Operator

After studying the behavior of the SNR in one operator network, we conclude that each mobile station can receive at least an acceptable signal from two neighbor cells. This makes the green communication idea applicable. Building on that, we decide to turn off one of the two cells by knowing which cell can serve all the mobiles with better signal quality. The following example clarifies the previous idea, figure (5.1) shows the SNR values for the active mobiles in wataniya operator. They serve from wat4cell0 or wat3cell1. We choose wat4cell0 to be ON, because it has only one mobile with moderate SNR below -80dBm after roaming all mobiles from wat3cell1 to it. On the contrary, if we choose wat3cell1, we have four mobiles with moderate SNR values.

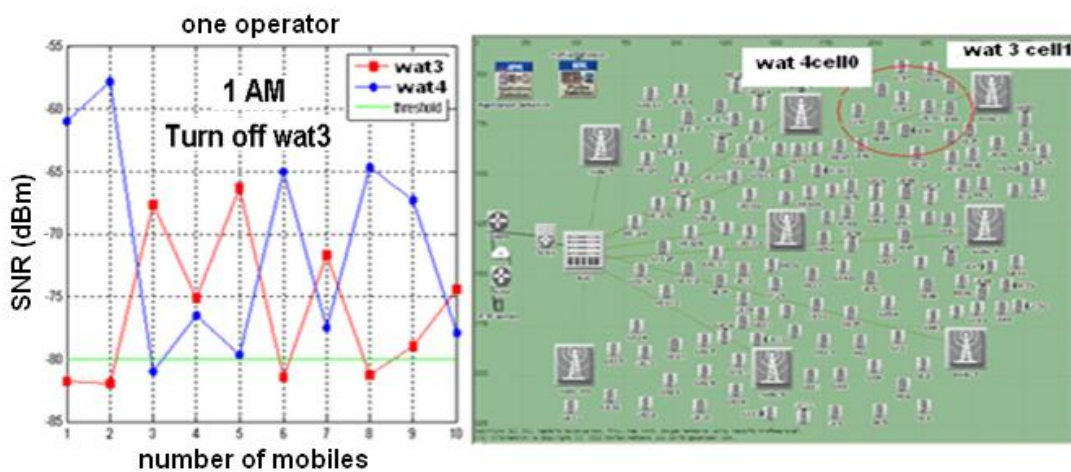


Figure (5.1) SNR values for the mobiles between nodeB3 and nodeB4

When we turn off some cells, we have almost reduction in the SNR level but it is not too much to make mobiles disconnect with the network while they are in the active mode. However, the quality of the call becomes little bit worse after applying the idea.

As in the previous example, it is possible to apply this mechanism in all cells in the network by monitoring the SNR values of the mobiles that exist between two cells and applying the green communication idea by turning off the cell that serves the mobiles with lower SNR and remain the other cell ON.

On the other hand, we have a total reduction of BTSs power approximately to 1846KW in the week and 88608 KW in the year. The reduction of BTSs power equals 17.8% of the total power consumption from the network if all BTSs are ON.

Possibility of Applying Green Communication in Palestinian Cellular Networks

Duration	Before applying(KW)	After applying(KW)	Percentage of saving
One week	1846	329.13	17.8%
One month	7384	1316.52	
One year	88608	15798.24	

Table (5.1): The power saving in the one network case

Figures (5.2) and (5.3) show the aggregated results with respect to the received SNR in the one network case in the low traffic period for Wednesday and Friday after applying the project idea. For each hour, there are some mobiles receive SNR below $\{-80 \text{ dBm}\}$ which is normal as a cost for the green communication idea. At each hour, we calculate the average SNR for those mobiles that receive power under the threshold as shown in the two next figures.

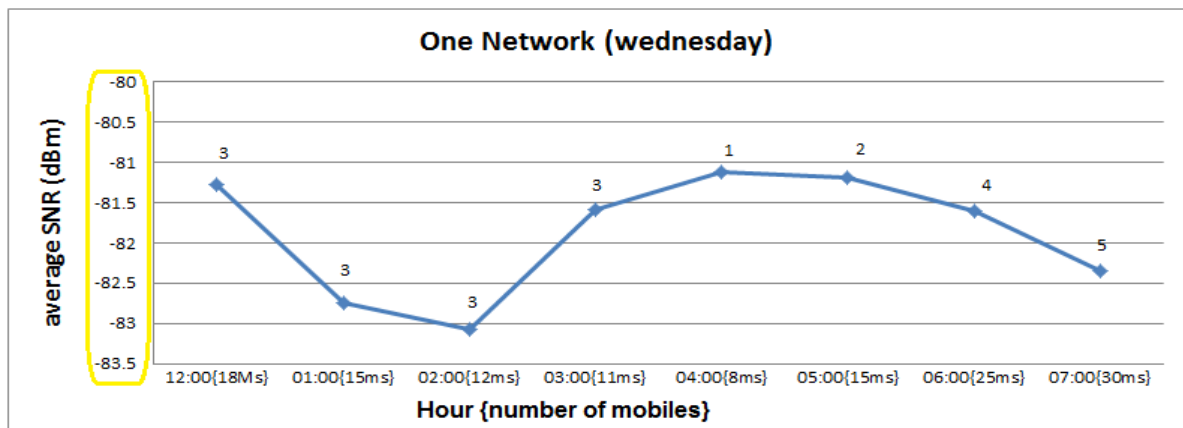


Figure (5.2): The number of user in the low traffic period with the average SNR under the threshold -80 dBm for Wednesday

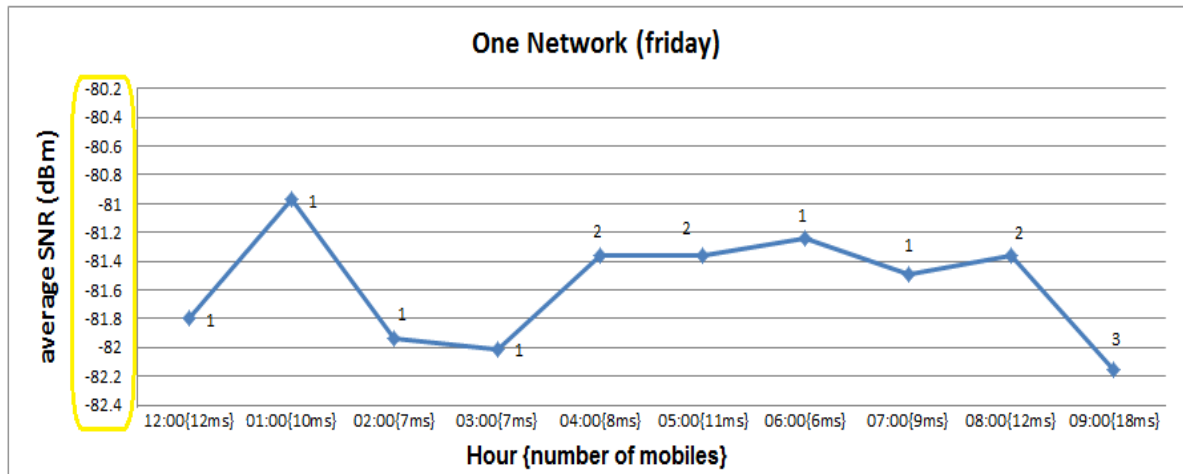


Figure (5.3): the number of user in the low traffic period with the average SNR under the threshold -80 dBm for Friday

It is notable from the last two figures that the number of mobiles that receive power under the threshold is very small compared with the other mobile that receive power above the threshold. So, the effect of the green communication idea is very little with respect to percentage of saving which is **17.8%** from the total power consumption.

5.2 Two Operators

5.2.1 Roaming-To-One

In the two operators {roaming to one}, the mechanism of applying the green communication idea is different completely. In this scenario, we turn off all BTSs (cells) of one network and keep the other one serve all users from both networks. This is possible because the two networks cover the same area.

The effects of applying the idea on the SNR take different cases. It could be increase, decrease, or approximately the same as in figure (5.4), but in all cases the SNR is still in good range.

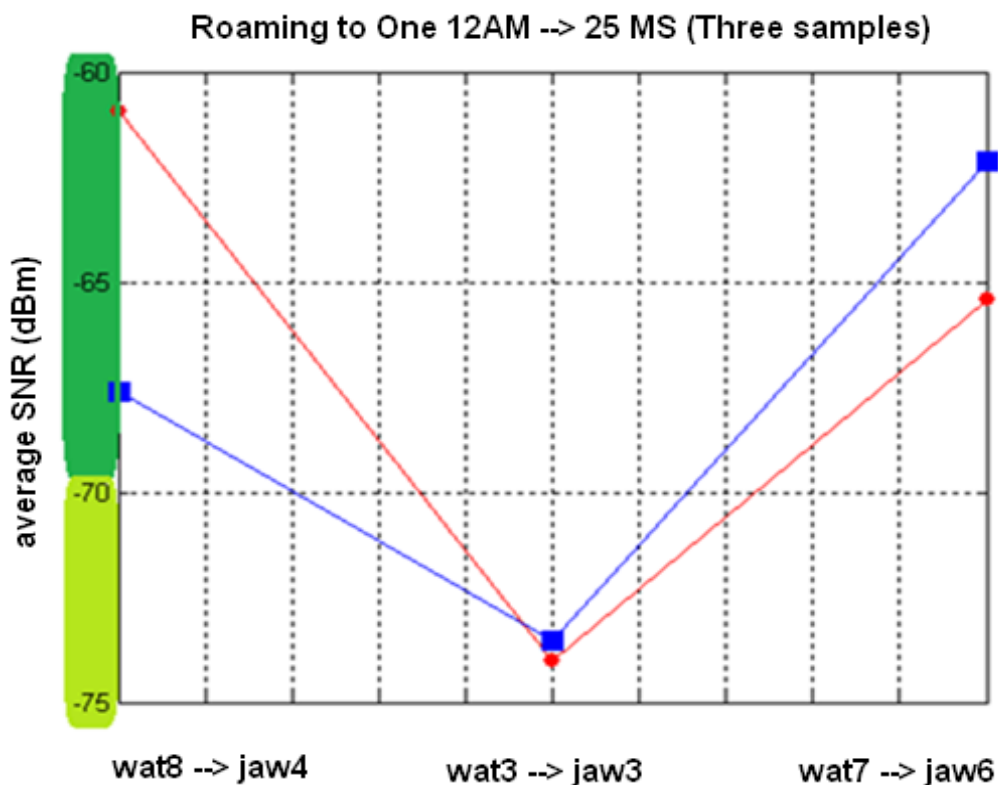


Figure (5.4): Received SNR for different mobiles in roaming to one case

On the other hand, we have a total reduction of BTSs power consumption approximately to 2318 KW in the week and 27821 KW in the year. If the turned off network is Jawwal, the reduction equals to **33.3%** from the total power consumption from the network. If the turned off network is Wataniya network, we can save 927.36 KW in one week and 13140 KW in one year as in the table (5.2).

	Duration	Before applying(KW)	After applying(KW)	Percentage of saving
Wataniya (on)	One week	1739	579.6	33.3%
	One month	6956	2318	
	One year	83472	27821	
Wataniya (on)	One week	2782	927.36	33.3%
	One month	6480	1080	
	One year	78840	13140	

Table (5.2): The power saving in Roaming-To-One case

5.2.2 Roaming-To-All

In this case, we turned off some cells from the two networks depending on the received power. The next two figures show the aggregated results for the two network case "Roaming to all" where the Y-axis expresses the average received power for the mobiles that receive power below the threshold in each hour, and the number besides the hour express the total number of users in each hour. We can note two things from the figures. The first one is that the percentage of those users that receive power below the threshold with respect to the total number of users is few. The second one is that the average received power at each hour exists in good range which is an advantage for the project in this case.

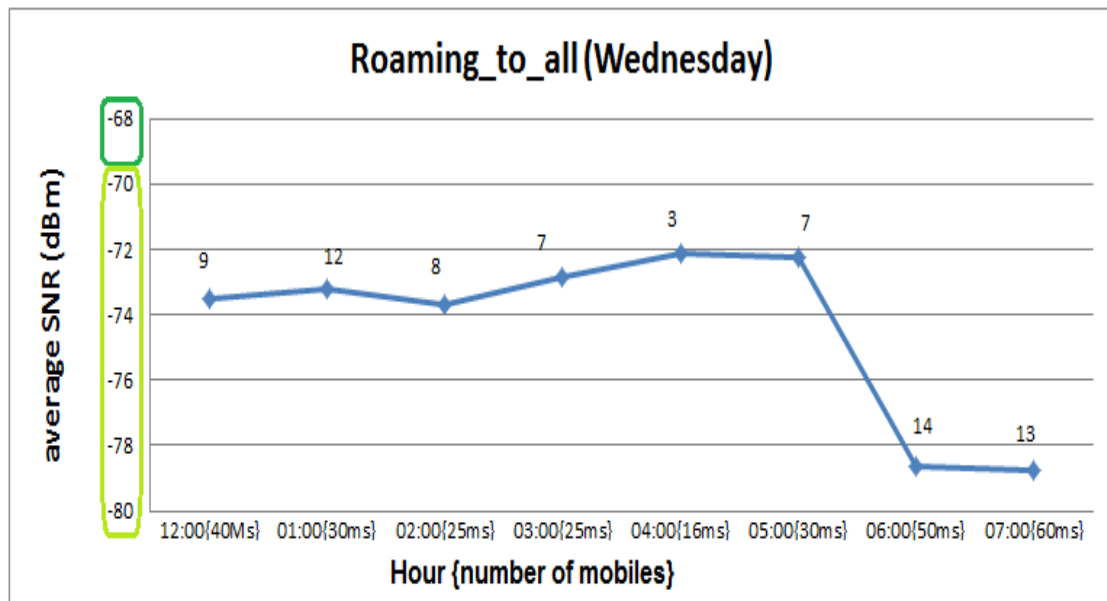


Figure (5.5): the aggregated results for the "Roaming to All" case in Wednesday

Possibility of Applying Green Communication in Palestinian Cellular Networks

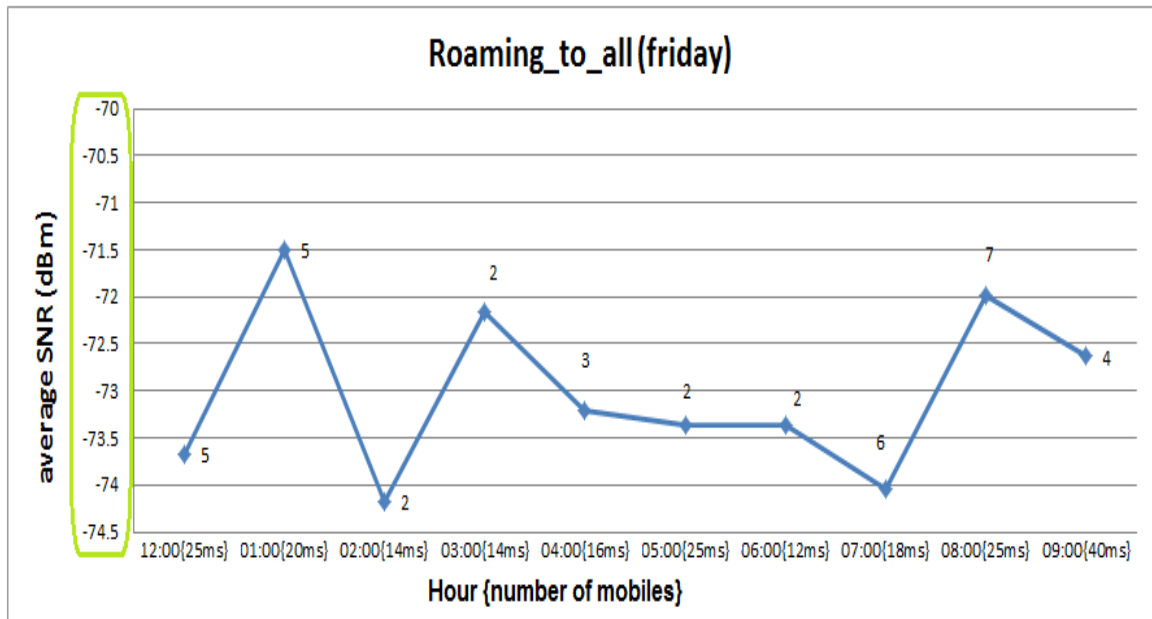


Figure (5.6): The aggregated results for the "Roaming to All" case in Friday

On the other hand, we have a total reduction of BTSs power approximately to 550.45KW in the week and 26421.6 KW in the year. The reduction of BTSs power equals to **16.93%** of the total power consumption from the two networks if all BTSs are ON.

Duration	Before applying(KW)	After applying(KW)	Percentage of saving
One week	3250.8	550.45	16.93%
One month	13003.2	2201.8	
One year	156038.4	26421.6	

Table (5.3): The power saving in the roaming to all case

Table (5.4) shows the complexity for each case in the simulation. The most complex case is the two networks case "Roaming to all" because it contains two steps. The better case in the project is the two network "Roaming to One" with respect to the receive SNR.

	SNR	Power saved	Complexity
One network	Acceptable	17.8 %	moderate
Two network(roam to one)	Good	33.3 %	low
Two network(roam to all)	Good+	16.93%	high

Table (5.4): The project cases complexity

5.3 Conclusions:

1. The green communication idea is possible in one network depending on the nature of the network in the specific area.
2. The green communication idea is possible in two networks or more with specific conditions :
 - ✓ The networks that cooperate in applying the idea must cover the same area with good coverage.
 - ✓ The network or networks that remain ON during applying the idea must be able to carry all the traffic form all operators.
 - ✓ The networks that cooperate in applying the idea must be stable; both networks must serve the whole area with acceptable quality.
3. There is a tradeoff between the SNR value and the reduction of power.
4. Applying green communication idea can be done in different mechanisms depending on the number of networks.
5. In one operator scenario, the SNR reduce obviously, but in two operator scenario the changing in the SNR values has different cases and is still in the good range.
6. The reduction of power in the two operator's scenario (Roaming-To-One) is more than the reduction of power in the two operator's scenario (Roaming-To-All) and one operator scenario.
7. Applying the green communication idea in the two networks (Roaming-To-One) is the most efficient scenario (good reduction of power with good SNR). Also, it becomes more efficient if we apply it in more than two networks.
8. Applying the green communication idea in one network is more sophisticated than the two networks or more. (Sophisticated protocols and algorithms).

5.4 Future Work

- Conducting the study for a larger network.
- Development of protocols and policies for realizing the Green Communications Idea.
- Study the effect of interference in the turning off criteria.
- Study the possibility of turning off some of TRXs (Part of the cell) in the cell.

References:

- [1] M. Ajmone Marsan, M. Meo, "Energy Efficient Management of two Cellular Access Networks," GreenMetrics2009, Seattle, WA, USA, June 2009.
- [2] M. Ajmone Marsan, L. Chiaraviglio, D. Ciullo, M. Meo, "Optimal Energy Savings in Cellular Access Networks," GreenComm'09 -First International Workshop on Green Communications, Dresden, Germany, June 2009.
- [3] M. AjmoneMarsan, L. Chiaraviglio, D. Ciullo, M. Meo, "Energy-Aware UMTS Access Networks," W-GREEN 2008 -First International Workshop on Green Wireless, Lapland, Finland, Sept. 2008.
- [4] M. Gupta, S. Singh, "Greening the Internet", In proceedings of ACM SIGCOMM'03.
- [5] A.P. Jardosh, K. Papagiannaki, E.M. Belding, K.C. Almeroth, G. Iannaccone, B. Vinnakota, "Green WLANs: On-demand WLAN Infrastructures", Journal of Mobile Networks and Applications, December 2008.
- [6] M.A. Marsan, L. Chiaraviglio, D. Ciullo, M. Meo, "A Simple Analytical Model for the Energy-Efficient Activation of Access Points in Dense WLANs", 1st International Conference on Energy-efficient Computing and Networking, e-Energy 2010, April 2010.
- [7] Green Communications - Wireless@Virginia Tech
- [8]Trend of green wireless access, Sunil vadgama, April 17, 2009
- [9]Overview of GSM: The Global System for Mobile Communications, John Scourias, March 1996.
- [10] <http://en.wikipedia.org/wiki/GSM>
- [11] http://en.wikipedia.org/wiki/GSM_frequency_bands
- [12] http://www.tutorialspoint.com/gsm/gsm_base_station_subsystem.htm
- [13]http://www.gsmworld.com/ourwork/mobile_planet/green_power_for_mobile/decision_tree/options_upgrade.htm
- [14] <http://www.cs.ucla.edu/ST/research.html>
- [15]http://people.seas.harvard.edu/~jones/cscie129/nu_lectures/lecture7/cellular/handoff/handoff.html
- [16] <http://www.tti.unipa.it/~ilenia/course/erlb.doc>

Possibility of Applying Green Communication in Palestinian Cellular Networks

[17] V. Cauwenberge, “study of soft handover in UMTS”, Master’s thesis, technical university of Denmark, 2003.

[18] R. A. Cheema, M.J. Irshad, “Issues and Optimization of UMTS Handover”, Marter’s thesis, Blekinge Institute of Technology, February 2008

[19] Mubeen, T. Tasadduq, I. A. Zubairi, J. Ahmed “Hand Off Issues in 3G UMTS Networks” International Bhurban Conference on Applied Sciences & Technology Islamabad pp. 44 – 48 Jan. 2007

[20] <http://www.opnet.com>