Long Term Evolution (LTE) Network Planning in Ipoh City

By

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FINAL PROJECT REPORT

Submitted to the Electrical and Electronics Engineering Programme in

Partial Fulfilment of the Requirements for the Degree

Bachelor of Engineering (Hons.)

(Electrical and Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September, 2014

CERTIFICATION OF ORIGINALITY

This is to certify that the Final Year Project titled "**Long Term Evolution (LTE) Network Planning for Ipoh City**" is a work of **Sivasanthini S.Mohan** submitted in partial fulfilment of the requirement for the Bachelor of Engineering (Hons) in Electrical & Electronic Engineering of University Teknologi PETRONAS. The orginal work is my own except for references that have been specified. The report have not been submitted to any other authorities or universities for the fulfilment of any other course requirement.

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Sivasanthini S.Mohan

ACKNOLEDGEMENT

Begin with praising the lord the almighty and most merciful who showered me with his unlimited blessing and supported me with good health and continuous strength to successfully complete this project in required time.

I would like to take this opportunity to place my gratitude to my parents and family who had given me moral support through the project and who had strongly believed in my capability to lead me at the stage of success, also thanking all my colleagues from Maxis and friends who had helped and support me in various issues.

I would like to take this chance to express my appreciation and honourably thank Associate Professor Dr. Aamir Saeed Malik who had accepted me as his student and willing to allocate his time to evaluate as well correcting my mistakes and shaped to as a good student. The most important person who I need to place my biggest gratitude is Mr. Firas Ousta who had guided me throughout this two semesters. Helping me in all up and downs in the project as well bringing me to the right track when I was about to lost. Mr Firas Ousta had been a great mentor and a good friend.

My appreciation to University Technology PETRONAS (UTP) for giving me an opportunity to gain knowledge as in technical and non-technical to shape their each and every student to be outstanding in all aspects. Not forgetting my deepest gratitude to the Head of Department Dr Rosdi Azli, FYP coordinator Dr Nasreen Baharuddin and the committee for their continuous hard work to make sure information had reached the student successfully as well organized our timeline effectively.

ABSTRACT

Long Term Evolution (LTE) is an evolutionary step towards improving telecommunication to higher step. Long Term Evolution (LTE) or also known as 4G is a radio platform technology which provides minimum latency with maximum data rates and speed. LTE have been implemented in latest phones and still some places does not have this facility due to transformation process. Another issue that we can look through is the capability of the network to support users in the area. The coverage and capacity that have been produced may not satisfy user demand and it might be the factor of a network planning. This project will investigate the impact of the antenna parameters on network planning as well identify range of coverage and capacity that can be provided with a LTE network architecture for Ipoh city. In addition to that, transmission power will be investigated with 2 type of sector which is 3 sector and 6 sector.

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CHAPTER

INTRODUCTION

This chapter explain the main purpose of the project including some introduction on the history of telecommunication continuing with the problem statement, objective or aim of the project and the scope of this project.

1.1 Background of Study

In 5th century BC communication were started by writing on a rock and sending to the person by someone than it had been improved by using animals such as birds in order to send any information. The duration for the information to reach a person takes almost few days and sometime a month. This revolution after the centuries had turned into more efficient and convenient type of communication. People use to write letters, telegram and telegraph to send messages. Improvement from that leads to Morse code in 1830s and the further extension of this is type writing. Each code represents an alphabet and these alphabets are combining into sentences or words. From Graham Bell who is the inventor one first phone become an inspiration in 19th century had made an evolution by having cell phones. This cell phones where in bulk and it weighs about 36.3 kilograms. Later on Mr Martin Cooper had invented smaller cell phone which weights 1.1 kilograms.

In 1970s century NTT had come out with a cell phones which can be carried as beg behind your shoulder. This type of phone can be seen in old type war movies where the soldiers will be carrying around to send messages or give some information. Further expansion leads to 1G and 2g mobile phones. This is mainly to give voice calls by using GSM (Global System for Mobile Communication) guide lines. Then slowly it had expanded to give SMS (Short Message Service) services and invention of 3G phones. 3G is 3rd generation mobile phones where the features are given importance for MMS (Multimedia Message Service), Bluetooth for packet data transfer, media such as photos, MP3 songs and GPRS (General Packet Radio Service).

21th century where the technology and science plays a big part had given big contribution to communication world. 4G or LTE (Long Term Evolution) had been implementing in most of the upcoming devices. Mobile phones and some other gadgets are invented to utilize this network. What is 4g network, most of the users a still questioning but this will be easy for those who are in communication world. The main purpose of 4G is to modify the structure of existing wireless communication to improve the speed of the network.

The problem arises when users are finding difficulties in sharing their material such as images, songs or any other documents via phone. This demand to pass the material via phone had increased in 2014. Thus 4G is an expansion of 3G network to emphasize on the speed of network, to ease packet data sharing, to edit more features in mobile phones such as IP (Internet Protocol) base communication and also to promise a good radio wave frequency duplex link for best communication experience.

LTE also called as radio access is E-UTRAN can provide scalable bandwidths with support of FDD paired and unpaired TDD spectrum. LTE created as to use IP for all the network traffic in addition to support the voice service which is VOIP (Voice over IP). LTE invented with the expectation to provide a high throughput, low in latency, increase user experience and provide a better capacity and coverage that can support user demands. LTE will Use of LTE not only will be in telecommunication devices but also will be expanded in other devices in future such as machines, cameras and it might be implemented in transportation area as well. Below is a figure briefly show, the evolution in telecommunication:

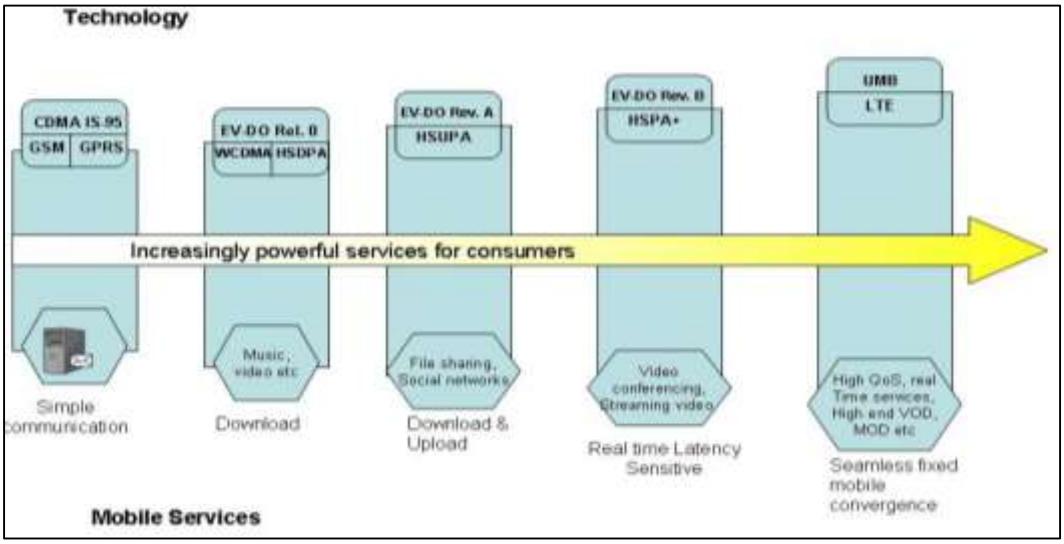


Figure 1 : Evolution of Wireless Telecommunication [14]

1.2 Problem Statement

Increase in number of users requires better coverage and capacity for better communication. Data and voice service capacity is an important issue in handling the user's requirement. Evolution of the network, technical aspects, standards and demands required need to be consider to provide maximum number of user in a network. The goal of planning network architecture to increase the throughput of the network which is successfully delivers the information from the source to destination. In addition to that, a network needs to have sufficient user to utilize it without any waste. Moreover, Quality of service is an important criterion in LTE network during the radio planning, where it defined as network usage optimization in addition to a guaranteed service to the subscribers.

During the planning procedure, link budget, service class, coverage threshold, an appropriate propagation model and appropriate channel allocation strategy will be addressed. This will include the study of LTE architecture, the important key element in order to contribute a good network that can provide good range of capacity and coverage. Lack of strength to support the users in that area may result in drop calls, slower browsing speed and other technical errors which are indirectly caused by the capacity the network can support and the coverage area of the network.

In addition to that creating LTE architecture will need some studies on the important parameters such as cell range, cell radius, propagation model to allow the calculation of capacity and other relevant parameters.

1.3 Objective

The project is to produce a novel architecture of Long Term Evolution (LTE) by considering the objectives as below:

1. Propose LTE network architecture in Ipoh City.
2. Number of sites and subscribers that can be supported in Ipoh City with the study of relationship on identified capacity and coverage range also its impact on planning process

3. Inspect the relationship of the antenna parameters with the site configurations.

1.4 Scope of Study

LTE Sim simulator will be used as the main platform in this project. Atoll Radio Planning and Optimization Software version 3.2 is a 64 bit simulator equipped a platform for wireless network design and optimisation, ease in mobility and also can varies the frequency and reuse for simulating purpose. It also supports user equipment (UE) and support in managing the data radio bearers for traffic which may due from application of multiple physical layers.

The progress of this simulator is through flexible scripting and Service-oriented architecture (SOA) after modelling a simple network architecture for testing purpose and improve the network with different parameters. The improvement done with several manipulative variables such as antenna type, number of users supported by the coverage and capacity of the antenna, distance that can cover by the antenna as well the network strength as mentioned before. Before the simulation is start some parameters need to be calculated and verified with the sample given. This is not to run out from the scope of the project. Some scripting need to be done this simulation in order to calculate and verify the parameters of interest. Atoll Radio Planning and Optimization Software is a virtual type where the software create a virtual window in order to operate and it works in Windows 7 with some other relevant specification as requested. Atoll also supports wide range of scenario to be tested and included with various network type such as GSM but we concentrate on Long Term Evolution template that have provided by the software.

The final approach of this project will be on getting the best network architecture to provide a good and strong network of LTE. Protocols, interfaces, number of users supported, cell radius, number of eNodeB supported, noise power, interference margin, fading margin and distance that can be covered and type of antenna are given importance in this project. Propagation techniques such as Okumura-Hata and Walfisch-Ikegami techniques can be used to develop in order to calculate the propagation loss of the network channel and other possible calculation to verify the algorithm which can lead to a good coverage as well study the behaviour of the antenna.

CHAPTER 2

LITERATURE REVIEW

This chapter explains background study on some of the important element that need to be acknowledged before proceed with the project. The elements are antenna features and some important parameters, multiple access technology comprises method spectrum allocation, propagation modal which is a mathematical formulation used for network prediction and radio or radio frequency link budget is a stack of calculation to create a database to be used in simulation.

2.1 **Antenna System**

Antenna is an equipment that uses to transmit signal or EM wave. Radio wave is classified as the EM wave. Frequency band is set in the antenna in order to operate effectively. Impairment might occur in case the transmission and receiver frequency band does not match [3]. Defined as “a means for radiating or receiving radio waves” in IEEE Standard Definitions of Term of Antennas [17]. Ariel is classified as a type of antenna. In other words, antenna is a metal equipment works as transmitter and receiver of EM wave as the transition medium between free spaces to create long distance communication. Below is the example of how transmitter and receiver antenna works:

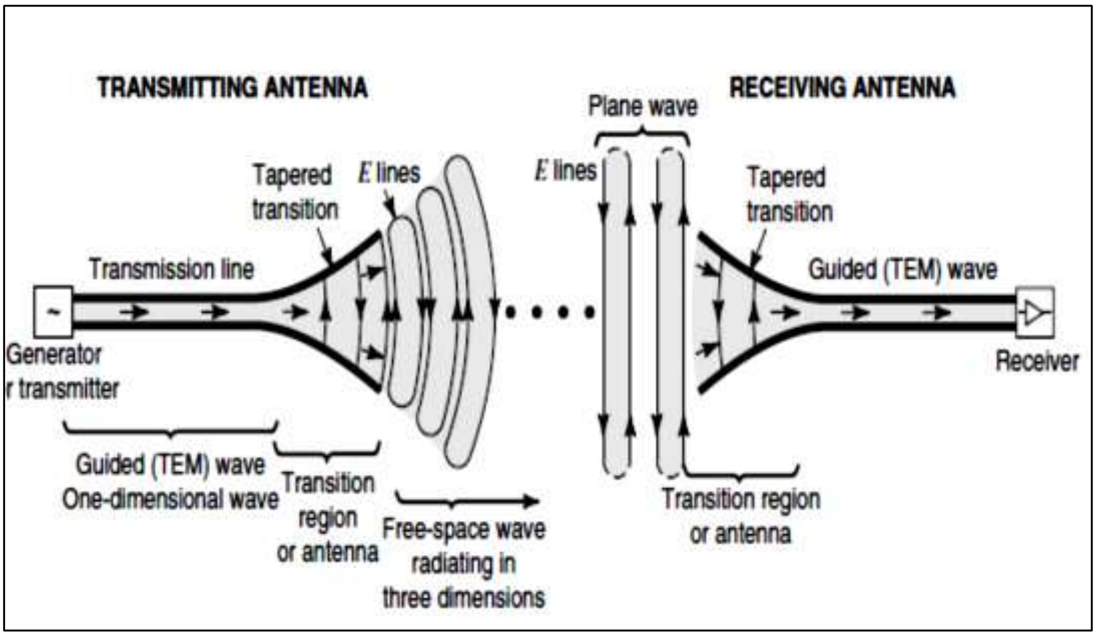


Figure 2 : Wireless communication link with transmitting and receiving antenna [11]

Some of the important parameters that are used in order to select or use an antenna in order to perform transmission are:

2.1.1 Polarization

Oscillation direction of the electrical field vector is known as polarization [18]. It is easy to determine the polarisation of an antenna which is by defining the angle and attenuation of antenna. For EM wave polarization is the plane of the electric wave vibrates [18].

2.1.2 Propagation Pattern

Radiation pattern or also known as propagation pattern is define as strength or the power distributed due to radio waves that is transmitted. In communication field it's divided into two fields which is H-plane the field components and E-plane the electrical field components [18].

2.1.3 Half-Power-Beam-Width (HPBW)

A horizontal and vertical plotted points on a diagram to show power of the radiation reached half of the amplitude of the main radiation is known as HPBW [18]. In general it is known as aperture antenna with 3dB beamwidth.

2.1.4 Gain

Gain is used to balance the uplink and downlink path loss when designing a network architecture [12]. Energy can't be increased using antenna gain but without gain, antenna radiation direction of the radiation is not controlled. Reference for defining gain is $\lambda/2$-dipole [18].

2.1.5 Impedance

Impedance in the measure of resistance to an electrical signal in an antenna which is usually adjusted by symmetry or transformation of the circuit [18]. It is important to make sure that impedance of radio, antenna and transmission line used to be same in order to perform an efficient antenna configuration. In addition to that, low loss equipment will help to increase the energy that is transferred between the antenna and transmission line [3].

2.1.6 VSWR

Voltage Standing Wave Ratio (VSWR) antenna compensation value measured to identify the loss or unusual power that is reflected [18]. The main purpose of measuring VSWR to know the condition of the cable [17].

There are two main antenna used in communication field which is Directional and Omnidirectional antenna. These antennas have their own features in order to suit specific purpose. Both of these antennas consist of the parameters that have been discussed before. Some of the main features are as below:

2.1.7 Directional antenna

Directional antenna main purpose to project RF energy for longer distance use with specific direction and receive signal at the direction it is facing [20]. This antenna effective in near LOS coverage which can be used in between building spaces, for long corridor and hallways [22]. The main disadvantage of this antenna is where it does not suit the best for indoor coverage. Figure show radiation of directional antenna. Some of the common type of antenna used are:

i. Parabolic antenna
ii. Yagi Uda antenna
iii. Dipole antenna

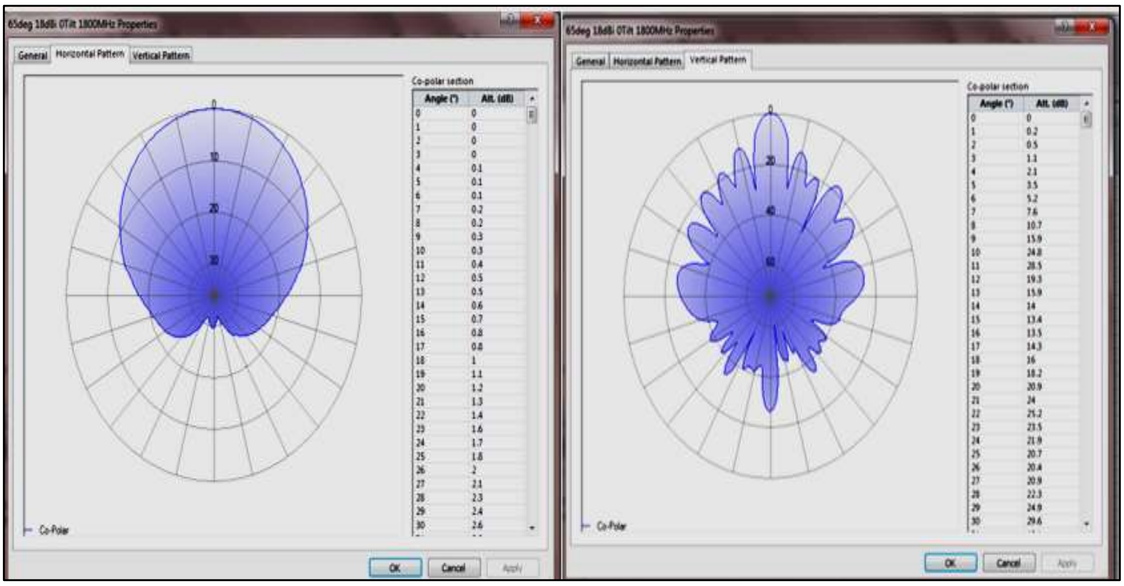


Figure 3 : Directional Antenna Radiation Pattern

2.1.8 Omnidirectional antenna

Omnidirectional antenna is an antenna that receive, radiate or intercept EM wave in all direction except for y-axis or the azimuth plane. This antenna does not radiate or receive on specific direction on a vertical plane [17]. Narrow down the beam width on the vertical plane can increase the gain of this antenna [3]. Omnidirectional antenna is the best used to provide indoor coverage [22].

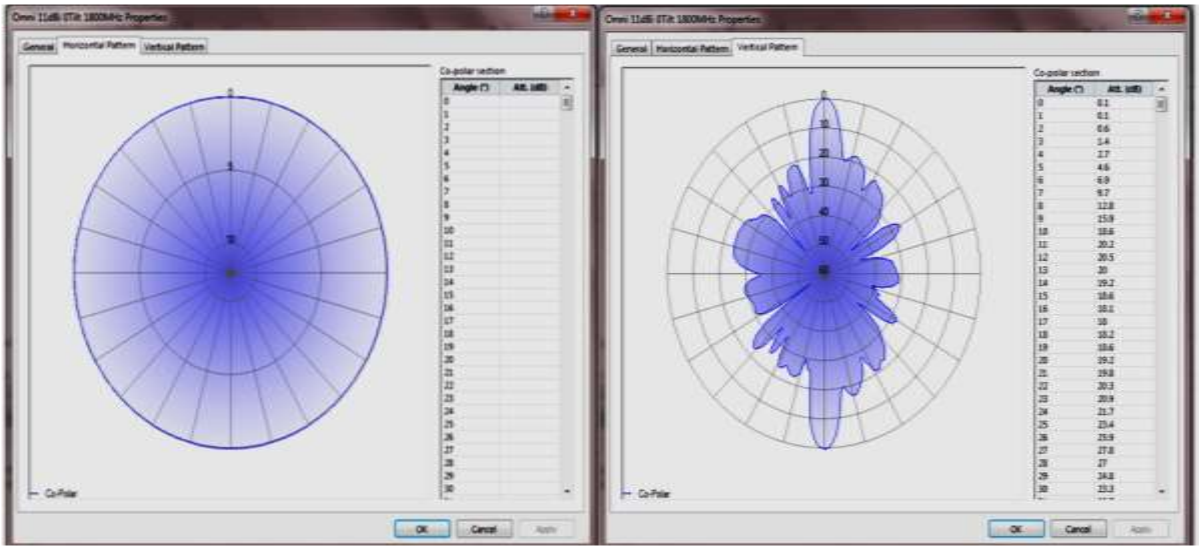


Figure 4 : Omnidirectional Antenna Radiation Pattern

2.2 Multiple access technology

Multiple access technology is to enable multiple users to access the network simultaneously. These schemes must be able to expand the spectrum efficiency without common interference to work at its best. There a many different schemes are introduced as the technologies improve. This includes the modulation methods such as QAM (Quadrature Amplitude Modulation), Quadrature Phase Shift Keying (QPSK) in 16QAM and 64QAM. 64QAM and MIMO transmission is the key to produce high peak data rates in LTE [17].

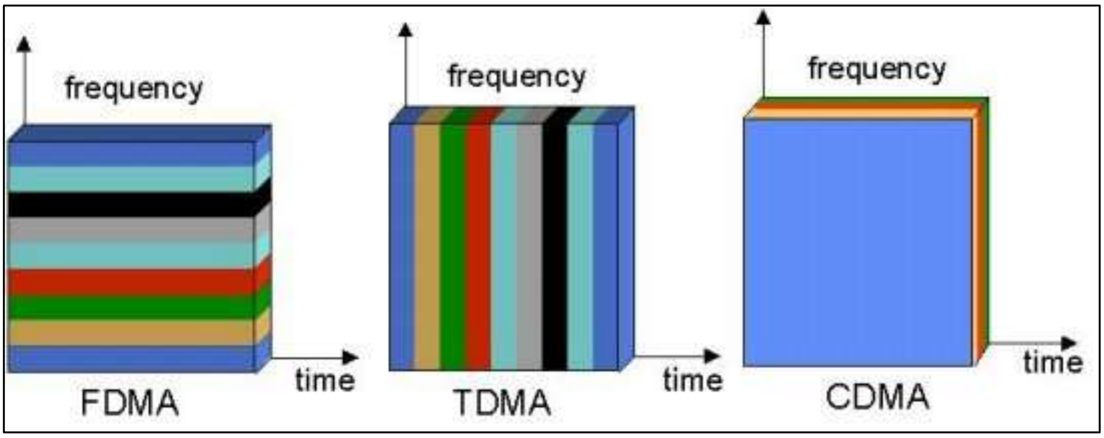


Figure 5 : Multi access techniques [9]

The main schemes are as below:

1. **FDMA: Frequency Domain Multiple Access**

FDMA schemes are initially used in the system. This is the simplest schemes where the switching of network does not affect the channel and frequency allocation for the system. As the subscribers keep changing, the slot and allocation and network can be accessed without any problem. Almost all analogue system used this system [16].

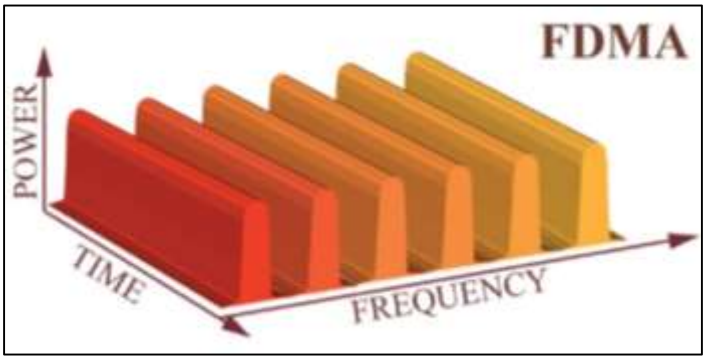


Figure 6 : Illustration of FDMA technique [28]

2. TDMA: Time Domain Multiple Access

This scheme is mainly for shared medium network. More than one user can allocated to share the frequency by allocating to different time slot. This is because the information such as voice or speech will be converted to digital signal and transmitted the data into short bursts. Any delay during the transmission will be ignored since it is very small. Thus it becomes easier to locate users in existing slot to transmit or receive information [16].

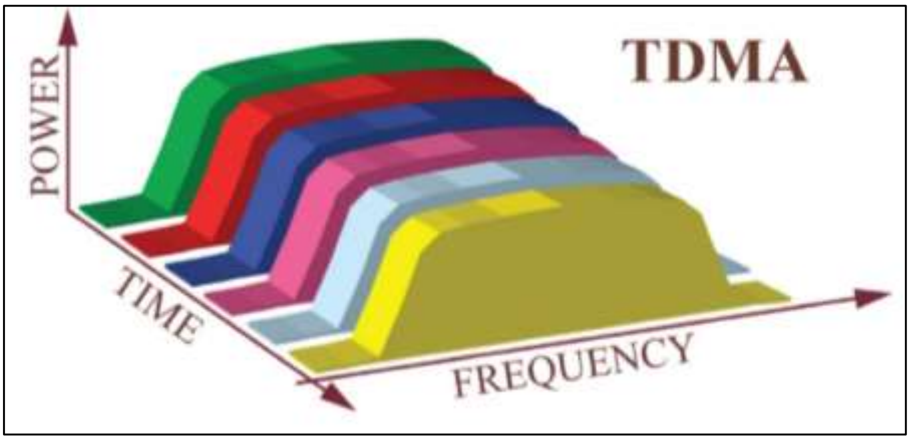


Figure 7 : Illustration of TDMA technique [28]

3. CDMA: Code Domain Multiple Access

CDMA scheme can allocate more than one user simultaneously for given frequency. It conveys ADC with combination of spread spectrum technology. The transmission depends on the code which is the unique pattern so that only user who required with the same pattern if not rejection might occur. There are trillions patterns are enhanced in order to keep the privacy and making another same pattern is a hard. Combination of unique patterns lead to wider spectrum of the signal, but it depends on the receiver to multiple the same patterns when generating a direct pattern spread spectrum. This pattern is invisible and will disappear during the process. Same frequency can be used for different network as the user who receiving is allocated with different code by the base station and another spreading pattern can be used to receive information from sender [16].

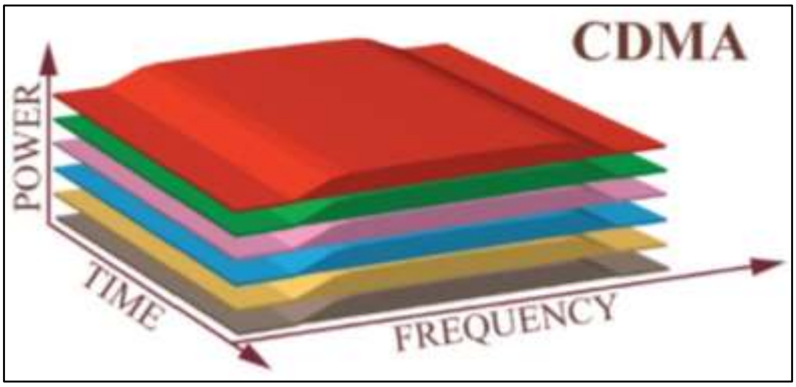


Figure 8 : Illustration of CDMA technique [28]

4. OFDMA: Orthogonal Frequency Division Multiplex

OFDMA uses big amount of closed spaced carrier which is modulated with low data rate. This scheme is the scheme used in LTE for UMTS / W-CDMA and UMB. Orthogonal method avoids the signal to interfere with other signals. This scheme consists of 2 methods which is uplink and downlink [16].

a. Uplink – Transmission from device to the tower. Use OFDMA

b. Downlink – Transmission from tower to device. Use SC-FDMA

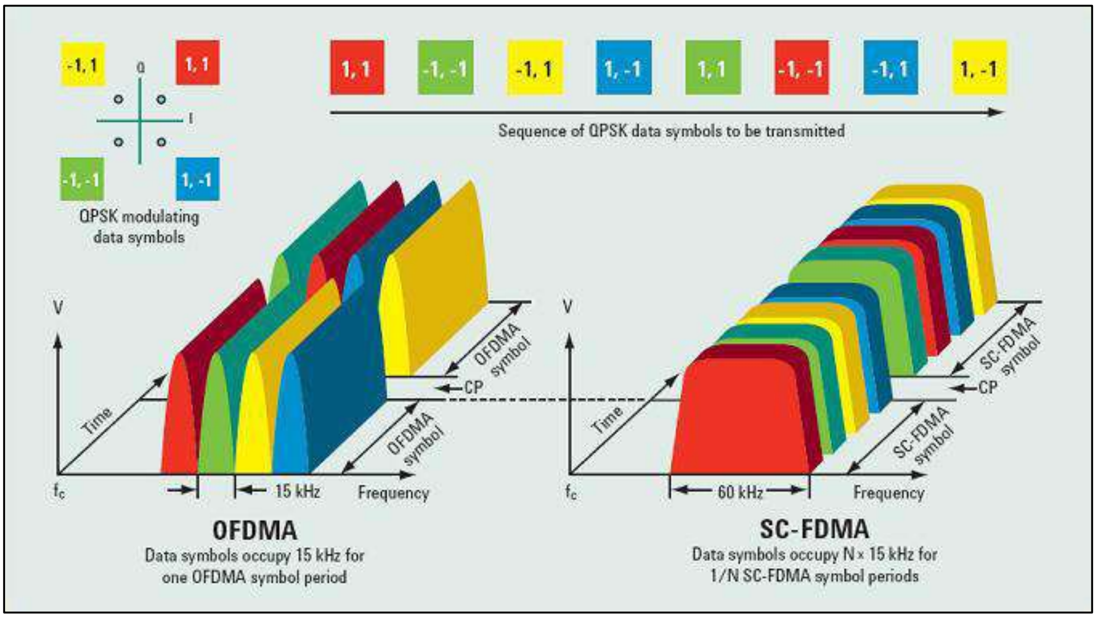


Figure 9 : Uplink and Downlink [10]

Parameters such as bandwidth, modulation, coding rate are important when dealing with physical layer of LTE for calculation of throughput [21]. SC-FDMA and OFDMA is a FFT based transmission with better peak-to-average power ratio [1]. OFDMA and SC-FDMA is used to solve the issue of multiple accesses in downlink and uplink respectively in LTE. Users are allocated with different group of subcarriers at the same time. OFDMA transmit information in orthogonal manner thus it helps to create multipath for the channel and lower the equalizer complexity at the receiver end. In the other hand SC-FDMA is based on single carrier modulation with FDE. FDE here is the frequency domain equalizer [9].

2.3 Propagation Model

There are several types of propagation model used to plan a network architecture. These propagation model is divided into 3 classes according to environment of the site we are investing. The most common model used Okumura-Hata this is but in this project we are implementing Cost Hata since it suits with the specification that have been set for this propagation model [5]. Okumura used for urban areas with the frequency range as per in the Table 2. Moreover Okumura Hata have the base station height of 30 – 1000 meter where the distance were set to 1 – 20 kilometre [8]. Table 2 explains the features of other propagation model that can be used for network architecture planning.

Table 1 : Propagation model features

Propagation model	**Frequency (MHz)**	**Geographical Profile**	**Recommendation**
ITU 370-7	100 to 400	Profile : Terrain	Distance = above 10 km Low frequencies Broadcast
ITU 1546	30 – 3000	Profile : Terrain	Distance = 1 between 1000 km Land and maritime mobile, broadcast
ITU 526-5 (theoretical)	30 - 10000	Profile : Terrain	Fixed receivers WLL
ITU 529-3	300 - 1500	Profile : Terrain Clutter : Statistical (at receiver)	Distance = 1 between 100 km GSM 900, CDMA2000, LTE
Okumura - Hata	150 - 1000	Profile : Terrain Clutter : Statistical (at receiver)	Distance = 1 between 20 km GSM 900, CDMA2000, LTE
Cost - Hata	1500 - 2000	Profile : Terrain Clutter : Statistical (at receiver)	Distance = 1 between 20 km GSM 1800, UMTS, CDMA2000,LTE
Standard Propagation Model	150 - 3500	Profile : Terrain Clutter : Statistical (at receiver)	Distance = 1 between 20 km GSM, UMTS, CDMA2000,WiMAX, LTE

Erecg - Greenstein (SUI)	1900 - 6000	Profile : Terrain Clutter : Statistical (at receiver)	Distance = 100 m between 8 km Urban and suburban areas Fixed WiMAX
Sakagami Extended	3000 - 8000	Profile : Terrain Clutter : Statistical (at receiver)	1 < d < 20 km WiMAX
Cross Wave Model	200 - 5000	Profile : Terrain Clutter : Statistical or deterministic 3D building	Any engineering (micro, mini, small and macro cells) GSM, UMTS, CDMA2000, WiMAX, LTE

2.4 Radio link Budget

The main purpose of calculating link budget is to identify all the transmission gains and losses between receiver and transmitter. Identifying these factors can help to optimize and recover the maximum loss of the transmission. Parameters such as power of transmission, gains from antenna, system losses, diversity gains, fading margins and other important measures [2]. The relevant formulas is mentioned in the related calculation section of the report. Figure 10 shows the main steps for link budget calculation process.

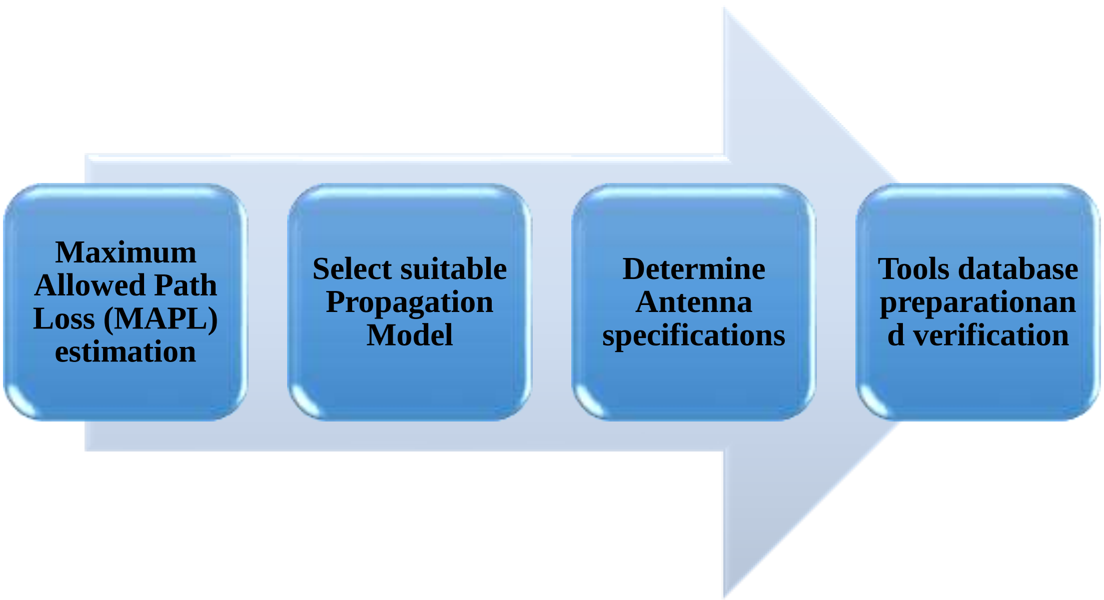


Figure 10 : Link Budget Process

2.4.1 Capacity Dimensioning

Predicting the capacity requires certain parameters before the simulation such as number of site, size of the cell and some other important parameters. Capacity planning is one of the objective of the project, thus it is important to study the impact and effectiveness of capacity applied on the network architecture that have been created. Theoretically capacity is limited by eNodeB (eNBs) in the network [2]. Factors that will be affecting the capacity of a network were the interference and noise during the transmission. Increasing number of users exceeding the maximum load or the range that can be applied to a cell will lead to high noise and interference.

To evaluate capacity of a network we need to [2]:

A. Derive the cell radius after estimating cell throughput and other settings.
B. Analyse the traffic demands of the area that comprises:
   i. Number of users
   ii. Geographical spread of user

2.4.2 Coverage Dimensioning

Coverage measure mainly after the simulation. It is done by defining transmitter, signal level, downlink throughput, Signal to noise ratio (SINR) [6]. Coverage estimation should be the first step before starting the simulation to obtain the result related to capacity. In addition to that QoS also included in coverage dimension process where defining the user related specification and parameters. DL and UL were one of the output that can be obtained from this process. Number of the sites can be calculated during base on coverage we obtained with relevant formula and data [2].

Dimensioning of both coverage and capacity can be followed as the figure:

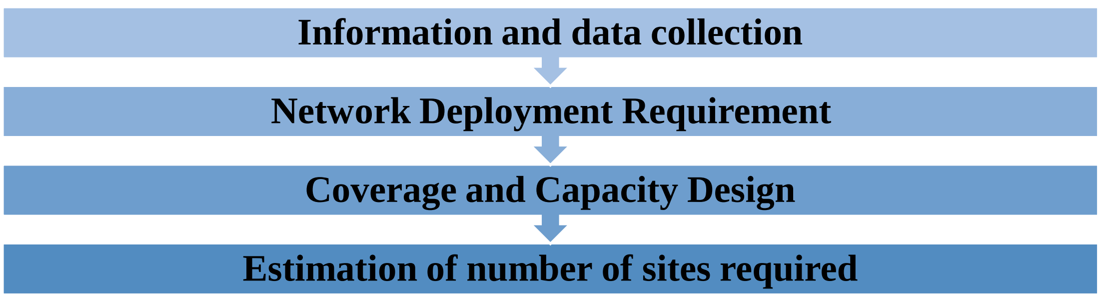


Figure 11 : Dimensioning of Capacity and coverage to obtain Number of sites

CHAPTER 3

METHODOLOGY

Methodology here describes the process of the project from the scratch until result is obtained. This includes time lines which is the Gantt chart and flow chart to elaborate more on how this project is done.

3.1 Procedure pathway

Planning a network is a challenging task that need a lot of data, calculations and the result form this planning should give an satisfactory capacity and coverage that can compensate the demand of the users. But before continuing with the simulation part, research had been done by collecting the methods, results and theory to help in this project. This is the first part of the project and more to literature review portion. FYP 1 is allocated more on theory rather than FYP 2 which is hand on.

There are more than hundreds on research is done on LTE network planning but each have their own specifications and area. Thus, they can't be used exactly to be implemented in this project but it is recommended to learn the way they have presented and done the project in their own way. Some difficulties have been faced during the research part where most of the planning is done using MATLAB and other software. Where else, in this project LTE Sim is introduced at first.

LTE Sim is a tool works best in Linux windows, using the tool in Windows 7 might not work at it best. Therefore, a computer requested in order to install this software to be used in my FYP 2. Unluckily they takes about more than a week to get a computer which have delayed the time to start the simulation earlier. In the other hand, Ubuntu is tried to install in personal laptop to be used but some software problem arises during the usage. Next Mr. Firas had suggest to use other software that can make my work easier without any programming which is Atoll 2.8 version and TEMS Cell Planner.

To obtain this software request letter has sent to Maxis, Digi and the vendors Ericsson, Ascom and Huawei to get at least the trial version. It was unsuccessful.

Mr Firas manage to get the TEMS Cell planner and Atoll version 2.8 and also the latest version 3.2 from one of his colleague.

Stepping to the phase two which is the FYP2, there are 3 phase to plan LTE network which are initial planning, detailed planning and optimisation of the network. In this project objective is opened for the first and second phase only, where optimization is not in the scope of this project.

Initial planning consist of collecting some data and information about the desired coverage area which is Ipoh City, the QoS criteria, capacity or coverage requirement and the range of service that can be provided. Under the initial planning we have the dimensioning process that this project concentrated is on network configuration, link budget, capacity estimation and traffic estimation. This is done by taking some formulas from journals, books and relevant websites to help in link budget. Link budget calculation is done in Microsoft Excel to ease the tedious type of calculation and to make sure there is no error in the values. Additional dimensioning process that is not included is business model input and financial clarification or anything regarding cost.

Detailed planning is the second phase in network planning which contributes on site selection, coverage and capacity planning, configuration planning such as antenna configuration, information from the geographical location of Ipoh and parameters planning and estimation. In order to design a network architecture it is important to study the geographical of the area which also known as geographic information system (GIS). There are different data types that have different roles in Atoll documents. GIS is important to acknowledge whether the network design suits the site that we are planning. In Atoll we can export or create our own traffic map. Traffic map here means to determine the density of user distribution in the location. Atoll provides 3 types of traffic maps which is sector, user profile and user density traffic map. User density traffic map are used in this project with 2 types of user profile that will be explained in Chapter 4.

After collecting all the relevant database for simulation we use the user manual that have been provided to lead step by step to create the simulation. Set the number of user to each environment, set the parameters according to out link budget, such as the power, frequency band to be used, cell radius and number of sites needed. Since the project are going to focus more on the Greentown area, the transmitters are placed in the Greentown. The first reason is because that is most populated area in Ipoh city and other places are very less and most of the user's maximum utilization expected to be when they are at work. Second reason is, out the Greentown area a mostly rural areas where the exposure of LTE is very less. In the other hand, we have minimized the number of sites from 22 to 10 which is 45.5% lesser than the calculation estimation. If predicted using the 22 sites will produce 100% coverage what would be the coverage and capacity percentage if using just 10 transmitters? This question is will be answered via this project.

Finally implementing all this settings in Atoll, simulation work had started. At first ACP (Automatic Cell Planning) is used for the simulation but it is too advance for this project scope. Therefor 2 types of prediction which is Coverage of Throughput for Uplink and Downlink were selected, simulation for connectivity which will calculate the total number of user connected, not connected, no coverage, no service and Uplink Downlink users. Additionally interference had been calculated to determine the best server in this network planning. After the simulation data is collected and saved in Excel files to ease the transfer of the values. To get the desired result we need to keep track on the antenna configuration and the parameters that is used in order to achieve the objective. Maxis LTE network antenna specification used as the guideline to proceed with the simulations. Results have been displayed in the Chapter 4. Relevant discussion after a thorough analysis of the result will lead to achieving the objective of the project. A methodology chart have been created to simplify the work flow of the simulation process. This chart explains briefly on the process how to set up a project in the Atoll tools.

1.2 Methodology Chart

The methodology chart illustrates the procedure path.

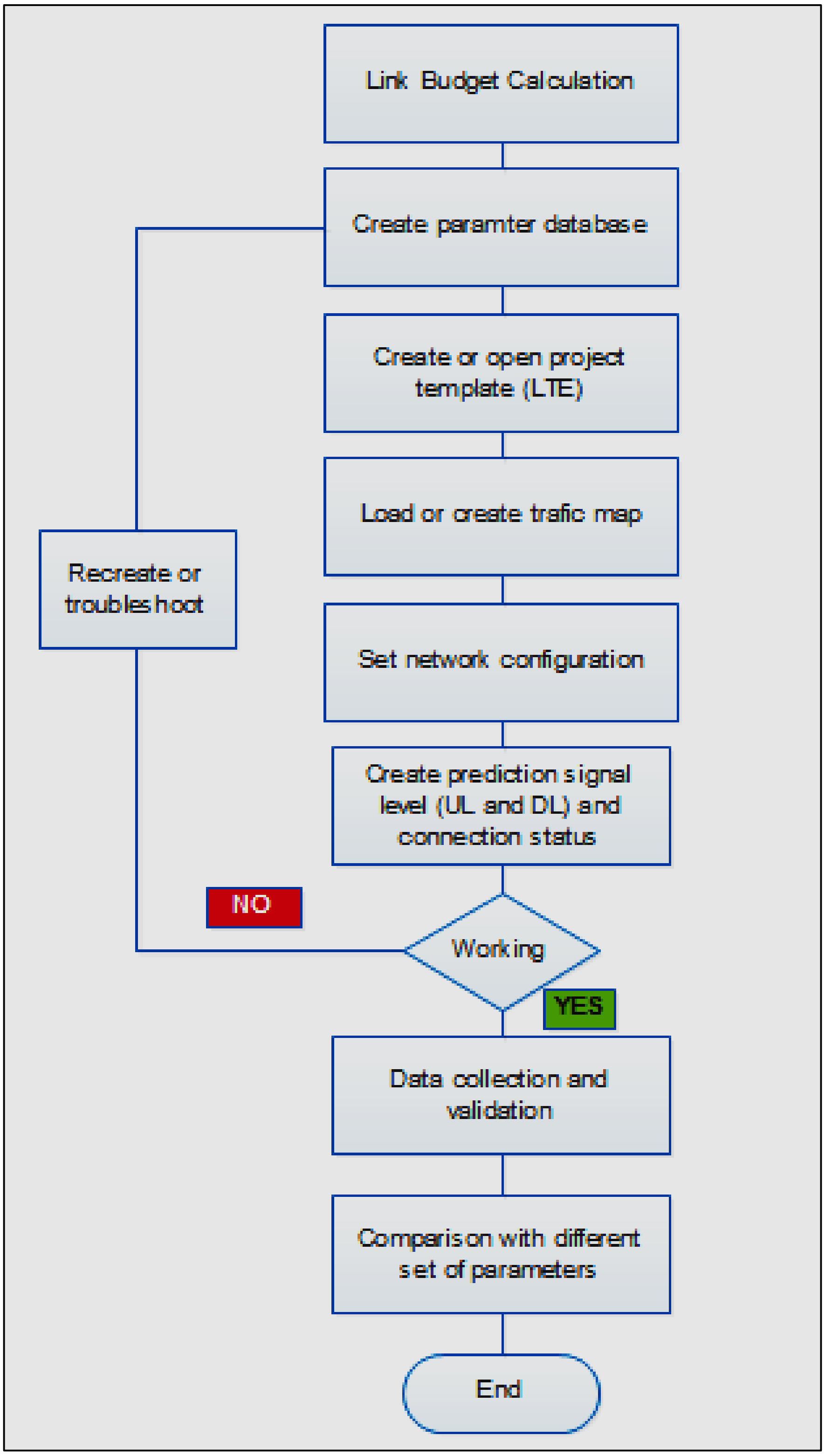


Chart 1 : Methodology chart

1.3 Network Architecture Design

A good communication is obtained through well planned network that able to fulfil the users demand. To design the network architecture first we need to decide on the number of sites and transmitter needed to suit LTE interface to produce suitable coverage and capacity to support the users. Changes in the number of users will change in the requirement and therefore might affect the number of sites in order to provide a good network.

In the other hand, antenna specification is investigated during the design work. Since LTE uses MIMO method where it consist of two antenna to deliver fast speed signal compare to other networks. This includes the electrical and mechanical properties of the antenna. As the progress of the project improves, more calculation are to be carried out to obtained values that will lead the project to achieve the objective such as the number of user per site, relationship and impact of coverage and capacity on the network planning.

In the end of the project, deliverables that expected to be present are such as:

a. Novel design architecture for LTE network.
b. Number of sites required for Ipoh city to provide good coverage and capacity.
c. Estimation for future demands of users in terms of number of sites to provide satisfactory network coverage and capacity.
d. Antenna specification which can contribute to achieve the objective.

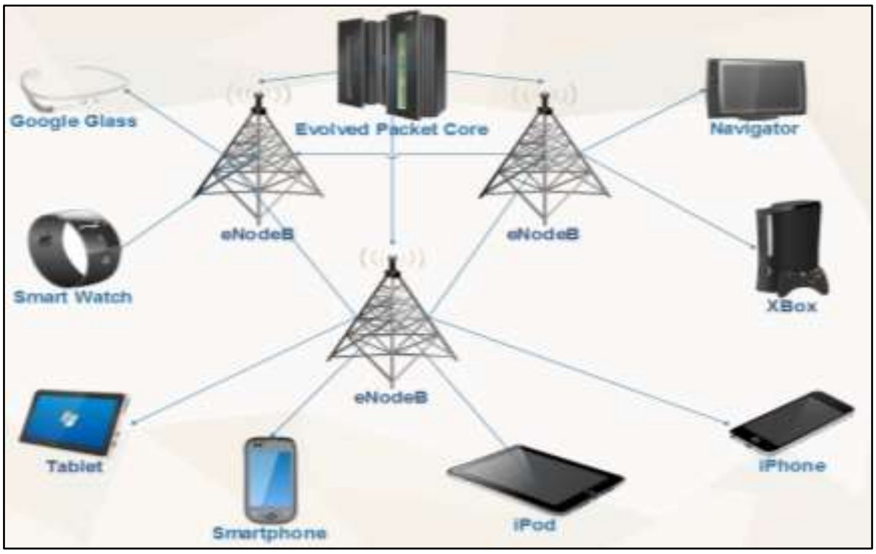


Figure 12 : Simple LTE network architecture design

1.4 Tools Used

Tools that used for the RF network planning is Atoll Radio Planning and Optimization Software version 3.2 which provides a comprehensive and integrated set of tools and features to create and define radio-planning in a single application [5]. Atoll uses familiar Windows interface elements to make it as user friendly and it is easy to integrate with other program or software such as MapInfo and Google Earth.

1.4.1 Atoll Radio Planning and Optimisation Software

Atoll is a simulation with less scripting and Service-Oriented Architectures (SOA) mechanism based which is the first LTE network planning software. Atoll comprises different geographical data to help in simulation on planning and dimensioning the network. Version 3.2 is released on 2014 provides a wide selection of tools to facilitate radio-planning, such as a search tool to locate either a site, a point on the map, or a vector [Atoll manual]. In addition to that Atoll provides automated calculation and decision in order to ease the simulation. Atoll support technologies as listed below:

a. LTE
b. GSM/GPRS/EDGE
c. UMTS/HSPA
d. CDMA2000 1xRTT/EV-DO
e. WIMAX/BWA
f. Wi-Fi
g. Microwave Links
h. TD-SCDMA

Atoll includes unlimited possibilities and improved performance to support increase in demand of network planning such as multi-technology Monte Carlo simulation and other predictions. With highly performed GIS developed with large scale and high resolution geographical lead to a good data manipulation of network planning as well optimisation. Multiple type of file supported in order to ease the user to work with this software. Multiple modelling network, provided ACP (Automatic Cell Planning) to give further network optimisation plan. With the help of Atoll's C++

SDK implementation of functional value added module can be customized. In the manual provided, each simulation and result are explained step by step for beginners. Additionally, tips and tricks are given for the user to master. Atoll is a virtual software with multi user base that can be used in various machine and compatible to Windows 7. Atoll allow the user to convert their report or result into other files format such as Excel files or text files for data collection. It is a very useful software for RF planning and there are many features that can be found especially for those who are expert under network planning.

Atoll allows to design the base station, number of sites on the location and calculate some parameters automatically without any manual scripting. Additional features can be added or created such as creating special antenna to be replaced in the simulation for better performance. Coverage and capacity of the network can be easily seen via colours or by numbers in the software. Almost all parameters can be edited before or after the simulation. Atoll allow us to study more than we needed from this project, this will help to understand the behaviour of the network we have created very well.

1.5 Gantt chart Final Year Project I and II

1.5.1 Gantt chart Final Year Project I:

DESCRIPTION	DURATION (WEEK)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TITLE SELECTION/PROPOSAL	√													
LITERATURE REVIEW		√	√	√	√					√	√	√		
EXTENDED PROPOSAL					√	√								
SOFTWARE INSTALLING AND CONFIGURATION				√	√		√							
LINUX OS PC REQUEST								√	√					
PROPOSAL DEFENSE									√					
PROGRESS EVALUATION									√					
Project Work in Progress											√	√		
DRAFT REPORT/INTERIM													√	
FINAL REPORT/INTERIM REPORT														√

Chart 2 : Gantt chart FYP I

1.5.2 Gantt chart Final Year Project II:

DESCRIPTION	DURATION (WEEK)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SELECTION OF PARAMETERS	√	√												
NETWORK DESIGNING			√	√	√									
SIMULATION OF NETWORK ARCHITECTURE					√	√	√							
PROGRESS REPORT								√						
SIMULATION AND PARAMETER COMPARISON								√	√	√	√	√		
ELECTREX											√			
DRAFT FINAL REPORT												√	√	
FINAL REPORT													√	√
TECHNICAL PAPER													√	√
VIVA	STUDY WEEK													

Chart 3 : Gantt chart FYP II

CHAPTER 4

RESULTS AND ANALYSIS

This chapter will show the parameters that have been used throughout this project as well some conversion to fit into the Atoll simulator to obtain the best results. The results will be analysed to conclude the best antenna and parameters that can be used in order to provide the best coverage and capacity by supporting the maximum user. Additionally we will analyse the interference and also the power to optimise the obtained result.

4.1 Input Data

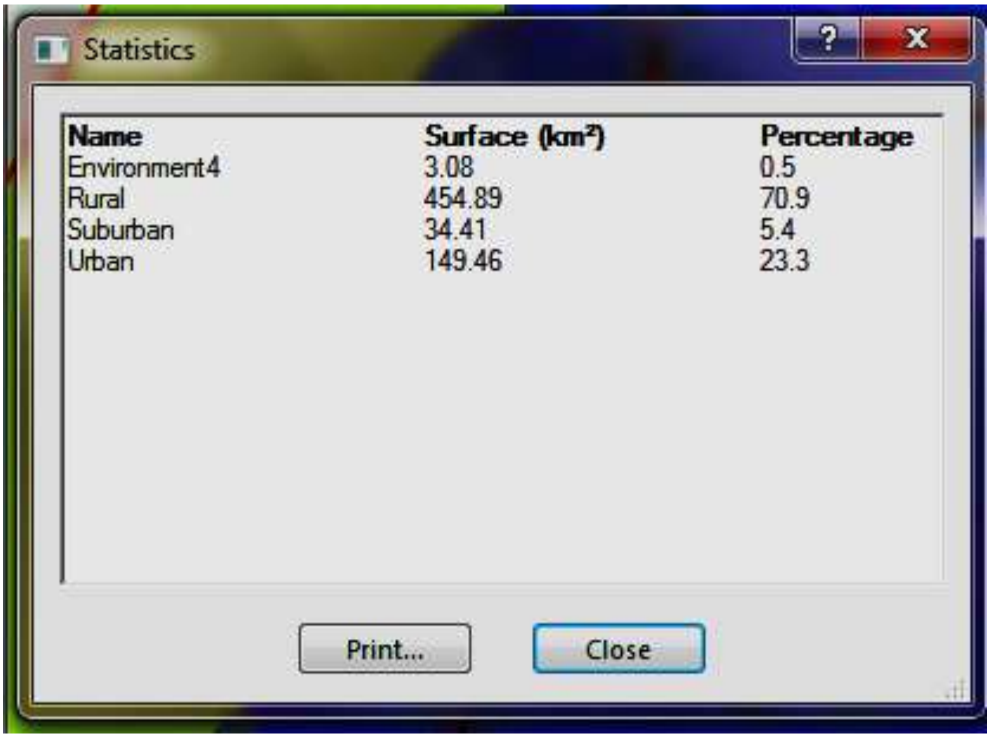
Input date here is the parameter that implemented in simulation to obtain the result. In addition to that, the map used as the input of traffic map is compared to show it is similar to the real area map.

4.1.1 Geographical area

Figure 13 : Ipoh City area [25]

Ipoh is the capital city of Perak Darul Ridzuan. Ipoh consist of 643 km^2 from 21035 km^2. Perak is known as second largest state in Peninsular Malaysia. Population of Perak is about 2.447 million (2013) and Ipoh consist of 213 578 [25]. Statistically Ipoh is about 8.73 % of Perak population with 3.05% area. In this project we are focusing on the Green town and with population demand of 20 000 which is about 150 km^2 of Ipoh city. Green town is the area most of the business and transactions are made compare to other small towns such as Batu Gajah. Therefore it is important to study the demographic of the area to help in LTE user estimation. In addition to that this information will help in creating the traffic map which is difficult to obtain from the online source.

In order to estimate population of user according to the area which also known as traffic map. An approximate map comprising the environment is need to be created. According to the Ipoh's real map and it's industrial also business distribution, a map created in Figure 14.



Name	Surface (km^2)	Percentage
Environment4	3.08	0.5
Rural	454.89	70.9
Suburban	34.41	5.4
Urban	149.46	23.3

Figure 14: Area Statistic of Ipoh City

As mentioned in the figure, the total area is 643 km^2 which the total area of Ipoh City. This have been illustrated in Atoll map for simulation.

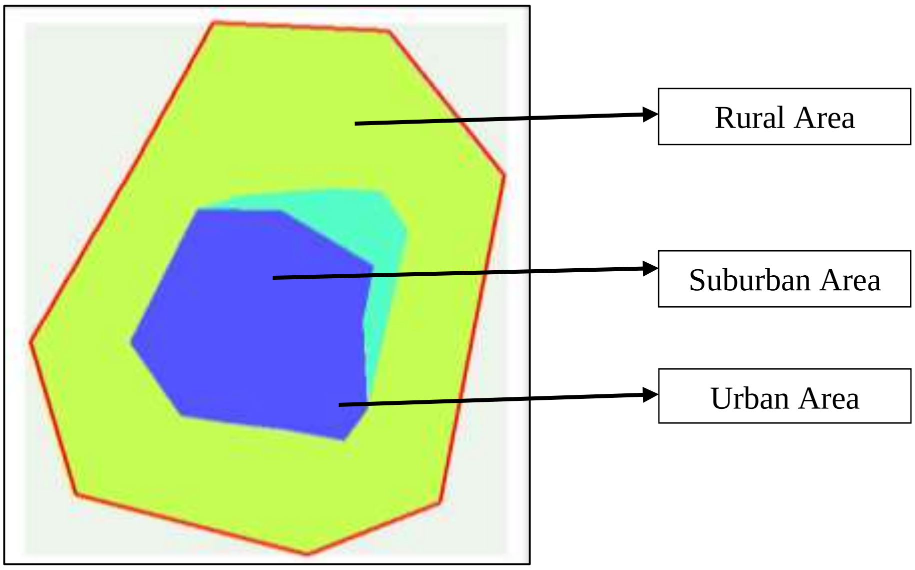


Figure 15: Ipoh City Traffic Map

Comparing both of the map from the Google earth and map that have been created in Atoll gives almost 99% similarities. Figure 15 show the both images for comparison.

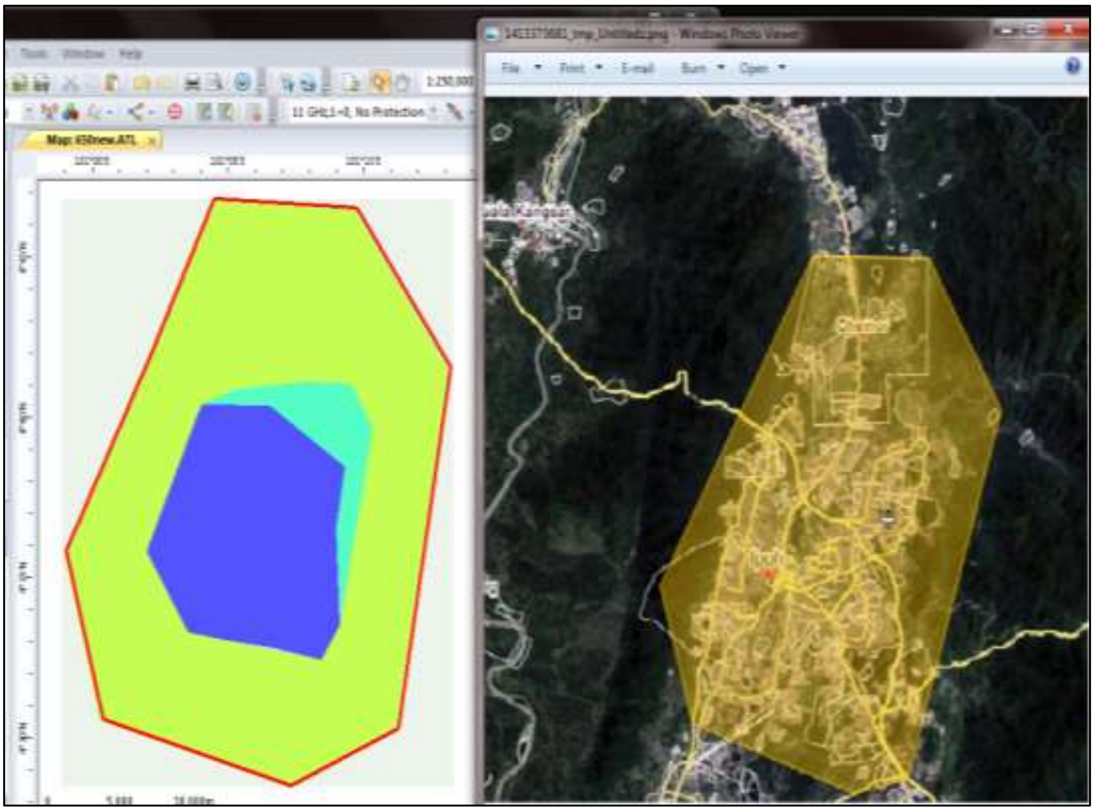


Figure 16 : Comparing map from Google Earth and Atoll traffic map

4.1.2 User Distribution

User distribution is a prediction of user population in Ipoh city which have divided into Business and Standard User as in the table with some specifications.

Table 2 : User profile and specifications

User Profiles	Service	Terminal	Calls/ hour	Duration (sec.)	UL Volume (KB)	DL Volume (KB)
Standard User	Mobile Internet Access	MIMO Terminal	0.1		700	4,500
	VoIP	Mobile Terminal	0.2	240		
Business User	High Speed Internet	MIMO Terminal	0.05		2,000	15,000
	Video Conferencing	MIMO Terminal	0.01	600		
	VoIP	Mobile Terminal	0.2	240		
	Mobile Internet Access	MIMO Terminal	0.1		700	4,500

By using this users profile we have set the distribution or the density of the users according to Traffic map as in Table 4. This will help to identify the maximum user that can be supported and the position of most LTE users are found. The user's mobility were selected to be fixed in order to maintain the total number of user in the respective area. Each environment have different density of user except for Environment 4 which is used as the forest area or area without any residents.

Table 3 : User profile density according to environment

Environment	User Profile	Density	Number of Users
Urban	Business User	84.37	12,609.7
	Standard User	49.98	7,469.7
Suburban	Standard User	1.71	58.9
Rural	Standard User	0.07	31.1

4.1.3 Other Input Parameters

These parameters are obtained from the link budget calculation. Some of the important formulas are explained in Chapter 4.2.

Table 4 : Link budget parameters

Parameters	**Symbol**	**Unit**	**Value**
Frequency	f	MHz	1800
Bandwidth	B		360000
Effective (Isotropic) Radiated Power	EIRP (UL)	dBm	24
Body Loss	Lb	dB	0
TX power	Pt	dB	43
TX antenna gain	Gt	dBi	18
BS Antenna Height	hb	m	30*
Mobile height	hr	m	1.5
Rx Antenna Gain	Gr	dBi	18
Rx Loss	Lr	dB	4
Rx Noise	Nr	dBm	-102.28
Noise Figure	Nf	dB	2
Interference Margin	Im	dB	2
Path Loss	L	dB	140.6923281
Free Space Path Loss	FSPL	dB	108.301832
Area of Hexagon shape of one eNodeB site	HeNBsite	sqkm	30.92360211
DL Cell Average Capacity	a	(Mbps)	8.9
Busy Hour DL Cell Loading	b	(%)	15
DL Cell Capacity in BH	c	(Mbps)	133.5
Peak to Average Ratio	d	(%)	20
BH DL Throughput/Sub.	e	(Kbps)	120
Sector Number/site	f		3*
Subs supported in a site	g		0.158928571
Max UE Power Transmission	dBm		33

Maximum Allowable Path Loss	MAPL		152.8244871
Link Distance	d	m	3.5
Path Loss (Hata Model)	Lhata	dB	137.0227547
Cell Radius (Hata Model)	Rcell-Hata	km	0.537903404
Rcell-Hata		km	3.45067
Select Cell Radius according to Propagation Model		km	3.45
Cell Area	Acell	km^2	20.591325
Inner Site Distance	D	km	6.9
Site Area	Asite	km^2	61.773975
Area to cover	A	km^2	175
Cell Range		km	6.9
Number of PRB			50
Power per PRB		dBm	31
Area of hexagonal shapefor one eNodeB site	Ahex		7.73067375
No of eNodeB for coverage			22.63709551

NOTE: * Values may vary

These parameters were calculated and some are extracted from [2] to maintain the assumption values to be correct and does not deviate from the real value that have been using worldwide. These values may vary according to country or might be changeable in the future.

4.1.4 Propagation Model

There are a lot of model that can be adapted, I have chosen Cost Hata as the propagation model due to some specification that suit Ipoh City area. Furthermore, most of the research is done on Urban areas are done by using Okumura Hata which is similar to Cost Hata but different in frequency range. In addition to that, Cost Hata model is nearer to the value that will be used in the simulation according to the calculated values compare to the Okumura Hata values. The criteria that used to select propagation model is as in the Table 4.

Table 5 : Propagation model criteria

Criteria	Range	Value used (Calculation)
Frequency (MHz)	1500 - 2000	1800
Base Station Antenna Height (m)	30 – 200	15 - 30
Link Distance (Km)	1 – 20	3.5
Mobile Antenna Height (m)	1 - 20	1.5

4.1.5 Types of Antenna

The table explains the antenna type that provided by Atoll with the features that have been implemented in this project.

Table 6 : Antenna and specifications

Name	Gain (dBi)	Comments	Pattern Electrical Tilt (°)	Half-power Beamwidth	Min Frequency (MHz)	Max Frequency (MHz)
30deg 18dBi 0Tilt 1800MHz	18	1800 MHz	0	30	1,710	1,900
33deg 18dBi 0Tilt 1800MHz	18	1800 MHz	0	33	1,710	1,900
60deg 18dBi 0Tilt 1800MHz	18	1800 MHz	0	60	1,710	1,900
65deg 18dBi 0Tilt 1800MHz	18	1800 MHz	0	65	1,710	1,900
70deg 18dBi 0Tilt (SA Broadcast)	18	Smart antenna broadcast pattern	0	70	1,710	1,900
90deg 14.5dBi 3Tilt (SA Element)	18	Smart antenna element pattern	0	90	1,710	1,900
Omni 18dBi 0Tilt 1800MHz	18	1800 MHz	0	360	1,710	1,900

4.2 Related Calculations

There are a lot of calculation involved in the simulation. All the calculations are done in Excel files with the help of Excel formulas to have a precise values as well to save time doing manual calculations.

4.2.1 Geographical coordinate converter

The coordinate of Ipoh city area from Google earth is converted from latitude and longitude to x and y coordinates to be edited in Atoll simulator for traffic map.

Table 7 : Coordinate of Ipoh city area

Name	Longitude °E	Latitude °N	Longitude, ° (Y)	Latitude, ° (X)	X coordinate	Y coordinate
A	101.1206034	4.73630018	101° 7' 14.1708"	4° 44' 10.6794"	735222.9926	523874.9853
B	101.0862711	4.71850813	101° 5' 10.575"	4° 43' 6.6282"	731418.9849	521895.4454
C	101.1552789	4.72124540	101° 9' 19.0038"	4° 43' 16.4814"	739076.2462	522221.5578
D	101.1786249	4.66547144	101° 10' 43.0494"	4° 39' 55.6956"	741686.3601	516060.0847
E	101.1626604	4.59104224	101° 9' 45.576"	4° 35' 27.7506"	739939.5823	507821.5943
F	101.1511216	4.49650901	101° 9' 4.0392"	4° 29' 47.4318"	738689.9094	497360.9875
G	101.1044297	4.48008006	101° 6' 15.9474"	4° 28' 48.288"	733511.8268	495528.6657
H	101.0048661	4.51499114	101° 0' 17.5176"	4° 30' 53.9676"	722448.8492	499359.0056
I	101.0254655	4.59644379	101° 1' 31.677"	4° 35' 47.1978"	724710.0796	508374.4695
J	101.0604844	4.68883678	101° 3' 37.7424"	4° 41' 19.8132"	728567.0528	518605.0182
K	101.0714708	4.72579056	101° 4' 17.2956"	4° 43' 32.8476"	729774.1544	522696.0464
L	101.0920701	4.50746144	101° 5' 31.452"	4° 30' 26.8596"	732131.1036	498553.399
M	101.0182557	4.55161175	101° 1' 5.721"	4° 33' 5.8032"	723923.8126	503413.5445
N	101.0718141	4.70491876	101° 4' 18.5304"	4° 42' 17.7084"	729819.1163	520387.543

4.2.2 Antenna Down tilt Angle

By using the height of the base antenna height and remote antenna height we can calculate the tilt angle or the distance. Below is the illustrations and formula used:

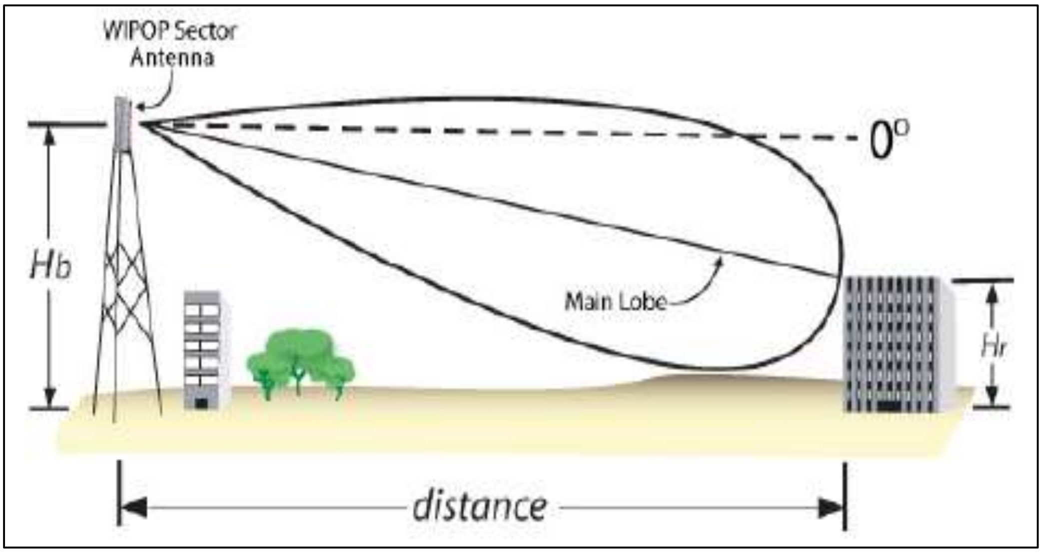


Figure 17: Example of the remote antenna and base antenna placement [26]

Formula:

$$\text{Distance} = \frac{\frac{\text{Hb} - \text{Hr}}{\text{Tan A}}}{D} \quad [26]$$

$$\text{Angle} = \text{Tan}^{-1}\left(\frac{\text{Hb} - \text{Hr}}{\text{D}}\right) \quad [26]$$

Hb = Height of base antenna

Hr = Height of remote antenna

D = Distance

A = Downtilt Angle (°)

4.2.3 Downtilt Coverage Radius

Downtilt coverage radius can be used to predict the coverage than can be produce by the antenna according to antenna height that we have set. This may vary if the parameters are changed. Below is the illustration and formula used:

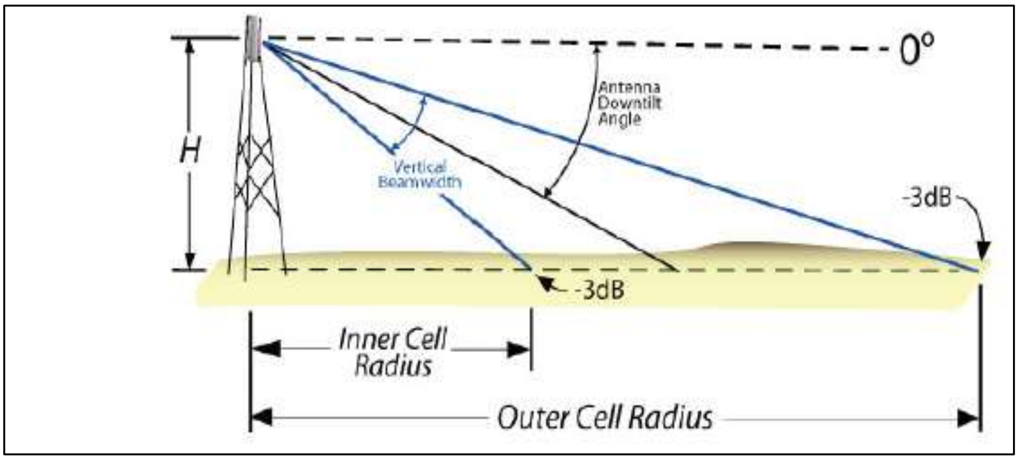


Figure 18 : Example of down tilt coverage [27]

Formula:

Inner Radius Distance

$$= \frac{\frac{H}{\mathrm{Tan}(A + \frac{B}{2})}}{D} \qquad [27]$$

Outer Radius Distance

$$= \frac{\frac{H}{\mathrm{Tan}(A - \frac{B}{2})}}{D} \qquad [27]$$

B = Bandwidth

D = Distance (km)

A = Downtilt Angle (˚)

A. Signal to noise ratio [23]

i. Thermal noise , N_T

$$N_T = 10\log_{10}(kT\Delta f)$$

T = Temperature [Kelvin]

k = Boltzmann constant

B = Bandwidth

ii. SNR (Signal to Noise Ratio) [23]

$$\text{SINR} = \frac{\text{MHA Gain } \times \text{Tx Power}}{\text{N}_\text{T} \times \text{Interference}}$$

4.2.3 Path loss

Path loss also known as the path attenuation where is a calculation of power density reduction or the attenuation of an EM wave as the wave propagates in space. The major component of link budget is the path loss.

[24]

$$\text{L} = \text{P}_\text{t} + \text{G}_\text{t} - \text{L}_\text{b} - \text{SINR} + \text{G}_\text{r} - \text{L}_\text{r} - \text{N}_\text{r}[]$$

P_t - Transmitter Power

G_t - Transmitter Antenna Gain (dBi)

L_b - Body Loss (dB)

G_r - Receiver Antenna Gain (dBi)

L_r - Receiver Loss (dB) 0.5

N_r - Receiver Noise (dBm)

4.2.4 Cell radius

Using Cost Hata propagation model, LTE cell radius determined with the following formula [23]:

$$L = 46.3 + 33.91 log_{10}\,(f) - 13.82\ log_{10}(h_b) - \ h_m + \left(44.9 - 6.55\ \ log_{10}\,(h_b)\right)\ log_{10}\,(d) + C_m$$

$$\text{h}_{(\text{mobile})} = (1.11\ \text{log}_{10}\ \text{f} - 0.7)\text{h}_\text{m} - (1.56\text{log}_{10} - 0.8)$$

d = cell radius (km)

C_m = 3 dB and 0 dB for urban area

h_b = Base station antenna height (m)

f = Downlink or Uplink frequency (Hz)

4.2.5 Cell area

$A_{cell} = K \times R^2$ [23]

R = cell radius (km)

K = Constant according too number of sector

Table 8 : Cell layout K parameter

Cell Layout	K
Omni	2.6
2 sector	1.95
3 sector (BW ≤ 90)	1.73
3 sector (BW > 90)	2.6
6 sector	2.6

4.2.6 Site Area

$A\ site = A\ cell \times S$ [23]

S = Sector number

4.2.7 ENodeB Number

$N_{eNB} = \frac{A}{Asite}$ [23]

A = Total area to cover

4.2.6 Uplink Dimensioning

Uplink basically known as the method of sending information from ground level to antenna or satellite in the space. If only uplink process happened it's known as download which a one way communication. Formula below can be used to calculate the uplink frequency of the

$$\text{Uplink: MAPL} = EIRP_{UL} - S_{eNB} - LNF - IM_{UL} - L_{pen} - L_{bodyLoss} + G_{eNB\ Antenna} + G_{eNB\ TMA}$$

network:

4.2.7 Downlink Dimensioning

Downlink known as the transmission of data or signal from the satellite to the ground level. If only downlink process is happening, it is known as the download process. Two way communication created if both uplink and downlink happens at the same time. The formula

$$\text{Downlink: MAPL} = EIRP_{DL} - S_{UE} - LNF - IM_{DL} - L_{pen} - L_{bodyLoss} + G_{EU\ Antenna}$$

below can be used to calculate the downlink frequency of the network:

Where;

- MAPL - Maximum Allowable Path Loss
- EIRP: Equivalent Isotropic Radiated Power
- S-Rx: Receiver Sensitivity
- LNF: log normal fading margin
- IM: Interference Margin
- G -antenna: Antenna Gain
- G-shad - Gain Against Shadowing
- L-pen - Penetration loss
- L-feeder: Feeder Loss
- L-body - Body Loss

4.3 Simulation Results

4.3.1 Parameter setting

Important properties that have been set in order to get the desired network coverage and capacity. There are 3 important parameters are changed in order to obtain the best coverage, capacity and maximum user that can be supported. According to the objective, antenna and its parameters are important since we are investigating the relationship between the impact of antenna towards the network coverage and capacity. Figure 18 illustrates the parameters that are involved in the simulation to achieve the objective.

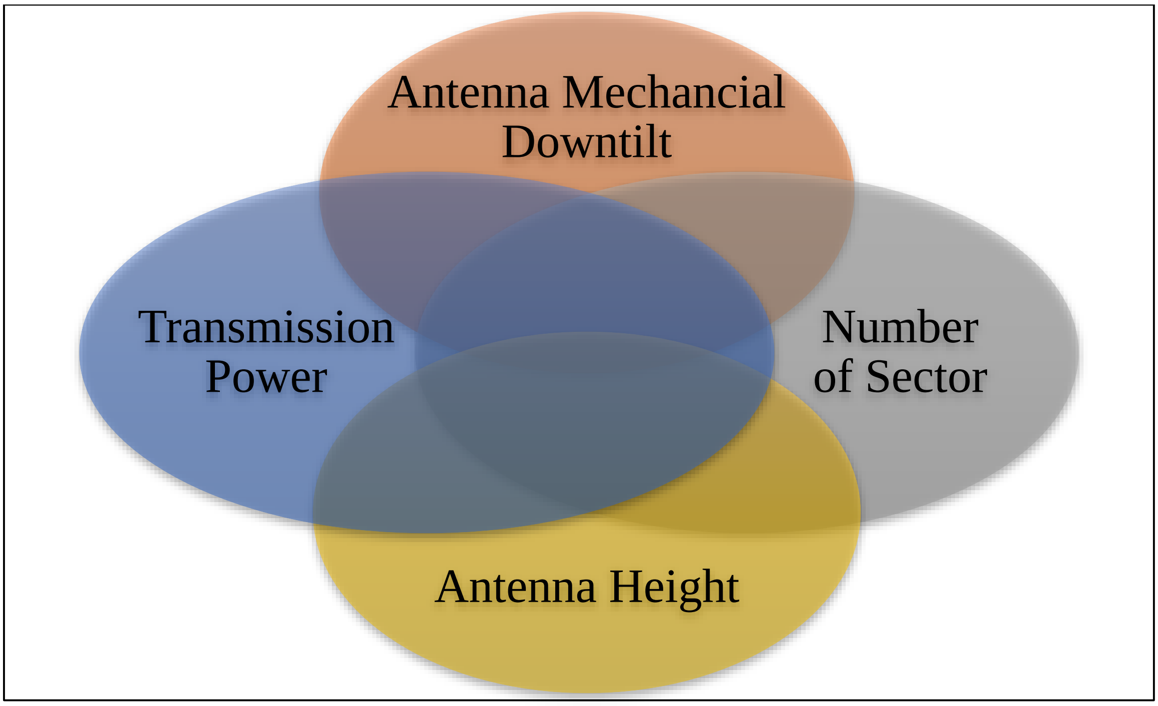


Figure 19 : Variable inputs that involved in simulation

Table 9 : Parameter and the range used

Parameter	Range
Antenna Mechanical Downtilt (˚)	0 - 10
Antenna Height (m)	15 - 30
Number of Sector	3 and 6
Transmission Power (dBm)	43 - 47

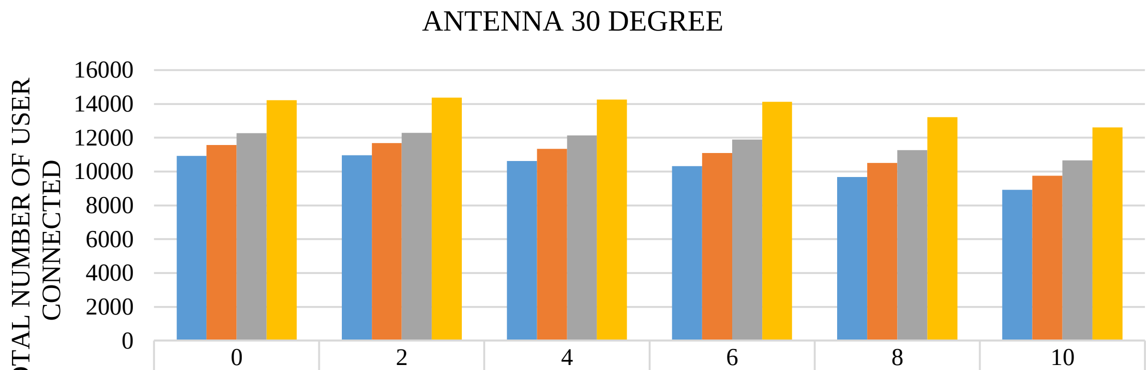
4.3.2 Antenna Study

Simulation with all the estimated parameters shows that antenna plays an important part in designing a network. In LTE network designing there are some specifications need to be satisfied in order to achieve the standard of the network. Thus, from antenna till setting the parameters as well placing the site is important. Antenna polarization, wavelength, bandwidth and other antenna parameters. Beginning study of antenna is essential in order to understand the features and specification. Some of the parameters are maintained as a constant since the real value can’t be obtained. The antenna are changed to be similar to the antenna that Maxis is using currently to produce LTE network in Malaysia which is the Agisson ATR451606 Triband Antenna (G900/W900, G1800/L1800, and W2100/L2600). In this project, seven types of antenna have be used to select the best medium to be used to prove LTE network. Each antenna’s gain and electrical tilt are sustained as mentioned above. After choosing the best antenna type, mechanical tilt and height, we continue simulation to find the best transmission power that can fit to perform at its best. Mechanical tilting here is antenna tilting without changing the input signal phase and electrical tilting here is changing the input signal phase to change the direction of signal to be transmitted.

4.4 Capacity

4.4.1 3 Sector antenna

A. Antenna 33 degree with multiple mechanical tilt and height

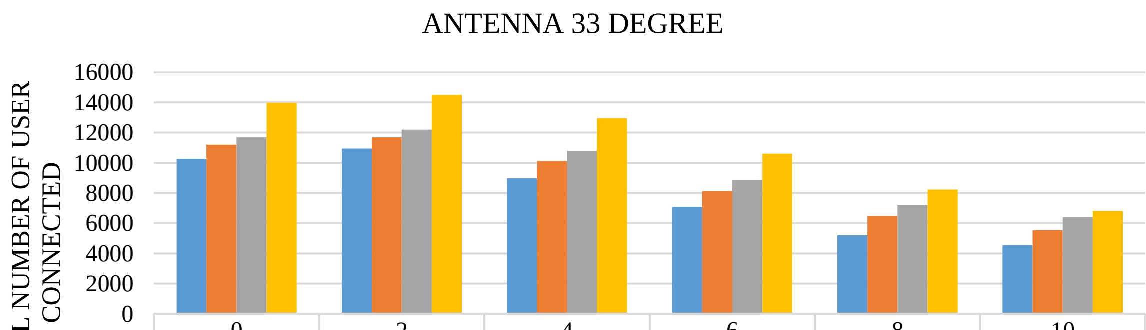


	0	2	4	6	8	10
30_15	10935	10960	10622	10327	9672	8918
30_20	11564	11691	11342	11093	10509	9754
30_25	12261	12283	12137	11899	11266	10658
30_30	14214	14373	14252	14120	13215	12614

Graph 1: Antenna 30 degree

The graph illustrates the result from antenna 30 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

B. Antenna 33 degree with multiple mechanical tilt and height

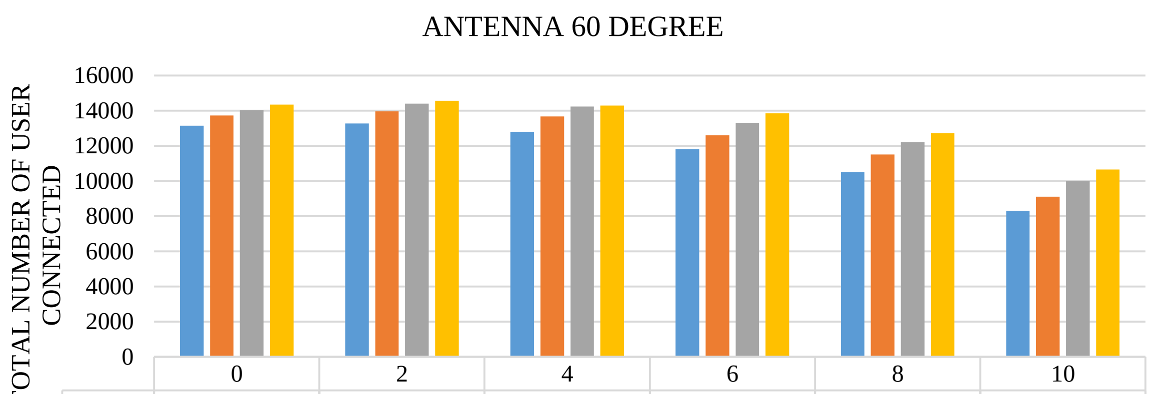


	0	2	4	6	8	10
33_15	10274	10957	8979	7096	5193	4555
33_20	11209	11685	10127	8124	6479	5550
33_25	11695	12201	10792	8857	7222	6412
33_30	13991	14511	12958	10611	8228	6811

Graph 2 : Antenna 33 degree

The graph illustrates the result from antenna 33 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

C. Antenna 60 degree with multiple mechanical tilt and height

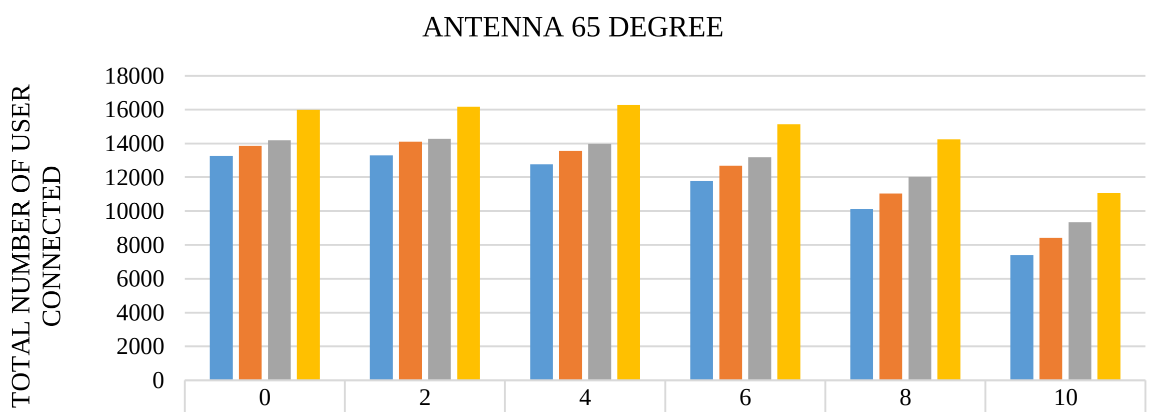


	0	2	4	6	8	10
65_15	13144	13265	12799	11818	10502	8299
65_20	13720	13952	13666	12595	11515	9104
65_25	14031	14394	14231	13297	12222	10006
65_30	14347	14567	14292	13857	12725	10649

Graph 3 : Antenna 60 degree

The graph illustrates the result from antenna 60 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 2˚ with the height 30 meter gives the highest total number of user connected.

D. Antenna 65 degree with multiple mechanical tilt and height

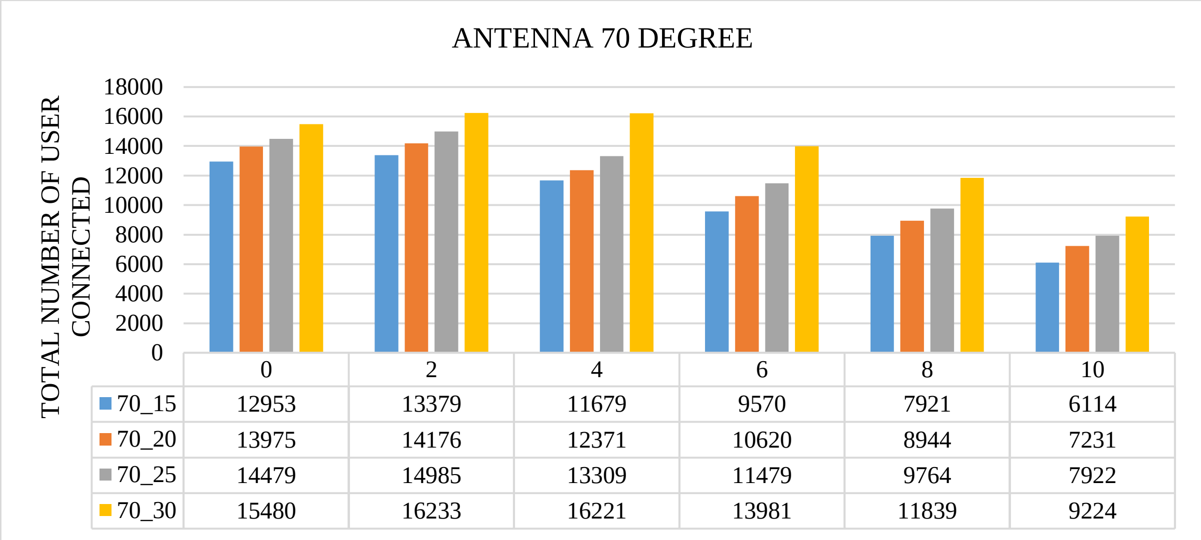


	0	2	4	6	8	10
60_15	13253	13294	12757	11776	10136	7397
60_20	13859	14099	13557	12690	11036	8432
60_25	14181	14273	13966	13180	12032	9328
60_30	15993	16168	16261	15134	14241	11064

Graph 4 : Antenna 65 degree

The graph illustrates the result from antenna 65 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 4˚ with the height 30 meter gives the highest total number of user connected.

E. Antenna 70 degree with multiple mechanical tilt and height

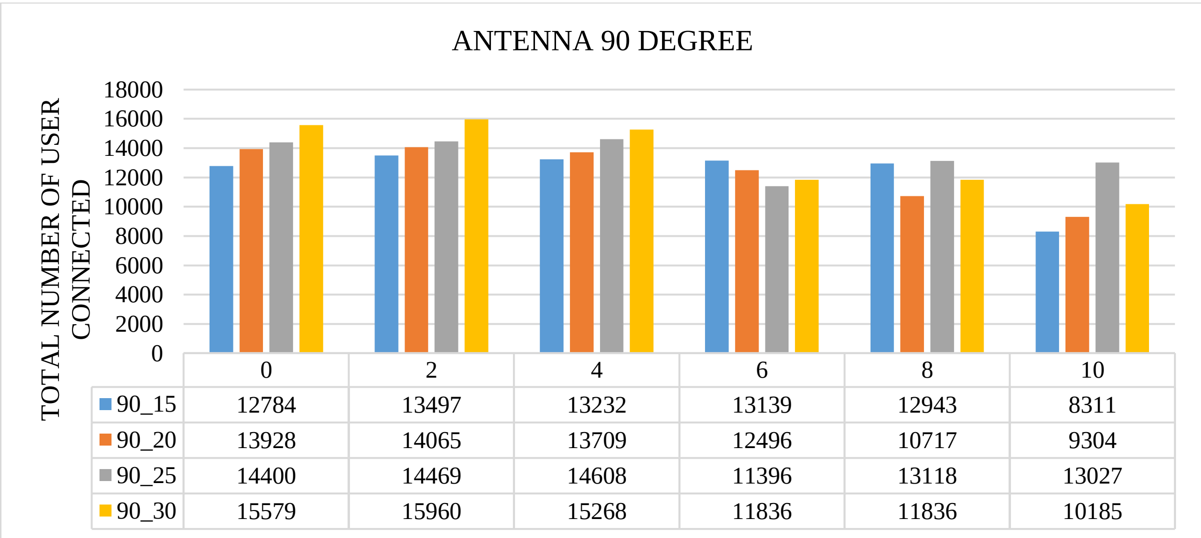


	0	2	4	6	8	10
70_15	12953	13379	11679	9570	7921	6114
70_20	13975	14176	12371	10620	8944	7231
70_25	14479	14985	13309	11479	9764	7922
70_30	15480	16233	16221	13981	11839	9224

Graph 5 : Antenna 70 degree

The graph illustrates the result from antenna 70 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 2˚ with the height 30 meter gives the highest total number of user connected.

F. Antenna 90 degree with multiple mechanical tilt and height

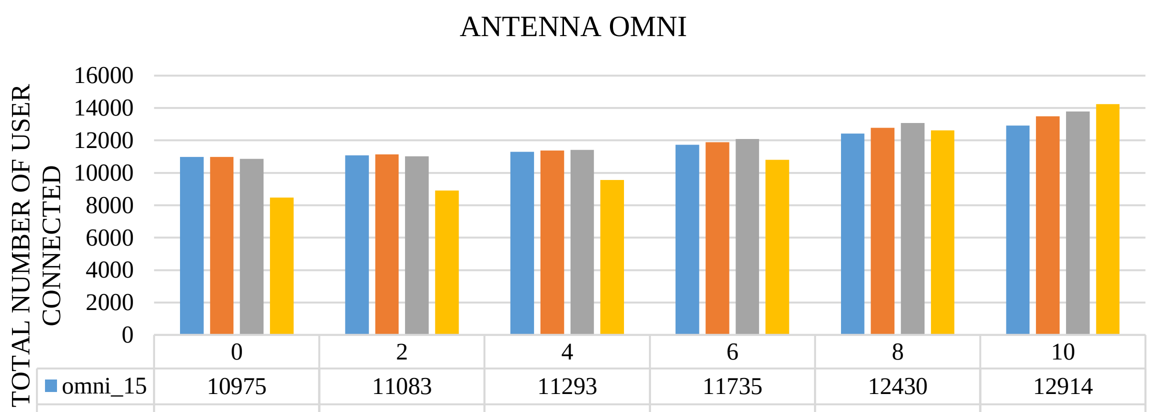


	0	2	4	6	8	10
90_15	12784	13497	13232	13139	12943	8311
90_20	13928	14065	13709	12496	10717	9304
90_25	14400	14469	14608	11396	13118	13027
90_30	15579	15960	15268	11836	11836	10185

Graph 6 : Antenna 90 degree

The graph illustrates the result from antenna 90 degree varying the mechanical tilt and height. The results shows that mechanical tilt with 2˚ with the height 30 meter gives the highest total number of user connected.

G. Omni antenna with multiple mechanical tilt and height



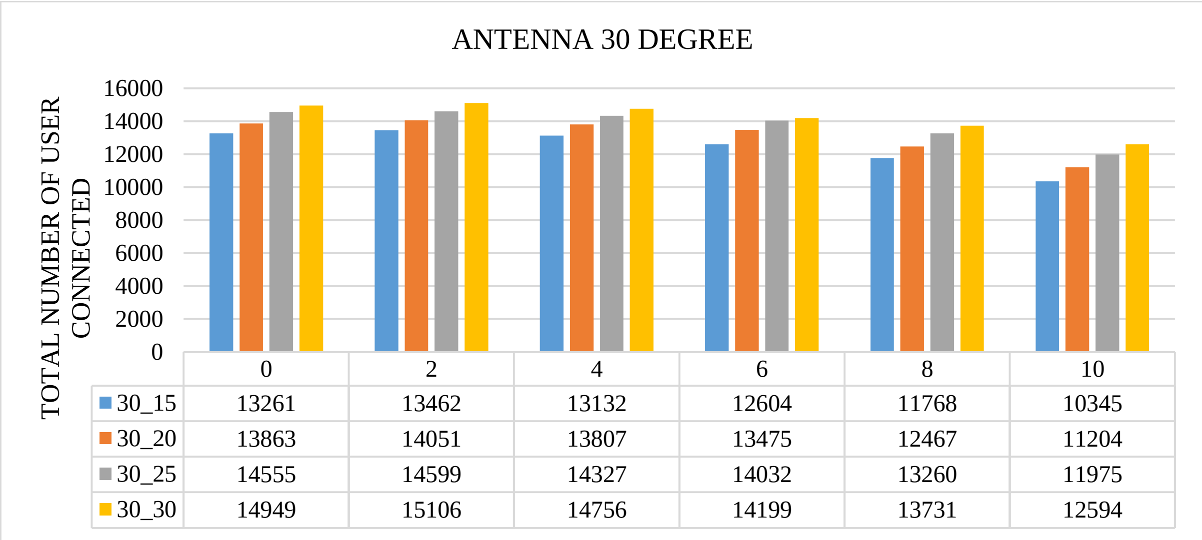
	0	2	4	6	8	10
omni_15	10975	11083	11293	11735	12430	12914
omni_20	10970	11138	11370	11889	12767	13496
omni_25	10853	11021	11419	12076	13065	13786
omni_30	8473	8902	9555	10795	12627	14239

Graph 7 : Omni antenna

The graph illustrates the result from Omni antenna varying the mechanical tilt and height. The results shows that mechanical tilt with 10˚ with the height 30 meter gives the highest total number of user connected.

4.4.2 6 Sector antenna

A. Antenna 30 degree with multiple mechanical tilt and height

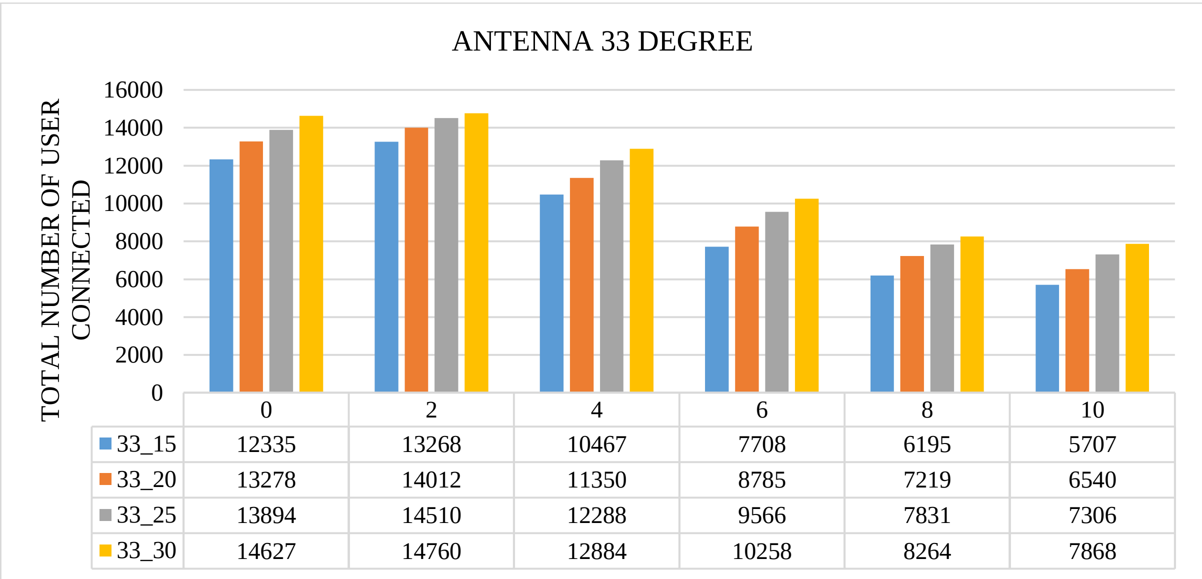


	0	2	4	6	8	10
30_15	13261	13462	13132	12604	11768	10345
30_20	13863	14051	13807	13475	12467	11204
30_25	14555	14599	14327	14032	13260	11975
30_30	14949	15106	14756	14199	13731	12594

Graph 8 : Antenna 30 degree (6 sector)

The graph illustrates the result from antenna 30 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

B. Antenna 33 degree with multiple mechanical tilt and height

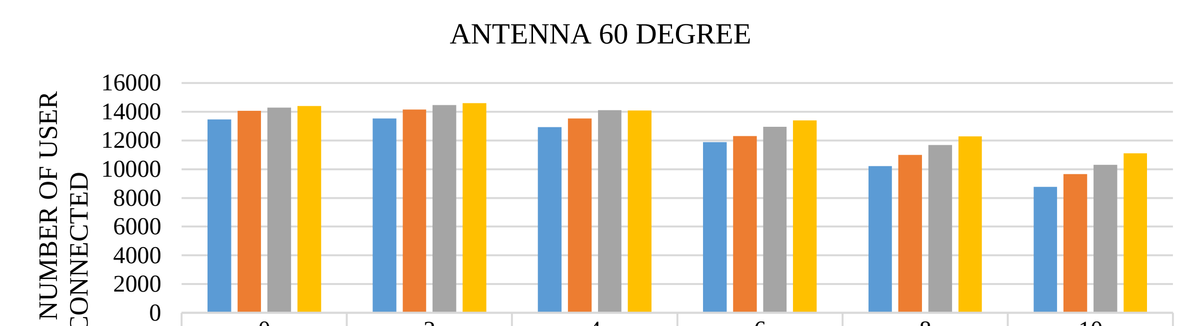


	0	2	4	6	8	10
33_15	12335	13268	10467	7708	6195	5707
33_20	13278	14012	11350	8785	7219	6540
33_25	13894	14510	12288	9566	7831	7306
33_30	14627	14760	12884	10258	8264	7868

Graph 9 : Antenna 33 degree (6 sector)

The graph illustrates the result from antenna 30 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

C. Antenna 60 degree with multiple mechanical tilt and height

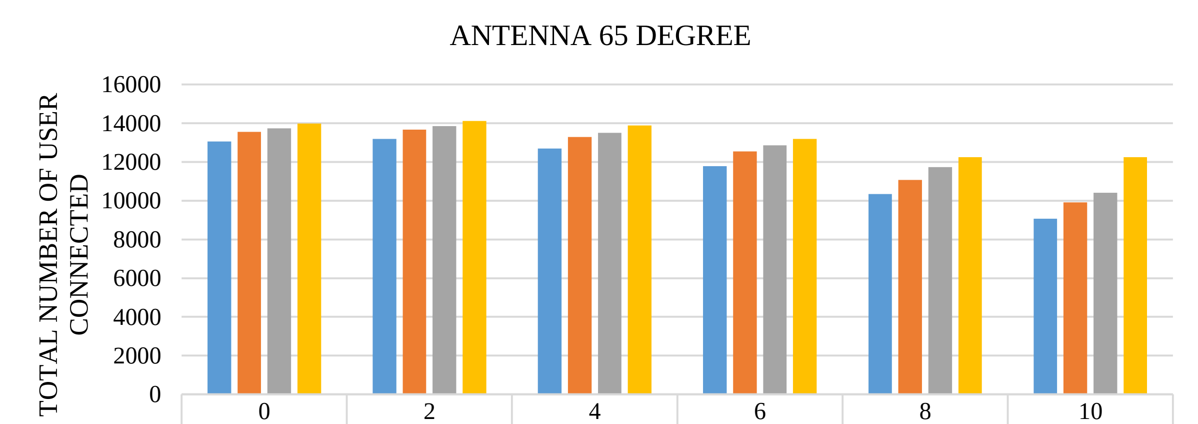


	0	2	4	6	8	10
60_15	13457	13530	12933	11885	10210	8774
60_20	14056	14138	13518	12301	10988	9654
60_25	14288	14453	14107	12949	11675	10294
60_30	14388	14600	14073	13396	12272	11091

Graph 10 : Antenna 60 degree (6 sector)

The graph illustrates the result from antenna 60 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

D. Antenna 65 degree with multiple mechanical tilt and height

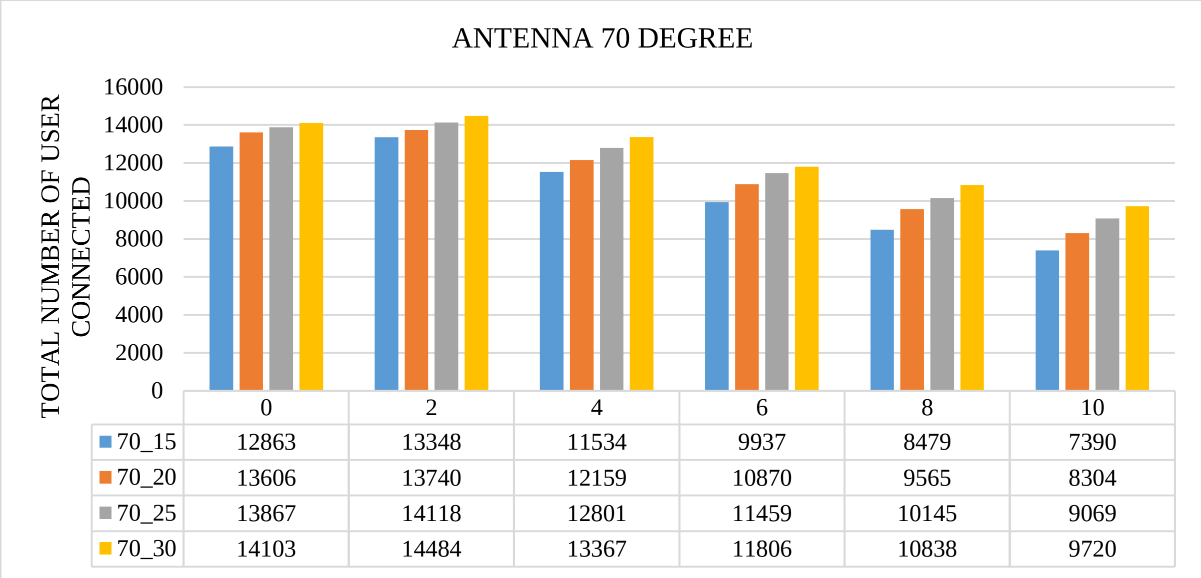


	0	2	4	6	8	10
65_15	13060	13181	12686	11777	10337	9066
65_20	13548	13669	13285	12546	11066	9916
65_25	13740	13856	13495	12853	11731	10412
65_30	13991	14122	13891	13182	12238	12238

Graph 11 : Antenna 65 degree (6 sector)

The graph illustrates the result from antenna 65 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

E. Antenna 70 degree with multiple mechanical tilt and height

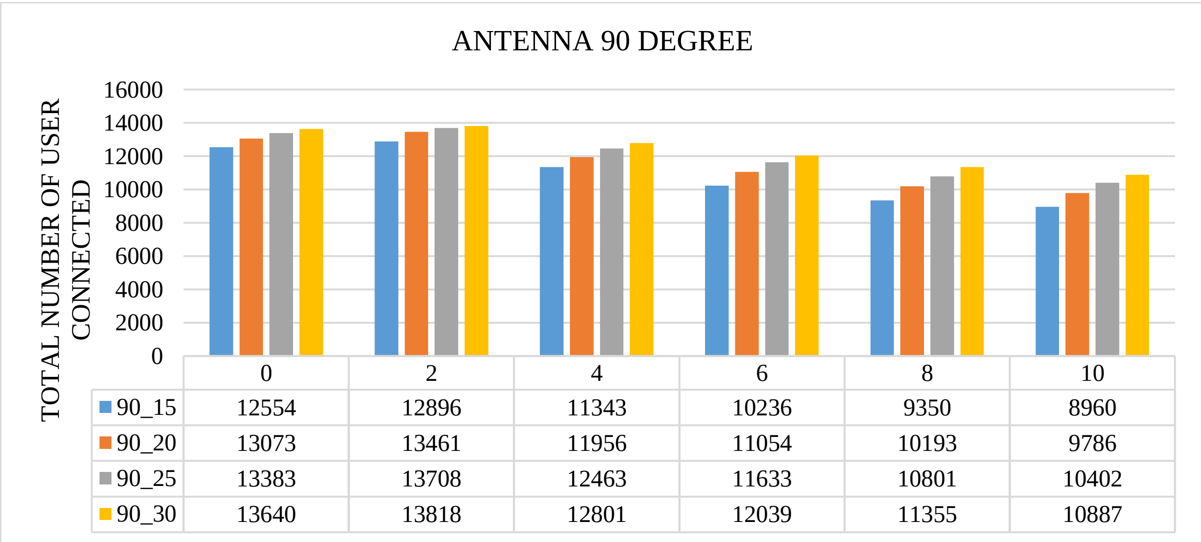


	0	2	4	6	8	10
70_15	12863	13348	11534	9937	8479	7390
70_20	13606	13740	12159	10870	9565	8304
70_25	13867	14118	12801	11459	10145	9069
70_30	14103	14484	13367	11806	10838	9720

Graph 12 : Antenna 70 degree

The graph illustrates the result from antenna 70 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

F. Antenna 90 degree with multiple mechanical tilt and height

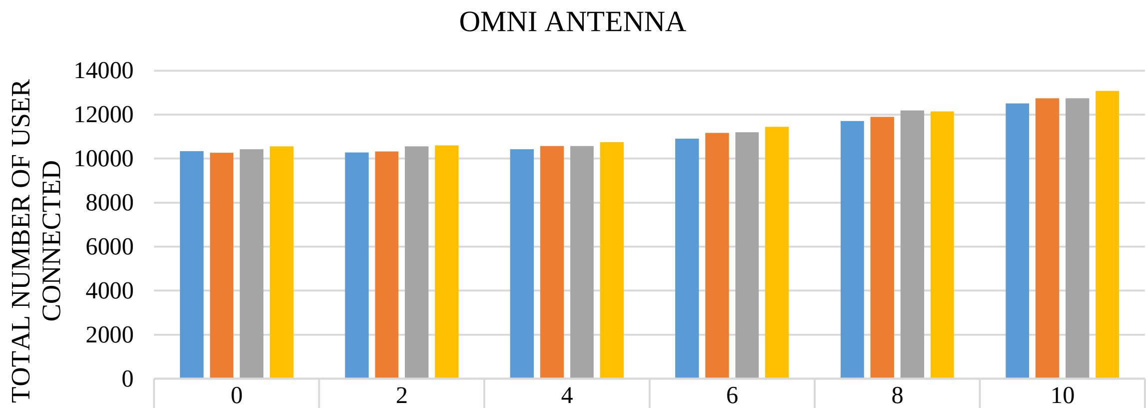


	0	2	4	6	8	10
90_15	12554	12896	11343	10236	9350	8960
90_20	13073	13461	11956	11054	10193	9786
90_25	13383	13708	12463	11633	10801	10402
90_30	13640	13818	12801	12039	11355	10887

Graph 13 : Antenna 90 degree

The graph illustrates the result from antenna 90 degree with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 2° with the height 30 meter gives the highest total number of user connected.

G. Omni antenna with multiple mechanical tilt and height



	0	2	4	6	8	10
Omni_15	10341	10284	10425	10906	11712	12505
Omni_20	10273	10323	10567	11173	11895	12738
Omni_25	10421	10552	10578	11199	12187	12744
Omni_30	10558	10597	10743	11440	12143	13080

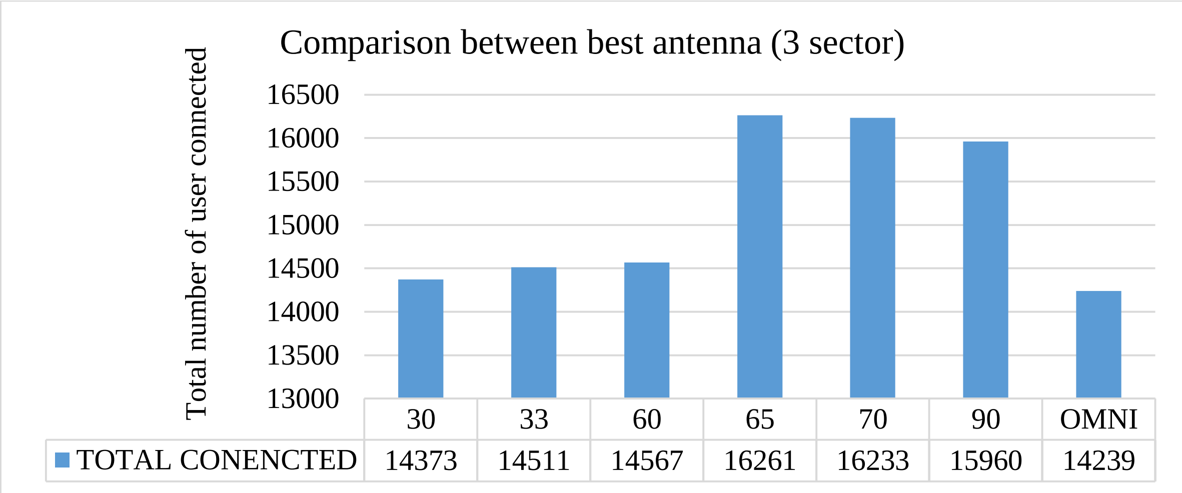
Graph 14 : Omni antenna

The graph illustrates the result from Omni antenna with 6 sector and varying the mechanical tilt and height. The results shows that mechanical tilt with 10˚ with the height 30 meter gives the highest total number of user connected.

4.4.3 Comparison of Result

The graph shows the comparison by taking the antenna and mechanical tilt that gives the most number of total user that can be connected using both 6 sector and 3 sector antenna.

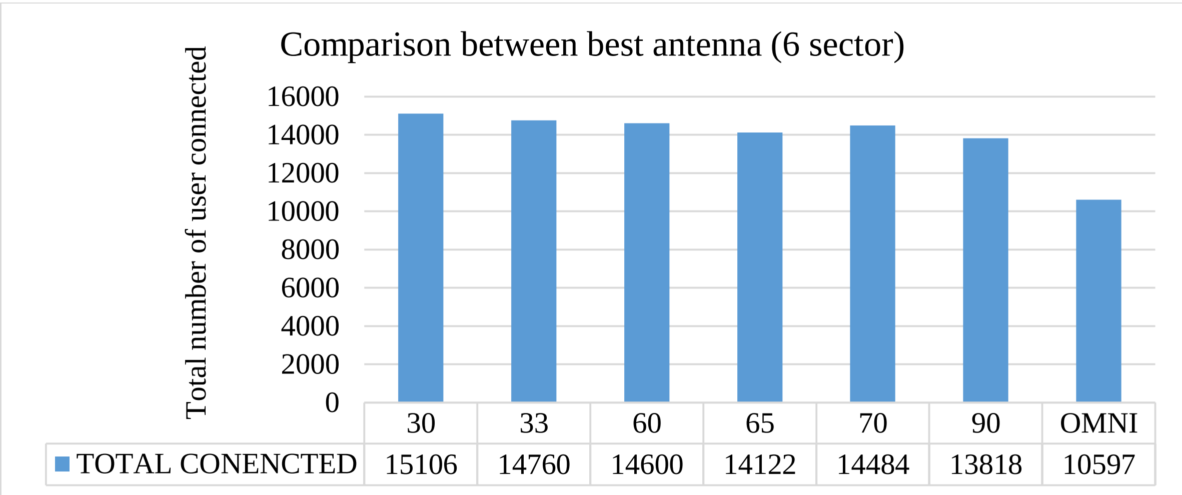
A. 3 sector antenna



Graph 15 : Comparison best result from each antenna (3 sector)

As shown in the graph, antenna 65 degree with tilt of 4˚ and height of antenna 30 metre gives the best result among other antennas.

B. 6 sector antenna



Graph 16 : Comparison best result from each antenna (3 sector)

As shown in the graph, antenna 30 degree with tilt of 2˚ and height of antenna 30 metre gives the best result among other antennas.

4.5 Data

This section will show the average data in High Speed Internet, Mobile Internet. Video

Conferencing and Voice over IP (VoIP) for Uplink and Downlink. These data are taken only for best tilt and height with the best antenna that gives maximum number of user supported for both 3 sector and 6 sector.

a. 3 sector – Antenna 65 degree, height 30 metre, mechanical tilt 4˚

Table 10 : Data speed from Antenna 65 degree, height 30 metre and mechanical tilt of 4˚ (3 sector)

Application	Average Data Speed (kbps)
High Speed Internet (DL)	10.30
High Speed Internet (UL)	15.30
Mobile Internet Access (DL)	40.69
Mobile Internet Access (UL)	10.71
Video Conferencing (DL)	1.20
Video Conferencing (UL)	1.07
VoIP (DL)	2.62
VoIP (UL)	2.62

b. 6 sector – Antenna 30 degree, height 30 metre, mechanical tilt 2˚

Table 11 : Data speed from Antenna 65 degree, height 30 metre and mechanical tilt of 4˚ (6 sector)

Application	Average Data Speed (kbps)
High Speed Internet (DL)	12.26
High Speed Internet (UL)	15.15
Mobile Internet Access (DL)	27.95
Mobile Internet Access (UL)	10.81
Video Conferencing (DL)	1.21
Video Conferencing (UL)	1.22
VoIP (DL)	3.06
VoIP (UL)	3.01

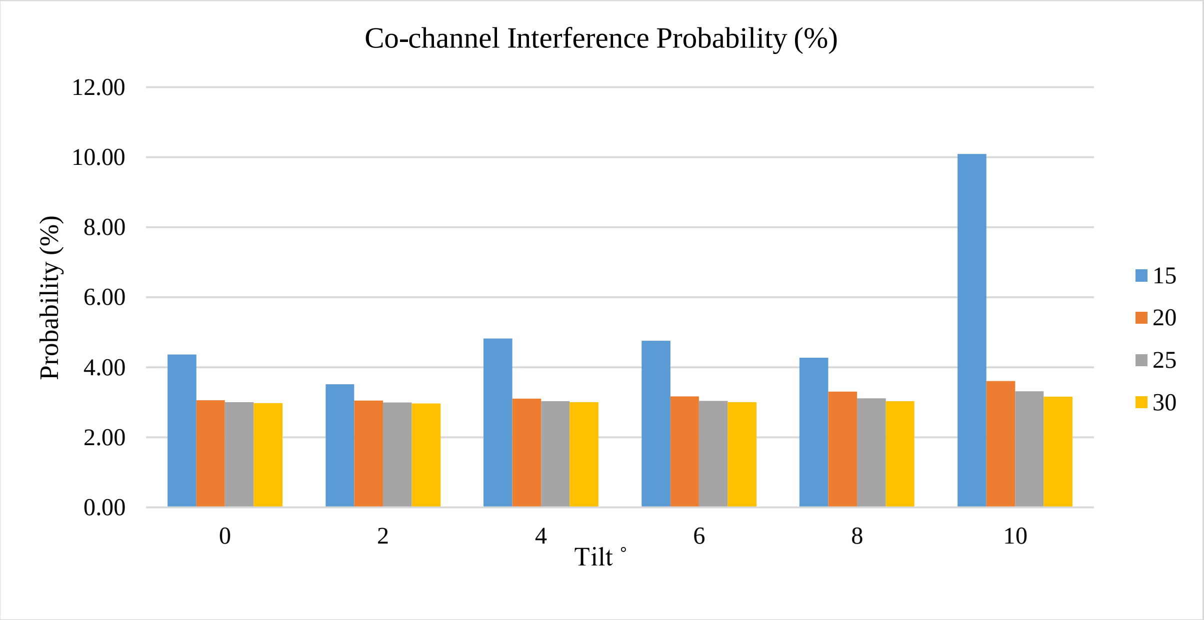
Comparing both data speed collected from the antenna that gives the best result for 3 sector and 6 sector, for High Speed Internet (DL), High Speed Internet (UL), and Mobile Internet Access (DL) 3 sector antenna gives better result compare to 6 sector. Where else for Mobile Internet Access (UL), Video conferencing (DL), Video conferencing (UL), VoIP (DL) and VoIP (UL) antenna with sector 6 gives better result compare to 3 sector antenna.

4.6 Interference

Interference is a signal that contain noise or signal that is modified from its original from before reaching the receiver from the source. This is usually caused by different type of noise that make unwanted signal added into a good signal.

4.6.1 3 sector antenna

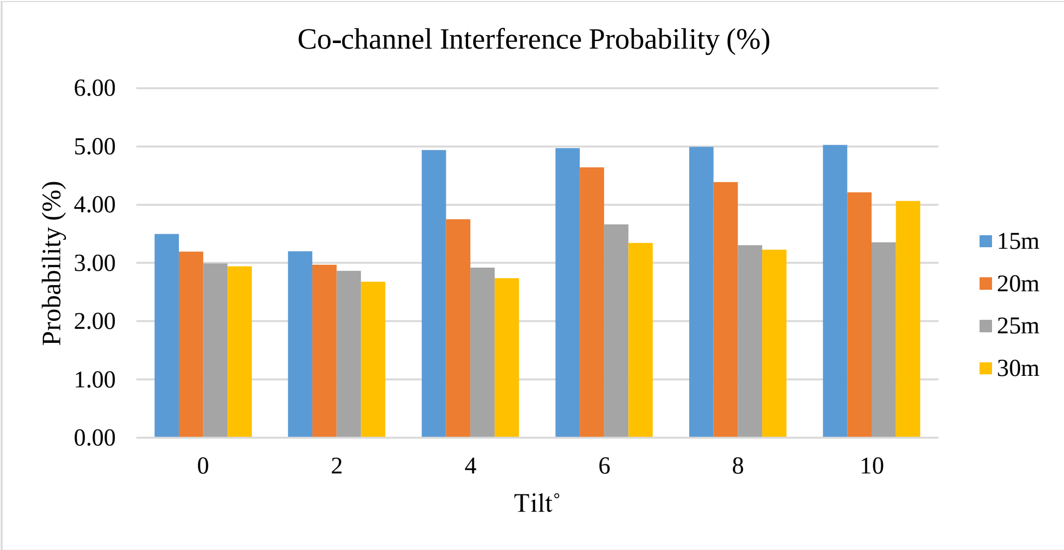
A. Antenna 30 degree



Graph 17 : Co-channel Interference Probability (%) Antenna 30 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 30 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage of interference probability.

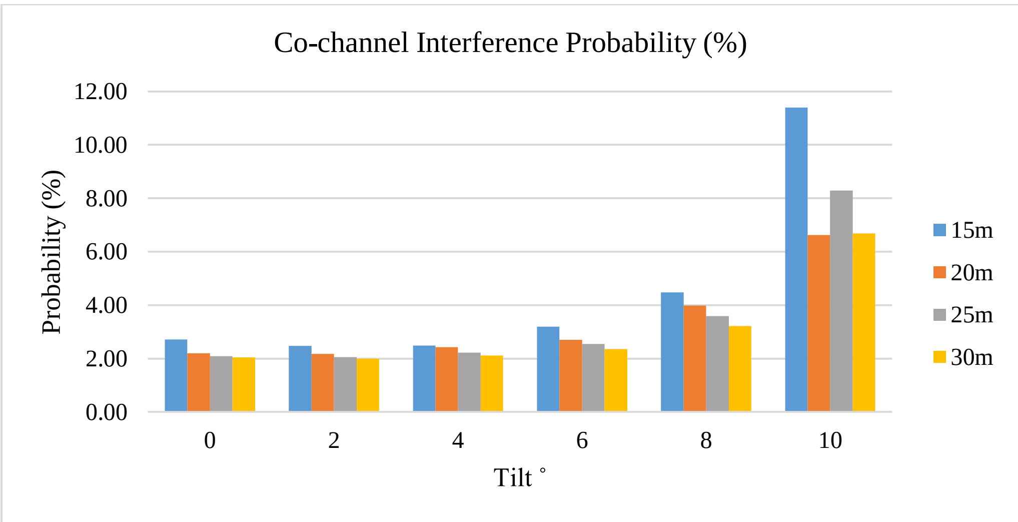
B. Antenna 33 degree



Graph 18 : Co-channel Interference Probability (%) Antenna 33 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 33 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

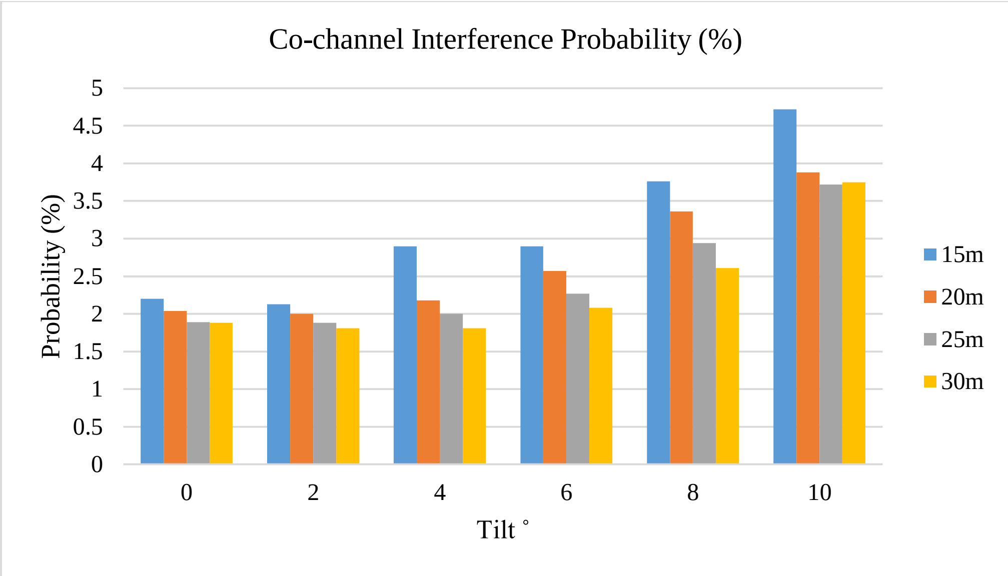
C. Antenna 60 degree



Graph 19 : Co-channel Interference Probability (%) Antenna 60 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 60 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

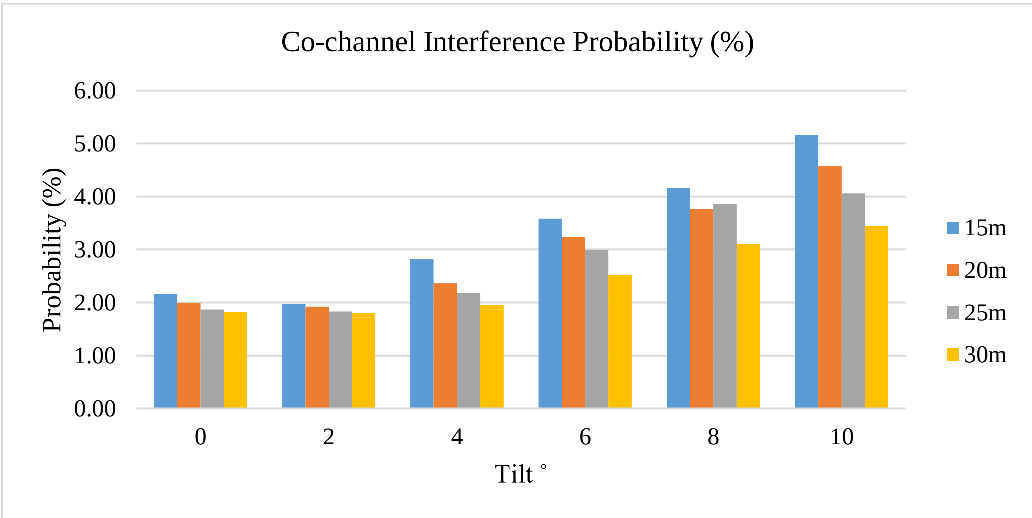
D. Antenna 65 degree



Graph 20 : Co-channel Interference Probability (%) Antenna 65 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 65 degree with height 30 and using mechanical tilt 4˚ gives the lowest percentage.

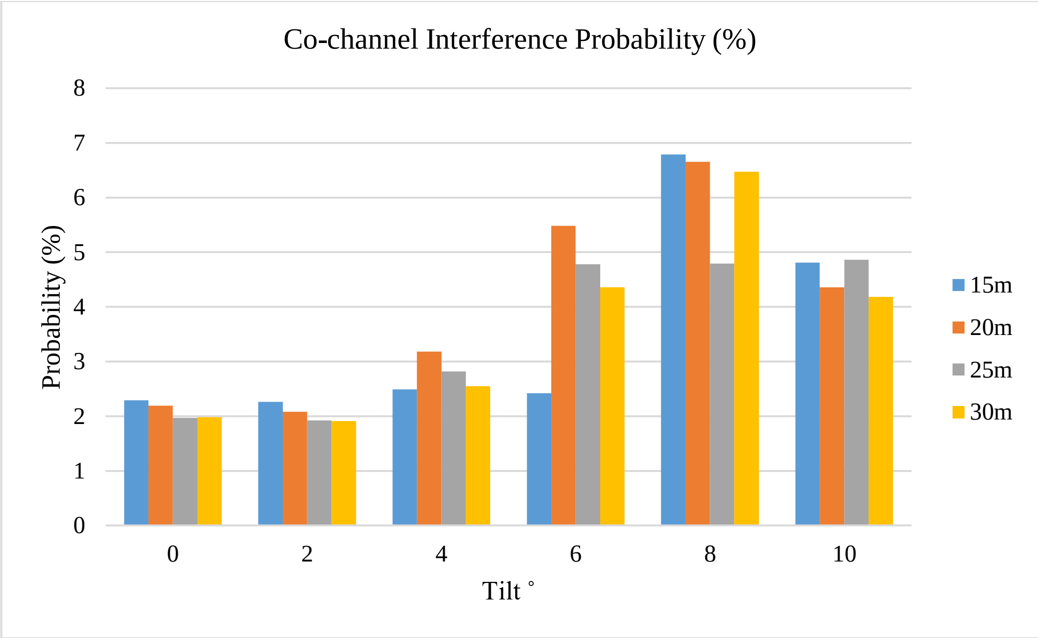
E. Antenna 70 degree



Graph 21 : Co-channel Interference Probability (%) Antenna 70 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 70 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

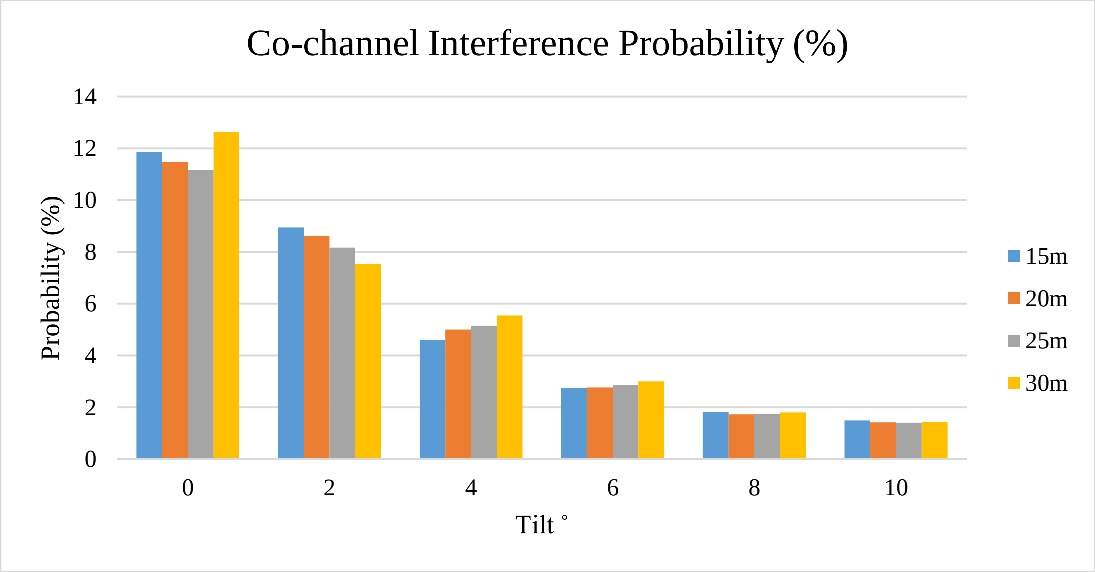
F. Antenna 90 degree



Graph 22 : Co-channel Interference Probability (%) Antenna 90 degree

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 90 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

G. Omni antenna

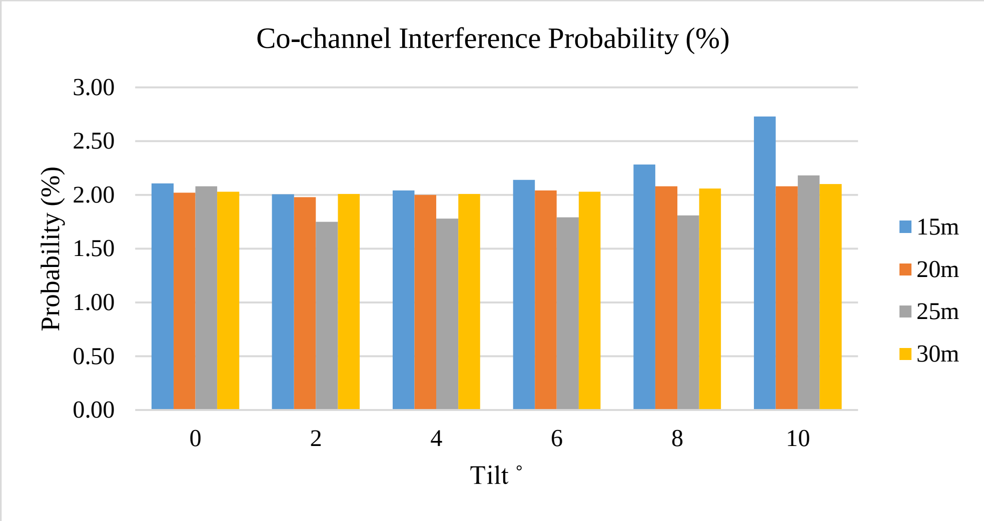


Graph 23 : Co-channel Interference Probability (%) Omni Antenna

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, Omni antenna with height 25 and using mechanical tilt 10˚ gives the lowest percentage.

4.6.2 6 sector antenna

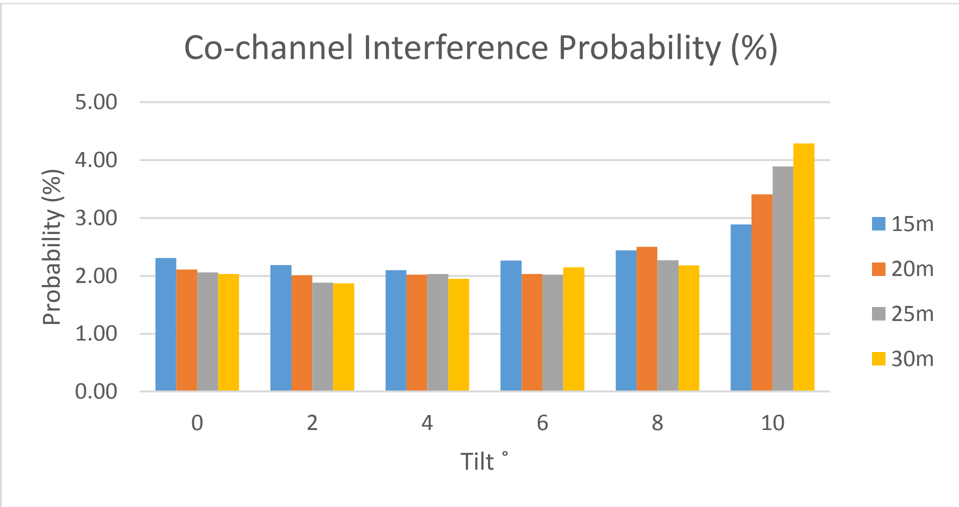
A. Antenna 30 degree



Graph 24 : Co-channel Interference Probability (%) Antenna 30 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 30 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

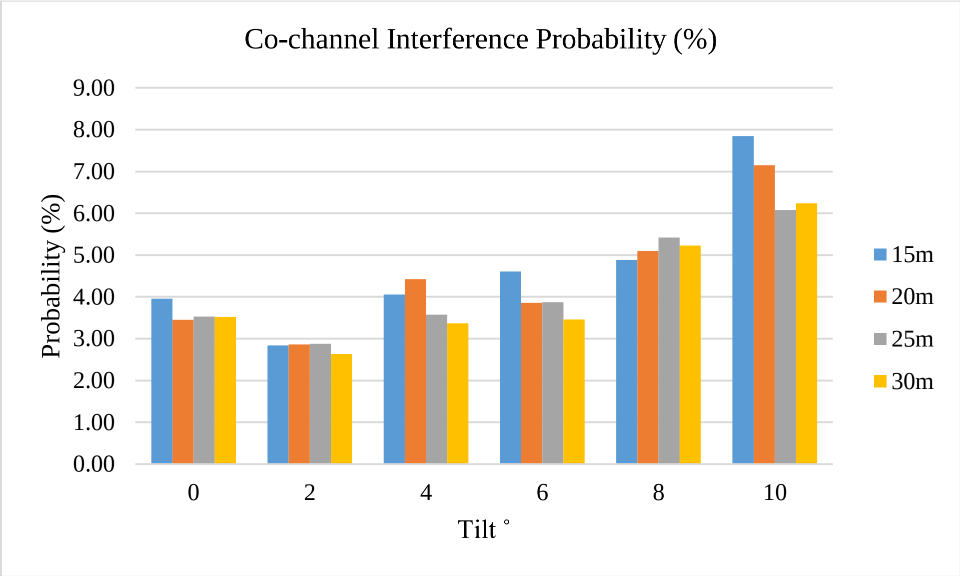
B. Antenna 33 degree



Graph 25 : Co-channel Interference Probability (%) Antenna 33 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 33 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

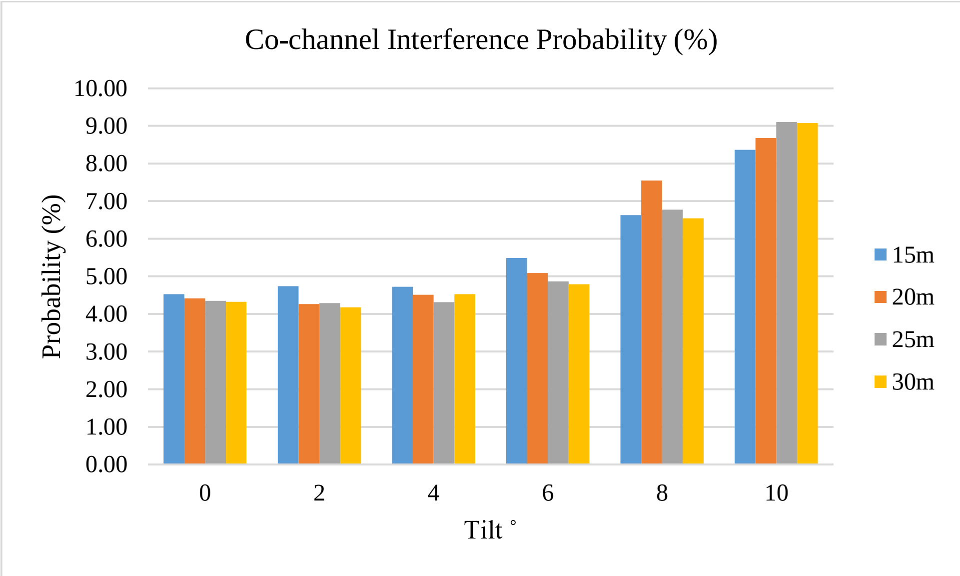
C. Antenna 60 degree



Graph 26 : Co-channel Interference Probability (%) Antenna 60 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 60 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

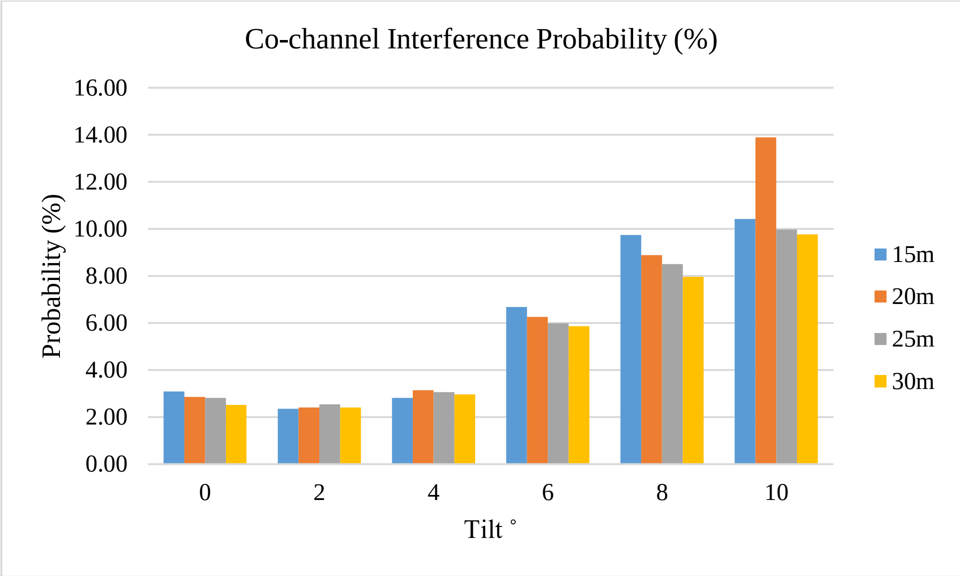
D. Antenna 65 degree



Graph 27 : Co-channel Interference Probability (%) Antenna 65 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 65 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

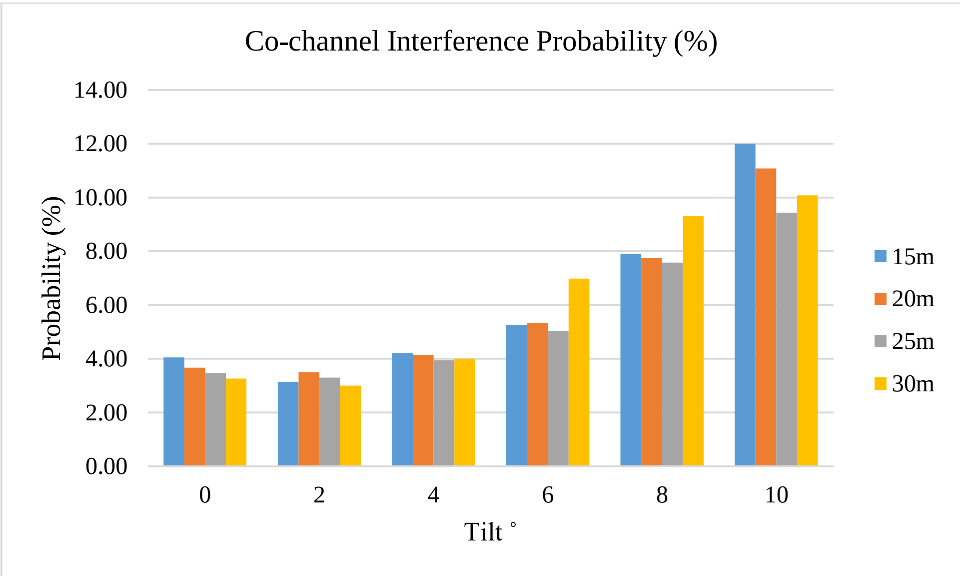
E. Antenna 70 degree



Graph 28 : Co-channel Interference Probability (%) Antenna 70 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 70 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

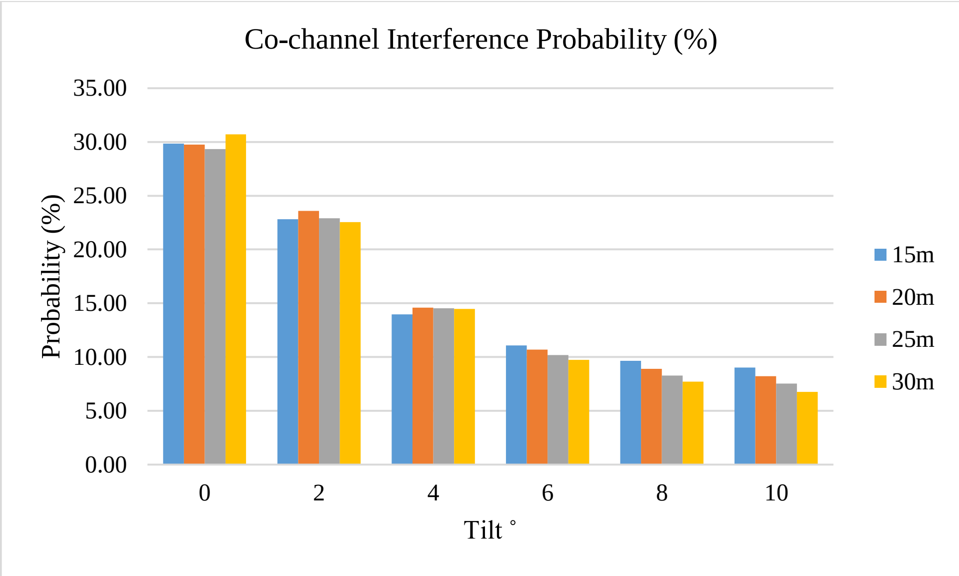
F. Antenna 90 degree



Graph 29 : Co-channel Interference Probability (%) Antenna 90 degree (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, antenna 90 degree with height 30 and using mechanical tilt 2˚ gives the lowest percentage.

G. Omni antenna

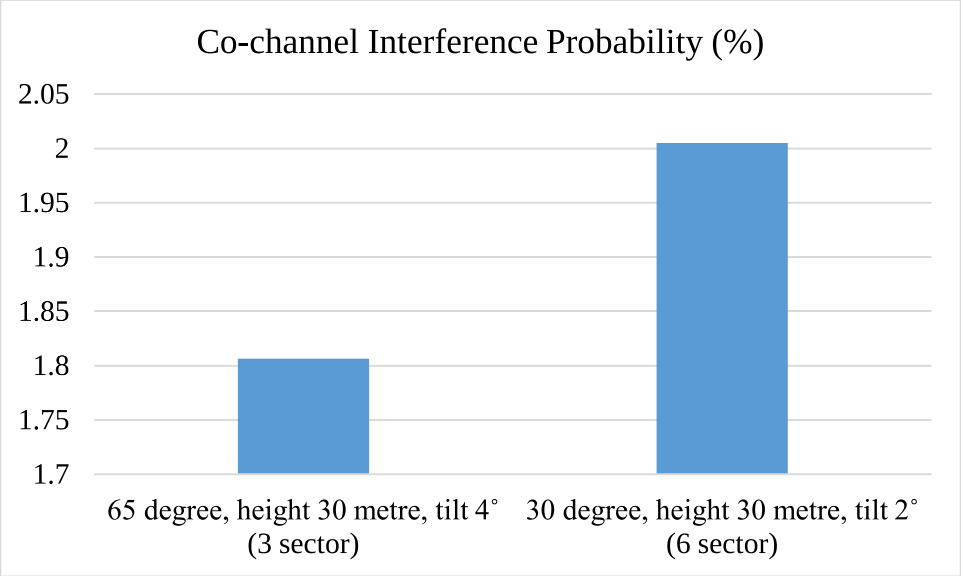


Graph 30 : Co-channel Interference Probability (%) Omni Antenna (6 sector)

In the graph show the interference between the co-channel and its average probability percentage. According to the graph, Omni antenna with height 30 and using mechanical tilt 10˚ gives the lowest percentage.

4.6.3 Comparison of Co-channel Interference Probability (%)

Taking the best antenna to compare the interference probability in percentage between the co-channels.

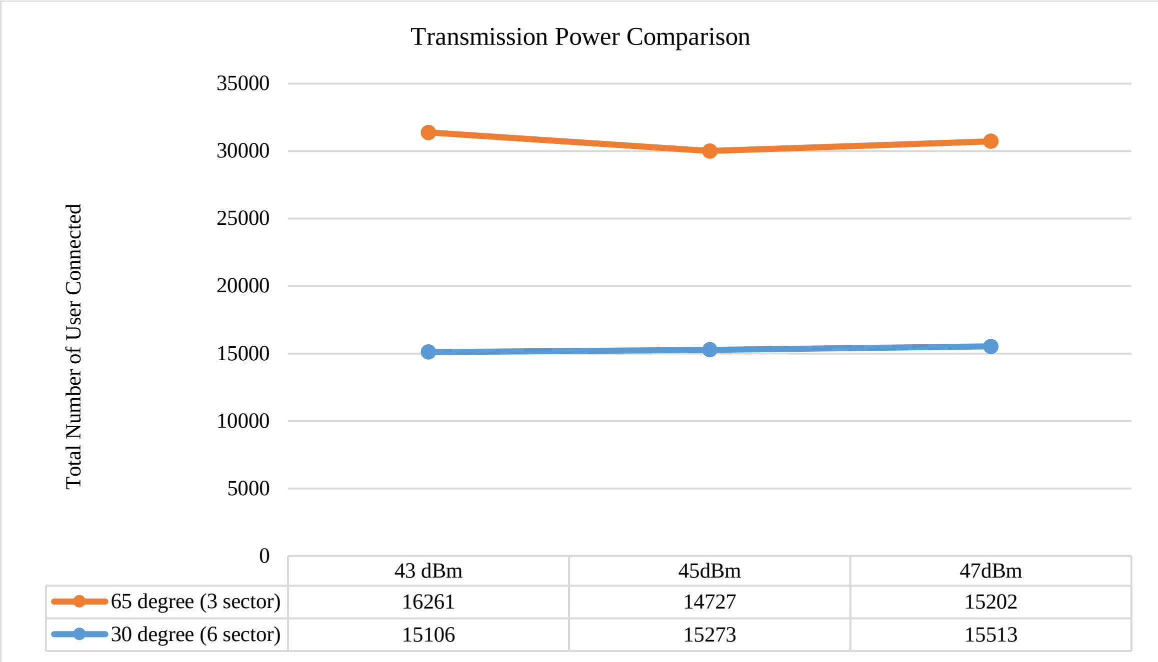


Graph 31 : Co-channel Interference Probability (%) comparison between 3 sector and 6 sector antenna

As the conclusion by comparing both interference as we can see in the graph, antenna with sector 3, degree 65, height 30 metre and mechanical tilt of 4˚ gives lower interference compare to sector 6, degree 30, height 30 metre and mechanical tilt of 2˚. Even some of the antenna does not give a consistent interference probability, average is taken from each antenna that have given the lowest percentage. However interference is important in order to determine the signal strength and packet lose to provide a quality network coverage to the user.

4.6 Transmission Power

Taking the best antenna selection, increasing of transmission power is applied to identify the maximum number of user that can be connected for both antenna with 3 sector and 6 sector.



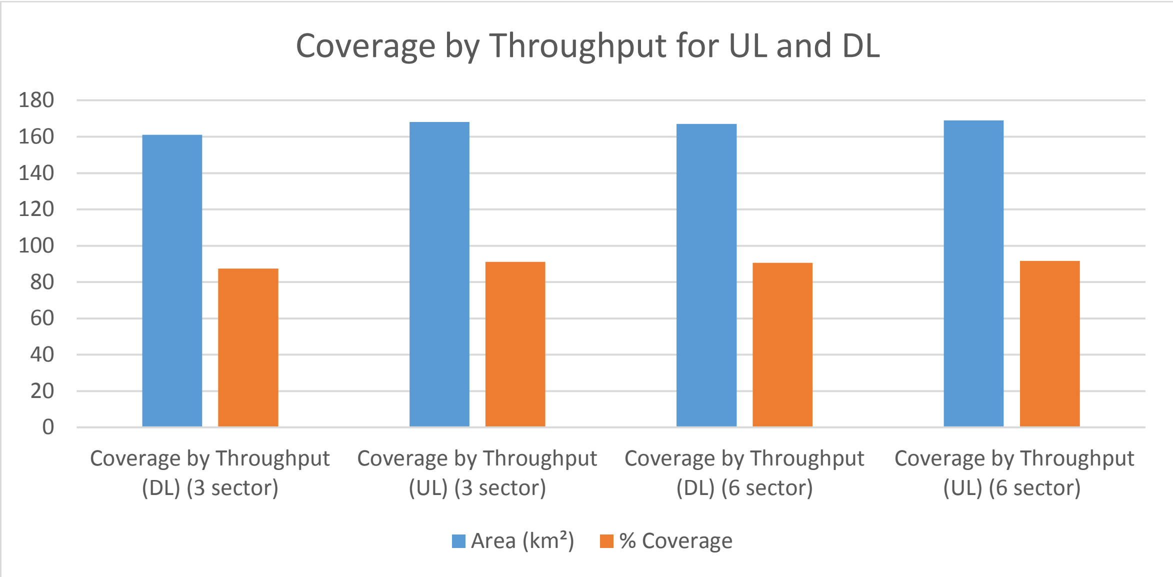
	43 dBm	45dBm	47dBm
65 degree (3 sector)	16261	14727	15202
30 degree (6 sector)	15106	15273	15513

Graph 32 : Transmission power comparison 3 sector and 6 sector antenna

Transmission power of 43 dBm gives better result compare to 45 dBm and 47 dBm for the 3 sector antenna which is 65 degree, 30 meter and with the mechanical tilt of 4˚. This shows that the perfect transmission power would be 43dBm. According to the graph, the best transmission power of 47 dBm gives better result compare to 43 dBm and 45 dBm when using 6 sector antenna which is 30 degree, 30 meter of height and mechanical tilt of 2˚.

4.7 Coverage by Throughput

Coverage calculation by throughput is measure for the best 2 antenna in order to select for antenna proposal. This prediction are made on urban and suburban area since it is more important area compare to rural area. This urban and suburban area consist of 180 km^2 which is about 28% of the total area.



Graph 33: Coverage by Throughput for UL and DL

The graph shows for Coverage by throughput (DL), 3 sector antenna which is antenna 65 degree gives about 87.4% of coverage compare to 6 sector antenna the 30 degree antenna gives 90.5%. For Coverage by throughput (UL) 3 sector antenna results in 91.1% of coverage and 6 sector antenna gives 91.6% coverage. Basically, antenna with 6 sector gives better coverage compare to 3 sector antenna which might due to increase in number of sector. Good coverage not only determined by the area it can covered but also must take interference as one of the important element in order to analyse the coverage.

CHAPTER 5

DISCUSSION

Network Planning is a first step before building a site or tower in a respective area. This includes some other process which divided into 3 main parts initial planning, detailed planning and optimization. This project just cover the first two main part. According to the result we obtained the best height that can support maximum number of user is antenna with height 30 metre. This will be more efficient if the antenna is a 65 degree antenna which contribute about 80.99% of the total user in Ipoh City. Another main part of selective the best antenna is the mechanical down tilt, the best down tilt that can provide a good coverage and capacity is antenna with which we obtain is tilt 4˚. This antenna selection are for the 3 sector antenna. Antenna 65 degree with 30 metre height and mechanical tilt of 4˚ analysed further by changing the transmission power.

There are two type of antenna classification had been tested in this project, first as discussed above is 3 sector antenna and now is 6 sector antenna. For 6 sector antenna, the best antenna selection uses the same criteria as for 3 sector antenna. Therefore the best antenna chosen among all the six types of antenna is antenna 30 degree which works the best on mechanical tilt of 2˚ and with the height of 30 metre. This antenna gives the maximum number of users that can be connected. 30 degree antenna contributes about 75.24% of the total user of Ipoh City.

In addition to that, data speed produced by this both 3 sector and 6 sector antenna are good at different applications. For 3 sector antenna which is antenna 65 degree gives better data speed on High Speed Internet (DL), High Speed Internet (UL), and Mobile Internet Access (DL) compare to 6 sector. Where else for Mobile Internet Access (UL), Video conferencing (DL), Video conferencing (UL), VoIP (DL) and VoIP (UL) antenna with sector 6 gives better result compare to 3 sector antenna.

The interference is very important in order to choose the best server. Therefore antenna with 3 sector which is antenna 65 degree produce interference about 18.1% compare to antenna 30 degree using 6 sector which is 20.1%. Both antenna works best at height of 30 metre but 65 degree antenna's mechanical tilt is 4˚ and 30 degree antenna's is 2˚.

Investigation using transmission power of 43 dBm, 45 dBm and 47 dBm results in giving the maximum number of user by comparing this 3 types of transmission power. Transmission power of 43 dBm gives better result compare to 45 dBm and 47 dBm for the 3 sector antenna which is 65 degree, 30 meter and with the mechanical tilt of 4˚. The maximum number of user that can be supported using this transmission power is about 80.99% from the total users. This shows that the perfect transmission power would be 43dBm. In the other hand, transmission power of 47 dBm which is about gives better result compare to 43 dBm and 45 dBm when using 6 sector antenna which is 30 degree, 30 meter of height and mechanical tilt of 2˚ can support 77.26% from the total users.

In addition to that, coverage by throughput have been investigated in order to analyse the coverage area that can be gained from this 2 antennas. Antenna with 3 sector can give about 87.4% of coverage for Downlink and 91.1% of coverage for Uplink. Where else, 6 sector antenna produces 90.5% and 91.6% respectively for Downlink and Uplink. This shows that 6 sector antenna can give better coverage compared to 3 sector. Not forgotten interference need to be taken into account when analysing the best antenna to produce less interference and good coverage.

CHAPTER 6

CONCLUSION

Radio frequency planning needs a lot of background knowledge on the telecommunication area. Obtaining some data from the existing company might not possible since it is confidential due to competitive companies. Completing this project successfully will give very good background in telecommunication network planning. In FYP1 we have studied research that have been done previously on LTE in all over the world including planning and optimising coverage, capacity, antenna specification and other related research. This shows LTE is leading the technology in communication field.

Study of antenna in creating a network architecture in order to produce the best coverage and capacity by fulfilling the demands of users can be achieved through this project. The most effective antenna that can be used as the conclusion of this project is antenna 3 sector with 65 degree, height of 30 metre and mechanical tilt of 4˚. This regardless of electrical tilt, antenna gain and other relevant parameters that can be different in the real world of LTE network planning. In addition to that antenna 65 degree produces about 18.01% of interference which is less than 6 sector's best antenna. Users that can be supported by 65 degree antenna is much higher than the 6 sector antenna which is about 5.75% more. Nevertheless, antenna works best with transmission power of 43 dBm which is standard use proven by LTE University. Talking about the coverage antenna 65 degree can give about 87.4% of coverage for Downlink and 91.1% of coverage for Uplink which is lesser than 6 sector antenna but considering the interference which is lower than 6 sector antenna. Antenna with 3 sector shows the best result.

In addition to that, some parameters are made by assumption with a valid reference, this may affect the result obtained. Number of sites according calculation were 33 sites and in this project only 10 sites are implemented. By this we can reduce the cost by 54.55% which might give higher capacity and user but it will increase in interference eventually as the users demand are not high enough to implement 22 sites in the Ipoh City area. When implementing 10 sites can give 80.99% of coverage, it is not necessary to double up the sites to support users more than the demand.

Moreover, the users in the Ipoh city not 100% user of LTE, where some user just using phone without LTE or just for the purpose of 1G and 2G use. In the other hand, knowledge of the tool used to achieve this is very important to master or at least to understand how it works. Finally study of the relationship of antenna on the network architecture planning shows that it is important to specify some of the parameters in order to create a coverage and capacity that can support maximum number of subscriber or user in Ipoh city.

Number of sites plays a part in defining the number of user that can be supported by the network as well studying the impact of capacity and coverage range on the network planning can lead to better understanding on network planning. For future work, as an recommendation optimization can be done to improve more on this project, by editing some values that have be used as assumption or by using different antenna's as the technology in telecommunication field is growing more faster than predicted. The future of LTE is very bright, where a baby step for wireless communication, analogically 1G is was the baby step for other upcoming 2G, 3G network.

Future work can be done by optimizing this planning which is by adding building structures in the city. In addition to implementing electrical tilt and applying different mechanical tilt for different site at the same time. This may give different result compare to what obtained in this project. Walfisch ikegami model can be used in this phase. In the other hand, the number of users can be obtained from the marketing department of any network provider if possible. What was implemented here is by taking the average user from the Maxis Network Operation Centre in order to estimate the total user.

CHAPTER 7

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CHAPTER 8

APPENDICES

Appendix 1

Agisson ATR451606 Triband Antenna (G900/W900, G1800/L1800, and W2100/L2600).

DXXX-790-960/1710-2690/1710-2690-65/65/65-16i/18i/18i-M/M/M

Model: ATR451606

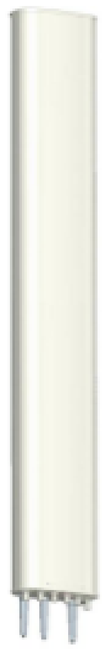
HUAWEI

Electrical Properties

Frequency range (MHz)	790 - 960									2 x (1710 - 2690)											
	790 - 862			824 - 894			880 - 960			1710 - 1990			1920 - 2200			2200 - 2490			2490 - 2690		
Polarization	+45°, -45°																				
Electrical downtilt (°)	0 - 10, continuously adjustable									0 - 10, continuously adjustable											
Gain (dBi)	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°
	15.7	15.9	15.6	16.0	16.1	15.6	16.1	16.3	15.8	17.5	17.3	17.0	17.8	17.8	17.3	18.0	18.0	17.6	17.8	18.2	17.7
Side lobe suppression (Typ.) (dB)	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°	0°	5°	10°
-for first side lobe above main beam	18	18	18	18	18	18	18	18	18	16	16	17	17	17	17	17	18	18	17	18	18
-within 0° - 15° sector above horizon	17	17	16	17	17	16	17	17	17	15	15	15	16	16	16	16	16	16	15	15	15
Horizontal 3dB beam width (°)	65			64			62			65			62			60			60		
Vertical 3dB beam width (°)	10.1			9.8			9.3			5.8			5.4			4.8			4.3		
VSWR	< 1.5																				
Isolation between ports (dB)	Intra-system: ≥ 28 Inter-system: ≥ 30																				
Front to back ratio, copolar (dB)	Typ. 28																				
Cross polar ratio (dB) 0°	Typ. 18																				
Cross polar ratio (dB) ±60°	Typ. 10																				
Max. power per input (W)	500 (at 50℃ ambient temperature)									250 (at 50℃ ambient temperature)											
Intermodulation IM3 (dBc)	≤-153 (2 x 43 dBm carrier)																				
Impedance (Ω)	50																				
Grounding	DC Ground																				

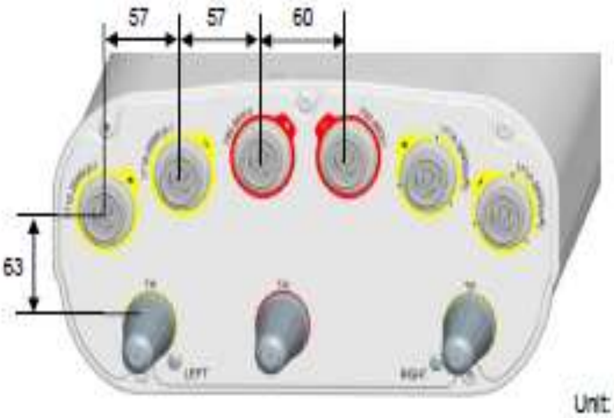
Mechanical Properties

Antenna dimensions (H x W x D) (mm)	1999 x 349 x 166
Packing dimensions (H x W x D) (mm)	2360 x 415 x 240
Antenna weight (kg)	24.5
Clamps weight (kg)	3.6 (2 units)
Antenna packing weight (kg)	39.9 (Included clamps)
Mast diameter supported (mm)	50 - 115
Radome material	Fiberglass
Radome colour	Light grey
Operational temperature (℃)	-55 .. +65
Wind load (N)	Frontal: 705 (at 150 km/h) Lateral: 230 (at 150 km/h) Rear side: 730 (at 150 km/h)
Max. operational wind speed (km/h)	150
Survival wind speed (km/h)	200
Connector	6 x 7/16 DIN Female
Connector position	Bottom

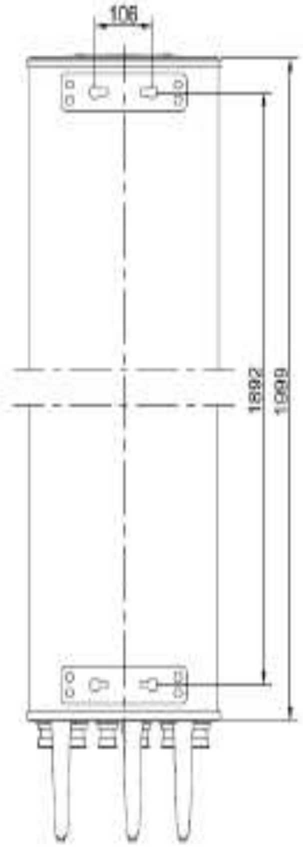


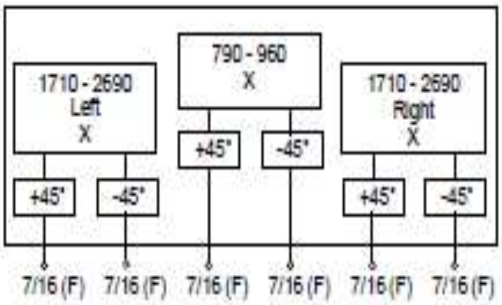
Accessories

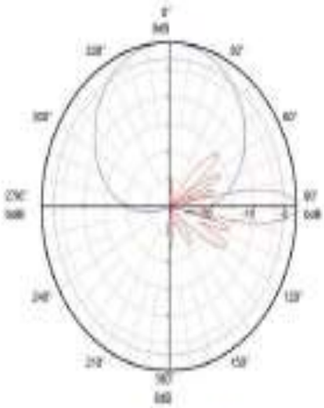
Item	Model	Description	Weight	Units per antenna
Downtilt kit	ASMDT0D01	Mechanical downtilt: 0 - 12 °	2.0 kg	1 (Separate packing)



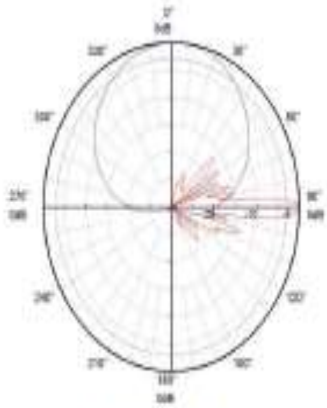
Unit: mm



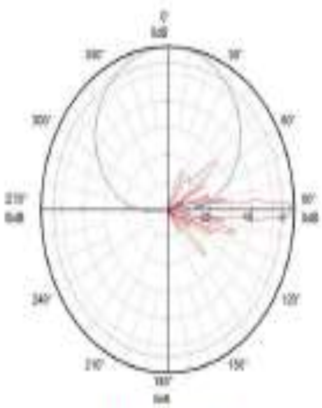




790 - 960 MHz



1710 - 2690 MHz
(Left)



1710 - 2690 MHz
(Right)

NOTE

Extraordinary operating conditions, such as heavy icing or storm wind, may result in the breakage of an antenna. These facts must be considered during the site planning process.

The installation team must be properly qualified and also be familiar with the relevant national safety regulations.

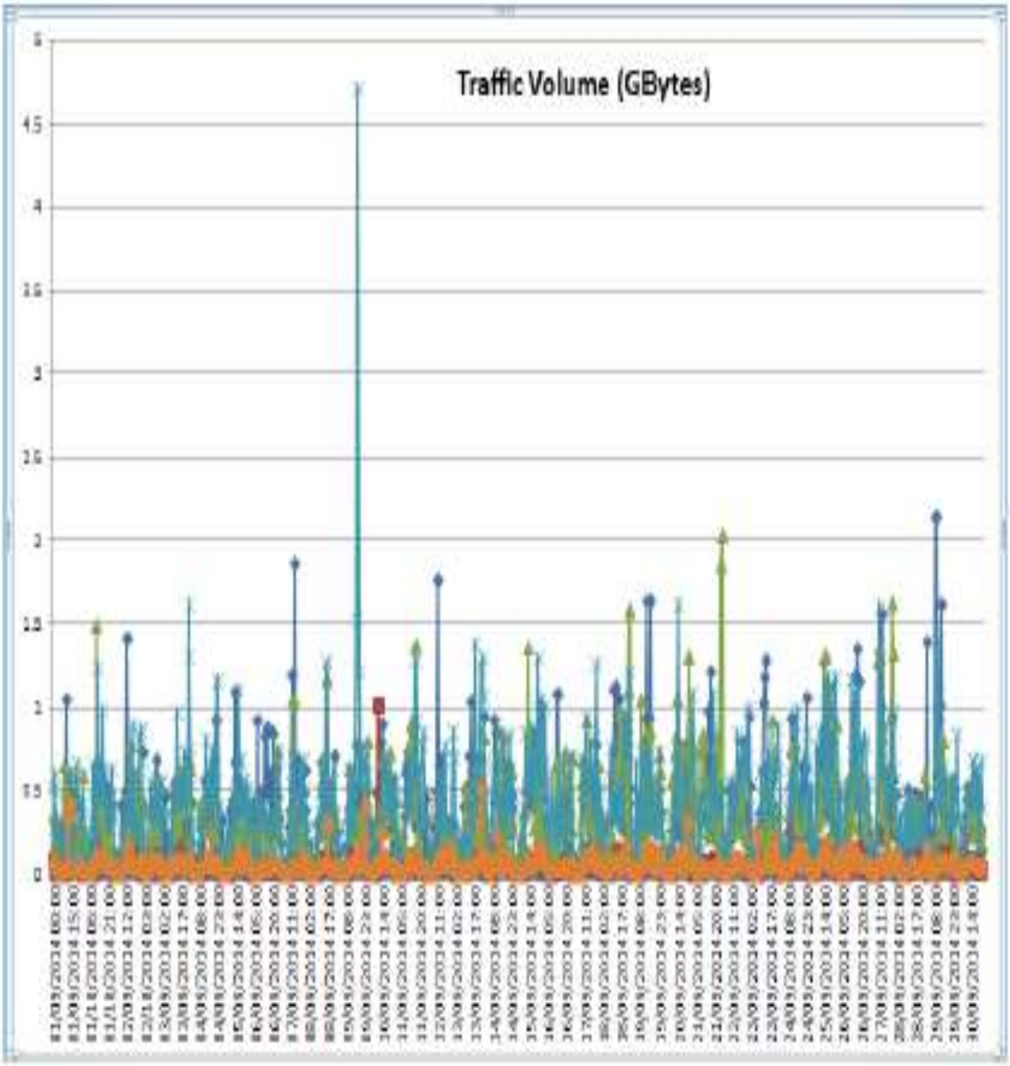
Appendix 2

Information from Maxis via email

Puvainderan Kuppusamy <KPUVAIN@maxis.com.my> Thu, Oct 2, 2014 at 4:55 PM
To: "SIVASANTHINI S.MOHAN" <siva10engr@gmail.com>

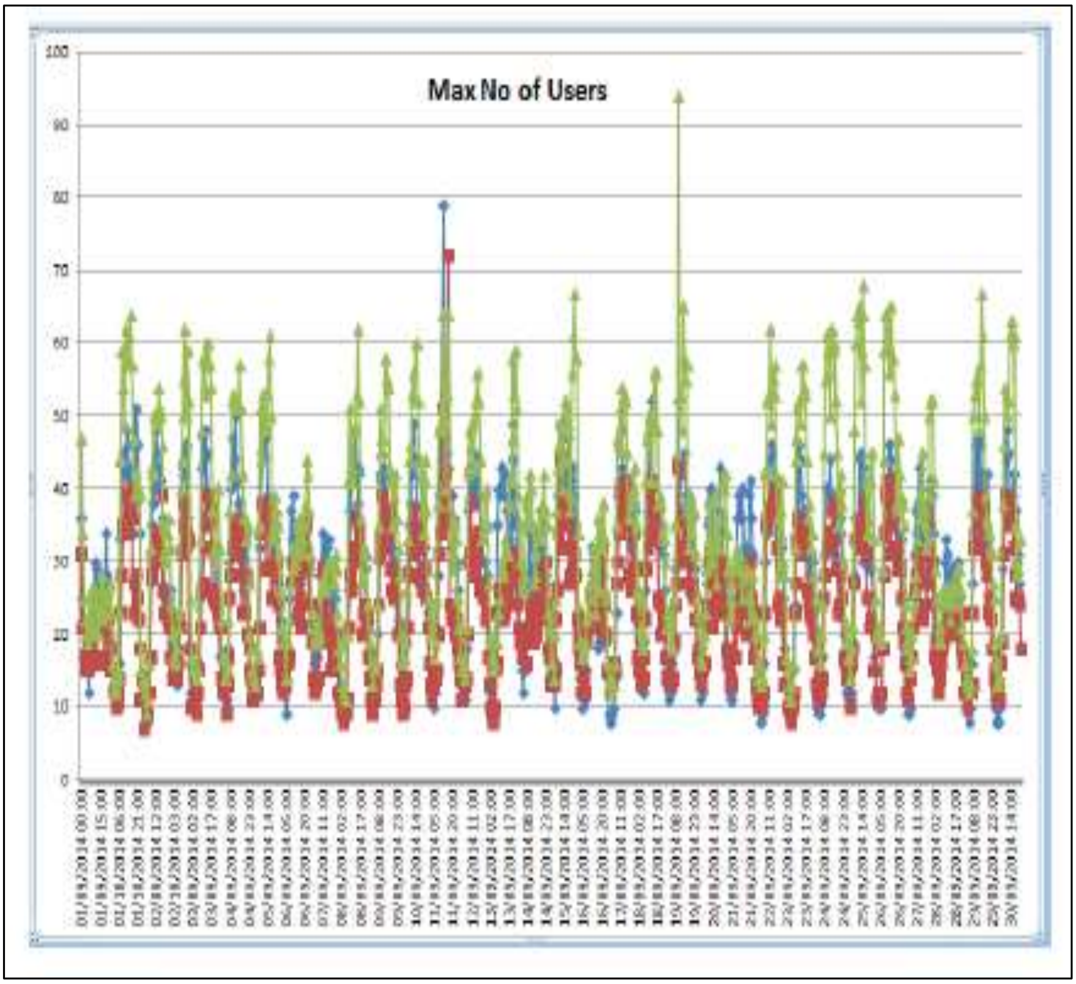
Please refer below info as requested. Thanks.

1. Peak hour



2. Types of antenna used

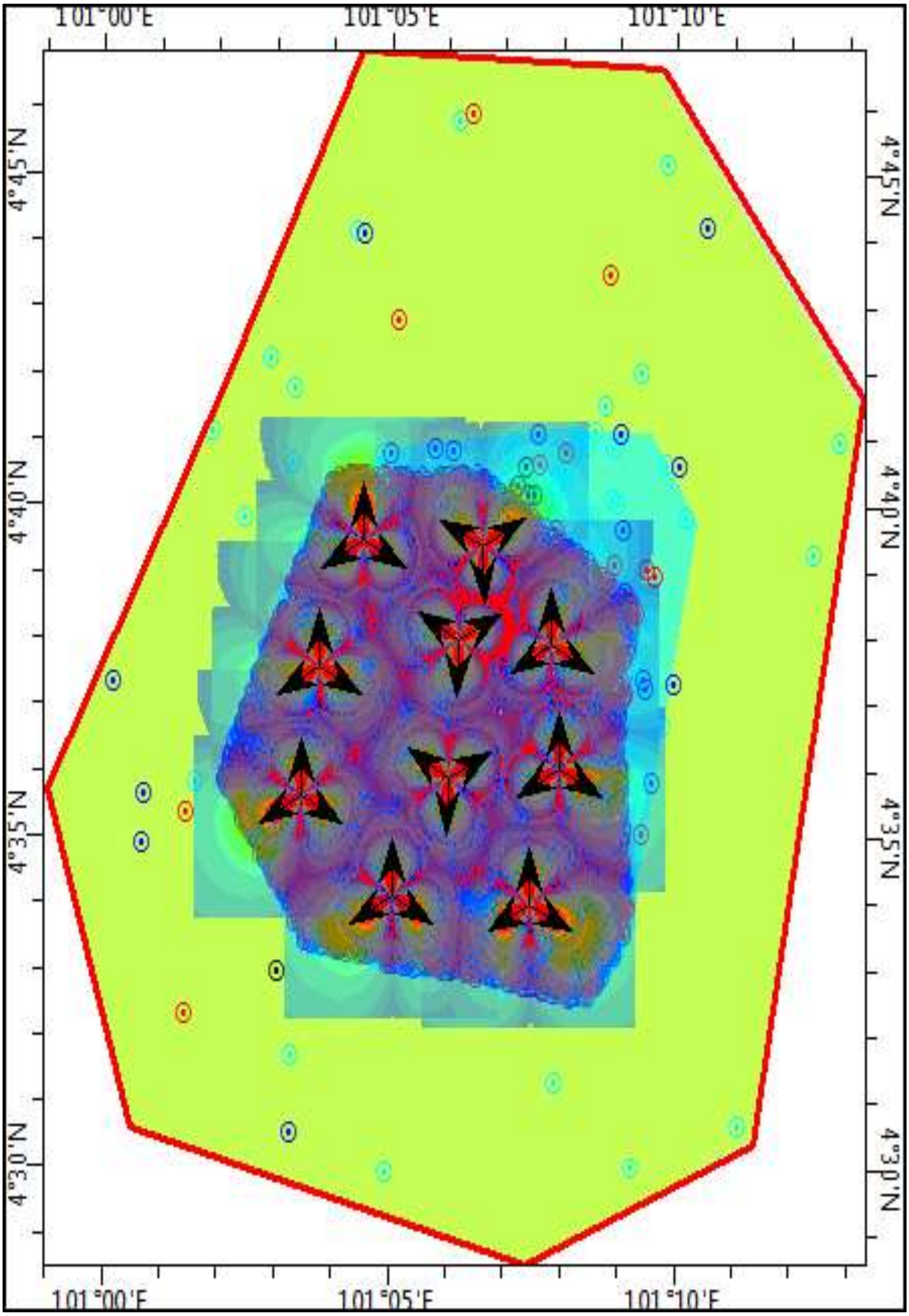
Agisson ATR451606 Triband Antenna (G900/W900, G1800/L1800, W2100/L2600)


Max No of Users

Appendix 3

Example of traffic Map with sites in Atoll Simulator – 3 sector antenna

User distribution, base station location in the traffic map.



Appendix 4

Example of raffic Map with sites in Atoll Simulator – 6 sector antenna