EVALUATION OF NETWORK MONITORING SOFTWARE TOOLS FOR CELLULAR RADIO SYSTEM

KHOIRUN NADIA BINTI ZAINOL

DISsertATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ENGINEERING

FACULTY OF ENGINEERING AND BUILD ENVIRONMENT
UNIVERSITI KEBANGSAAN MALAYSIA
BANGI

2011
PENILAIAN PERISIAN PENGAWASAN RANGKAIAN BAGI SISTEM RADIO SELULAR

KHOIRUN NADIA BINTI ZAINOL

DISERTASI YANG DIKEMUKAKAN UNTUK MEMENUHI SEBAHAGIAN DARIPADA SYARAT MEMPEROLEH IJAZAH SARJANA KEJURUTERAAN

FAKULTI KEJURUTERAAN DAN ALAM BINA UNIVERSITI KEBANGSAAN MALAYSIA BANGI

2011
DECLARATION

I hereby declare that the work in this dissertation is my own except quotations and summaries which have been duly acknowledged.

4th August 2011

KHOIRUN NADIA BINTI ZAINOL
P55841
ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful.

The completion of this master’s degree would not have been possible if not the support of many outstanding individuals in my life.

Foremost, I would like to express my sincere gratitude to my supervisor, Prof. Dr. Mahamod Ismail for the continuous support of my master thesis, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor for my master thesis study. Thank you to the lecturers and staffs of Department Electric, Electronic and Systems, UKM for teaching and guiding me during my study.

I would like to shower a millions thank to my beloved parents, Tuan Haji Zainol Bidin and Hajah Saudah Din, for their sponsorship, endless moral supports and dhu’a throughout this journey.

Last but not least to my dearest friends, it is such an honor to meet such a pleasant and supportive companionship during this period. To all those people who were directly or indirectly involved in the completion of this thesis, my sincere thanks to each and everyone. May Allah bless you for all the kindness and help you have given to me.
ABSTRACT

A cellular radio network is a network distributed over land area called cells. Each cells served by at least one transceiver recognized as cell site or base station. When cluster together these cells able to provide wide radio coverage over a geographical area or service area. This allows portable transceivers to communicate among them while roaming within the service area. To date various cellular networks had been deployed such as GSM and WCDMA. In such network, network monitoring and auditing is important to observe and evaluate the performance of the cellular network in order to provide the best services to the subscribers. The main objective of this research is to evaluate various network software tools features and their performances during network monitoring activities. Six network software applications (RF Signal Tracker, Open Signal Maps, Cellumap, Antennas, StMurray Cell Connectivity Tracker and Signal Finder) installed in Android based smartphone were used to monitor the network activities, signal reception and services activated from a stationary mobile user while in indoor and outdoor environment. From the observation, it is shown that the RF Signal Tracker turn out to be the best tool that is capable of measuring and display all the nine criteria that were monitored. Open Signal Maps is the second best application and followed by Cellumap application. Antennas and StMurray Cell Connectivity Tracker has similar capabilities of monitoring the cellular network. Signal Finder has the lowest ability in monitoring the network as it is only able to estimate the distance between the serving base station towers to the mobile user. Finally, an automated software tool selection guide for a teaching or simple monitoring guidance based on the software features was developed using Visual Basic.
ABSTRAK

TABLE OF CONTENTS

DECLARATION iii
ACKNOWLEDGEMENT iv
ABSTRACT v
ABSTRAK vi
TABLE OF CONTENT vii
LIST OF TABLES x
LIST OF FIGURES xi
LIST OF ABBREVIATIONS xiii

CHAPTER I INTRODUCTION
1.1 Introduction 1
1.2 Problem Statement 3
1.3 Research Objectives 4
1.4 Dissertation Summary 4

CHAPTER II LITERATURE REVIEW
2.1 Introduction 5
2.2 Cellular Standard and Evolution 5
  2.2.1 First Generation 5
  2.2.2 Second Generation 6
  2.2.3 Third Generation 6
  2.2.4 Fourth Generation 7
2.3 Cellular Fundamental 8
  2.3.1 GSM Network Architecture 9
  2.3.2 UMTS Network Architecture 13
    2.3.2.1 Serving Area Concept 17
  2.3.3 Radio Channel Access Schemes 18
    2.3.3.1 Frequency division multiple access (FDMA) 18
    2.3.3.2 Time division multiple access (TDMA) 19
    2.3.3.3 Code Division multiple access (CDMA) 20
2.3.4 Frequency Assignment

2.4 Radio Resource Management and Services

2.4.1 Power Control
   2.4.1.1 Open loop power control
   2.4.1.2 Closed (inner) loop power control
   2.4.1.3 Outer loop power control

2.4.2 Admission Control

2.4.3 Handover
   2.4.3.1 Hard handover
   2.4.3.2 Intersystem handover
   2.4.3.3 Intrafrequency handover

2.4.4 Localization
   2.4.4.1 Assisted GPS

2.5 Propagation, Fading and Doppler

2.6 Link Monitoring and Network Planning
   2.6.1 Network Monitoring Parameters

2.7 Software Tools
   2.7.1 Commercial and Free software tools
   2.7.2 Evaluation of Mobile device
   2.7.3 Mobile platforms
      2.7.3.1 Android
      2.7.3.2 Iphone
      2.7.3.3 Symbian

2.8 Summary

CHAPTER III METHODOLOGY

3.1 Introduction

3.2 General Methodology

3.3 Software Features Evaluation

3.4 Software Tools
   3.4.1 RF Signal Tracker
   3.4.2 Open Signal Maps
   3.4.3 Cellumap
   3.4.4 Antennas
   3.4.5 StMurray Cell Connectivity Tracker
   3.4.6 Signal Finder

3.5 Software Installation
### CHAPTER IV  RESULTS AND DISCUSSION

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>52</td>
</tr>
<tr>
<td>4.2</td>
<td>Software Tools Features Evaluation for Outdoor</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>and Criteria</td>
<td></td>
</tr>
<tr>
<td>4.2.1</td>
<td>RF Signal Tracker</td>
<td>52</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Open Signal Maps</td>
<td>55</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Cellumap</td>
<td>57</td>
</tr>
<tr>
<td>4.2.4</td>
<td>Antennas</td>
<td>59</td>
</tr>
<tr>
<td>4.2.5</td>
<td>StMurray Connectivity Tracker</td>
<td>59</td>
</tr>
<tr>
<td>4.2.6</td>
<td>Signal Finder</td>
<td>60</td>
</tr>
<tr>
<td>4.3</td>
<td>Software Tools Signal Reception for Outdoor</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>Software Tools Signal Reception for Indoor</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>Results for Indoor Environment</td>
<td>63</td>
</tr>
<tr>
<td>4.4</td>
<td>Software Monitoring Guide</td>
<td>63</td>
</tr>
</tbody>
</table>

### CHAPTER V  CONCLUSION

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Conclusion</td>
<td>65</td>
</tr>
<tr>
<td>5.2</td>
<td>Future Work</td>
<td>66</td>
</tr>
</tbody>
</table>

### REFERENCES

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>67</td>
</tr>
</tbody>
</table>

### APPENDIX
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>GSM Frequency Allocation</td>
</tr>
<tr>
<td>2.2</td>
<td>Criteria in Commercial and Free software tools</td>
</tr>
<tr>
<td>2.3</td>
<td>Android features and specification</td>
</tr>
<tr>
<td>4.1</td>
<td>Results from software tools (outdoor)</td>
</tr>
<tr>
<td>4.1</td>
<td>Results from software tools (indoor)</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figures</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Cell clusters</td>
<td>2</td>
</tr>
<tr>
<td>1.2 Cell layout for cellular radio</td>
<td>2</td>
</tr>
<tr>
<td>2.1 The separate evolutionary tracks of CDMA and GSM infrastructure</td>
<td>8</td>
</tr>
<tr>
<td>2.2 General architecture of a GSM network</td>
<td>12</td>
</tr>
<tr>
<td>2.3 UMTS Network Architecture</td>
<td>13</td>
</tr>
<tr>
<td>2.4 User Equipment domain</td>
<td>14</td>
</tr>
<tr>
<td>2.5 UMTS Area</td>
<td>18</td>
</tr>
<tr>
<td>2.6 Frequency Division Multiple Access</td>
<td>19</td>
</tr>
<tr>
<td>2.7 Time Division Multiple Access</td>
<td>20</td>
</tr>
<tr>
<td>2.8 Code Division Multiple Access</td>
<td>21</td>
</tr>
<tr>
<td>2.9 Typical locations of RRM algorithms in a WCDMA network</td>
<td>23</td>
</tr>
<tr>
<td>2.10 Open loop power control algorithm</td>
<td>24</td>
</tr>
<tr>
<td>2.11 Closed loop power control algorithm</td>
<td>25</td>
</tr>
<tr>
<td>2.12 Outer loop power control algorithm</td>
<td>25</td>
</tr>
<tr>
<td>2.13 Hard Handover</td>
<td>27</td>
</tr>
<tr>
<td>2.14 Intersystem handover</td>
<td>28</td>
</tr>
<tr>
<td>2.15 Soft handover</td>
<td>29</td>
</tr>
<tr>
<td>2.16 Softer handover</td>
<td>29</td>
</tr>
<tr>
<td>2.17 Assisted GPS</td>
<td>30</td>
</tr>
<tr>
<td>2.18 Handover based on distance</td>
<td>31</td>
</tr>
<tr>
<td>2.19 Iphone OS Layer</td>
<td>36</td>
</tr>
<tr>
<td>3.1 General methodology</td>
<td>41</td>
</tr>
<tr>
<td>3.2 Example screenshot of RF Signal Tracker</td>
<td>43</td>
</tr>
<tr>
<td>3.3 Sample screenshot of Open Signal Maps</td>
<td>44</td>
</tr>
<tr>
<td>3.4 Sample screenshot of Cellumap</td>
<td>45</td>
</tr>
<tr>
<td>3.5 Sample screenshot of Antennas</td>
<td>46</td>
</tr>
<tr>
<td>3.6 Sample screenshot of StMurray Cell Connectivity Tracker</td>
<td>47</td>
</tr>
<tr>
<td>3.7 Sample screenshot of Signal Finder</td>
<td>48</td>
</tr>
<tr>
<td>3.8 Andorid’s Market Software Download Application</td>
<td>49</td>
</tr>
</tbody>
</table>
3.9 RF Signal Tracker Application installation 49
3.10 Screen captured of collected data using RF Signal Tracker 50
3.11 Program develop flowchart 51
4.1 RF Signal Tracker window screen captured (a) phone (b) network (c) location (d) wifi 54
4.2 RF signal Tracker Google map view 55
4.3 Signal tower directions 56
4.4 Open Signal Map’s Map 56
4.5 Cellumap screen captured 57
4.6 Map from uploaded server 58
4.7 Signal Strength Indicators for Cellumap 58
4.8 Screen captured of Antennas application 59
4.9 StMurray Cell Connectivity Tracker Window 60
4.10 Signal Finder 61
4.11 Selection program window 64
4.12 Program running 65
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5G</td>
<td>Generation 2.5</td>
</tr>
<tr>
<td>3G</td>
<td>Third Generation</td>
</tr>
<tr>
<td>AMPS</td>
<td>Advanced Mobile Phone Services</td>
</tr>
<tr>
<td>ASU</td>
<td>Android Signal Unit</td>
</tr>
<tr>
<td>AuC</td>
<td>Authentication Center</td>
</tr>
<tr>
<td>BS</td>
<td>Base station</td>
</tr>
<tr>
<td>BSS</td>
<td>Base station subsystem</td>
</tr>
<tr>
<td>BSC</td>
<td>Base station controller</td>
</tr>
<tr>
<td>BTS</td>
<td>Base transceiver station</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division multiple access</td>
</tr>
<tr>
<td>EIR</td>
<td>Equipment Identity Register</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>FDD</td>
<td>Frequency division duplex</td>
</tr>
<tr>
<td>FDMA</td>
<td>Frequency division multiple access</td>
</tr>
<tr>
<td>GIWU</td>
<td>GSM Interworking Unit</td>
</tr>
<tr>
<td>GMSC</td>
<td>Gateway Mobile Switching Centre</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile</td>
</tr>
<tr>
<td>HLR</td>
<td>Home Location Register</td>
</tr>
<tr>
<td>IMEI</td>
<td>International mobile equipment identity</td>
</tr>
<tr>
<td>LA</td>
<td>Location Area</td>
</tr>
<tr>
<td>LAC</td>
<td>Location Area Code</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>MAC</td>
<td>Medium access control</td>
</tr>
<tr>
<td>MCC</td>
<td>Mobile Country Code</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple-input multiple-output</td>
</tr>
<tr>
<td>MNC</td>
<td>Mobile Network Code</td>
</tr>
<tr>
<td>MSC</td>
<td>Mobile services switching center</td>
</tr>
<tr>
<td>NMT</td>
<td>Nordic Mobile Telephone</td>
</tr>
<tr>
<td>NSS</td>
<td>Network and switching system</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal frequency-division multiple access</td>
</tr>
<tr>
<td>OS</td>
<td>Operating System</td>
</tr>
<tr>
<td>OSS</td>
<td>Operation and support system</td>
</tr>
<tr>
<td>PDC</td>
<td>Personal/Pacific Digital Cellular</td>
</tr>
<tr>
<td>PLMN</td>
<td>Public Land Mobile Network</td>
</tr>
<tr>
<td>PUK</td>
<td>PIN unblocking key</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>RRM</td>
<td>Radio Resource Management</td>
</tr>
<tr>
<td>RSS</td>
<td>Radio subsystem</td>
</tr>
<tr>
<td>RSSI</td>
<td>Received Signal Strength Indicator</td>
</tr>
<tr>
<td>SIM</td>
<td>Subscriber Identity Module</td>
</tr>
<tr>
<td>TDD</td>
<td>Time division duplex</td>
</tr>
<tr>
<td>TDMA</td>
<td>Time division multiple access</td>
</tr>
<tr>
<td>TMSI</td>
<td>Temporary mobile subscriber identity</td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunication System</td>
</tr>
<tr>
<td>VLR</td>
<td>Visitor Location Register</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over Internet Protocol</td>
</tr>
<tr>
<td>WCDMA</td>
<td>Wideband Code Division Multiple Access</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

1.1 INTRODUCTION

A cellular radio network is a system land based cell which allows portable transceivers such as mobile phone to communicate with other transceivers through large geographical coverage areas by using a single, high powered transmitter with an antenna mounted on a tall tower. The advantage of a cellular radio network over a network relying on a single transmitter is the fact that a series of cells can reuse a particular frequency for totally separate transmissions. With a single transmitter, one frequency only can be used to accommodate one transmission or else, it would cause interference over adjacent cells.

The cellular concept is a system-level idea that replaces high power transmitter (large cell) with many low power transmitters (small cells), that provide coverage to only a small size of the service area. Each base station is allocated a portion of the total number of channels available to the entire system and nearby base stations is assigned different groups of channels so that the interference between base stations (and the mobile users under their control) is minimized. The available channels are distributed systematically throughout the geographic region and be reused many times as necessary so long as the interference between co channel stations is kept below acceptable levels (Rappaport 2002).

Mobile phones users can move around between the cells of a cellular radio network without facing any drop calls because the handover system is not manually
switched. The new base station will efficiently notify the mobile phone that it needs to switch to a new channel. It is capable of doing that without doing any interruption to communication. The covering area of an operator is divided into cells. A cell corresponds to the covering area of one transmitter or a small collection of transmitters. The size of a cell is determined by the transmitter's power. Figure 1.1 shown the example of three, four and seven cell clusters while Figure 1.2 shows how coverage of an area is achieved using a large number of seven cell clusters.

![Figure 1.1 Cell clusters](source: Rappaport 2002)

![Figure 1.2 Cell layout for cellular radio](source: Rappaport 2002)

With the rapid development of communication technology, it provides mobility for us to able to make and receive calls anywhere at any time. However, there are many challenges in providing the good services for subscribers because the mobility of the users will effects the quality of the services and might cause an improper handoff and dropped call. In cellular radio network environment, various parameters such as bit error rate, signal to noise ratio, distance, traffic load, signal strength and various combinations of these parameters could be considered to decide handoff (Kwon et al. 2005).
Today’s subscribers want access to content regardless whether they are at home or on the move. As the user travels away from the base station at a very slow speed, the average signal strength does not decay rapidly. Even when the user has traveled far beyond the designed range of the cell, the received signal strength at the base station may be above the handoff threshold, thus handoff cannot be made. This creates a potential interference and traffic management problem. Therefore monitoring the network is important to review and watch the performance of the cellular network in order to provide the best services to the subscribers.

Along with the development of cellular network and wireless location technologies, using smart mobile phones as software tools seem to be a promising method of monitoring and network information acquisition. There are a few of operating system platform for smartphone that is widely popular nowadays. iOS, Android, Symbian, Blackberry are some examples of them.

This research focuses on the software tools evaluation that serve as monitoring to assess and monitor the radio cellular in network system. The capabilities and data information gathered discussed.

1.2 PROBLEM STATEMENT

Parallel with the growth of technology, there are various software tools with different capabilities to monitor the radio network cellular by using mobile smartphone. The smartphone with the different platform of operating systems as well as variability of monitoring software tools are available on market nowadays. Free software or commercial can be downloaded and installed into the smartphone.

Even though there are various types of software tools available on the market but not all of the software features are functioning well as what it is claimed by the manufacturer. Therefore, there is a need to evaluate the software tools for network monitoring to verify that the tools are working correctly as it is mentioned. The outcome of this project can be used by the advisor or guidance for class teaching
proposed or it also can be used as a simple cellular monitoring for the undergraduate and postgraduate students.

1.3 RESEARCH OBJECTIVES

The objectives of research in this project are:

i. To evaluate cellular software tool features and capabilities in cellular monitoring for Android based smartphone
ii. To gather and analyze data using selected network monitoring cellular software tools
iii. To propose an automated software tools selection system for network abilities activities

1.4 DISSERTATION SUMMARY

The structures of this dissertation are divided into five chapters. Chapters one introduces the cellular monitoring concept, the important of cellular monitoring and as well as the software tools for the monitoring.

Chapter two, literature review is elaborating more on the radio network standard and evolution, cellular fundamental, the radio resources and management and link planning and network monitoring. Methodology used in this research is describes in Chapter three.

Chapter four discussed the result gathered during the research. The last chapter presented the conclusion and suggestions for future work of this research.
CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

These days, mobile wireless communications has grown and become the most advances form of communication ever. In past few years, radio communication industry has developed and improves in many areas such as Radio Frequency (RF) circuit integrations, new large scale circuit integration and other miniaturization technologies which make portable radio equipment smaller, cheaper and more reliable.

2.2 CELLULAR RADIO STANDARD AND EVOLUTION

2.2.1 First Generation

With a rapid growth of communication technologies, tremendous interests in various services are fueling the need for very high data rates in future wireless networks. The first generation of mobile cellular telecommunication systems appeared in the 1980s. Nordic Mobile Telephone (NMT), Total Access Communications System (TACS), and Advanced Mobile Phone Services (AMPS) were the most successful standards during that period. The first generation systems are represented by the analog mobile systems designed to carry the voice application traffic. Scandinavia was initially the first place which used NMT and adopted in some countries in central and southern Europe. NMT - 450 was the older system, using the 450 MHz frequency band while NMT - 900 used 900 MHz (Korhenen 2001).
2.2.2 Second Generation

Second generation mobile cellular systems use digital radio transmission format. The capacity for the second generation is much higher than the first generation systems. There are four main standards for second generation systems which are Global System for Mobile (GSM) communication and its derivatives, Digital AMPS (D-AMPS), Code Division Multiple Access (CDMA) and Personal/Pacific Digital Cellular (PDC). The first GSM network was opened in 1991 in Finland. The GSM network provides a variety of network access, voice and data services and its frequency normally operates at 900 MHz and 1800 MHz except North America 1900 MHz frequency band.

However, now third generation (3G) systems already growing because of the demands imposed by increasing mobile traffic and the emergence of new type of services. The new systems, such as HSCSD (High Speed Circuit Switched Data), GPRS (General Packet Radio Service), and IS-95B, are commonly referred as generation 2.5 (2.5G) (Chen 2003).

2.2.3 Third Generation

The success of 2G technologies, lead to the third generation existence. 3G system offered multi-megabit Internet access, communications using Voice over Internet Protocol (VoIP), voice-activated calls, unparalleled network capacity, and ubiquitous access are just some of the advantages being touted by 3G developers. The Universal Mobile Telecommunication System (UMTS) is a visionary air interface standard that has evolved since late 1996 under the support of the European Telecommunications Standards Institute (ETSI). A fixed chip rate of 3.84 Megachips per second (Mcps) is used in the UMTS radio network giving a carrier bandwidth of approximately 5 MHz (Cauwenberge 2003). UMTS applied Wideband Code Division Multiple Access (WCDMA) at the radio interface. UMTS is a system and WCDMA is the radio access technology in UMTS. 3GPP is an organization that develops specifications for 3G system based on the UTRA radio interface and on the enhanced GSM core network and it is also liable for the future GSM specification work. UTRA system supports
two modes of operation: frequency division duplex (FDD) and time division duplex (TDD). Uplink and downlink for FDD mode used separate frequency bands with a bandwidth of 5 MHz carriers while for TDD, uplink and downlink separated by time.

2.2.4 Fourth Generation

The main two candidates for 4G systems are WiMAX technology, based on IEEE802.16 standards, and the Third Generation Partnership Project’s (3GPP’s) Long Term Evolution (LTE), both of which are being further enhanced to be considered and potentially endorsed by ITU-R as IMT-Advanced systems. WiMAX and LTE have somewhat different designs; there are many concepts, features, and capabilities commonly used in both systems to meet a common set of requirements and expectations. For example, at the physical layer both technologies deploy orthogonal frequency-division multiple access (OFDMA) based designs combined with various modes of multiple-input multiple-output (MIMO) configurations and fast link adaptation with time-frequency scheduling. Also, medium access control (MAC) of both systems support multicarrier operation and heterogeneous networks of cells, consisting of a mix of macrocells, femtocells, and relay nodes, which bring all kinds of challenges and solutions for mobility, interference, and traffic management. (Etemad & Riegel 2010).

Figure 2.1 shows, traditional wireless and mobile telecommunication architectures are already converging into the LTE architecture, and expected that the next generation air interface development efforts to also include IEEE Wimax protocols for the IMT-Advanced architecture. This will offer wireless providers a new set of architectural choices for networks.
2.3 CELLULAR FUNDAMENTAL

A connection between two people, a caller and the called person is the basic service of all network telephone networks. To provide this service, the network must able to set up and maintain a call which involve a number of tasks, identifying the called person, determine the location, routing the call, and ensuring that the connection is sustained as long as the conversation lasts. After the transaction, the connection is terminated and normally the calling user is charged for the services that he has used. In a mobile network, the subscriber has to located and identified to provide him/her with the requested services. In order to understand how we are able to serve the subscribers, it
is necessary to indentify the main interfaces, the subsystems and network elements in the cellular network as well as their functions.

### 2.3.1 GSM Network Architecture

Global System for Mobile Communications (GSM) is a digital wireless network standards designed by standardization committees from major European telecommunications operators and manufacturers. The GSM standard provides a common set of compatible services and capabilities to all mobile users across Europe and several million customers worldwide.

A GSM network is composed of several functional entities, whose functions and interfaces are specified. Figure 2.2 shows the layout of a generic GSM network. The GSM network can be divided into three broad parts. The GSM network is divided into three major systems (Holma & Toskala 2004):

**a) The radio subsystem (RSS)**

The RSS comprises all radio specific entities examples are the mobile station (MS) and the base station subsystem (BSS). A MS can be identified via International Mobile Equipment Identity (IMEI).

**b) The Subscriber Identity Module (SIM)**

The SIM card contains many identifiers and tables, such as card type, serial number, a list of subscribed services, a personal identity number (PIN), a PIN unblocking key (PUK), an authentication key K, and the Internationals Mobile Subscriber Identity (IMSI). A user can personalize any MS using his or her SIM. Without the SIM only emergency call a possible. MS stores dynamic information while logged into the GSM
system, such as, e.g., the cipher key KC and the location information consisting of a Temporary Mobile Subscriber Identity (TMSI) and the Location Area Identification (LAI).

c) **Base station subsystem (BSS)**

The GSM radio access network is also known as the base station subsystem (BSS). The BSS performs all functions necessary to maintain radio connections to an MS coding/decoding of voice, ands rate adaptation to/from the wireless network part. It may divide into two parts, base station controller (BSC) and base transceiver station (BTS) or base station (BS). BSC controls a group of BTSs and manage their radio resources. Handovers, frequency hopping, exchange functions and power control over each managed BTSs will be in charge by a BSC. A BTS will maps transceivers and antennas used in each cell of the network. Normally it will be place in the center of a cell. Its transmitting power defines the size of a cell.

d) **The Network and switching system (NSS)**

The switching system (SS) is responsible for performing call processing and manage the communications between the mobile users and others user, such as mobile users, ISDN users, fixed telephony users, etc. The switching system includes the following functional units.

**Mobile services switching center (MSC)** is the central component of the NSS. The MSC performs the switching functions of the network. It also provides connection to other networks.

**Gateway Mobile Switching Centre (GMSC)** is a gateway that interconnects two networks: the cellular network and the PSTN. It is in charge of routing calls from
the fixed network towards a GSM user. The GMSC is often implemented in the same machines as the MSC.

**Home Location Register (HLR)** stores information and management of the subscribers belonging to the coverage area of a MSC; it also stores the current location of these subscribers and the services to which they have access. The location of the subscriber maps to the SS7 address of the Visitor Location Register (VLR) associated to the MN. When an individual buys a subscription from one of the PCS operators, he or she is registered in the HLR of that operator. As soon as an MS leaves its current location area (LA), the information in the HLR is updated. It is necessary to localize a user in the worldwide GSM networks.

**Visitor location register (VLR)** contains information from a subscriber's HLR necessary to provide the subscribed services to visiting users. When a subscriber enters the covering area of a new MSC, the VLR associated to this MSC will request information about the new subscriber to its corresponding HLR. The VLR will then have enough data to assure the subscribed services without having to interrogate the HLR each time a communication is established. The VLR is always implemented together with a MSC; thus, the area under control of the MSC is also the area under control of the VLR.

**Authentication Center (AuC)** provides the parameters needed for authentication and encryption functions. These parameters allow verification of the subscriber's identity.

**Equipment Identity Register (EIR)** stores security-sensitive information about the mobile equipments. It maintains a list of all valid terminals as identified by their International Mobile Equipment Identity (IMEI). The EIR prohibit calls from stolen or unauthorized terminals (for example a terminal which does not respect the specifications concerning the output RF power).
GSM Interworking Unit (GIWU) provides an interface to various networks for data communications. During these communications, the transmission of speech and data can be alternated.

e) The Operation and support system (OSS)

It is connected to the NSS and the BSC components, in order to control and monitor the GSM system. It is also in charge of controlling the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system.

![Figure 2.2 General architecture of a GSM network](Source: Mohammad & Imam 2008)
2.3.2 UMTS Network Architecture

The UMTS system utilizes the same well-known architecture that has been used by all main second generation systems and even by some first generation systems. Figure 2.3 below displays the UMTS network architecture as specified in the 3GPP requirements. Basically the network can be split up into three different parts: the User Equipment (UE) domain, the UMTS Terrestrial Radio Access Network (UTRAN) and the Core network (CN) part. The interface between UE and UTRAN (Uu) interface and between the UTRAN and CN (Iu) are open multivendor interfaces (Korhonen 2001).

![Figure 2.3 UMTS Network Architecture](source: Holma & Toskala 2004)

a) User Equipment

The User Equipment Domain (UE) explains the equipment used by the user to establish a radio connection to the UMTS network and hence access the services offered. The User Equipment can be seen as the counterpart of the other network elements as its functionality and procedures implemented are also present in the RNC, Node B and the Core Network. Principally the UE consists of two functional parts – as can be seen on the Figure 2.4 below: the UMTS Subscriber Identity Module (USIM) domain and the Mobile Equipment (ME) domain.
The Mobile Equipment (ME) is the radio terminal used for radio communication over the Uu interface. MT represents the termination of the radio interface and by that, the termination of an IMT-2000 family, specific unit while TE represents termination of the service. The UMTS Subscriber Identity Module (USIM) is a smartcard that holds the subscriber identity, performs authentication algorithms, and stores authentication and encryption keys and some subscription information that is needed at the terminal (Holma & Toskala 2004). The main difference between a USIM and GSM SIM is that the USIM is a downloadable (by default), can be accessed via the air interface, and can be modified by the network. The USIM is a Universal Integrated Circuit Card (UICC), which has much more capacity than GSM SIM. It can store JAVA applications. It can also store profiles containing user management and rights information and descriptions of the way applications can be used (Krecher & Rudebusch 2005).

b) **UTRAN**

The UTRAN consists of radio network controllers (RNCs) and Node Bs (base stations). The internal interfaces of the UTRAN include the Iub and Iur. The Iub connects a Node B to the RNC and the Iur is a link between two RNCs. The Node B converts the data flow between the Iub and Uu interfaces. It also participates in radio resource management. The Node B is also responsible for Power Control, to perform the inner loop power control, which measures the actual SIR, compares it with the
specific defined value, and may trigger changes in the TX power of UE. Measurement Report task where it will give the measured values to the RNC and Microdiversity combining. The Node B is the physical unit to carry one or more cells (1 cell = 1 antenna). There are three types of Node Bs:

i. UTRA-FDD Node B

ii. UTRA-TDD Node B

iii. Dual Mode Node B (UTRA-TDD and UTRA FDD)

The Radio Network Controller (RNC) owns and controls the radio resources in its domain (the Node Bs connected to it). RNC is the service access point for all services. UTRAN provides the CN, for example, management of connections to the UE. There are three types of RNCs:

i. Serving RNC (SRNC)

Responsible for basic radio resource management operations such as handover decision and power control.

ii. Drift RNC (DRNC)

Controls cells used by the mobile and perform macro diversity combining and splitting.

iii. Controlling RNC (CRNC)

The CRNC controls, configures and manages an RNS and communicates with Node B Application Part (NBAP) with the physical resources of all Node Bs to the CNRC.
c) **Core Network**

The core network provides all the central processing and management for the system. It is the equivalent of the GSM Network Switching Subsystem or NSS. The Core Network (CN) has two domains: Circuit Switch (CS) domain and Packet Switch (PS) domain, to cover the need for different traffic types.

The CS elements are Mobile Switching Center (MSC), including Visitor Location Register (VLR) and Gateway MSC (GMSC). MSC is the center of the circuit switched network. The same MSC can be used to serve both the GSM BSS and the UTRAN connections. This type MSC have to improve to meet the 3G requirement, but the same MSC can be used to serve the GSM networks. MSC is used to switch the CS transactions and VLR holds a copy of the visiting user’s serving profile. GMSC is the switch that is connected to the external CS network. All incoming and outgoing CS connections go through GMSC. GMSC is the switch at the point where UMTS PLMN is connected to external CS networks. All incoming and outgoing CS connections go through GMSC.

The PS elements are Serving GPRS Support Node (SGSN), which covers similar functionality as the MSC for the packet data, including VLR type functionality while Gateway GPRS Support Node (GGSN) functionality is close to that of GMSC but is in relation to PS services.

Home Location Register (HLR) is a database located in the user’s home system that stores the master copy of the user’s service profile. The service profile consists of, for example, information on allowed services, forbidden roaming areas, and supplementary service information such as status of call forwarding and the call forwarding number. It is created when a new user subscribes to the system, and remains stored as long as the subscription is active. For the purpose of routing incoming transactions to the UE (e.g. calls or short messages), the HLR also stores the UE location on the level of MSC/VLR and/or SGSN, i.e. on the level of the serving system. Equipment Identity Register (EIR) contains the information related to the
terminal equipment and can be used to, example, prevents a specific terminal from accessing the network.

d) External Networks

The external network can be divided into two groups which are Circuit Switch (CS) networks and Packet Switch (PS) network. CS Networks provide circuit-switched connections, like the existing telephony service. ISDN and PSTN are examples of CS networks. PS networks provide connections for packet data services. The Internet is one example of a PS network.

2.3.2.1 Serving Area Concept

The area of 2G will be continuously used in UMTS. UMTS will add new group of locations specifying the UTRAN Registration Areas (URAs). These areas will be smaller Routing or Location Areas and will be maintained by UTRAN itself, covered by a number of cells the URA is configured in the UTRAN, and broadcast in relevant cells (Figure 2.5). The different areas are used for Mobility Management, examples Location Update and Pagging procedures.

Location Area (LA) is a set of cells (defines by the mobile operator) throughout which a mobile will be paged. The LA is identified by the Location Area Identity (LAI) within a Public Land Mobile Network (PLMN) and consists of Mobile Country Code (MCC), Mobile Network Code (MNC) and Location Area Code (LAC).

One or more Routing Area (RA) is control by SGSN. Each UE informs the SGSN about the current RA. RAs can consist of one or more cells. Each RA is identified by Routing Area Identity (RAI). The RAI is used for pagging and registration purposes and consists of LAC and Routing Area Code (RAC). The RAC (length: 1 octet fixed) identifies an RA within an LA and is part of the RAI.
The Service Area (SA) identifies an area of one or more cells of the same LA, and is used to indicate the location of a UE to the CN. The combination of the Service Area Code (SAC), Public Land Mobile Network Identifier (PLMN-ID) and LAC is the Service Area Identifier.

Utran Registration Area (URA) is configured in the UTRAN is broadcast in relevant cells, and covers an area of a number of cells (Krecher & Rudebusch 2005).

2.3.3 Radio Channel Access Schemes

The radio spectrum is a limited resource. It usage must be carefully restricted. There are various techniques in mobile cellular that allow multiple users to access the same radio spectrum at the same time. Frequency division multiple access (FDMA), Time division multiple access (TDMA), Code Division multiple access (CDMA) are three major access techniques used to share the available bandwidth in the wireless communication system.

2.3.3.1 Frequency division multiple access (FDMA)

FDMA divide the spectrum available into several frequency channels (Figure 2.6). Each user is allocated two channels, one for uplink and one for downlink. No other user is allocated the same channels at the same time. In FDMA method was applied in 1G system.
2.3.3.2 Time division multiple access (TDMA)

Time Division Multiple Access systems, as shown in Figure 2.7, divide the radio system into time slots and each time slot only one user is allowed to either transmit or receive. GSM is based on TDMA technology. In GSM, each frequency channel is divided into several time slots (eight per radio frame), and each user is allocated one or more slots.
2.3.3.3 Code Division multiple access (CDMA)

In Code Division Multiple Access system all users occupy the same frequency, and their signals are separated from each other using a special code (Figure 2.8). Each user is assigned a code applied as a secondary modulation, which is used to transform user’s signal into spread spectrum coded version of the user’s data stream. Then the spread spectrum is converting back to its original user’s data stream using the same spreading code.

![Figure 2.8 Code Division Multiple Access](image)

In 3G systems, CDMA method is employ for radio resources usage. UMTS applied wideband CDMA (WCDMA) method which exploits wide frequency band of 5 MHz. Wideband frequency channel allows for lowering the power the power density, so signal may be even weaker than the thermal noise level.

2.3.4 Frequency Assignment

For GSM there are two standard frequencies, GSM 900 MHz and 1800MHz with carrier frequency interval of 200 KHz and up down frequencies as Table 2.1 below.
The GSM standard provides the option for highest traffic capacities by supporting microcells and advanced features providing exceptional resistance against co-channel interference. PCN (personal communication network) is a synonym for such a network philosophy which is going to be realized in the 900 MHz and 1800 MHz band based on the GSM and DCS (which is the expansion of GSM to 1800 MHz) standards recommended by ETSI, the European telecommunications standardization body (Brechtmann et al. 1993).

<table>
<thead>
<tr>
<th>Frequency Band (MHz)</th>
<th>Bandwidth (MHz)</th>
<th>Frequency number</th>
<th>Carrier frequency number</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM 900 Up 890-915</td>
<td>25</td>
<td>1-24</td>
<td>124</td>
</tr>
<tr>
<td>GSM 900 Down 935-960</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSM 18000 Up 1710-1785</td>
<td>75</td>
<td>512-885</td>
<td>374</td>
</tr>
<tr>
<td>GSM 18000 Down 1805-1880</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Brechtmann et al. 1993

“Up” and “Down” are classified according to the Base Station. Base Station transmitting while mobile station is receiving is called “down”, and “up” is when mobile station transmitting and Base station is receiving.

2.4 RADIO RESOURCE MANAGEMENT AND SERVICES

Radio Resource Management (RRM) algorithms are responsible for efficient utilization of the air interface resources. RRM is needed to guarantee Quality of Service (QoS), to maintain the planned coverage area, and to offer high capacity. The family of RRM algorithms can be divided into handover control, power control, admission control, load control, and packet scheduling functionalities (Holma & Toskala 2004). Typical locations for RRM algorithm in WCDMA network as in Figure 2.9.
2.4.1 Power Control

Power control algorithms are crucial for operating a WCDMA system. To counter the ‘near-far effect’ it is essential to equalize the received power at the base station for all mobile terminals transmitting in the same frequency band (Cauwenberge 2003). This issue is not present in existing second generation systems, such as GSM and IS-95, but are new in third generation systems and therefore require special attention. Therefore three power control algorithms have been developed for the WCDMA radio link interface: open loop, outer loop and inner (or closed) loop power control.

2.4.1.1 Open loop power control

OL power control is the ability of the user equipment (UE) to set its power to a specified value suitable for the receiver. The OL algorithm is illustrated in Figure 2.10 below. This method is used for setting up initial uplink transmission powers. The desired power level is calculated from measurement information about the pathloss, the target Signal to Interference Ratio (SIR) and the interference at the cell’s receiver, broadcasted on the Broadcasting Channel (BCH).
2.4.1.2 Closed (inner) loop power control

CL power control algorithms (Figure 2.11) are responsible to counter the uplink near-far effect. The goal of the CL power control is to equalize the received power of all User Equipments (UE) at all times. UE(s) adjust the output transmission power based on signal to interference ratio target value.

2.4.1.3 Outer loop power control

This algorithm sets the Eb/No target for the fast (closed loop) power control. This outer loop aims at providing the quality of communication, while preventing capacity waste and using as low power as possible. Figure 2.12 below illustrate how the outer loop power control algorithm working.
The outer loop is needed in both uplink and downlink because there is fast power control in both uplink and downlink. The uplink outer loop is located in RNC and the downlink outer loop in the UE. In IS-95, the outer loop power control is used only in the uplink because there is no fast power control in the downlink (Holma & Toskala 2004). RNC calculated the SIR target value and sends to Node B. The SIR target value is evaluated accordingly to the Block Error Rate (BER or BLER) value of existing radio connection between UE and Node B. If the received quality is better than the quality that has to be achieved, the SIR target is decreased; in the other case the SIR target is increased.

A disadvantage of this method is that it can happen when a mobile has reached its maximum transmission power, the target SIR gets gradually increased as the user’s signal quality is below the desired value and the MS is unable to better the situation because the maximum transmission power is reached. This windup phenomenon can be countered by setting boundaries for the SIR target.

### 2.4.2 Admission Control

Admission control accepts or rejects a request to establish a radio access bearer in the radio access network. The admission control algorithm is executed when a bearer is set up or modified. The admission control functionality is located in RNC where the load information from several cells can be obtained. The admission control algorithm
estimates the load increase that the establishment of the bearer would cause in the radio network. This has to be estimated separately for the uplink and downlink directions. The requesting bearer can be admitted only if both uplink and downlink admission control admit it, otherwise it is rejected because of the excessive interference that it would produce in the network. The limits for admission control are set by the radio network planning.

2.4.3 Handover

As the mobile moves from one cell area to another, an active call must undergo a switch from one channel to another. This process is called a handover or handoff. Handover aims to provide continuity of mobile services to a user travelling over cell boundaries in a cellular infrastructure. Handover is initiated because of many reasons. The drop of signal strength usually is the common cause for the handover at the edge of a cell. For load balancing, the handover is needed to relieve traffic congestion by shifting calls in a highly congested cell to a lightly loaded cell. Handover procedures can reduce the number of drop calls caused by the signaling error or lack of resources and the quality of services can be maintained. Handover are either initiated by the base station controller (BSC), based upon radio subsystem criteria such as RF level (RXLEV), signal quality (RXQUAL) or distance, or they are a result of network traffic loading. Appropriate decisions are made by a handover algorithm. The measurements performed by the MS and base station transceiver (BTS) which are collated by the BSC include: (1) by MS — RXLEV, RXQUAL (for serving downlink and adjacent BSs), and (2) by BTS — RXLEV, RXQUAL, Distance (uplink for serving BS) (Garg 2004). There are several categories of handover, for examples intersystem, inter frequency and intra frequency handover.

2.4.3.1 Hard handover

Hard Handover (HHO) is known from second generation systems. In HHO as show in Figure 2.13 below, the connection is broken before a new radio connection is established between the user equipment and the radio access network. A user entering
a new cell resulted in tearing down the existing connection before setting up a new connection at a different frequency in the target cell. The algorithm behind this handover type is quite simple; the mobile station performs a handover when the signal strength of a neighbouring cell exceeds the signal strength of the current cell with a given threshold.

![Figure 2.13 Hard Handover](image)

**Figure 2.13 Hard Handover**

Source: Chen 2003

### 2.4.3.2 Intersystem handover

Intersystem handover (Figure 2.14) occurred when there is a handover between two cells belonging to two different Radio Access Technologies (RAT) or different Radio Access Modes (RAM), for example between WCDMA and GSM.

![Figure 2.14 Intersystem handover](image)

**Figure 2.14 Intersystem handover**

Source: Adnan 2010
2.4.3.3 Intrafrequency handover

Soft and soft handover are in intrafrequency handover. Soft handover occurred when the connection is established before the old connection is released. Majority of handovers in WCDMA are interfrequency soft handovers. In soft handover, a cell phone is simultaneously connected to more than one base station during a call. Soft handover (SHO) is normally employed in cell boundary areas where cells overlap as seen in Figure 2.15 below. Without SHO, a communicating base station would have to transmit at higher power level to reach the UE, which would probably increase the overall system interference level. Since all cells in WCDMA use the same frequency, it is possible to make the connection to a new cell before leaving the current cell. This is known as “make-before-break” or soft handover.

![Figure 2.15 Soft handover](source)

![Figure 2.16 Softer handover](source)

In the softer handover situation as illustrated in Figure 2.16 above, a mobile is controlled by at least two sectors under one BS, the RNC is not involved and there is only one active power control loop.

2.4.4 Localization

Localization is the process of finding the geometric locations of wireless sensor nodes according to some real or virtual coordinate system. It is an important task when direct
measurements of the wireless sensor locations are not available. For system localization, GPS is the common used but GPS based localization is very expensive solution and is liable to signal attenuation under thick foliage, indoor, basements, etc. GPS performance is very bad in indoor or in the presence of dense vegetation or other obstacles that block the line sight from GPS Satellites. Global Positioning System requires line-of-sight from GPS Satellites. GPS consumes more power and thus reducing the effective lifetime of the entire network. In Received Signal Strength Indicator (RSSI) method, the receiver uses the signal strength to measure its distance to the transmitter. The mobility and the fast fading of the environment make the received signal strength values to oscillate. This can be solved by measuring received signal strength a number of times and filter out the estimation error with statistical techniques (Sabatto et al. 2009).

2.4.4.1 Assisted GPS

Most accurate location measurements can be obtained with an integrated GPS receiver in the mobile. The network can provide additional information, like visible GPS satellites, reference time and Doppler, to assist the mobile GPS measurements. The assistance data improves the GPS receiver sensitivity for indoor measurements, makes the acquisition times faster and reduces the GPS power consumption. The principle of assisted GPS is shown in Figure 2.17. A reference GPS receiver in every base station provides the most accurate assistance data and the most accurate GPS measurements by the mobile. The assisted GPS measurements can achieve accuracy of 10 meters outdoors and a few tens of meters indoors. That accuracy also meets the FCC requirements in the USA. If the most stringent measurement probabilities and accuracies are not required, the reference GPS receiver is not needed in every base station, but only a few reference GPS receivers are needed in the radio network. It is also possible to let the mobile GPS make the measurements without any additional assistance data (Holma & Toskala 2004).
2.5 PROPAGATION, FADING AND DOPPLER

Radio propagation in the land mobile channel is characterized by multiple reflections, diffractions and attenuation of the signal energy (Holma & Toskala 2004). Buildings, hills and other natural obstacle are the factors that influence in multipath propagation. Fading is used to describe to rapid fluctuations of the amplitudes, phases, or multipath delays of a radio signal over a short period of time or travel distance. Fading is caused by the interference between or more versions of transmitted signal which arrive at the receiver at slightly different times. There are three important effects when a multipath in the radio channel creates small scale fading effects.

a. Rapid changes in signal strength over a small travel distance or time interval
b. Random frequency modulation due to varying Doppler shifts on different multipath signals
c. Time dispersion (echoes) caused by multipath propagation delays

In built-up area, the height of the mobile antennas which is below the height of surrounding structures occurs a fading because there is no line-of-sight path to the base station. Multipath also occurs due to reflections from the ground and surrounding structures. The received radio waves arrive from multiple directions with different directions and different propagation delay. The signal received by mobile at any point in space may content of a wide number of plane waves having randomly scattered

Figure 2.17 Assisted GPS
Source: Holma & Toskala 2004
amplitudes, phases, and angles of arrival. The signal received by the mobile can distort or fade due to these multipaths. The received signal still may fade even when a mobile receiver is stationary due to movement of surrounding objects on the radio channel (Rappaport 2002).

There are many factors that influence small scale fading in the radio propagation channel. These include the following:

a. **Multipath propagation** – The dissipation in signal energy of amplitude, phase and time are due to the presence of the reflecting objects and scatters in the channel. The random phase and amplitudes of the different multipath components cause fluctuations in signal strength, thus inducing small scale fading, signal distortion or both. Signal smearing due to intersymbol interference.

b. **Speed of the mobile** – The different Doppler shifts on each of the multipath components are caused by the relative motion of the base station and the mobile results in random frequency modulation. The moved of the mobile receiver, inward or outward from the base station will affect the positive or negative value of the Doppler shift.

c. **Speed of the surrounding objects** – A time varying Doppler shift on multipath components is induce when objects in the radio channel are in motion.

d. **The transmission bandwidth of the signal** – the received signal will be distorted if the transmitted radio signal bandwidth is greater than the “bandwidth” of the multiple channels but the received signal strength fade will not be so significant.

A shift in frequency occurred due to the relative motion between the mobile and the base station. The shift in received signal frequency due to motion is called the Doppler shift and it is directly proportional to the velocity and direction of motion of the
mobile with respect to the direction of arrival of the received multipath wave. Doppler shift also occurs from the motion of the scattering of the radio waves example, cars, trucks and vegetation.

### 2.6 LINK MONITORING AND NETWORK PLANNING

#### 2.6.1 Network Monitoring Parameters

In wireless environment, various parameters such as bit error rate, signal to noise ratio, distance, traffic load, signal strength and various combinations of these parameters could be considered to decide handover. Received Signal Strength Indicator (RSSI) is the basic parameter to decide handover because of simplicity and good performance. In soft handover mechanism, UE received more than two Base Stations (BS) signal in overlapped region, RSSI value could be used as threshold value such as handover threshold and receiver threshold. If the RSSI value is bigger than handover threshold than, UE starts handover procedures by receiving new BS signal. If the RSSI value is smaller than receiver handover, UE ends handover procedure by ignoring new BS signal (Kwon et al. 2005).

Distance between UE and the serving Node-B can determine whether the handover process will occurred or not. This is because when UE move, it will change the distance between UE and Node-B. When the UE is moving away from a Node-B and moving closer to another Node B, the handover will occur to maintain the quality services. Figure 2.18, explained how the handover based on distance happened. As we can see, D2 distance between UE and Node B is shorter than D, therefore handover occurred.

![Figure 2.18 Handover based on distance](Source: Adnan 2010)
Quality of Service (QoS) refers to the ability of a telecommunications system to provide an appropriate transport service to deliver various types of communications traffic to different user’s satisfaction. Sometimes it can be difficult to define the exact technical parameters required, especially due to the fact that perception of service quality may differ from one user to another. QoS monitoring is required to detect and locate any degradation of QoS performance below the planned values. Thus, it may be observed that whatever global QoS management concept is realized in a network, by definition it could never produce results that would guarantee the same level of satisfaction to each and every user. This becomes even more complicated in a cellular network, where the interface between the network and users realized via radio connection, is not stationary. This nonstationary nature of connectivity in cellular networks is partly a result of the circumstances common to any kind of telecommunications network (bandwidth overloading, its randomness over time) but also due to inherent mobility features of cellular networks, the unexpected and ever changing physical location of mobile users.

The nonstationary nature of the radio network interface means that the chances of successful communication (establishing and completing a call) depend on the physical location of a user relative to the serving network node, which typically will be the closest base station. It is obvious if that terminal will be located within an optimal distance and a favorable radio visibility conditions, a chance of successful communication would be greatly increase with high QoS. Dissimilarly, if it located near the edge of the coverage area (cell) makes communications more difficult and resource demanding (Algimantas et al. 2004).

2.7 SOFTWARE TOOLS

In the last five years mobile devices have evolved into valuable companions for private and professional users. While in the beginning a mobile phone merely provided telephony function, it was augmented bit by bit with organizer, camera and audio functions, increasingly powerful processors and chipsets as well as Internet access (Hense et al. 2009).
Mobile devices become more influential and persistent even as mobile computing has become more important nowadays. Mobile technologies such as smartphones are enabling a new generation of consumer and business applications. From web, email to remote access and Customer Relationship Management (CRM), there is no end to what can now be accomplished with the mobile devices. Mobile device such as the iPhone and Android-based smartphones can be turned into useful tools for researchers in the field.

2.7.1 Commercial and Free Software Tools

Rohde and Schwarz ROMES4 drive test software, ASCOM Network Testing and Radio Network Telecommunication Planning (AKOSIM) are some of the examples of commercial software test platform for measurements in all mobile radio networks. It is forms a complete system for coverage and quality of service (QoS) measurements. Besides pure recording and visualization of test parameters, data is processed instantly and statistics are calculated in real time.

RF Signal Tracker, GMON2, Open Signal Maps, Celltrack, Antennas and other are the examples of the free software monitoring tools that are available. However the capabilities of freeware tools are limited compared to the commercial software tools. Table 2.2 below discusses some of criteria that available in Commercial and Free software tools.

Table 2.2 Criteria in Commercial and Free software tools

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Commercial</th>
<th>Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to replay recorded data</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Display signal Interference</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Monitor network activities</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Able to save monitoring data</td>
<td>Yes</td>
<td>Yes (not all)</td>
</tr>
</tbody>
</table>
2.7.2 Evaluation of Mobile device

Lately, there are massive explosions of the smartphone mobiles technology in the market. The sales are grows to 60% which is nearly 115 million devices. A mobile platform for smartphone has several necessary conditions. First, it offers sufficient service like operating systems for PC such as memory management, virtualization, and process management. Second, it has a graphic processing unit or GPU (also occasionally called visual processing unit or VPU), which is a specialized processor that offloads 3D or 2D graphics rendering from the microprocessor in order to address higher User Interface (UI) before. Third, it needs function for using a service based on Web without modification (Cho et al. 2010). Nowadays there are exists a few type of platform for smartphone, a few examples will be discuss below.

In 2007, the Apple iphone revolutionized the market with further innovative features such as a touch-sensitive display, proximately and light sensors, accelerometer and most recently GPS and Wi-Fi based locating as well as a digital compass. Beyond that, it is also possible to develop a third party hardware device that can be connected to the iPhone and interact with corresponding program. Since Apple provided the required software tools and documentation for developing iPhone applications for free in 2008 and established the App Store – a market place for iPhone software, the number of iPhone applications has surged. Up to then developers at least had to buy an environment like e.g. Microsoft Visual Studio to program applications for the Windows Mobile platform. Additionally, Apple introduced specialised solutions for enterprises to configure iPhones and deploy business software centrally (Hense et al. 2009). Iphone OS, is a mobile operating device that is marketed and developed by Apple Inc. The OS is a closed source of type. The iphone OS is a default operating system for the iPhone, the iPad Touch and the iPad. It is derived from Mac OS X, with which it shares the Darwin Foundation and is therefore an Unix-like operating system by nature (Cho et al. 2010).

In the same time, the Open Handset Alliance under the leadership of Google announced an operating system for mobile devices similar to that of the iPhone, the Android platform. Android differs from other mobile operating systems in three
important aspects: First, most of the code base of Android is open-source. Second, Android applications are written in the popular programming language Java. Last, the distribution of applications does not depend on a third party, whereas Apple can deny the distribution of an application via the App Store. Google operates the Android Market, that is a similar concept to the App Store, but Google’s influence is restricted to legal and moral monitoring. In addition, Android applications can easily be installed by copying the program file or downloading it from the Internet. In November 2008 the first Android-based mobile device was available (HTC Dream, mostly known as T-Mobile G1) (Hense et al. 2009).

Symbian OS, is another mobile phone manufacturers, account for 46.9% of global smart phone sales, making it the world’s most popular mobile operating system. It is a lightweight operating system designed for mobile devices and smart phones, with associated libraries, user interface, frameworks and reference implementations of common tools, originally developed by Symbian Ltd. Since mobile phones resources and processing environments are highly constrained, Symbian was created with 3 design principles: (i) Real time processing, (ii) Resource limitation, and (iii) Integrity and security of user data. To best follow these principles, Symbian uses a hard real-time, multithreaded microkernel, and has a request-and-callback approach to services (Maji et al. 2010).

2.7.3 Mobile Platforms

The market of smartphone is growing at a remarkable rate and is one of the important emerging issued. People who use the smartphone go on increasing in the world. There are a lot of applications for smartphone and they are more complicated. Therefore, various mobile platforms are available and have been improved to meet such conditions. Below section discuss some of mobile platforms offered.
2.7.3.1 Android

The android is one of the open sources operating systems for mobile devices that include middleware and key application and use a modified version of the Linux Kernel. Some features and specifications for Android are shown in Table 2.3 below.

Table 2.3 Android features and specification

<table>
<thead>
<tr>
<th>Features</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handset Layout</td>
<td>VGA, 2D/3D graphics, OpenGL ES 2.0</td>
</tr>
<tr>
<td>Storage</td>
<td>SQLite</td>
</tr>
<tr>
<td>Connectivity</td>
<td>GSM/EDGE, IDEN, CDMA, EV-DO, UMTS, Bluetooth, WiFi, WiMAX</td>
</tr>
<tr>
<td>Messaging</td>
<td>SMS, MMS</td>
</tr>
<tr>
<td>Web Browser</td>
<td>Webkit application framework</td>
</tr>
<tr>
<td>Java Support</td>
<td>Dalvik Virtual Machine</td>
</tr>
<tr>
<td>Media Support</td>
<td>H.263, H.264, MPEG-4 SP, ARM, ARM-WB, AAC, HE-AAC, MP3, MIDI, Ogg Vorbis, WAV, JPEG, PNG, GIF, BMP</td>
</tr>
<tr>
<td>Additional Hardware Support</td>
<td>Touchscreens, GPS, accelerometers, magnetometers</td>
</tr>
<tr>
<td>Development environment</td>
<td>A device emulator, tools for debugging, memory and performance profiling, and plugin Eclipse-IDE</td>
</tr>
<tr>
<td>Market</td>
<td>Android</td>
</tr>
</tbody>
</table>

Source: Cho et al. 2010
2.7.3.2 Iphone

Iphone OS has four abstraction layers as shown in Figure 2.19, the Core OS layer, the Core Service layer, the Media layer, and the Cocoa Touch Layer. The OS uses approximately 500 Mbytes of the device storage.

![Figure 2.19 Iphone OS Layer](image)

Source: Cho et al. 2010

Core OS and Core service are for processing service of system over kernel. This layer allows developers to access file system, socket for network, and data processing in low level. It is based on C-language and includes Core Foundation, CFNetwork, and SQLite functionality. Media layer is mixed by C-language and Object-C. It can control audio and video and processes 2D/3D graphic interface. It contains OpenGL-ES Quartz based on C-language, Core-Audio, and Core-Animation based on Objective-C. Cocoa Touch layer based on Object-C provides a framework for establishing and offering the basic structure of an application. That is, Cocoa Touch wraps an under layer then makes an environment in terms of foundation framework. This framework provides an interface based on object to work file and network system. Most of applications are implemented on this layer, Cocoa Touch. When you want to change a pattern defined before, you can access lower layer to customize it. When deciding what additional technologies to use, it is recommended
that you start with frameworks in higher-level layers and fall back on the frameworks in the lower layers as needed (Cho et al. 2010).

2.7.3.3 Symbian

Symbian is optimized for low-power battery-based devices and ROM-based systems. Here, all programming is event-based, and the CPU is switched into a low power mode when applications are not directly dealing with an event. Similarly, the Symbian approach to threads and processes is driven by reducing memory and power overheads. Symbian’s system model is segmented into 3 main layers (Maji et al. 2010).

a) **OS Layer**: Includes the Hardware Adaptation Layer (HAL) that abstracts all higher layers from actual hardware and the Kernel including physical and logical device drivers. It also provides programmable interface for hardware and OS through frameworks, libraries and utilities etc. and higher level OS services for communications, networking, graphics, multimedia and so on.

b) **Middleware Layer**: Provides services (independent of hardware, applications or user interface) to applications and other higher-level programs. Services can be specific application technology such as messaging and multimedia, or generic to the device such as web services, security, device management, IP services and so on.

c) **Application Layer**: Contains all the Symbian provided applications, such as multimedia applications, telephony and IP applications and other.

2.8 SUMMARY

Propagation of radio signals can be affected by many factors such as vegetation, fading and other. Therefore monitoring the cellular radio system is important to observe and evaluate the performance of the cellular network in order to provide the most excellent services to the subscribers. High technology devices such as Iphone
and Android-based smartphone can be turned into useful tools for researchers in the field. In this research, only Android based smartphone will be used as a tool to monitor the cellular network. By using the same based platform, various software tools will be used to evaluate the software capabilities in providing the best monitoring cellular results.
CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

The scope of this project focuses on the process of evaluation the suitable smartphone software tools for network monitoring. The appropriate software has to be chosen to make sure that the netmonitoring is working properly.

3.2 GENERAL METHODOLOGY

The methodology of this software can be divided into several sections as shown in Figure 3.1. Firstly, cellular network, smartphone operating system’s platform and its capabilities were study. Then, the suitable software tools for network monitoring are chosen. After that, the data of network is collected. The measurement or data collected were performed stationary at one place. The data was recorded using six different software tools. The field data gathered then was compared and the performance of each monitoring software discussed. Lastly, Visual Basic software was integrated for guidance or teaching proposes.
3.3 SOFTWARE FEATURES EVALUATION

This research is limited to Android based smartphone. A suitable monitoring network software features are selected through Android’s market and also by research from the internet. There software selections are based on a few criteria, for examples the Signal/Quality reception measurement, the ability to monitor the network identity, the
accuracy of displaying the cell tower location if applicable and other. There are six software tools that have been chosen in this research.

Some netmonitor tools have different features in their software. For examples some of the application tools cannot display the signal tower location, cannot show the map of the user location, cannot provide data such as longitude and latitude of the mobile location, MNC, LAC or Bit Error Rate and other. The features of each software tools are further discussed in below section.

3.4 SOFTWARE TOOLS

The RF Signal Tracker, Open Signal Maps, Cellumap, Antennas, STMurray Cell Connectivity Tracker and lastly Signal Finder are the software application tools.

3.4.1 RF Signal Tracker

This RF Signal Tracker 2.2.7 version is an RF engineering application for performing ad-hoc drive tests. It allows for monitoring and recording of signal strength for GSM, CDMA, and EDVO and serving cell location as we travel. It is also monitor Ec/Io, BER or SNR and initialization with GPS. It is only can be install in Android OS version 2.x and higher. Figure 3.2 show the sample screenshot data of RF Signal Tracker tools.
3.4.2 Open Signal Maps

Coverage maps for GSM, CDMA; for 2G, 3G, and 4G. This application able to show the direction of the signal, signal graph, views map radar of cellular and WiFi routers, detailed in signal strength data and it is able to save data in SD card and as well as show the history of signal readings. Sample screenshot data of Open Signal Maps is show in Figure 3.3 below.
3.4.3 **Cellumap**

Cellumap can record CDMA, GSM or UMTS cellular network information (signal strength, Cell ID, etc) along with GPS data, and uploads it to the Cellumap server to be viewed in real-time on the coverage map at www.cellumap.com.

The data points can be uploaded one at a time by pressing the Send-Once button or the Auto-Send Button can be enabled which will automatically upload data points based on a pre-selected distance interval (chosen in the settings menu). Figure 3.4 show the sample of Cellumap’s screenshot window.
This application monitors the GSM/CDMA cellular network connection; displays a map of approximate cellular antenna locations and their RF signal strength and can log the data to a text or KML file. The sample screenshot of antennas is show in Figure 3.5 below.
3.4.5 StMurray Cell Connectivity Tracker

This Application records the various cell network and data connection information in the phone. Monitor network information such as, cell signal strength, cell id, BER, MNC, MCC and etc. However this info cannot be save in SD memory card. The sample of the screenshot is show in Figure 3.6 below.
3.4.6 Signal Finder

This application provides the opportunity never to lose reception, showing where the nearest towers are for the best cell phone reception available as well as the strength the towers have at that location. Figure 3.7 show the screenshot sample data of running Signal Finder tool.
3.5 SOFTWARE INSTALLATION

All of the above applications were downloaded from Android’s market and installed in Android OS smartphone. Figure 3.8 show the market’s window of the smartphone. Android market is an application where all the software that suitable for Android OS is located. In this research, smartphone Samsung Galaxy S was used to install the applications. Figure 3.9 show the example of how RF Signal Tracker was downloaded. First of all, at Install, click “FREE”. The application will be downloaded to the phones after Accept permission “OK” was selected.

After installation completed, the application was tested to make sure it is working accordingly as it is expected. If the applications have a bugs it may disrupted the process of collecting data where it may force the application to close during the test. Figure 3.10 demonstrated the screen captured of the data field collected using RF Signal Tracker application tool.
Figure 3.8 Android’s Market Software Download Application

Figure 3.9 RF Signal Tracker Application installation
3.6 DATA COLLECTION

In this research, the cellular network was monitored at outdoor nearby the Faculty of Engineering and Built Environment, UKM and for indoor; the data was collected at inside of UKM’s library building. The data were observed and collected stationary, at one place without moving. Six selected applications tool were run one by one by using the Samsung Galaxy S smartphone. The sample data acquired were saved by captured screen of the window applications. The data were analyzed and results will be discussed in the following chapter.

3.7 SOFTWARE MONITORING SELECTION GUIDE USING VISUAL BASIC

Visual Basic programming was used to write a selection system window to see whether the criteria applicable or not in the software tools chosen. Examples of the criteria such as the ability to measure the RSSI, ASU, to identify network type and so...
on. It can be used as a guidance or teaching purposes. Figure 3.11 illustrated the flow chart of developed program.

For example here, if the RF Signal Tracker is able to measure RSSI, a message box will appear saying that the software tool is able to measure the RSSI. If it does not able to measure RSSI then the message box will also appear mentioning that this tool is not able to measure RSSI.
CHAPTER IV

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss all of the outdoor and indoor data that have been collected. Six software tools have been chosen to monitor the cellular network radio. It is capabilities and performance will be observed and compared. Criteria that were observed are the abilities to measure RSSI, ASU, to display Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC), Cell ID, Mobile Latitude and Longitude and lastly Tower Latitude and Longitude.

4.2 SOFTWARE TOOLS FEATURES EVALUATION FOR OUTDOOR AND CRITERIA

The data observed, in every software tools are evaluated and their available features are discussed further as below.

4.2.1 RF Signal Tracker

The main tab of this application displays primary phone, network, location and WiFi data. Figure 4.1 below show the data for the RF Signal Tracker while Figure 4.2 show the RF signal Tracker Google map view. In Phone column, the “Number” represents the mobile cell phone number that is used but it is not available in here. GSM is the device phone type. Device type is the unique device ID, for example IMEI for GSM and MEID for CDMAOne/CDMA 2000 phones. SIM SN is the serial number of the SIM whilst SIM State indicating the state of the device SIM card which show
STATE_READY in figure below. Software Version is the software version number for the device which is 01. Sub ID is the unique subscriber ID, for example the IMSI for the GSM phone. The bit error is -1. Evolution Data Optimized (EVDO) a telecom standard for the wireless transmission of data through radio signals, typically for broadband Internet access. It uses multiplexing techniques including CDMA as well as TDMA to maximize both individual user’s throughput and the overall system throughput. $E_c/I_o$ is the ratio of received pilot energy, $E_c$ to total received energy or total spectral density, $I_o$. SNR is a signal to noise ratio, a measure that used to quantify how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the noise power corrupting the signal.

The Network window column displays operator of the current registered carrier. The network state is currently connected and HSPDA is RF network type. MCC/MNC is the mobile country code and mobile network code used by the carrier. 502 represented Malaysia and 12, Telco’s provider MAXIS. System ID and Network ID is a CDMA system identification number, -1 will be replay if it is unknown. LAC/Cell ID is location area code and cell id. Android presents the cell ID as a hexadecimal number. This is converted to decimal for the user. Base Station ID is a CDMA base station identification number, -1 display as unknown. Data activity is the current state of data traffic (IN, OUT, INOUT, DORMANT) and data state is the current data connection state (cellular). Roaming device is currently not roaming on the current network, for GSM purposes and International is not internationally roaming. Call state showed the current call state whether it is idle, ringing or offhook. Reselection neighbours is the number of neighbours being considered for selection as well as their individual RSSIs.

Location Service indicates whether you are using Google, Open Cell ID, or your own Local Site Database to determine site locations. Lat, Long is the current latitude and longitude in Degree-Minutes-Second format (DMS). Speed returns the speed of the device over ground. GPS accuracy returns the current accuracy of the fix in meters. Site LAT and Site LONG is the latitude and longitude of serving cell. Distance to cell is the distance of mobile to the serving cell, which is 0.354 miles.
WiFi data information is not discussed here. The yellow dot in Figure 4.2 is a mark indicates the RSSI at this point is moderate. The RSSI is -91 dBm.

Figure 4.1 RF Signal Tracker window screen captured for (a) phone (b) network (c) location (d) wifi
4.2.2 Open Signal Maps

On the Open Signal Maps’s screen as shows in Figure 4.3, the signal strength is displayed in dBm as well as in ASU. ASU is just a representation of the rate at which the phone is able to update its location by connecting to the towers near it. It basically measures the same thing as dBm, but on a more linear scale. ASU can convert to dBm with this formula: \( \text{dBm} = -113 + (2 \times \text{ASU}) \) (Polymenakos 2011). The RSSI measured using Open Signal Maps is -89 dBm. The tower latitude and longitude is 2º 55’ 43” and 101º 46’ 28”. The distance of the mobile of serving cell to the tower is approximately 577m. Figure 4.4 shows the view of Open Signal Maps’s Map.
Figure 4.3 Signal tower directions

Figure 4.4 Open Signal Maps’s Map
4.2.3 Cellumap

Cellumap captured screen in Figure 4.5 below shows the RSSI is -91dBm, value of ASU is 11. LAC is 25400 and Cell ID (CID) is 6985272. MCC is 502 and MNC is 12.

![Figure 4.5 Cellumap screen captured](image)

Figure 4.5 Cellumap screen captured

Figure 4.6 below shows the map that has been uploaded to the server after “Send Data 1x” button is pressed. CID/BID stand for Cell ID, for GSM/UMTS networks while BID is for Base station ID for CDMA network. LAC is for Location Area Code and SID is for System ID for CDMA networks.
Figure 4.6 Map from uploaded server

The red dot in figure above represented the signal strength of the cellular network. The Signal Strength indicator for this application is shown in Figure 4.7 below:

Figure 4.7 Signal Strength Indicators for Cellumap
4.2.4 Antennas

A red circle indicates the ASU value which is 11 therefore the RSSI is -91 dBm. Smaller blue circle indicates user location as reported by the GPS (G). Using a valid GPS location, a separate darker blue circle marked (N) indicates the “Network Location” determined by looking at the nearby mobile and WiFi antennas. The GSM LAC is 25400 and CID is 38456. Type of network is HSPDA, MY MAXIS.

Figure 4.8 Screen captured of Antennas application

4.2.5 StMurray Cell Connectivity Tracker

Figure 4.9 shows the window of StMurray Cell Connectivity Tracker. It displays the phone type is a GSM. The device Id, Sim State, Sim Operator MMC + MNC is 50212, the Cell Id is 6985272, Cell Signal Strength or RSSI is -91 dBm, GSM Bit Error Rate is -1. LAC is 25400. This application does not have a map that shows the location of the tower as well as the user location.
4.2.6 Signal Finder

Main application screen as shown in Figure 4.10, show map with information about the location, cell towers and signal coverage. It does not provide other data such as MNC, MCC, Cell ID and etc. Cell towers location is based on information obtained from Google Mobile Maps web services via the internet connection. Cell tower have two different colors (green and grey) based on the current connected cell towers. Current location is indicated by the blue dot. It is based on GPS or Network information. The red circle highlights nearest theoretical cell coverage. Zone radius is calculated based on maximum known reception distance to each cell. Black lines indicate active cell towers (cells currently used by the device).
4.3 SOFTWARE TOOLS SIGNAL RECEPTION FOR OUTDOOR ENVIRONMENT

Tables 1 below summaries the Received signal strength (P_r) results of six application tools that have been chosen to monitor the network radio system at outdoor.

Table 4.1 Results from software tools (outdoor)

<table>
<thead>
<tr>
<th>Software</th>
<th>Received signal strength (P_r) (dBm)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Signal Tracker</td>
<td>-91</td>
<td>RSSI is weak</td>
</tr>
<tr>
<td>Open Signal Maps</td>
<td>-89</td>
<td>RSSI is weak</td>
</tr>
<tr>
<td>Cellumap</td>
<td>-91</td>
<td>RSSI is weak</td>
</tr>
<tr>
<td>Antennas</td>
<td>-91</td>
<td>RSSI is weak</td>
</tr>
</tbody>
</table>
From the table above, all four applications show the same value of RSSI which is -91 dBm except Cellumap which show -89 dBm. This signal decreased probably due to atmospheric absorption and vegetation. The movement of the surrounding objects also will contribute the losses in signal strength. The RSSI value obtained classified as weak by referring to scale at Figure 4.7, Signal Strength Indicators for Cellumap. Mean Received signal strength ($P_r$) is -90.6 dBm while the standard deviation is 0.8944.

**4.4 SOFTWARE TOOLS SIGNAL RECEPTION FOR INDOOR ENVIRONMENT**

Tables 4.2 below summaries the Received signal strength ($P_r$) results of six application tools that have been chosen to monitor the network radio system in indoor environment.

<table>
<thead>
<tr>
<th>Software</th>
<th>Received signal strength ($P_r$) (dBm)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Signal Tracker</td>
<td>-75</td>
<td>RSSI is strong</td>
</tr>
<tr>
<td>Open Signal Maps</td>
<td>-75</td>
<td>RSSI is strong</td>
</tr>
<tr>
<td>Cellumap</td>
<td>-75</td>
<td>RSSI is strong</td>
</tr>
<tr>
<td>Antennas</td>
<td>-73</td>
<td>RSSI is strong</td>
</tr>
</tbody>
</table>
From Table 4.2 above, RF Signal Tracker, Open Signal Maps, Cellumap, StMurray Cell Connectivity Tracker has a same RSSI value which is -75 dBm. Meanwhile for Antennas application tools the RSSI value is -73 dBm. Referring to Figure 4.7, Signal Strength Indicators for Cellumap, the RSSI is strong at the place. Mean Received signal strength (\(P_t\)) is -74.6000 dBm and standard deviation is 0.8944. The RSSI value for

Even though the data was collected inside of a building, the RSSI value is better than RSSI data that was collected at outdoor environment. This is because the distance of user to the cell tower is nearer, approximately 140 m while the distance for outdoor is a bit far, 577 m (referring to Open Signal Maps application).

4.5 SOFTWARE MONITORING SELECTION GUIDE

Figure 4.11 show the selection window of the created program. User/student can tick the box to see whether the selected software tools application is applicable to measure or display the criteria that the users want or not. Figure 4.12 show the running window of the created program. When RF Signal Tracker with the RSSI criteria is tick, a small message box will pop out state that the tools is applicable to measure the RSSI.
Figure 4.11 Selection program window

Figure 4.12 Program running
CHAPTER V

CONCLUSION

5.1 CONCLUSION

Evaluation of the different software tools application monitoring network in cellular system was fruitfully done. The abilities of application tools were successfully obtained and results were gathered. The differences of abilities in each softwares can be compared and suitable software can be chose for a simple cellular monitoring network.

From the observation that were carried out by referring to a summarize results in Appendix A and Appendix B, the RF Signal Tracker turn out to be the best tool that is capable of measuring and display all the criteria that were monitored except measuring the ASU. Followed by Open Signal Maps as the second best application and third is Cellumap application. Antennas and StMurray Cell Connectivity Tracker has similar measuring abilities of monitoring the cellular network. Signal Finder has the lowest ability in monitoring the network as it is only capable to measure the distance of the tower to the user (mobile).

User/student software tool selection system was successfully created using Visual Basic to show the capabilities in software chosen. In overall, all the objectives have been met. However, more work should be done to achieve objective three since the created program only able to show whether the selected software tools is applicable or not to display or show data/information in each criteria.
5.2 FUTURE WORK

Since the objective three is not fully achieved, future work to develop the program can be continued. A program that is able to show which software tools are available to measure all the criteria chosen can be develop.

Other future work proposed is instead of doing a stationary data collection, a drive test can be carried out to evaluate the efficiency of the software tools chosen. The cellular radio system network also can be monitor by using different operating system platform such as Symbian, iphone and Blackberry to compare the ability of each of the tools. Below are the titles recommended for future work research;

a) Software tools test drive performance evaluation for cellular radio system
b) Software tools evaluation using different OS platform for cellular radio system
REFERENCES


Polymenakos, M.S. 2011. Antennas for Android 1.0


### APPENDIX A

**Summaries data for Outdoor**

<table>
<thead>
<tr>
<th>Criteria\Software Application Tools</th>
<th>RF Signal Tracker</th>
<th>Open Signal Maps</th>
<th>Cellumap</th>
<th>Antennas</th>
<th>StMurray Cell Connectivity Tracker</th>
<th>Signal Finder</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSI</td>
<td>-91 dBm</td>
<td>-89 dBm</td>
<td>-91 dBm</td>
<td>-91 dBm</td>
<td>-91 dBm</td>
<td>N/A</td>
</tr>
<tr>
<td>ASU</td>
<td>N/A</td>
<td>12</td>
<td>11</td>
<td>11</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>MCC</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>N/A</td>
</tr>
<tr>
<td>MNC</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>N/A</td>
</tr>
<tr>
<td>LAC</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>N/A</td>
</tr>
<tr>
<td>Cell ID</td>
<td>38456</td>
<td>38456</td>
<td>6985272</td>
<td>38456</td>
<td>6985272</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile Latitude</td>
<td>2° 55' 26.692&quot;</td>
<td>N/A</td>
<td>2.92405</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile Longitude</td>
<td>10° 1 46' 28.122&quot;</td>
<td>N/A</td>
<td>101.77194</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Tower Latitude</td>
<td>2° 55' 42.622&quot;</td>
<td>2° 55' 43&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Tower Longitude</td>
<td>101° 46' 28.142&quot;</td>
<td>101° 46' 28&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Network Type</td>
<td>HSDPA</td>
<td>HSDPA</td>
<td>HSPDA</td>
<td>HSDPA</td>
<td>HSDPA</td>
<td>N/A</td>
</tr>
<tr>
<td>Antenna distance from User</td>
<td>564.88 m</td>
<td>577 m</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>634 m</td>
</tr>
</tbody>
</table>

N/A representing Not Applicable
## APPENDIX B

Summaries Data for Indoor

<table>
<thead>
<tr>
<th>Criteria/Software Application Tools</th>
<th>RF Signal Tracker</th>
<th>Open Signal Maps</th>
<th>Cellumap</th>
<th>Antennas</th>
<th>StMurray Cell Connectivity Tracker</th>
<th>Signal Finder</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSSI</td>
<td>-75 dBm</td>
<td>-75 dBm</td>
<td>-75 dBm</td>
<td>-73 dBm</td>
<td>-73 dBm</td>
<td>N/A</td>
</tr>
<tr>
<td>ASU</td>
<td>N/A</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>MCC</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>502</td>
<td>N/A</td>
</tr>
<tr>
<td>MNC</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>N/A</td>
</tr>
<tr>
<td>LAC</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>25400</td>
<td>N/A</td>
</tr>
<tr>
<td>Cell ID</td>
<td>38466</td>
<td>38462</td>
<td>6985283</td>
<td>6985278</td>
<td>6985277</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile Latitude</td>
<td>2° 55' 33.404&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile Longitude</td>
<td>101° 46' 54.784&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Tower Latitude</td>
<td>N/A</td>
<td>2° 55' 36&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Tower Longitude</td>
<td>N/A</td>
<td>101° 46' 49&quot;</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Network Type</td>
<td>HSDPA</td>
<td>HSDPA</td>
<td>HSPDA</td>
<td>HSDPA</td>
<td>HSDPA</td>
<td>N/A</td>
</tr>
<tr>
<td>Antenna distance from User</td>
<td>N/A</td>
<td>140 m</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>79 m</td>
</tr>
</tbody>
</table>

N/A representing Not Applicable