UMTS RADIO NETWORK PLANNING FOR BATU GAJAH AREA

By

SABRIN OMER MUKHTAR TAHIR

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Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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Dr. Mohd Zuki Yusoff

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Sabrin Omer Mukhtar Tahir

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ABSTRACT

This report is a primary step towards planning a high quality communication network providing users with sufficient coverage and capacity. The main goal of the project is to plan a network that can efficiently serve the maximum possible number of users simultaneously. It concerns mainly about third generation (3G) mobile communication systems and UMTS standard that uses UTRAN radio access network, it also concerns about the service level that users can experience. The project is implemented using a Matlab Implementation named as Network Planning Strategies for Wideband CDMA (NPSW), and the most significant results are a best possible coverage of 87.91% and a capacity of approximately 61% which is considered to be acceptable with a possibility of further improvements. The objectives of this work have been successfully achieved and this benefits the users by providing a satisfactory level of communication services.

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LIST OF ABBREVIATIONS

BS	Base Station
MS	Mobile Station
CPICH	Common Pilot Channel
DL	Downlink
UL	Uplink
FDMA	Frequency Division Multiple Access
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
WCDMA	Wideband Code Division Multiple Access
SHO	Soft Hand Over
NPSW	Network Planning Strategies for Wideband CDMA
Tx	Transmit(ter)

1. CHAPTER 1 INTRODUCTION

1.1 Background of Study

This background will discuss the history of wireless communication systems to make sure that the topic is understood well, the idea of a wireless communication-regardless the media used for this reason - relates back to the very early ages and kept growing and improving until today.

Starting from the 70’s, individuals attempted many ways to come up with technologies to ease the communication between people in different locations, those technologies started with the optical telegraph that was invented by Claude Chappe 1794 and was improved to voice transmission that continued to grow after discovering the telephone principle by Philip Reis on 1861, this has been developed over the decades and we eventually found ourselves today dealing with internet based wireless telecommunication systems with strong indications of even more development in the soon future [1].

The first generation 1G of mobile telecommunication systems has been deployed in the eighty’s and was using an analog technologies that was transmitting only voice to other destinations, In Finland 1991 the second generation 2G mobile systems came to declare the beginning of using the digital signals and enabled the users to get the benefits of using the text massages and multimedia massages services in addition to the voice transmission services, this generation can be either TDMA Time Division Multiple Access, FDMA Frequency Division Multiple Access or CDMA that is the Code Division Multiple Access. Number of operators all over the world depended on the GSM Global System for Mobile Communication standard that was using the TDMA technique transmission air interface.

Soon after that, and as an evolution of the second generation, the third generation was a reality, it aimed to support many more applications like the advanced multimedia services, and offer a better data transfer rate than 2G technology, it also focused on increasing the bandwidth and efficiency. The main focus in this report is going to be basically on the 3G technology using Universal Mobile Telecommunication System UMTS Wideband CDMA which has 1.92Mbps downlink speed [2].

1.2 Problem Statement

The world has experienced a wide spread of Wideband CDMA technology lately, and the number of users is increasing every day trying to get the maximum benefit of the services offered by this technology. This increment in the number of users and which means more capacity caused many phone calls to be dropped because of the noise floor in network.

Data services and voice capacity has become a serious issue in terms of planning as it should be considering the future evolution of the network as well as coinciding with the future standards and demands if required, keeping in mind that the maximum number of simultaneous users is to be allowed in a network.

1.3 Objectives and Scope of Study

UMTS service quality defines the service level that users can experience, and the successfulness of this project provides a very good knowledge on a UMTS network high quality planning. The objectives of this project can be summarized as follow:

- To investigate the relationship between coverage and capacity.
- To study the relationship between networks planning process and cell load.
- To inspect the relationship of the antenna parameters with the site configurations.
- To investigate the relationship between the user mobility and data rate.

1.4 Feasibility of the Project

The UMTS Radio Network Planning Project is considered to be feasible due to the availability of the required tools, and the possibility of implementing the project within the time frame specified by the university. The project basically depends on the knowledge gained in mobile telecommunication networks before getting started with the project implementation and the main tool required is a Matlab simulator for WCDMA network planning.

2. CHAPTER 2 LITERATURE REVIEW

2.1 Generations of Mobile Network

1980 was the start of the cellular mobile networks generations where it met the invention of the first generation that used the analogue systems in order to transmit the voice, but wasn't able to transmit other data such as massages, this generation was using the Frequency Division Multiple Access technique where the calls are being transmitted between radio towers after being modulated to 150 MHz approximately [2]. The first generation systems had some advantages such as having the capability of maintaining a connection no matter how long the phone call takes, it also had many disadvantages that is related to the connection quality, security and others.

The second generation of mobile networking was an evolution for the first generation where it was based on the digital signals instead of the analogue ones, In addition to the services it is providing for voice transmitting, text massages and others; this generation was an attempt to overcome the capacity and security issues, and succeeded to increase the capacity as well as to ensure security for both transmitter and receiver, this technology uses either CDMA which assigns a specific code for each user or TDMA that divides the signal in terms of time slots[2]. For this generation many operators were using the Global System for Mobile Communication GSM standard that uses TDMA technique.

After the first two generations and as a success of the 2G; a new technology generation appeared as an internet based technology that enables the user to avail themselves of many wireless based services anytime and anyplace. To introduce this technology with a Universal Mobile Telecommunication Systems UMTS, WCDMA air interface was used and Universal Terrestrial radio Access Network UTRAN - which is a totally new radio subsystem - had to be installed, the evolution of 2G technology to the 3G was to greaten the spectral efficiency – the information transfer rate through a communication media - of transmitting packet switched data with high speeds and also to support many multimedia applications [2].

The components related to the third generation systems and that should be known are the base station BS, WCDMA Mobile Switching Center WMCS, and also the Radio Network Controller that is being referred to as RNC. 3G WCDMA has up to 5.8 Mbps uplink speed that refers to the speed from the Mobile Station to the Base Station and 14.4 Mbps downlink speed that is from the Base Station BS to the Mobile Station MS which is considered to be an important feature of the 3G technology and named as High Speed Packet Access HSPA [4].

Table (1) below shows the comparison between the mobile network generations up to the third generation in many terms

Table1 Comparison between Mobile Network Generations

Generation	Year	Definition	Features	Speed
1G	1980	Analogue	Transmitting Voice	14.4 Kbps
2G	1990	Digital, circuit data packet data	Voice, SMS, MMS, Web Browsing	56Kbps to 115Kbps
3G	1999	Digital broadband packet data	Universal Access Portability, Video/ Conference Call	5.8Mbps to 14.4Mbps

2.2 Multiple Access Techniques

The multiple access techniques has been introduced in order to help avoiding the interference between the multiple access at the same exact time by splitting the physical recourses provided - such as the frequency - into a several sound channels, those techniques are:

2.2.1 Time Division Multiple Access TDMA

The technique is about splitting the frequency bandwidth into time slots where a user can have the entire bandwidth but only for his specific time slot, which means that it needs an extremely precise synchronization between the sender and the receiver where the users share the same bandwidth. The TDMA has quite small guard time between channels, greater bandwidth and higher data rate compared to the FDMA due to the various number of time slots used [5]. Figure 1 below shows concept of the TDMA technique

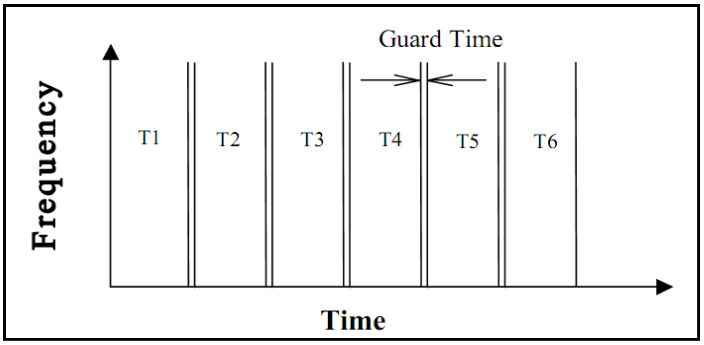

Figure 1 Time Division Multiple Access Technique

A mathematical expression that expresses the buffering, coding and modulation of a signal using TDMA technique can be:

$$S_{TDMA}^{(j)}(t) = \sum_m \sum_{K=1}^{N_{bps}} a_{k+mN_{bps}}^{(j)} \, \delta \left(t - KT_c - c_m^{(j)} T_S - mT_F\right) \quad (1)$$

Where: $s^{(j)}(t)$ is the digital signal of the user *(j)*

$a_k^{(j)}$ Is the k-th binary antipodal symbol generated by user *(j)*

T_c Is the time interval between symbols after compression

$c_m^{(j)}$ Is the TDMA code assigned to user *(j)* for the m-th frame

Nbps is a group of original signal's symbol

T_s Is the single time slot duration T_f is the frame duration [6].

2.2.2 Frequency Division Multiple Access FDMA

Moving on to the FDMA that is an analogue based technique, a guard band exists in this technique in order to lower the overlapping between the neighboring channels where the frequency band is divided to equal bandwidth for each call as appears in Figure 2 below[5].

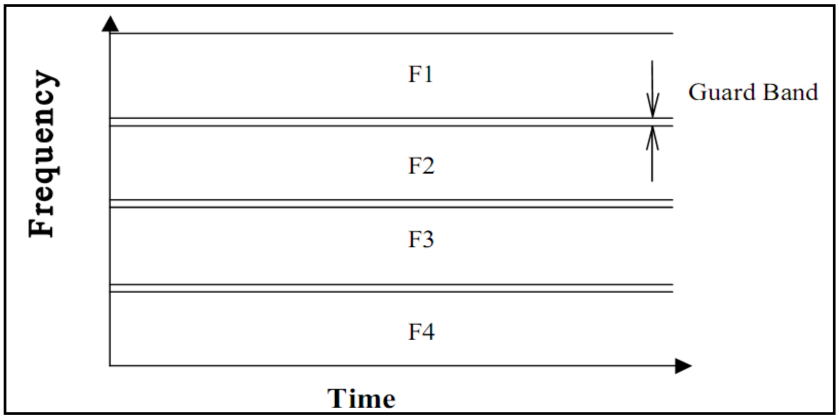

Figure 2   Frequency Division Multiple Access Technique

And can be expressed as:

$$S_{FMDA}^{(j)}\ (t) = \sqrt{2P_{TX}}\ s_{bb}^{(j)}(t)\ sin\ (\ 2\pi\ \left(f_P + c^{(j)}(t)\Delta f\ \right)t +\ \varphi^{(j)}) \tag{2}$$

Where: Δf is the frequency between neighboring channels (users)

$c^{(j)}$ Is the FDMA user's assigned code assigned

$S_{bb}^{(j)}$ Is the base band signal

2.2.3 Code Division Multiple Access CDMA

When it comes to the Code Division Multiple Access CDMA, the technique is taking different method of differentiating between users where it assigns a unique code for each user in a way that every user can get the benefit of using the whole time period and frequency bandwidth for the duration of the call, these codes basically turns the user's signal into a greater spectrum before transmitting it and the receiver will decode it and recover it back to get the actual signal using a similar code, in the case of transmitting signals by many users at the same time the receiver will decode the received signal that will have a power that is usually greater than the noise power, on the other hand; the other signals will be considered as noise[7]. Figure 3 shows the technique of the CDMA:

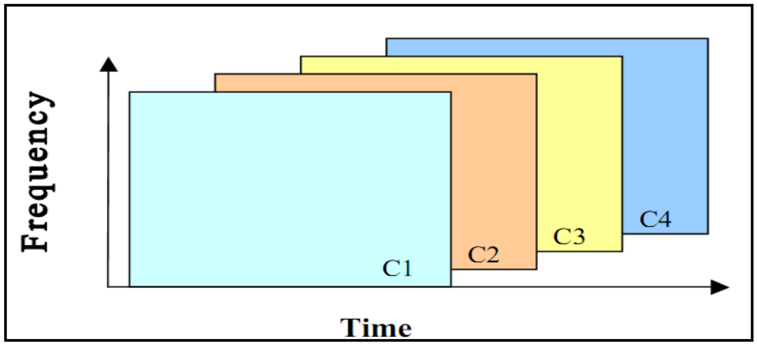

Figure 3 Code Division Multiple Access

The formula for the direct sequence CDMA coded signal is shown in formula number (3) considering the spreading signal mentioned earlier

$$S_{DSCDMA}^{(t)}\ (t) = \sum_k a_k^{(j)} \sum_{m=1}^{N_{ps}} c^{(j)}[m]\ \delta(t - mT_c - kT) \qquad (3)$$

N_{DS} Is the length of the codeword

T_c Referrers to the chip time

Wideband CDMA radio interface technique is an asynchronous network and uses a number of various long codes to split up the users, the nominal bandwidth for all the third generation propositions is a minimum of 5 MHz that is used by WCDMA, the reason of using this value of bandwidth is the achievability of the 3G systems' goals and objectives and also because it helps improving the performance by separating more multi routes than it is for the narrow bands [7]. This technique has been chosen to be used with the Universal Mobile Telecommunication System UMTS according to the CDMA concept of sharing both the time and frequency, and the interference levels should be the lowest it can be where these levels are responsible for determining the capacity and the coverage of the system in the UMTS.

2.3 Universal Mobile Telecommunication System UMTS

UMTS based 3G mobile systems are the most extensively deployed communication networks in the world [8]. The UMTS wireless radio standard is an improvement of the Global System for Mobile Communication GSM, where it presented greater bandwidth and capacity thus required new air interface named as WCDMA in order to provide 2 Mbps data rate. "The great advantage of UMTS is the more efficient use of resources, and the capability to incorporate a multitude of services [9].” Satisfying the requirements of different QoS along with conveying different types of traffic presents the major challenge for the UMTS network [10].

2.3.1 UMTS Architecture

In order to be more familiar with the UMTS standard, it is important to first understand the UMTS architecture that consists basically of the User Equipments UE, Universal Terrestrial Radio Access Network UTRAN and the Core Network CN, each component of the above stated will be explained separately for further clarification. Figure 4 below clearly shows the components of the UMTS network:

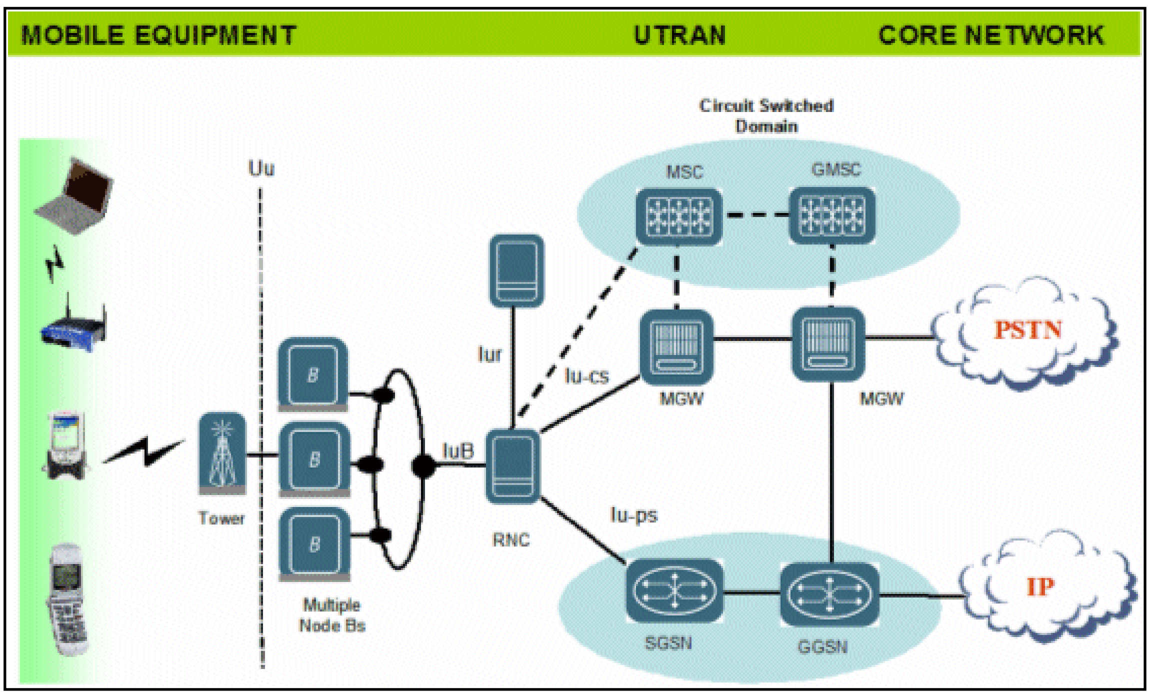

Figure 4 UMTS Architecture

Starting with the User Equipment, it can be defined as the equipment that is being used by the subscriber and that makes use of the UMTS network services provided; it is basically divided into the mobile equipment that does most of the radio operations, and the USIM that contains the information of a subscriber.

The coverage area is usually being divided into cells each has a Base stations (Node B) that acts like a radio interface provider for the mobile equipment, Base Stations take care of tasks such as the basic control tasks related to radio recourses, channel coding and modulation. One or more Node Bs - as shown in Figure 4 above - is connected through the Radio Network Controller to the Core network where the RNCs provide radio channels' management of the base stations connected to it [9], and also handles the high level tasks compared to the Node Bs that handles the low level tasks usually. The Base stations and RNCs and their radio functionalities specifically form the radio interface for the UMTS network which is referred to as the Universal Terrestrial Radio Access Network (UTRAN).

The third component in the architecture is the Core network including the a serving GPRS (General Packet Radio Service) support node (SGSN) and the mobile switching center (MSC) which are linked to the RNCs in the UTRAN radio interface. This type of network is considered as a base for all services related to communication such as the packet data routing and calls' switching [11]. The MSC is based on circuit switching and it focuses on the setup and routing of telephone calls and provides access to the public switched telephone network (PSTN), the SGSN on the other hand; is based on packet switching and provides data session management, mobility support and Gateway GPRS Support Node (GGSN) according to [12].

There are two air interfaces duplexing that are included in the UMTS network; those interfaces are named as the Universal Terrestrial Radio Access Frequency Division Duplex (UTRA FDD) and Universal Terrestrial Radio Access Time Division Duplex respectively (UTRA TDD). As to clarify the differences between the two air interfaces; the TDD separates the communication between the uplink and downlink in terms of time slots while the FDD uses different frequencies for the separation of the UL and DL communication [13], Table 2 shows the frequencies for the UL and DL in Europe considering the two air interfaces explained above:

‘

Table 2 Universal Frequency Allocation

	Uplink [MHz]	Downlink [MHz]	Total [MHz]
UMTS-FDD	1920-1980	2110-2170	2·60
UMTS-TDD	1900-1920	2010-2025	20+15

2.3.2 *Cellular Concepts*

Hexagonal shape is usually used in a network design when it comes to dividing the area of interest, as it helps to cover the whole area without leaving gaps which means providing a perfect overlapping in order to avoid weak coverage in areas that might not be covered if different shape is used(e.g. circle).

The overlapping criteria is somehow related to the handover from one cell to another so to avoid call drops for a moving user, Handover is one of the essential features of cellular mobile communication systems and has three schemes named as soft handover, softer handover and hard handover. Hard handover is where the Mobile station is connected to only one Base Station at a specific time and needs to break the connection when a transition to a new base station is needed, that happens when the user moves from a cell range to another. On the other hand; soft handover is about a Mobile Station being connected to more than one BS for a period of time to enable building a new connection with the new BS prior to breaking the first one[14]. The soft handover is becoming quite significance because it's more suitable to UMTS and Wideband CDMA based communication systems [15]. The third scheme which is the softer handover as stated in [16] "refers to links corresponding to the same base; in this case, diversity combining techniques are possible at the receiver, before message decoding."

2.3.3 *Parameters that Require Dimensioning*

Some parameters should be taken into consideration when talking about 3G network planning specifically with the UTRA FDD, these parameters can be explained in three categories as bellow:

- Signal Path Parameters

This category involves those parameters that affect the signal path between the User Equipment and the Base Station such as; the Node B sites' placement, the sectorization degree used, the number of transmitters and receivers used at one Node B and also the height of the antenna itself. The antenna bandwidth, direction and down tilt are also considered as signal path parameters as well as the usage of the amplifier of the tower top at the receiver. The adjustable parameters among those mentioned mainly concerns about the capacity and coverage problems

- Power Allocation:

An important property of UMTS is providing the required support of Quality of Service QoS for various levels according to what is required by the subscribers and their applications [14], but to satisfy the required QoS there should be a proper channel allocation of the power in terms of UTRA FDD.

An interference source for a mobile terminal in UMTS network can be caused by another mobile terminal accessing the network, which is a known characteristic of the WCDMA radio interface. Some difficulties may arise when dealing with radio interface regarding the recourses sharing between the mobile terminals' base stations, which means not being able to have a complete separation between system levels in the source end [17], those interference problems most probably leads to the call drops, poor signals and other coverage problems, but to control the cell coverage the pilot power can be increased or decreased as it affects the cell size, the pilot power management also enables cell load control and improves the capacity of the network with reducing the network interference.

- System Settings

The parameters under this category control the User equipment and the UTRA FDD network behavior, as examples of these parameters are the UL and DL power control, Handover Control, the control of radio link failure and the acquisition of network together with the access of the UE.

Propagation Models:

There are two propagation models that are widely used all over the world, each has its own conditions to be used typically depending on the cell range, those two model are named as Okumura Hata model and Walfisch-Ikegami model which are important to calculate the propagation losses.

Okumura-Hata Model

This model is widely used for a macro cells network areas for the coverage calculations [18], the formulas of Okumura-Hata are used when the frequency range is from 150 MHz to 1000 MHz. From the theoretical point of view; the mobile station height is from 1 to 20m and the base stattion's height is not less than 30m but not more than 200m, moreover that distance between the base station and the mobile station should not be less than 1 km (typically 1- 20 km). "Of the available propagation models the Okumura-Hata is the most frequently referred to. It therefore became reference to which other models are compared [19]."

The Okumura-Hata equation representing the cell range is as follow:

$$R = 10^{\alpha}, \text{ where } \alpha = [L_{path} - A + 13.82 \log H_b + a(H_m)]/[44.9 - 6.55 \log H_b]\ ) \qquad (4)$$

Where

L_{path} = Propagation path loss in dB

H_b and H_m = BS antenna height and Ms antenna height respectively in meters.

$a(H_m)$ = Mobile antenna gain in dB

R = Cell range

Walfisch-Ikegami Model

In this model it is assumed that the signal transmitted from the source is propagating above the rooftops with a multiple diffraction process [19]. The distance acceptable between the transmitter and receiver in this model can be less that 1 km, hence it is divided into two divisions that are the line-of-sight (LOS) when there are no obstacles in the transmitted signals path, and non-line-of-sight (NLOS) when there are obstacles or buildings that can cause signal diffraction, the difference between them mainly depends on the buildings' height. The formulas used to calculate the propagation path loss using Walfisch-Ikegami as for LOS and NLOS are shown in equations 5 and 6 respectively

$$L_{path} = 42.6 + 26 \log d + 20 \log f \quad (5)$$

$$L_{path} = 32.4 + 20 \log d + 20 \log f + L_{rst} + L_{msd} \quad (6)$$

Where:

L_{path} = Total path loss in dB

L_{rst} = Rooftop-to-street diffraction and scatter loss in dB

L_{msd} = Multi-screen diffraction loss in dB

f = Frequency

In this project the Okumura-Hata model will be used.

3. CHAPTER 3 METHODOLOGY

3.1 Procedure Identification

As the main objective of this project is to do planning for the wideband CDMA, network design can be kind of challenging task to be done [20], where the planning of the capacity should be able to satisfy the future demands considering providing adequate services according to the expected growth in users' demands[21].

There are three phases that WCDMA planning should go through which are; the initial planning phase named as dimensioning, detailed planning and optimization for the radio network. Only the first two phases will be covered in this project.

Talking about the dimensioning stage, site configuration and estimation for the required site density is to be done for the area of Batu Gajah, it also concerns about the activities of the initial RAN planning that includes capacity estimation, radio link budged and coverage analysis and also an estimation for the number of hardware and equipments to be used such as the base station hardware number estimation. The results later on will be related to the input parameters including the Quality of Service and traffic information.

The second stage that is the detailed planning that depends on topology planning and configuration planning, this aims to get some information about the geographical location of the site, the traffic volume in various areas and not forgetting to mention considering collecting the radio parameters' information like the gains and losses in the communication route where this process is referred to as Link Budget Calculations. This stage does not focus on the coverage area estimations but mostly concerns about capacity and interference analysis.

3.2 Project Design

In order to make sure of having a good operation of a communication network; careful planning should be implemented. For the purpose of this project's implementation and firstly to make a decision on the required number of sites, a planning design should be used where it has to suit the desired WCDMA interface regarding the capacity and coverage, If the users in the specified area required a greater amount of data than what can be provided by the network, then the number of sites should increase.

A decision should be made on how many sites among all are sufficient to provide us with good voice service and then investigate the service quality of the other sites, the allocation of data will be a circuit switched channel when the transmission delay is less that few seconds, and that is basically to guarantee the delay, therefore data traffic on packet data channel will be considered as non real time traffic. Later after that, some calculations are to be carried out to know the number of the accurate sectors' so to provide a percentage of coverage to a specified number of users in an area.

Some deliverables have to be prepared by the end of this project such as:

1. An estimation of the sites' number that are needed for providing the capacity and coverage for the specified area.
2. An estimation of the number of sites required to provide coverage and capacity as to satisfy the subscribers' demands.

3.3 Tools

The project work needs a portable work station with a simulator named as NPSW that is a Network Planning Tool for Wideband CDMA, this simulator dimensions and plans a network considering a flat area.

The flow chart in Figure 5 below shows clearly the expected methodology to be followed for the number of sites' estimation:

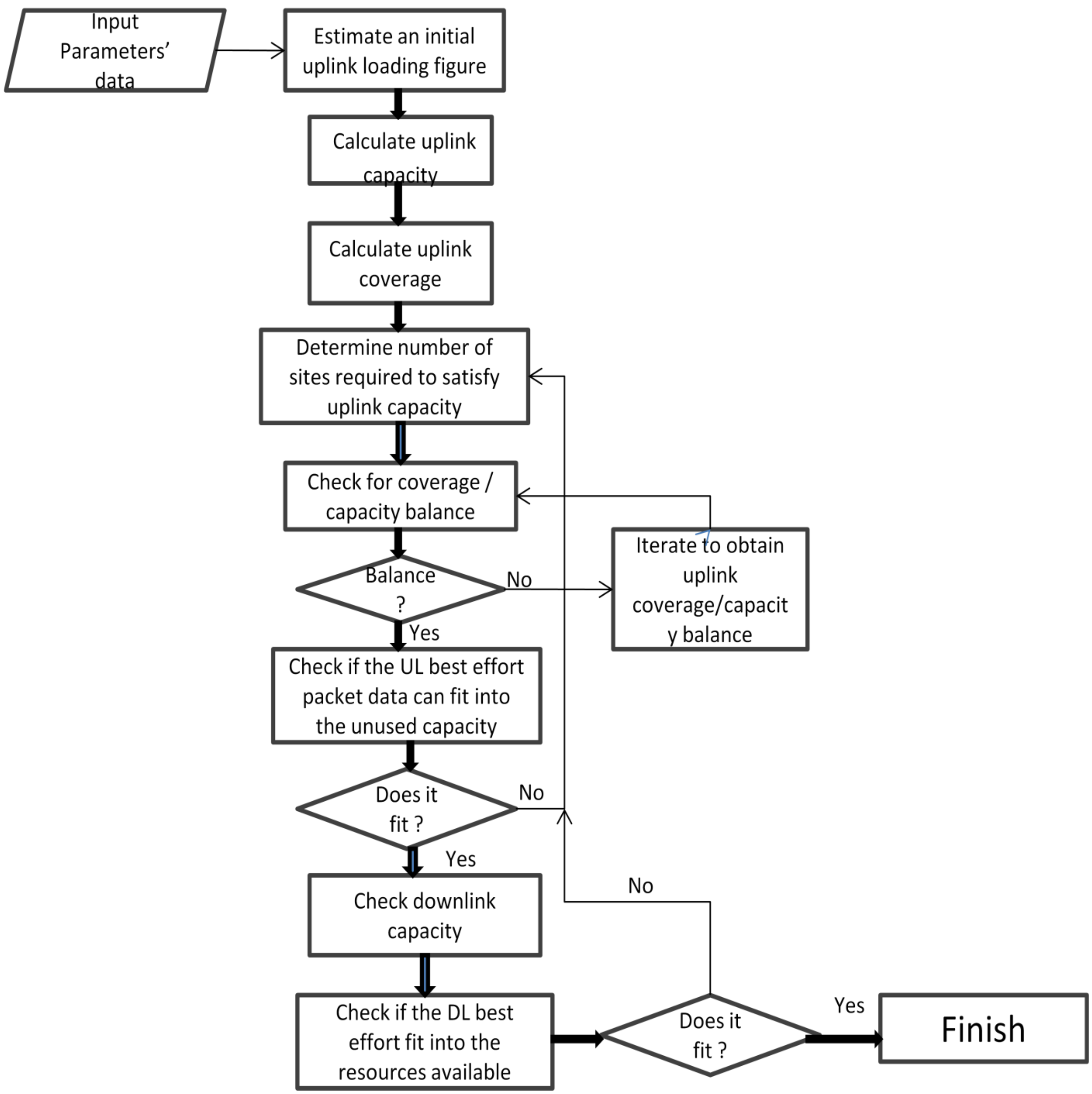

Figure 5 Project Calculations Flow Chart

3.3.1 NPSW Simulator

"NPSW is a Matlab implementation of static radio network planning tool for WCDMA [20]." It is a simulator that helps planning and dimensioning a flat terrain area using snap shots to symbolize an instance of time [22]. The latest versions of this simulator has provided more facilities as it included more accurate modeling for DL, and more parameters were specified from the network to the cell or Mobile Station [23]. The area of the project which is Batu Gajah area is shown in Figure 6:

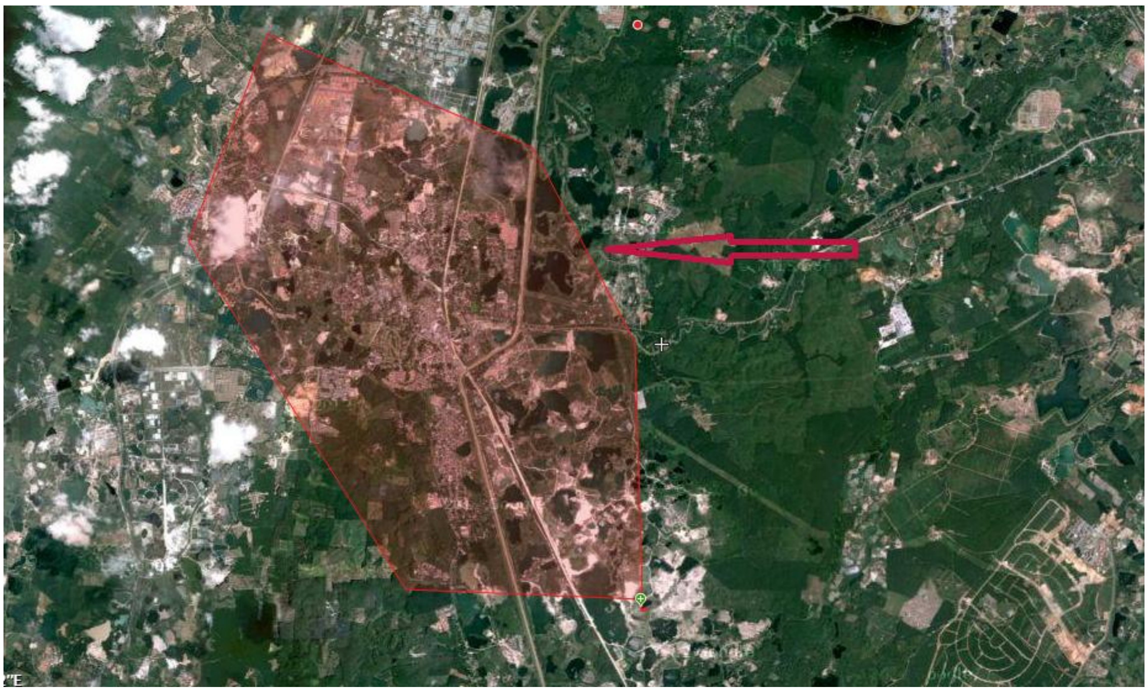

Figure 6 Project Area of Batu Gajah

This simulator allows the designer to distribute the base stations needed according to the path loss and link budget calculations, but this will defiantly be affected by the suitable locations of BSs on the real site, thus the simulator also provides the facility of editing the BS parameters and locations in order to get the best results in terms of coverage and capacity. Figure 7 below shows the screen where a new Base Stations can be created and Base Stations' parameters can be edited before running the simulator; the parameters are clearly shown in the Figure:

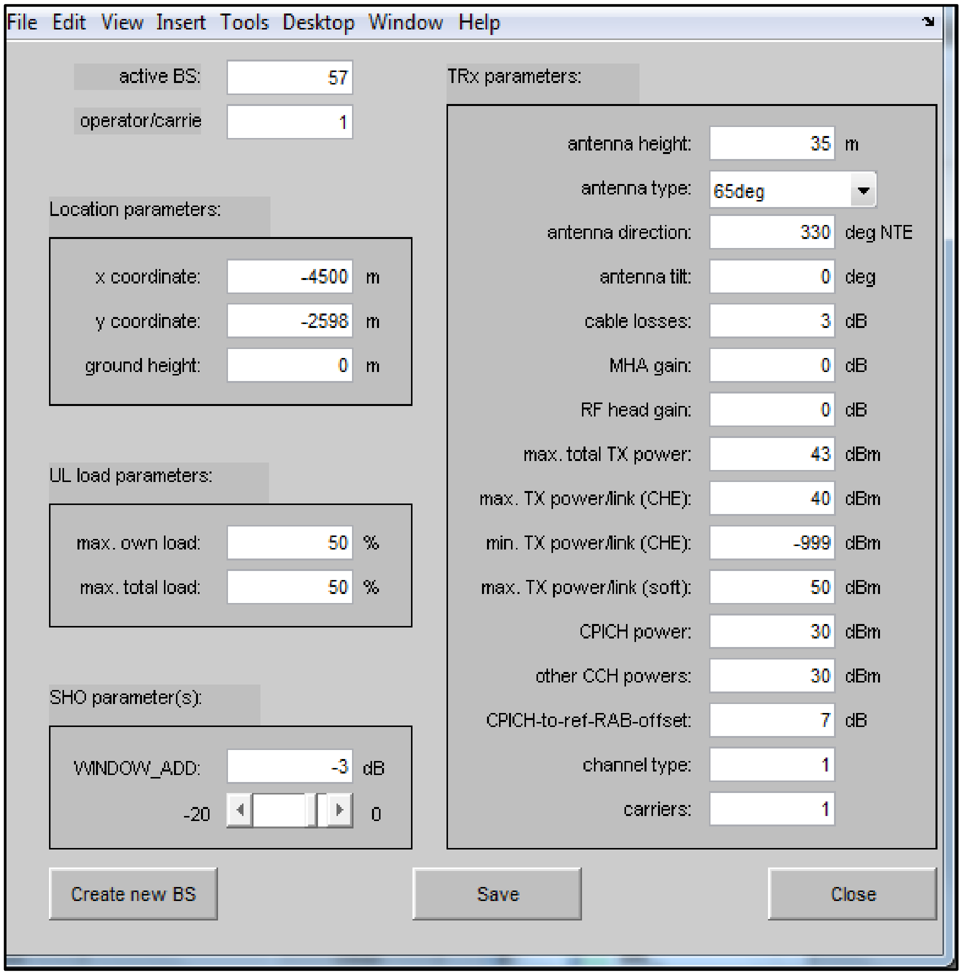

Figure 7 Base Stations Parameters' Screen

The NPSW is used to study and analyze the number of served users, un served users, power limitation, soft handover and the interference of other cells on a specified cell and many other parameters, it can also show the coverage and capacity in terms of data rate, this is going to be shown in the results of this report later on, but the studies will be mainly focusing on the antenna parameters such as antenna height, tilt degree and type as well as the maximum transmit power and speed.

3.4 Gantt Chart for Fyp I & Fyp II

Table 3 FYP I Gantt Chart

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of the project topic														
Preliminary research work														
Preliminary report submission														
Proposal Defense (Oral Presentation)														
Project Work Continues														
Submission of Interim draft report														
Submission of Interim Report														

Table 4 FYP II Gantt Chart

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
start simulation work															
Submission progress report															
Simulation work continues															
Pre - EDX															
Break												☆			
Submission of draft report															
Submission of dissertation (soft bound)															
Submission of Technical Paper															
Oral presentation															

4. CHAPTER 4 RESULTS AND DISCUSSION

4.1 Input Data

As the initial step for the UMTS network planning, the input data should be provided form the operator, some of the values used in the calculations of the Link Budget (LB) are based on assumptions in order to get the best results of the simulation. The number of three-sector sites should be calculated for the urban area of Batu Gajah that is 33 km2 with 20000 users, targeting to provide coverage of 95% for 2000 simultaneous users. The mentioned calculations will be based on the following traffic figure in Table 5:

Table 5 Traffic Table

Service	**Traffic Per Subscriber (Busy Hour) Uplink / Downlink**	**Voice Activity Factor**
Speech 12.2 kbps	45mE /45mE	30%
Packet 128 kbps	200 kbyte/h /700 kbyte/h	Best Effort

4.2 Related Calculations

This part will be discussing the coverage and capacity calculations in details for both UL and DL. The calculations involved are as bellow:

4.2.1 Uplink Dimensioning

The upper loading constrains for both UL and DL are considered to be 60% in this project, with a speech Grade of Service of 2% and a maximum UE output power PUE equals to 21 dBm. Okumura Hata model is used to calculate the cell range based on the Link Budget calculations, the value of the target bit energy to interference power ratio Eb/Io in [dB] usually depends on the environment and can be shown in Table 6 bellow for this specific case.

Table 6 Uplink Values of Eb/Io

RAB	**Pedestrian A**
Speech 12.2 kbps	4.2
Circuit 64 kbps	3.9
Packet 128 kbps	1.9

Uplink Capacity

In order to calculate the uplink pole capacity, Mpole which is the limit for the mobile station number that can be supported by a cell, the following equations are to be used:

$$M_{Pole} = 1 + \frac{1}{(1+F)\gamma} \quad (7)$$

Where the value of the C/I target of the RAB in linear units (γ), can be calculated from equation 8 as bellow:

$$\gamma = 10^{\frac{(E_b/I_0)-PG}{10}} = \frac{10^{(E_b/I_0)/10}}{R_{chip}/R_{\inf o}} \quad (8)$$

Where:

F = Ratio of the interference generated from other cells and interference generated in own cell = 0.93,

PG = Processing Gain that is the ration between the chip rate and the information bit rate,

Eb/Io = Ratio of target bit energy to interference power in [dB],

R_{chip} = Chip rate (3.84 Mcps),

$R_{\inf o}$ = Information bit rate for the RAB [bps].

By using the equations stated above with considering the different services, the UL values for Mpole can be summarized in Table 7:

Table 7 Uplink Values for Mpole

RAB	**Mpole**
Speech 12.2kbps	95
Circuit 64 kbps	14
Packet 128 kbps	11

- **Uplink speech capacity calculations**

Loading = Mspeach/95 = 0.4 = 40%

Mspeach = 38 Channels

From the Erlang Table (Refer to Appendix A): 38 channels → 29.2E

The number of subscribers per Sector/Site = 29.2E/45m = 649 subscriber per Sector/Site

The number of Sites required = 20000/649 = 31Sector/11sites

Uplink Coverage

Before going into details on the Uplink coverage calculations, the link path loss should be found according to the Uplink Radio Link Budget which is stated in Table 8:

Table 8 WCDMA Link Budget

Parameter	**Service**
Mobile Velocity (pedestrian)	3 km/h
Mobile Velocity (transportation)	50 km/h
Chip rate	3.84 M chip/s
Cable and Connector losses (Lf+j)	3 dB
Tx antenna gain	17 dBi
Rx antenna gain	0 dBi
Body loss (BL)	0 dB
Receiver Noise Figure (Nf)	4 dB
Thermal noise density (Nt)	-174 dBm/Hz
Required Eb/ Io	4.2 dB
RBS sensitivity (RBS sens)	-124.9 dB
Maximum UE output power (PUE)	21 dB
Limiting environment	Outdoor
Log normal fading margin (LNF marg)	9 dB
Noise rise (IUE)	2 dB
Car penetration loss (CPL)	6 dB
Indoor loss	0 dB
Power control headroom (PC marg)	3 dB
Antenna height	30m
UE antenna height	1.5m
Ground height	0m
Allowed propagation loss	139.9 dB

The maximum allowed path loss can is found from the equation 9

$$L_{pat\,hmax} = P_{UE} - RBS_{sens} - I_{UL} - LNF_{marg} - PC_{marg} - BL - CPL - BPL + G_{ant} - L_{f+j} \quad (9)$$

Where the Radio Base Station (RBS) sensitivity:

$$RBS_{sens} = N_t + N_f + 10\log(R_{user}) + E_b/I_0 \quad (10)$$

RBS_{sens} = -174+4+ 10log 12.2k+4.2= -124.9

$L_{pat\,hmax}$ = = 21+124.9 – 2-9-3-0-6-0+17-3 = 139.9 dB

In order to find the cell range(R) of each cell in the UMTS configuration, Okumura Hata model should be used for ranges greater than 1 km (Refer to Equation 4);

→139.9 – 155.1 + 13.82 log (30) = (44.9 – 6.55 log 30) log R

α = 5.2/33.72 = 0.154

R = 10^α = 1.42 km

So the coverage area of a 3 sector cell can be calculated as:

$3/8\sqrt{3}\,R^2 = 3/8\sqrt{3}\,(1.42^2) = 1.3\ km^2$

Which means the number of Sectors/Sites = 33/1.3 = 26 Sector/ 9 sites

From the results gotten its shown that the number of sites are capacity limited because more sites are required for the capacity.

-Iterations to balance the number of sites

To make the iteration process more convenient, the loading can be changed in steps of 10% which will increase the noise rise by 1 dB as attempts to find the best loading Figure

<u>First iteration (Capacity):</u>

loading = 50 % → (I dB worse)

0.5 = Mspeach/95

Mspeach = 48 Channels → 38.4E

So the number of subscribes = 38.4/45m = 853 subscriber per Sector/Site

The number of Sectors/Sites = 20000/853 = 24 Sector/ 8 Site

<u>(Coverage):</u>

The cell Range is found to be:

→138.9-155.1 + 14.82 log 30 = (44.9 -6.55 log 30) log R

α = 0.124

$R = 10^\alpha$ = 1.33 km

The coverage area for a cell = $3/8 \sqrt{3} \, (1.33^2) = 1.15 \ km^2$

So the number of Sectors/Sites = 33/1.15 = 29 Sectors/10 Sites

This appears to be enough number of sites. This means that the best loading is 50% that makes 10 sites with 1 dB worse.

-Check if the UL best effort packet data can fit into the unused capacity

When assuming 10 sites which is 30 sectors, then the number of subscribers = 20000/30 = 667 subscriber per Sector/Sites

To find the Erlang value: 667 x 45m = 30.015 E in total.

The number of channels = 95 x 0.5 = 48 channel

The Erlang valuefor Packet Switched data with (Gos = 1.5%) = 37.34E

So with 10 sites the load available = 0.5 – (37.34)/95 = 0.107

Mmax-P128 = 11 **(Refer to Table7)**

The total load in sectors = Mmax * Load available * Data rate * 3600/8

= 11x 0.107x 128 x (3600/8) = 67.795 Mbyt/h/sector

Then the actual demand should be calculated:

Actual demand = 667x 200 = 133.4 Mbyte/h/sector

The number of sites is not enough to cover so they will be increased by 3 for simplicity:

Number of sites = 10 + 3 = 13 Site / 39 Sector

The number of subscribers = 20000/39 = 513 subscribers/ sector.

The Erlang value = 513*45m = 23.085E in total.

The load available = 0.5 – (23.085/95) = 0.257

This load can support: 11*0.257*128* (3600/8) = 162.84 Mbyte/h/sector.

The actual demand: 513 * 200K = 102.6 Mbyte/h/sector.

Now the capacity is enough.

4.2.2 Downlink Dimensioning

From the Downlink Link Budget the Dl margin can be found form equation 9 bellow:

$$DL_{marg} = BL + CPL + BPL + \Delta G_{ant} + L_{f+j} + L_{slant} + L_{TMA} + \Delta N_f + \Delta A_0 \quad (11)$$

Where:

BL: Body loss = 3 dB.

CPL: Car penetration loss = 0 db

BPL: Building penetration loss = 18 dB

Δ Gant: Difference in antenna gain compared to the value used in the downlink curves shown in Figure 8:

→ Δ Gant = 17.5 – Gant[dBi] = - 0.5

L_{f+j}: Feeders and jumpers loss = 0 dB.

ΔN_f : Difference in UE noise Figure and the curve value = N_f –7 = 0 dB.

L_{slant} : slant loss = 1 dB

L_{TMA}: Insertion loss of the TMA = 0.4

ΔA0: Difference between the distance independent term, in Okumura Hata and the curve value,

- ΔA0 = A0 – A0curves,
- where A0 = A – 13.82 logH_b = 155.1 – 13.82 log 35 =133
- A0curves is 134.7
- So A0 = 133 – 134.7 = -1.7

Form above information, DL_{marg} = 20.2

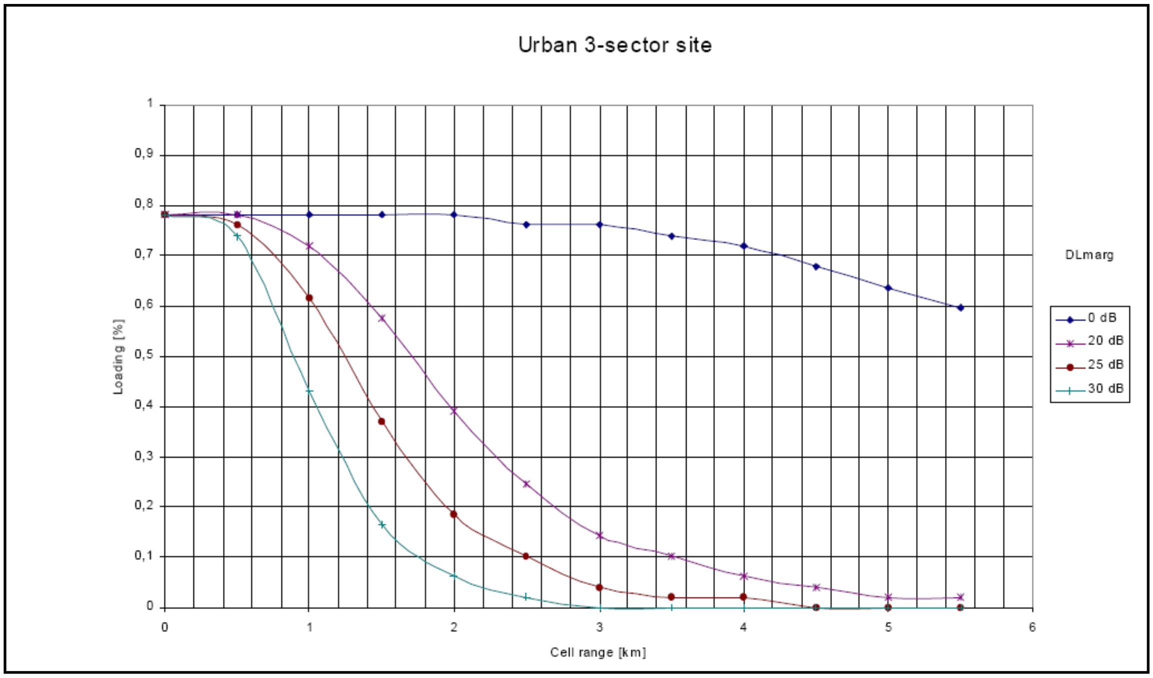

Figure 8 Downlink Curves

-**<u>Downlink Capacity:</u>**

Now the Downlink capacity is to be checked for a range of 1.14 km and DLmarg 20 dB, the load range considered form the curves is from 40% to 78%.

Table 9 Downlink Values of Mpole

RAB	**Mpole**
Speech 12.2kbps	110
Circuit 64 kbps	14
Packet 144 kbps	11

Let's take a loading figure of 60 % = 0.6 (it shouldn't be dimensioned for more than 60%)

The number of subscribers supported for a cell = 0.4 x 110 = 66 Channels

44 Channels → 55.33 E that is 1230 subscriber

Which is acceptable since only 853 subscriber are needed to account for.

The number of sectors in the DL capacity = 20000/1230 = 16 Sector / 6 Site.

Which means it is ok to use the UL results.

-Check if the DL best effort fit into the resources available

For PS 66 channels with GOS = 1.5% → 55.33 E

To calculate the load available: 0.6 – (55.35/110) = 0.097

Which means it can support : 0.097 x 11x 128 x (3600/8) = 61.459 Mbyte/h/sector.

According to the input data, the demand can be found as:

1230 x 700 = 861 Mbyte/h/sector.

This result is not acceptable and more capacity is needed to account for the DL which means the number of sites should be increased until satisfying the best effort resources availability.

So as a beginning the number of sites can be increased by 2:

sites + 2 = 18 sites = 54 sectors

The number of subscribers = 371 subscribers per Sector/ Sites

The Erlang value = 371 x 45m = 16.695E

So the resources available for PS128 = 0.6 – (16.695/110) = 0.45

Hence it can support: 0.45 x 11 x 128 x (3600/8) = 285.12 Mbyte/h/Sector.

Then the demand = 700 x 371 = 259.7 Mbyte/h/Sector.

So 18 sites are enough.

Area = 33 km2

Cell area = 33/54 = 0.61 km2

But Area = 3/8 √3 R^2

R^2 = A/ (3/8 √3) = 0.61/ (3/8 √3) = 0.94

R = 0.97 km .

4.3 Simulation Results

MS Distribution

The users at the beginning are being distributed randomly targeting the areas where users may exist; this is being estimated depending on the site visit that has been done. In order to create the MS distribution file that is to be used in the simulator, we used a program that has been developed by the project supervisor Mr. Firas Ousta using C# language. The distribution of MS will only target the speech and packet switch data services as shown in Figure 9:

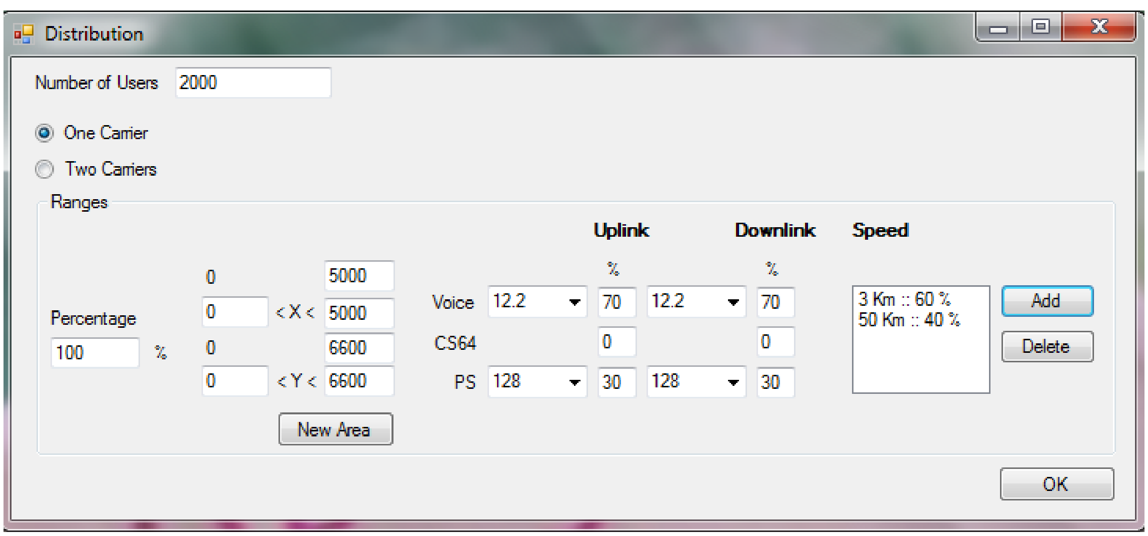

Figure 9 User Distribution Window

In the window above, we can see that 2000 simultaneous users are distributed with an uplink loading of 70% for the speech with 12.2 Kbps and 30% for packet switch data with 128 Kbps. The speeds were also distributed initially as 40% for a speed of 50 Km that represents the users in transportation and 60% for a speed of 3 Km per hour that represents the pedestrian. Moreover, the MS antenna height is set to be 1.5m and the maximum Tx power is 21 dBm where the minimum is -50 dBm, in this project, we only use one carrier and all these parameters are set in the MSparam_2tier.txt file.

BS Parameters

After setting all the parameters related to the MS in MSparam_2tier.txt, mapini.m and npswini.m simulator code files; it is now the turn for changing the BS parameters as in the link budget calculations, the coming section will explain more about the studies made on the antenna type antenna height and down tilt degree in addition to the speed and maximum transmit power needed.

4.3.1 Antenna Height and down tilt degree

The study on the antenna height and down tilt degree has been carried out together as the study aimed to get the best results for coverage probability and capacity considering both parameters, the simulations has been done for the antenna heights 15, 20, 25, 30 and 35m and for tilt degrees of 0, 2, 4, 6, and 8 degrees with 65deg antenna type, the results are shown in Table 10 where 25m is found to be the most suitable height with a tilt of 6 degrees for the BS antenna in this configuration:

Table 10 Antenna Height & Tilt Vs Coverage and Capacity

Height	15		20		25		30		35	
Tilt Degree	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**
0	1221	85.82	1207	85.5	1191	85.84	1135	83.74	1108	88.14
2	1218	88.69	1208	86.23	1202	85.71	1204	80.55	1185	85.38
4	1210	82.98	1213	87.8	1201	88.11	1209	84.37	1209	84.2
6	1174	85.05	1204	83.35	1220	87.91	1232	85.62	1233	86.42
8	984	72.41	1093	75.88	1160	84.73	1200	84.89	1232	84.66

Figure 10 below represents the relationship between the height and tilt with the number of users served in accordance to the parameter variations.

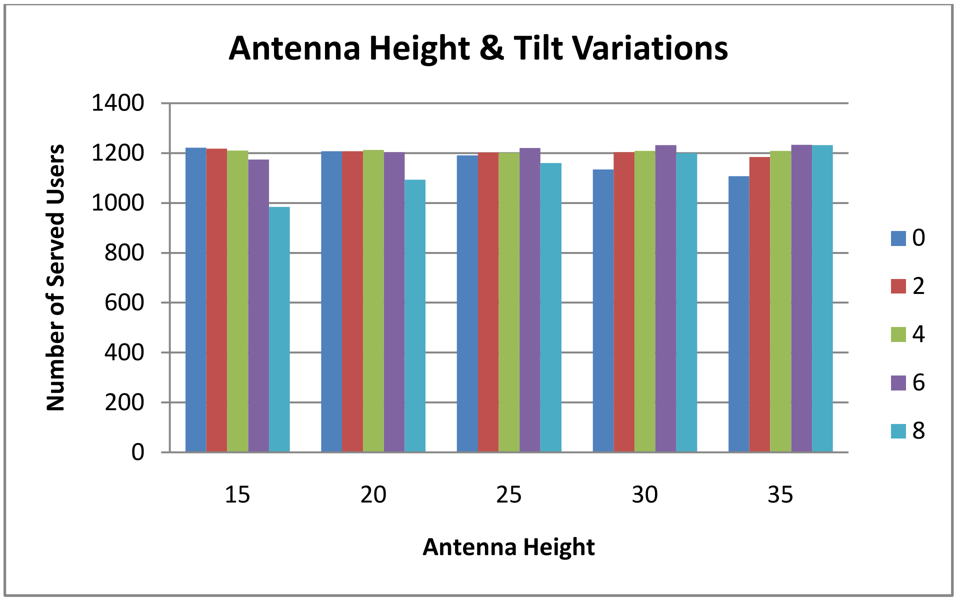

Figure 10 Relationship between the Height and Tilt Variations and the Number of served Users (P=47dBm)

The coverage variations due to the change of parameters can also be seen clearly in the graph below in Figure 11:

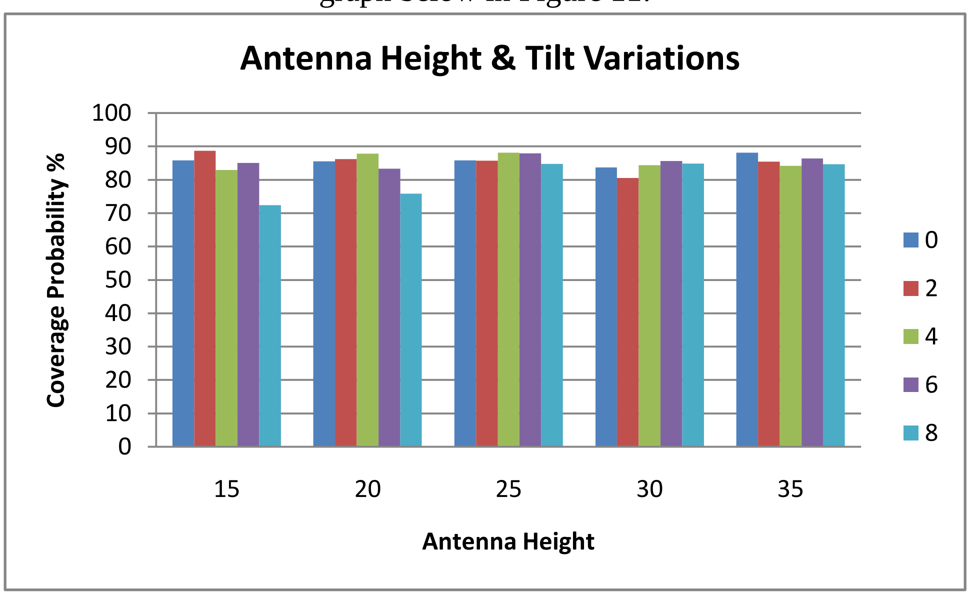

Figure 11 Relationship between the Height and Tilt Variations and the Percentage of Coverage Probability (P=47dBm)

The best result found was considering 25m antenna height and 6 degrees down tilt as mentioned earlier, these parameters resulted in 1220 served users and 87.91% of coverage probability. Refer to appendix B for the Figure s that shows the simulations implemented for purpose of studying the antenna height and tilt degree parameters.

4.3.2 Maximum Transmit Power

The second parameter that has been under study in this project is the maximum transmit power for the base stations, the powers 40dBm, 43dBm and 47dBm has been tested and simulations for coverage and capacity has been carried out for each power, these simulations were again attempted for all the antenna heights and tilts degrees mention earlier. The results out of transmit power simulations are shown in Table 11 and below:

Maximum Transmit Power = 40 dBm:

Table 11 Antenna Height & Tilt Vs Coverage and Capacity with 40dBm Tx Power

Height	15		20		25		30		35	
Tilt Degree	Cap	Cov%	Cap	Cov%	Cap	Cov%	Cap	Cov%	Cap	Cov%
0	758	99.96	761	99.97	716	99.79	634	99.99	644	99.99
2	765	99.92	710	99.97	726	99.79	748	99.98	713	99.99
4	796	99.71	782	99.97	982	99.97	739	99.97	724	99.98
6	810	99.62	833	99.75	833	99.75	812	99.87	771	99.96
8	716	89.41	794	97.84	794	97.84	811	99.055	814	99.55

Figure 12 below shows the relationship between the height and tilt and the number of served users with to a 40 dBm transmit power.

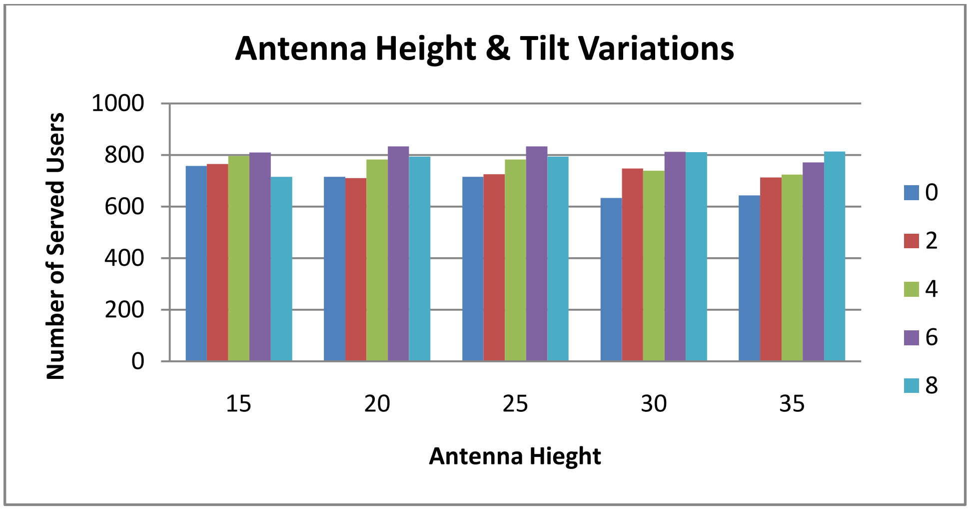

Figure 12 Relationship between the Height and Tilt Variations and the Number of Served Users (P=40dBm)

The coverage variations due to this parameter can be shown in Figure 13:

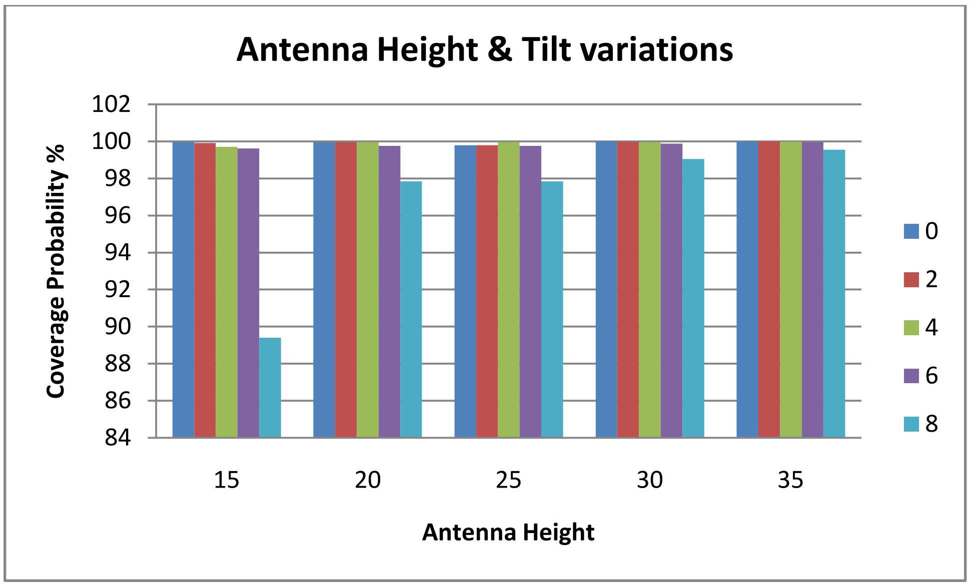

Figure 13 Graph Shows the Effect of Antenna Height on the Coverage Probability (P=40dBm)

Maximum Transmit Power = 43 dBm:

Table 12 Antenna Height & Tilt Vs Coverage and Capacity with 43dBm Tx Power

Height	15		20		25		30		35	
Tilt Degree	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**	**Cap**	**Cov%**
0	861	99.89	861	99.89	822	99.7	839	99.78	721	99.55
2	980	99.56	879	99.48	899	99.75	849	99.91	829	99.92
4	961	98.84	962	99.55	943	99.84	872	99.52	886	99.8
6	977	96.19	1003	98.4	979	99.33	989	99.61	919	99.61
8	876	83.89	941	91.57	967	95.44	998	97.95	1004	98.58

Figure 14 represents the relationship between the height and tilt with the number of served users according to a transmit power of 43dBm.

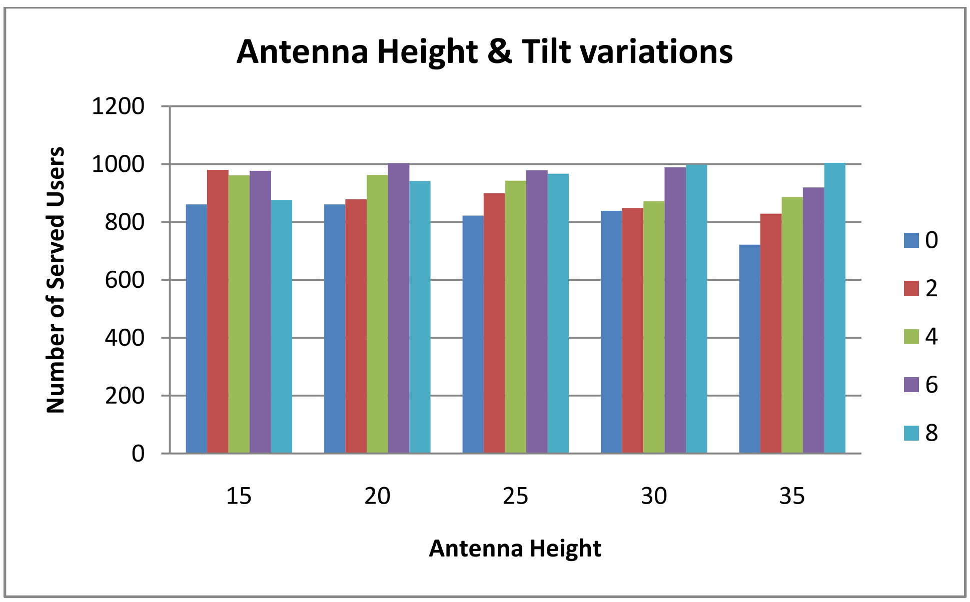

Figure 14 Relationship between the Height and Tilt Variations and the Number of Served Users (P=43dBm)

The coverage variations due to 43dBm power can be shown in Figure 15:

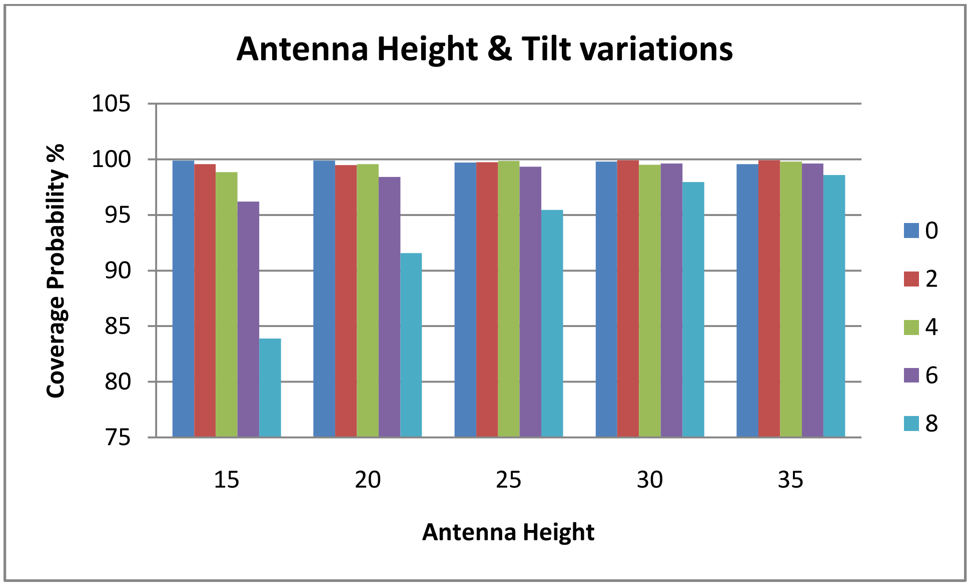

Figure 15 Relationship between the Height and Tilt Variations and the Coverage (P= 43dBm)

The results for a transmit power of 47 dBm are shown in Table10 and Figures 10 and 11 that were shown in the antenna height and tilt degree parameters study earlier. From the results it's found that a maximum transmit power of 47dBm gives the best possibilities for the coverage and capacity, it is noticed that with a power of 40 dBm or 43dBm the coverage is found relatively high, but they were not preferred as they provide a quite poor capacity. A power of 47dBm enhances the capacity but the coverage decreases a bit in this case, this is basically due to the interference introduced when increasing the power. Taking into consideration both coverage and capacity the 47dBm power gives the best capacity that is 61% of the overall simultaneous users with an acceptable coverage that is 87.91%. Figure 16 is a comparison between the 3 options of transmits power with 25m antenna height, 6 deg antenna tilt and 65 antenna type:

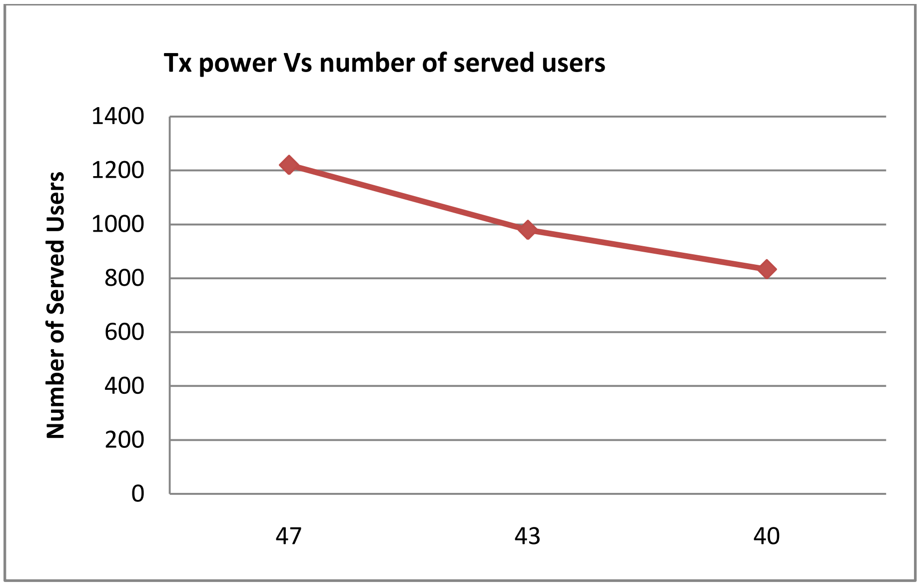

Figure 16   Tx Power Vs Number of Served Users

4.3.3 Antenna Type

To study the best antenna type that can be used, the antenna heights and tilt degree has to be also considered in order to get an accurate results and the best type of antenna will be the type that can provide the highest capacity of users. The antenna types should be studied with fixed height and varying tilt as the first step, and then will be studied considering a fixed tilt and varying height, the height will first be fixed to 25m in table 13.

Table 13   Effect of Tilt on Served Users (With Fixed Height)

Height	Tilt	33 deg		65 deg		120 deg	
		Cap.	**Cove%**	**Cap.**	**Cove%**	**Cap.**	**Cove%**
25	0	1168	81.12	1191	85.84	988	68.36
25	2	1150	84.01	1202	85.71	1023	78.11
25	4	1160	81.1	1201	88.11	1034	78.62
25	6	1148	81.21	1220	87.91	1017	80.22
25	8	1121	83.48	1160	84.73	1054	76.19

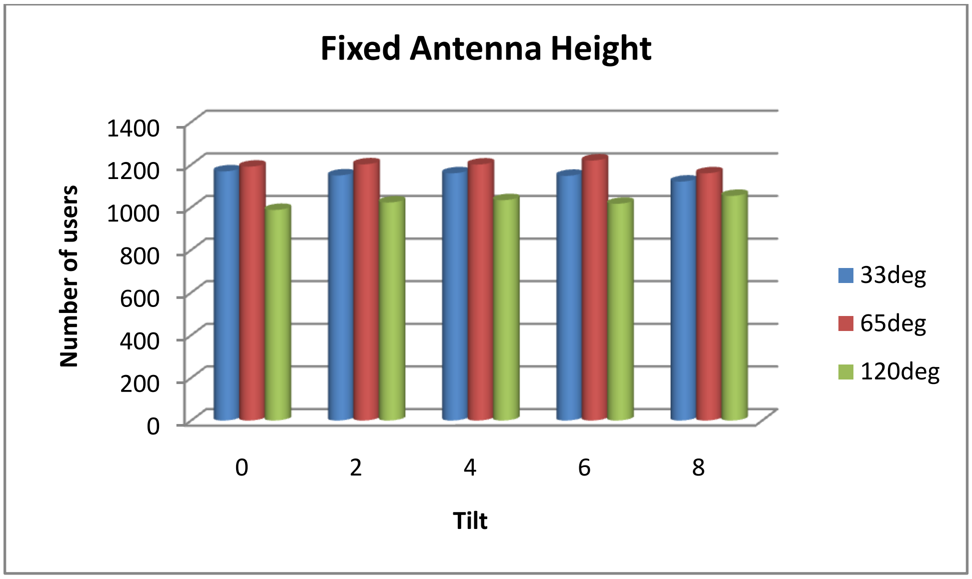

Figure 17 Effect of Tilt on Served Users (with Fixed Height)

After that we check again with fixed tilt that is to be 6 degrees as in Table 14 and Figure 18 below:

Table 14 Effect of Height on Served Users (With Fixed Tilt)

Height	Tilt	33 deg		65 deg		120 deg	
		Cap.	**Cove%**	**Cap.**	**Cove%**	**Cap.**	**Cove%**
15	6	1096	79.73	1174	85.05	1037	81.6
20	6	1116	83.35	1204	83.35	1051	78.35
25	6	1148	81.21	1220	87.91	1017	80.22
30	6	1148	82.25	1232	85.62	1042	79.47
35	6	1164	83.95	1233	86.66	1071	75.62

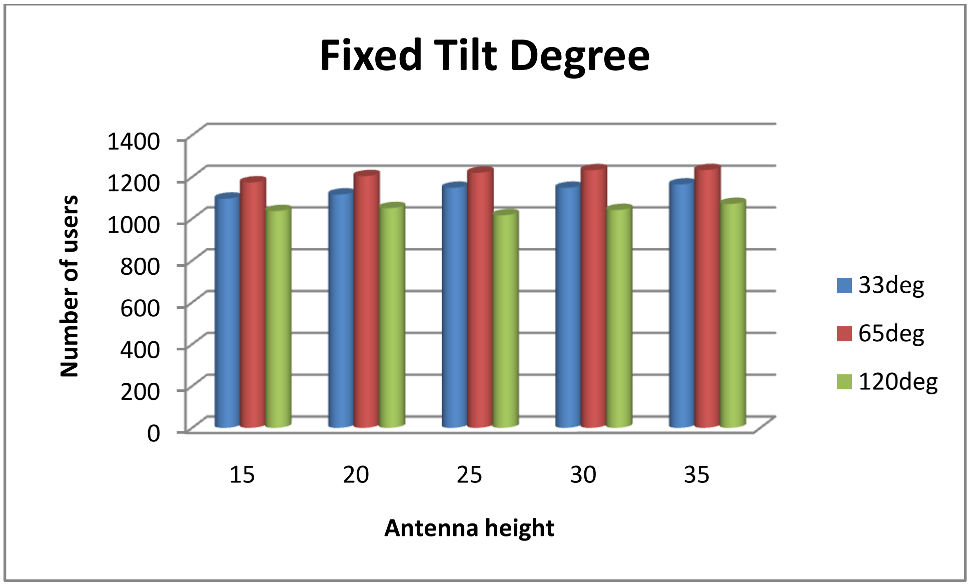

Figure 18 Effect of Height on Served Users (With Fixed Tilt)

From the graph and tables above, it can be shown clearly that 65deg antenna type gives the best results in terms of coverage and capacity. This supports the theoretical analysis where the 65 degree has a beam of 130deg and can cover for 3*130 = 390deg, this means that there will be an overlapping of 390-360 = 30deg. For a 120deg antenna type the coverage can be for 3*240 = 720deg which gives an unacceptable overlapping of 720-360 = 360deg.

The third type which is 33deg antenna type on the other hand covers for 3*66 = 198deg, in this case the focus won't be in the overlapping but will be mainly on the coverage itself, where this type covers for 198deg out of 360 which mean having a 126deg uncovered. From both theoretical and simulation analysis, 65 deg type is proved to be the best that can be used in our case. The graphs in the Figures 19 and 20 show a representation of the effect of tilt on the number of users with fixed height and also the effect of height on the number of users with a fixed tilt for the 65ddeg antenna type.

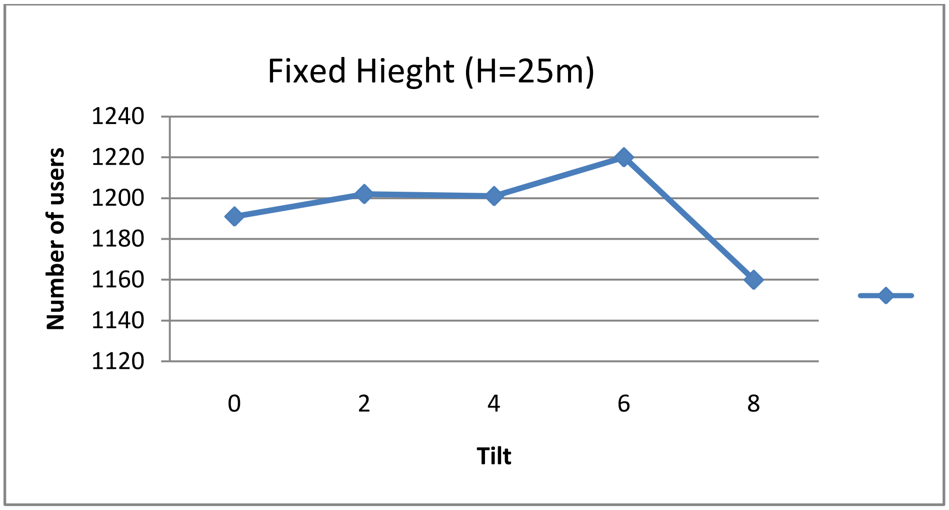

Figure 19 Tilt Effect on 65° Antenna (Fixed Height)

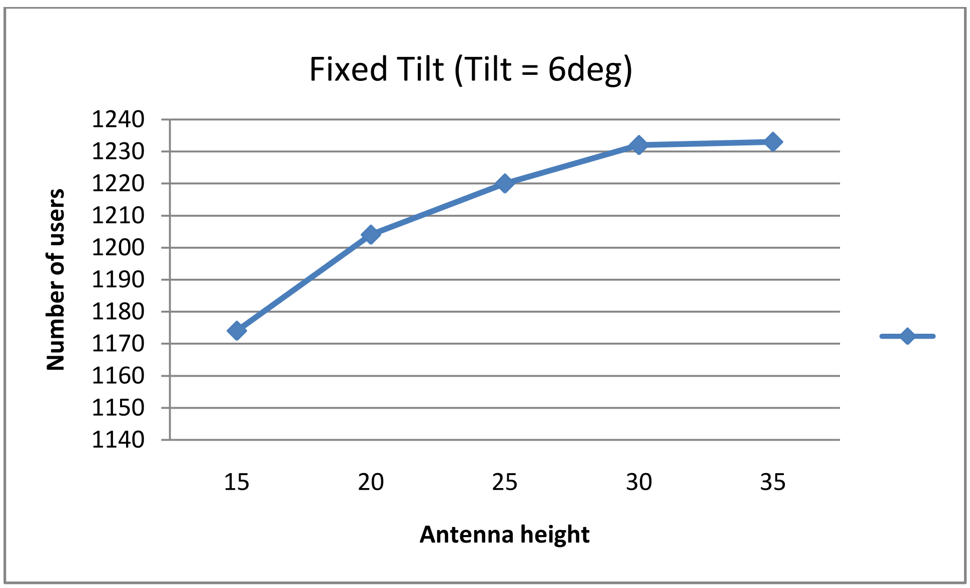

Figure 20 Height Effect on 65° Antenna (Fixed Tilt)

Figure 20 indicates that the best range for the antenna height with a 65deg antenna type is in the range from 25m to 35m, but with considering both the coverage and capacity 25m height is chosen to be the best height.

4.3.4 Speed

The services included in this project are 2 services which are the speech service with a data rate of 12.2kbps and packet data service with a 128kbps data rate, each of these services has been studied for two speeds; 3km/h for pedestrians and 50km/h for users on vehicles separately as primary study and for the final result the loading was divided as 60% for walking users and 40% for users on transportation, the Table 15 shows the coverage and capacity for 100% loading for each speed with each of the 2 services:

Table 15 Effect of Speed on Coverage and Capacity

Speed	Service	Capacity	Coverage %
3km	12.2kbps	1931	99.74
3km	128kbps	513	89.98
50km	12.2kbps	1948	99.77
50km	128kbps	528	97.93

It is noticed form the Table that the coverage is overall high, but the number of users is highly affected by the speed, this is because the speech service which depends on circuit switching is more stabilized even with high speeds unlike the packet data that depends on packed switching service.

The best simulation results that represent all of the above mentioned studies are shown in the following screenshots in Figure 21 and 22:

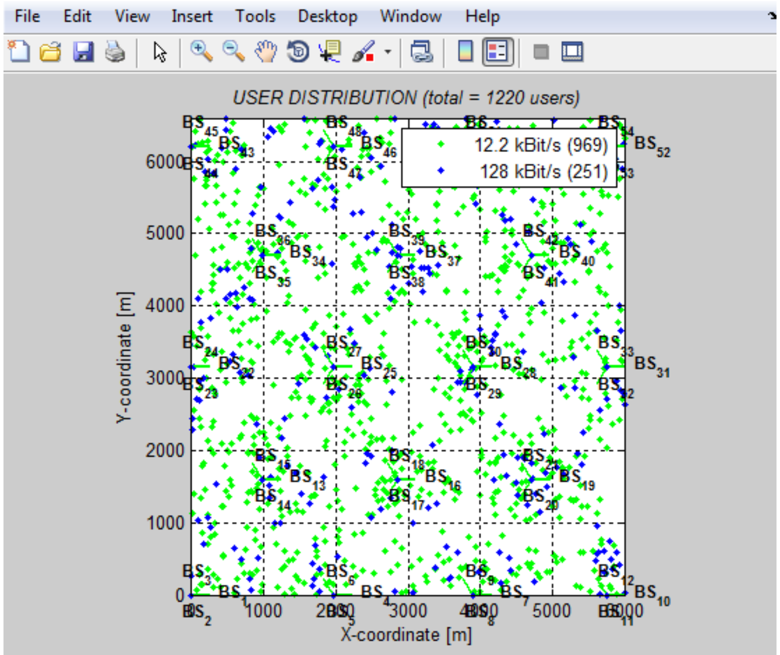

Figure 21 Best Result for Capacity with H = 25, Tilt = 6deg, P = 47dBm

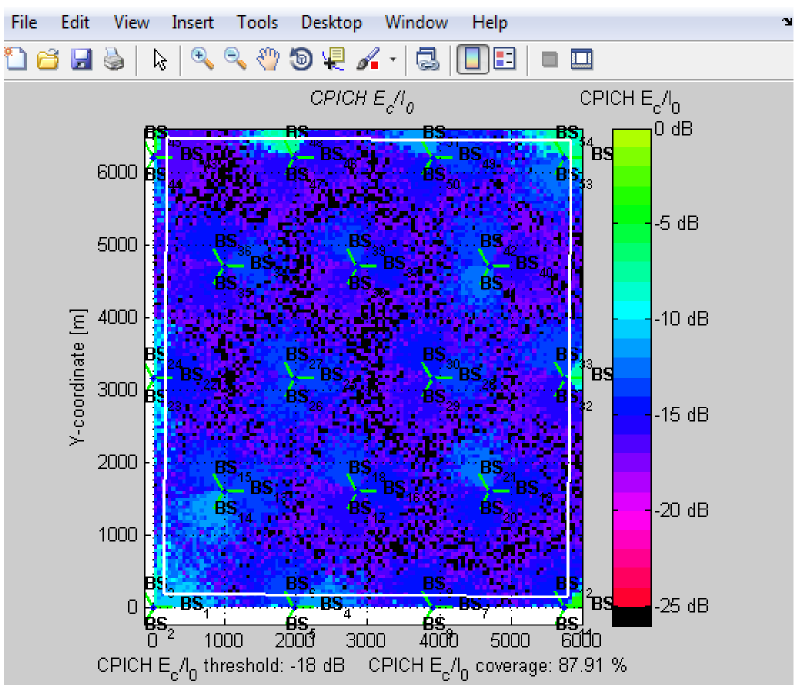

Figure 22 Best Result for Coverage with H = 25, Tilt = 6deg, P = 47dBm

5. CHAPTER 5 CONCLUSION& RECOMMENDATION

As a result of all the studies a 25m antenna height, 6 degree tilt and 65 degree antenna type were the best choices to get the best possible coverage that is 87.91% and capacity of 61% capacity for the 2000 simultaneous users, that is with considering a power of 47dBm. FYP1 semester was a start for getting a valuable knowledge and information about network planning specifically third generation network with Wideband CDMA air interface, it focused mainly on research work in order to understand the main components of the UMTS network and what’s necessary to be considered in terms of coverage and capacity network planning. On the other hand, the second semester of the final year project covered most of the practical work.

The objectives of this project have been met where a real site study was done, and studies on site locations and the relationship between the cell load and network planning has been covered with investigating their relevancy to the coverage and capacity, and the way they can be affected by different parameters. It is recommended for future work to include a micro and pico cells to cover for the areas and indoors that cannot be covered by the marco cells used in this project, these additions will enquire the use of Walfisch-Ikegami propagation model, more advanced work can be done by different simulators that downloads all the buildings in the area considering their materials to account for the interference and other parameters that causes signals loss. The successfulness of this project has introduced a great knowledge on high quality planning for UMTS network for 3^{rd} generation technology which can very helpful for any communication related future career.

6. CHAPTER 6 REFERENCES

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7. APPENDICIES

APPENDIX A   Erlang Table

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34

44	24.33	26.53	27.64	30.80	32.54	34.68	38.56	43.09	47.09	51.09	59.92	71.01
45	25.08	27.32	28.45	31.66	33.43	35.61	39.55	44.17	48.25	52.32	61.35	72.67
46	25.83	28.11	29.26	32.52	34.32	36.53	40.55	45.24	49.40	53.56	62.77	74.33
47	26.59	28.90	30.07	33.38	35.22	37.46	41.54	46.32	50.56	54.80	64.19	76.00
48	27.34	29.70	30.88	34.25	36.11	38.39	42.54	47.40	51.71	56.03	65.61	77.66
49	28.10	30.49	31.69	35.11	37.00	39.32	43.53	48.48	52.87	57.27	67.04	79.32
50	28.87	31.29	32.51	35.98	37.90	40.26	44.53	49.56	54.03	58.51	68.46	80.99
51	29.63	32.09	33.33	36.85	38.80	41.19	45.53	50.64	55.19	59.75	69.88	82.65
52	30.40	32.90	34.15	37.72	39.70	42.12	46.53	51.73	56.35	60.99	71.31	84.32
53	31.17	33.70	34.98	38.60	40.60	43.06	47.53	52.81	57.50	62.22	72.73	85.98
54	31.94	34.51	35.80	39.47	41.51	44.00	48.54	53.89	58.66	63.46	74.15	87.65
55	32.72	35.32	36.63	40.35	42.41	44.94	49.54	54.98	59.82	64.70	75.58	89.31
56	33.49	36.13	37.46	41.23	43.32	45.88	50.54	56.06	60.98	65.94	77.00	90.97
57	34.27	36.95	38.29	42.11	44.22	46.82	51.55	57.14	62.14	67.18	78.43	92.64
58	35.05	37.76	39.12	42.99	45.13	47.76	52.55	58.23	63.31	68.42	79.85	94.30
59	35.84	38.58	39.96	43.87	46.04	48.70	53.56	59.32	64.47	69.66	81.27	95.97
60	36.62	39.40	40.80	44.76	46.95	49.64	54.57	60.40	65.63	70.90	82.70	97.63
61	37.41	40.22	41.63	45.64	47.86	50.59	55.57	61.49	66.79	72.14	84.12	99.30
62	38.20	41.05	42.47	46.53	48.77	51.53	56.58	62.58	67.95	73.38	85.55	101.0
63	38.99	41.87	43.31	47.42	49.69	52.48	57.59	63.66	69.11	74.63	86.97	102.6
64	39.78	42.70	44.16	48.31	50.60	53.43	58.60	64.75	70.28	75.87	88.40	104.3
65	40.58	43.52	45.00	49.20	51.52	54.38	59.61	65.84	71.44	77.11	89.82	106.0
66	41.38	44.35	45.85	50.09	52.44	55.33	60.62	66.93	72.60	78.35	91.25	107.6
67	42.17	45.18	46.69	50.98	53.35	56.28	61.63	68.02	73.77	79.59	92.67	109.3
68	42.97	46.02	47.54	51.87	54.27	57.23	62.64	69.11	74.93	80.83	94.10	111.0
69	43.77	46.85	48.39	52.77	55.19	58.18	63.65	70.20	76.09	82.08	95.52	112.6
70	44.58	47.68	49.24	53.66	56.11	59.13	64.67	71.29	77.26	83.32	96.95	114.3
71	45.38	48.52	50.09	54.56	57.03	60.08	65.68	72.38	78.42	84.56	98.37	116.0
72	46.19	49.36	50.94	55.46	57.96	61.04	66.69	73.47	79.59	85.80	99.80	117.6
73	47.00	50.20	51.80	56.35	58.88	61.99	67.71	74.56	80.75	87.05	101.2	119.3
74	47.81	51.04	52.65	57.25	59.80	62.95	68.72	75.65	81.92	88.29	102.7	120.9
75	48.62	51.88	53.51	58.15	60.73	63.90	69.74	76.74	83.08	89.53	104.1	122.6
76	49.43	52.72	54.37	59.05	61.65	64.86	70.75	77.83	84.25	90.78	105.5	124.3
77	50.24	53.56	55.23	59.96	62.58	65.81	71.77	78.93	85.41	92.02	106.9	125.9
78	51.05	54.41	56.09	60.86	63.51	66.77	72.79	80.02	86.58	93.26	108.4	127.6
79	51.87	55.25	56.95	61.76	64.43	67.73	73.80	81.11	87.74	94.51	109.8	129.3
80	52.69	56.10	57.81	62.67	65.36	68.69	74.82	82.20	88.91	95.75	111.2	130.9
81	53.51	56.95	58.67	63.57	66.29	69.65	75.84	83.30	90.08	96.99	112.6	132.6
82	54.33	57.80	59.54	64.48	67.22	70.61	76.86	84.39	91.24	98.24	114.1	134.3
83	55.15	58.65	60.40	65.39	68.15	71.57	77.87	85.48	92.41	99.48	115.5	135.9
84	55.97	59.50	61.27	66.29	69.08	72.53	78.89	86.58	93.58	100.7	116.9	137.6
85	56.79	60.35	62.14	67.20	70.02	73.49	79.91	87.67	94.74	102.0	118.3	139.3
86	57.62	61.21	63.00	68.11	70.95	74.45	80.93	88.77	95.91	103.2	119.8	140.9
87	58.44	62.06	63.87	69.02	71.88	75.42	81.95	89.86	97.08	104.5	121.2	142.6
88	59.27	62.92	64.74	69.93	72.82	76.38	82.97	90.96	98.25	105.7	122.6	144.3
89	60.10	63.77	65.61	70.84	73.75	77.34	83.99	92.05	99.41	107.0	124.0	145.9
90	60.92	64.63	66.48	71.76	74.68	78.31	85.01	93.15	100.6	108.2	125.5	147.6

91	61.75	65.49	67.36	72.67	75.62	79.27	86.04	94.24	101.8	109.4	126.9	149.3
92	62.58	66.35	68.23	73.58	76.56	80.24	87.06	95.34	102.9	110.7	128.3	150.9
93	63.42	67.21	69.10	74.50	77.49	81.20	88.08	96.43	104.1	111.9	129.8	152.6
94	64.25	68.07	69.98	75.41	78.43	82.17	89.10	97.53	105.3	113.2	131.2	154.3
95	65.08	68.93	70.85	76.33	79.37	83.13	90.12	98.63	106.4	114.4	132.6	155.9
96	65.92	69.79	71.73	77.24	80.31	84.10	91.15	99.72	107.6	115.7	134.0	157.6
97	66.75	70.65	72.61	78.16	81.25	85.07	92.17	100.8	108.8	116.9	135.5	159.3
98	67.59	71.52	73.48	79.07	82.18	86.04	93.19	101.9	109.9	118.2	136.9	160.9
99	68.43	72.38	74.36	79.99	83.12	87.00	94.22	103.0	111.1	119.4	138.3	162.6
100	69.27	7~.25	75.24	80.91	84.06	87.97	95.24	104.1	112.3	120.6	139.7	164.3

N is the number of servers. The numerical column headings indicate blocking probability B in %. Table generated by Dan Dexter

APPENDIX B   Figures Show the Effect of Antenna height and tilt on the capacity and coverage Probability

<u>H = 20m</u>

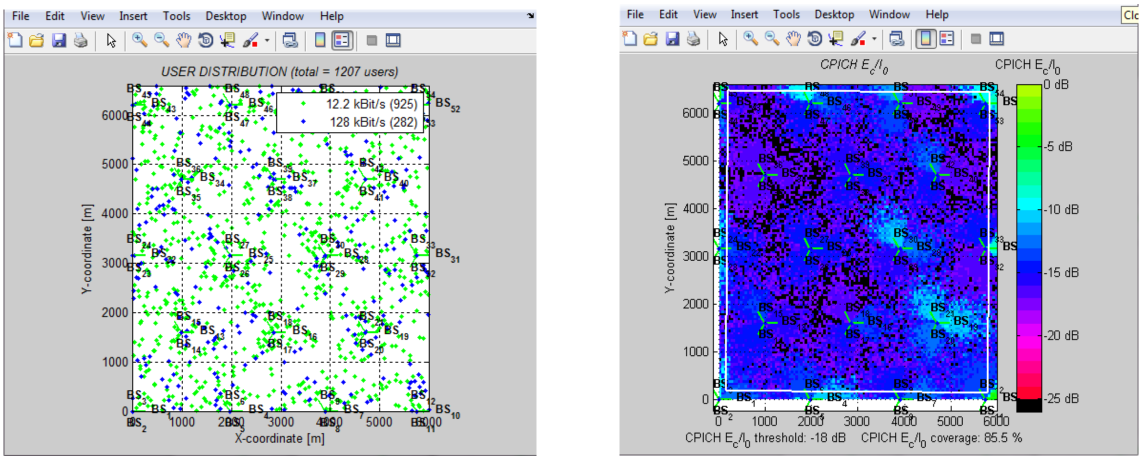

Figure 23   Capacity and Coverage for H= 20m, tilt = 0deg

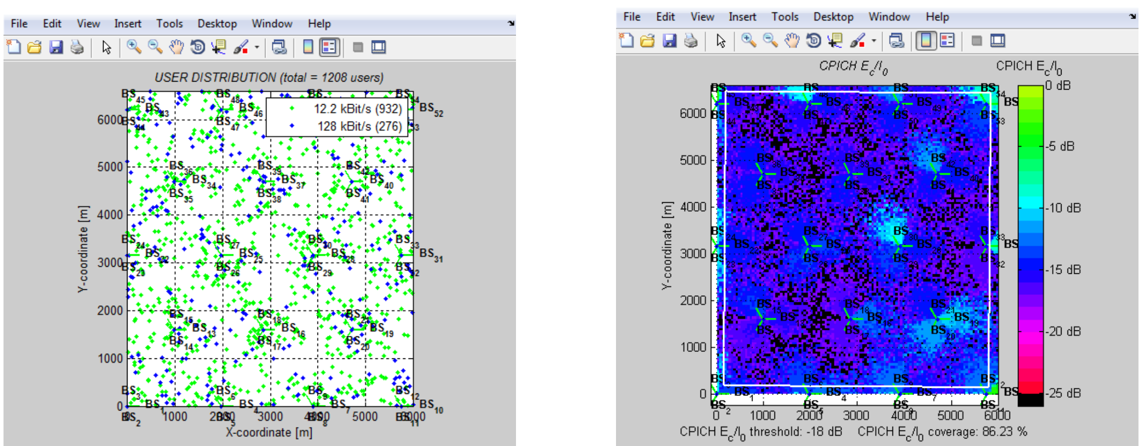

Figure 24   Capacity and Coverage for H= 20m, tilt = 2deg

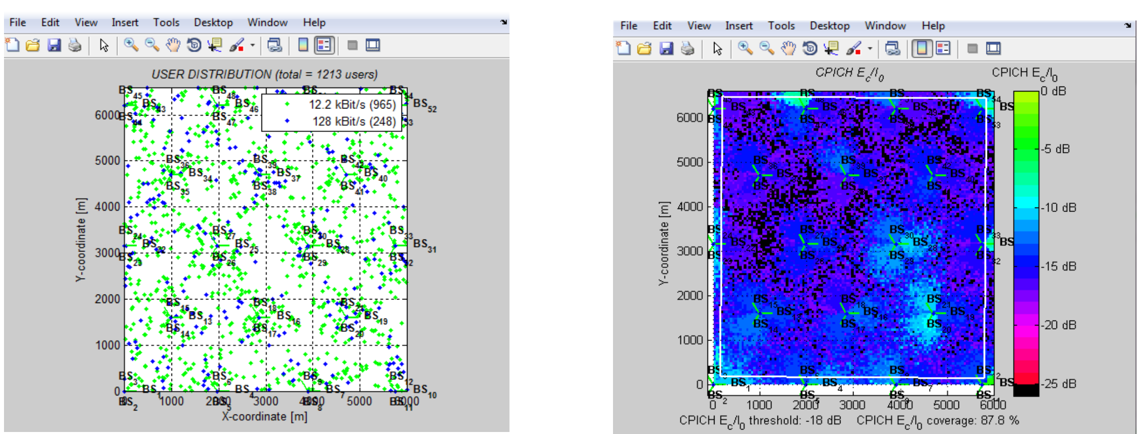

Figure 25   Capacity and Coverage for H= 20m, tilt = 4deg

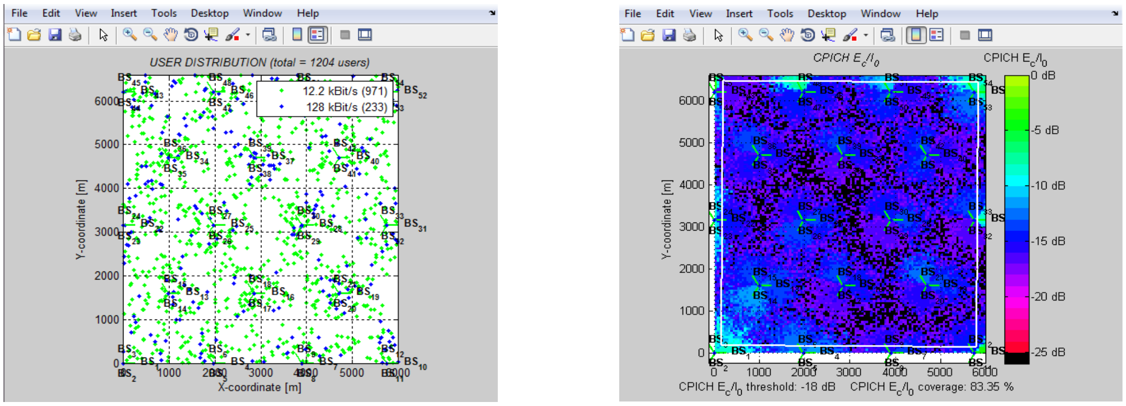

Figure 26 Capacity and Coverage for H= 20m, tilt = 6deg

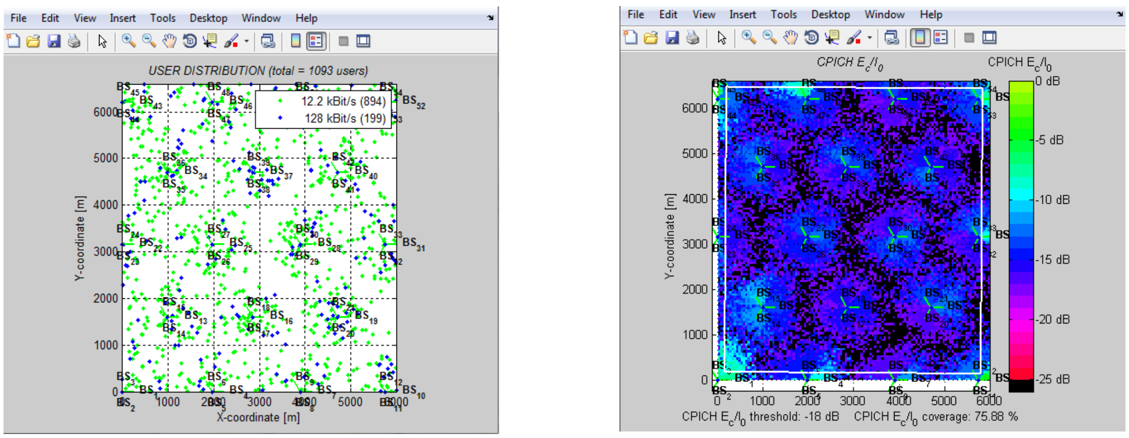

Figure 27 Capacity and Coverage for H= 20m, tilt = 8deg

H = 25

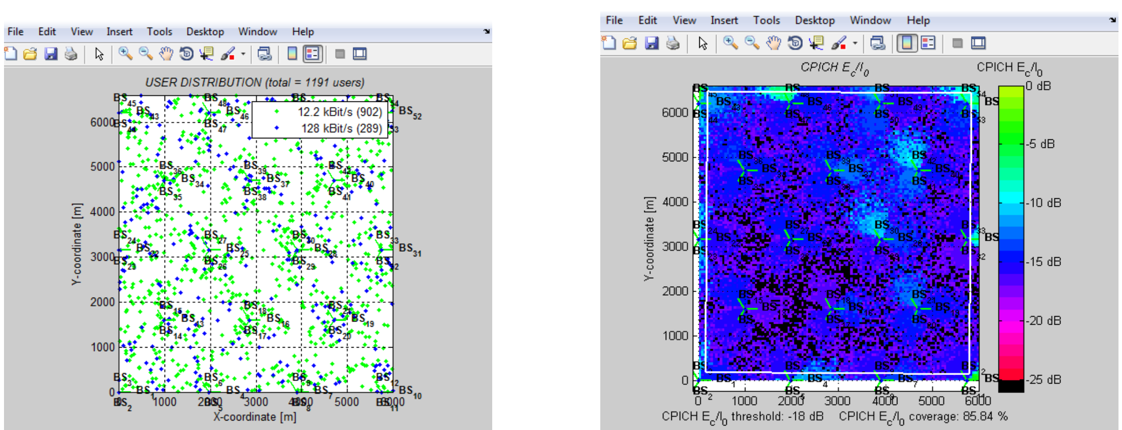

Figure 28 Capacity and Coverage for H= 25m, tilt= 0deg

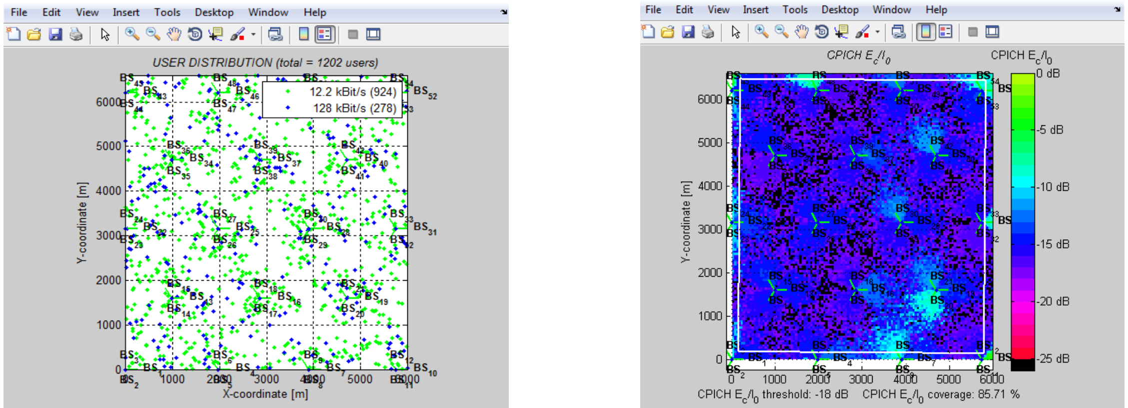

Figure 29 Capacity and Coverage for H= 25m, tilt= 2deg

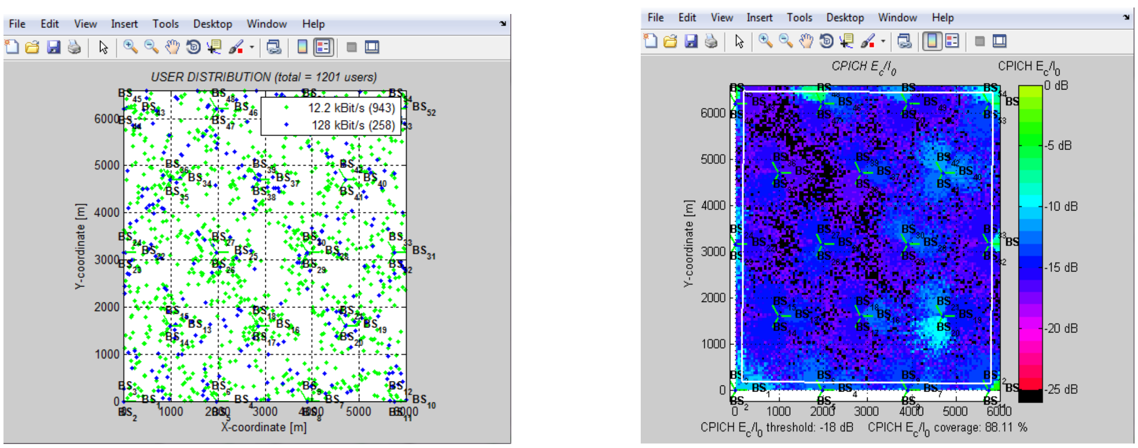

Figure 30 Capacity and Coverage for H= 25m, tilt= 4deg

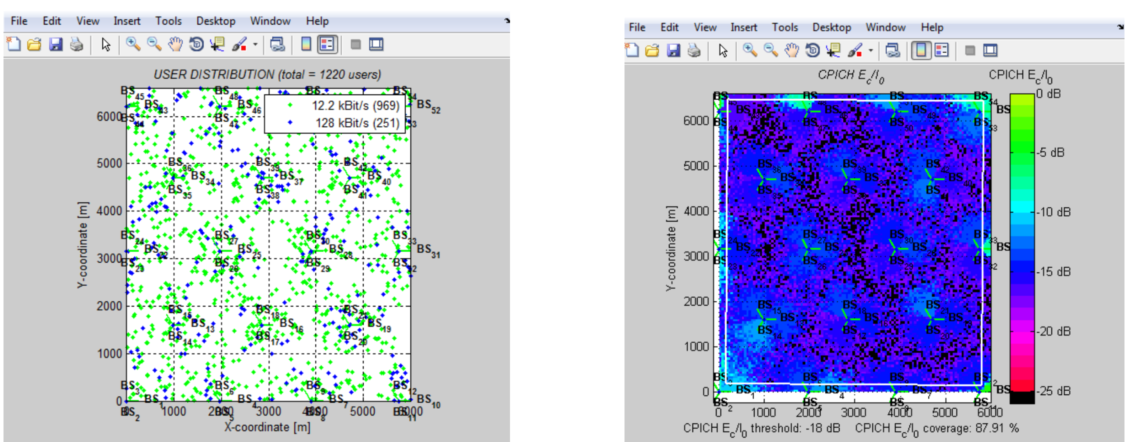

Figure 31 Capacity and Coverage for H= 25m, tilt= 6deg

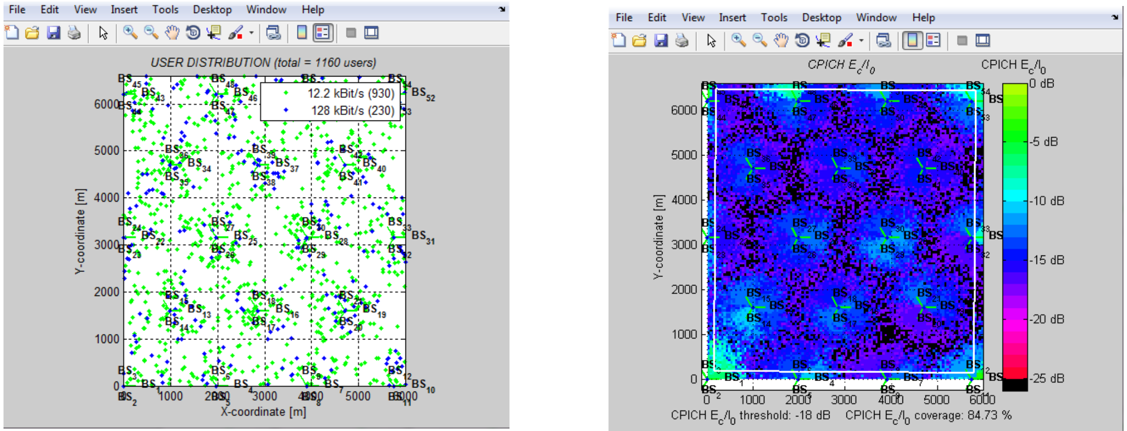

Figure 32 Capacity and Coverage for H= 25m, tilt= 8deg

H= 30m

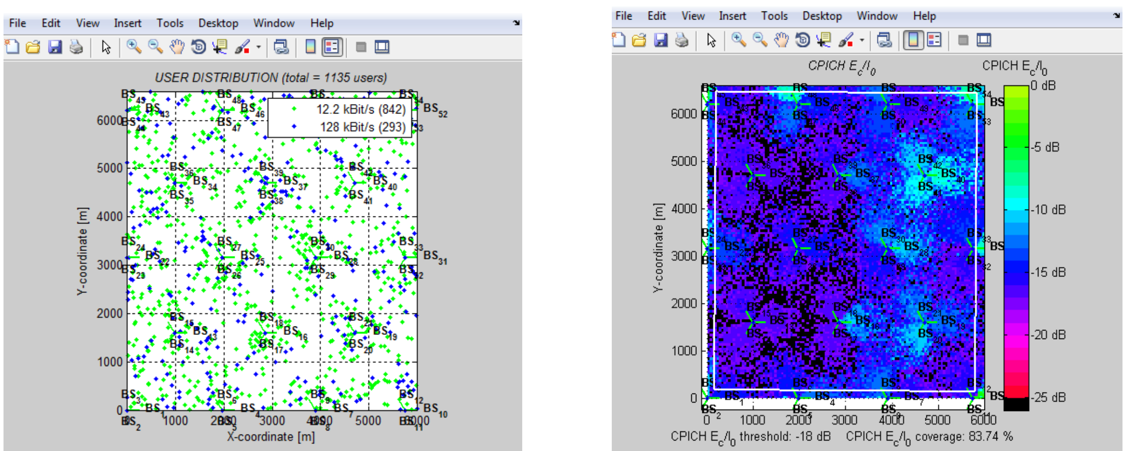

Figure 33 Capacity and Coverage for H= 30m, tilt= 0deg

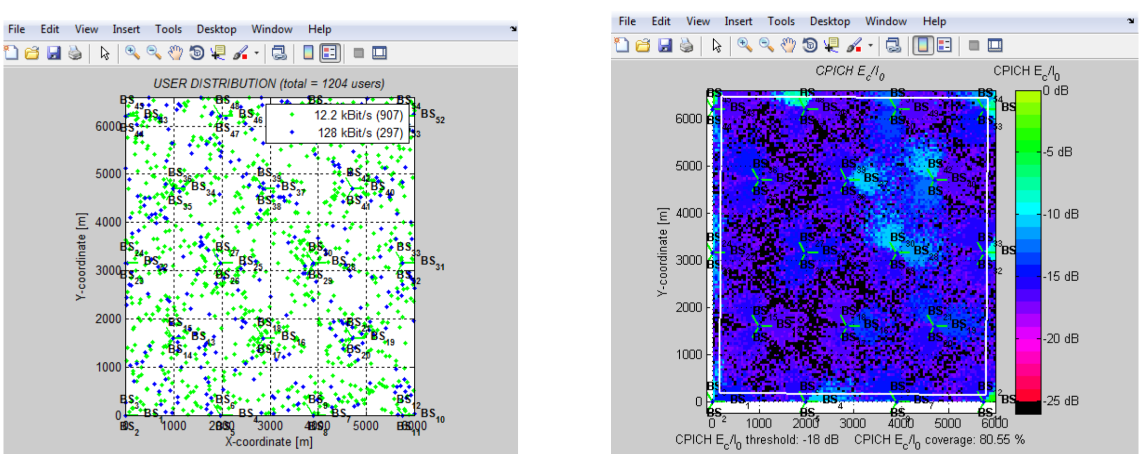

Figure 34 Capacity and Coverage for H= 30m, tilt= 2deg

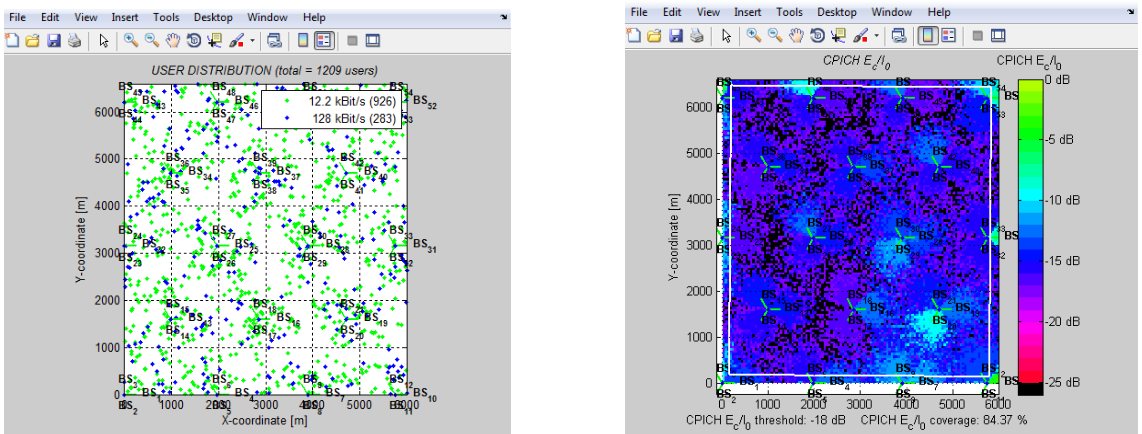

Figure 35 Capacity and Coverage for H= 30m, tilt= 4deg

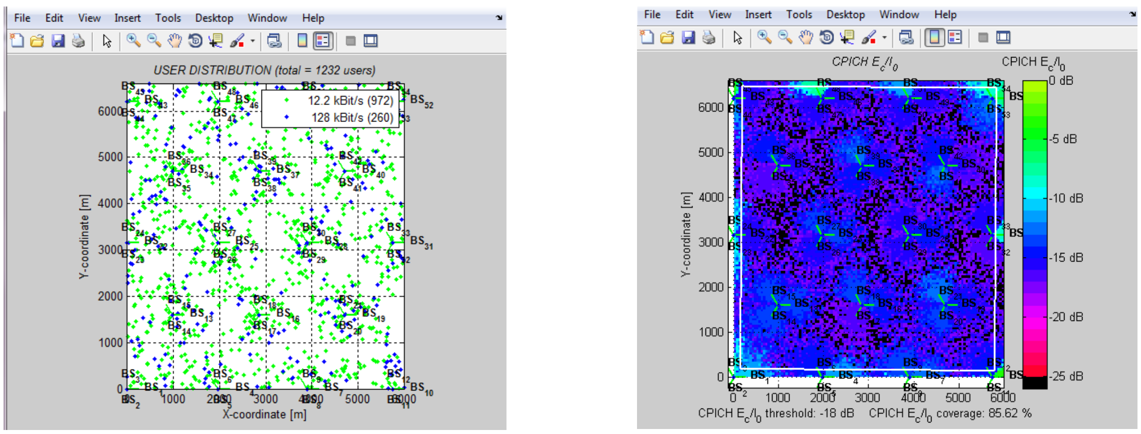

Figure 36 Capacity and Coverage for H= 30m, tilt= 6deg

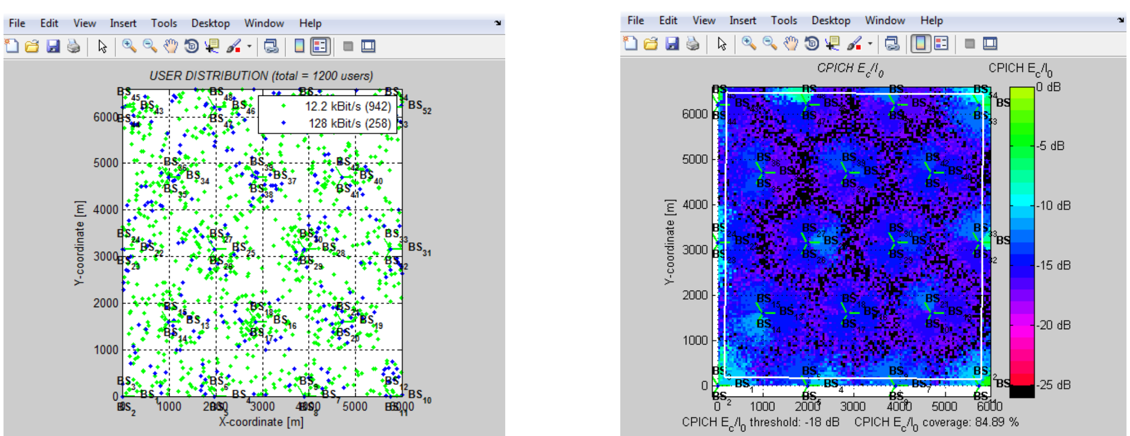

Figure 37 Capacity and Coverage for H= 30m, tilt= 8deg

H=35m

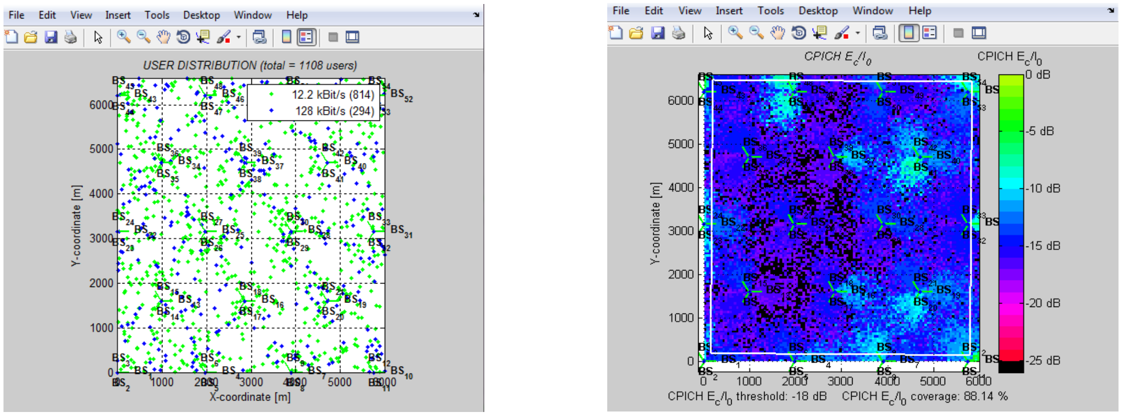

Figure 38 Capacity and Coverage for H= 35m, tilt= 0deg

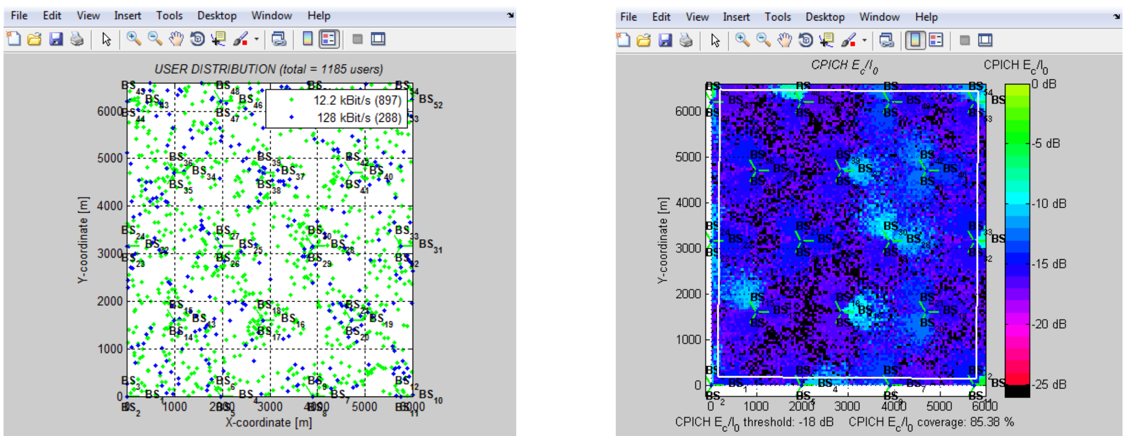

Figure 39 Capacity and Coverage for H= 35m, tilt= 2deg

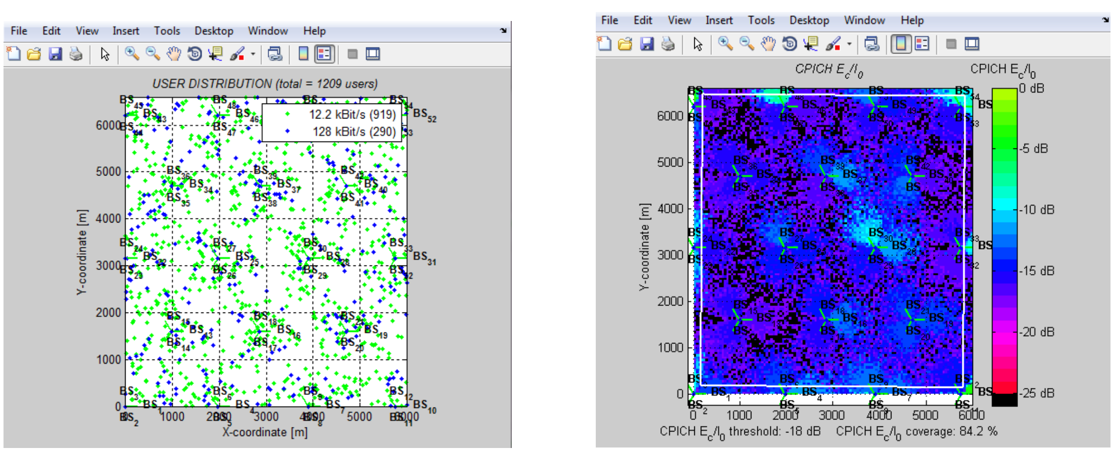

Figure 40 Capacity and Coverage for H= 35m, tilt= 4deg

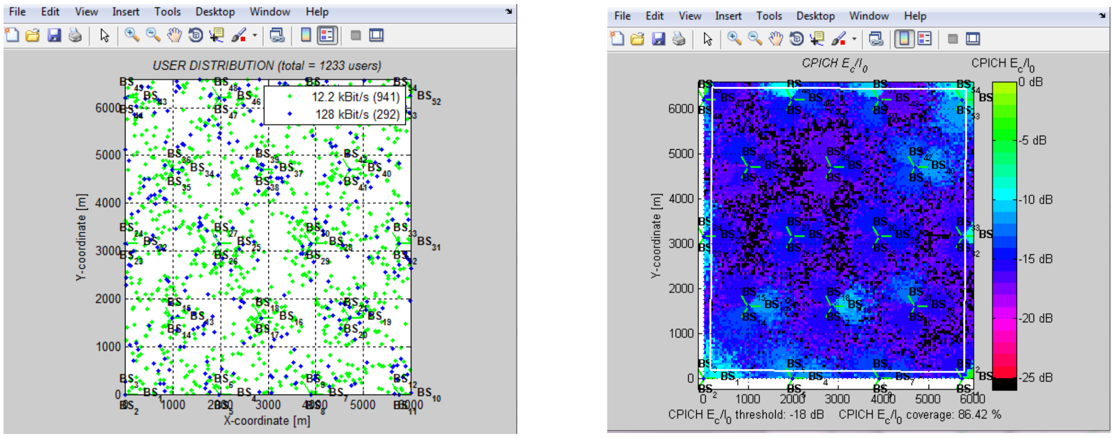

Figure 41 Capacity and Coverage for H= 35m, tilt= 6deg

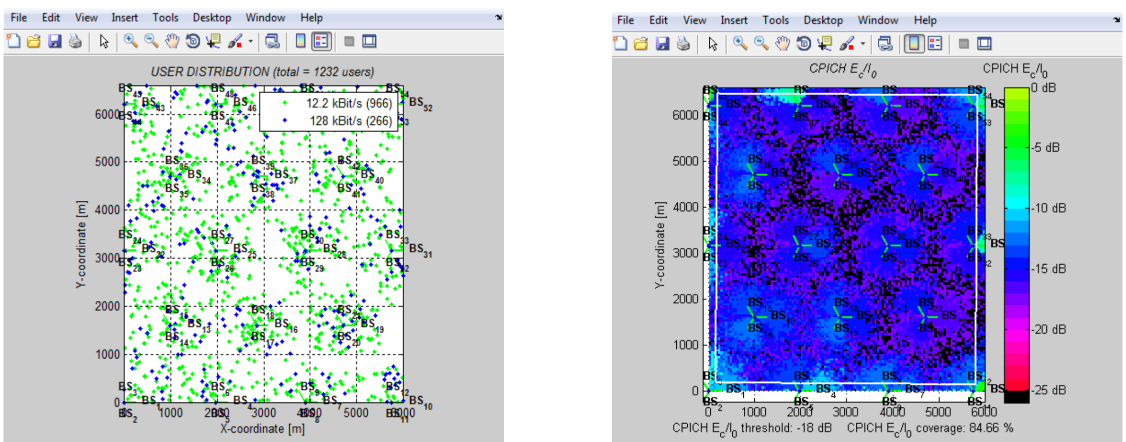

Figure 42 Capacity and Coverage for H= 35m, tilt= 8deg