

DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES

WIRELESS POSITIONING BASED ON
GSM NETWORK

by
Cenk TOSUN

February, 2013
İZMİR

WIRELESS POSITIONING BASED ON GSM NETWORK

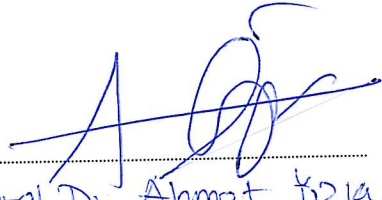
**A Thesis Submitted to the
Graduate School of Natural and Applied Sciences of Dokuz Eylül University
In Partial Fulfillment of the Requirements for the Degree of Master of Science
in Electrical and Electronics Engineering**

**by
Cenk TOSUN**

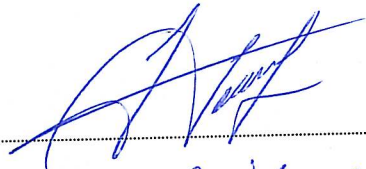
**February, 2013
İZMİR**

M.Sc THESIS EXAMINATION RESULT FORM


We have read the thesis entitled “**WIRELESS POSITIONING BASED ON GSM NETWORK**” completed by **CENK TOSUN** under supervision of **ASST. PROF. DR. AHMET ÖZKURT** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.


Asst. Prof. Dr. Ahmet Özkurt

Supervisor


Yrd. Doc. Dr. Yavuz Sencel

(Jury Member)


Yrd. Doc. Dr. İlker Kılıç

(Jury Member)



Prof. Dr. Mustafa SABUNCU

Director

Graduate School of Natural and Applied Sciences

ACKNOWLEDGMENTS

First and foremost, I would like to express my deepest gratitude to my advisor assistant professor Asst. Prof. Dr. Ahmet Özkurt not only for his support and advices in this thesis but also for his guidance in my life. His valuable insights, experiences and encouragement will guide me in all aspects of my life.

I cannot forget to mention my family's support and love, giving me the opportunity to become the engineer that I have decided to be since I was a child. I dedicate this thesis to my family.

I would also like to thank to Berna Çiçek, who has always believed in me, for her encouragement.

I want to present my thanks to the staff of Graduate School of Natural and Applied Science, especially Mrs. Filiz Gürsan.

Finally, I would like to thank Turkcell which is the one of the biggest GSM operators in Turkey.

This thesis was supported by Turkcell Academy graduate program for a year.

Cenk TOSUN

WIRELESS POSITIONING BASED ON GSM NETWORKS

ABSTRACT

Mobile localization is one of the most important issues in navigation systems. Although there are lots of methods and algorithms for general localization including Wi-Fi, GPS, indoor optic and sound localization, GSM network may be used to localize anything because of system advantages. GSM localization can be grouped into two types of systems in general: These are network based localization systems and mobile handset based localization systems. Network based systems is completely depend on the mobile operator and its algorithm independent from user mobile handset model; other mobile handset solutions depend on mobile phone. There are many different solutions available for positioning the mobile phone using Gsm signals. Most known solutions are Cell-Identification, Angle of arrival, Time of difference (Time difference of arrival), etc.

In this thesis, Cell-ID (cellular antenna identification) and RSSI (receiving signal strength indicator) method was used to design a localization system using GSM RF signal; Android-based cell phones to quantify the advantage easy to get data such as RSSI and Cell-ID number. To obtain more sensitive and accurate position, we prossessed the data in Kalman Filter.

Keywords: GSM, GSM localization, RSSI, cell-identification, Android, Kalman Filter

WIRELESS POSITIONING BASED ON GSM NETWORKS

ÖZ

Mobil lokalizasyon navigasyon sistemleri içindeki önemli konulardan biridir. Wi-fi, GPS, optik lokasyon yöntemleri ve ses lokalizasyonu olmak üzere birçok lokalizasyon metodu ve algoritması olmasına rağmen çeşitli avantajları GSM yapısını lokalizasyon için kullanılabilir kılar. Genel olarak iki başlık altında toplanabilir. Bunlar ağ tabanlı ve kullanıcı mobil taraflı olarak sınıflandırılır. Ağ tabanlı sistemler tamamıyla GSM operatörüne bağlı olan ve mobil kullanıcıdan bağımsız olan yöntemler içerir. Diğer taraftan mobil kullanıcı taraflı uygulamalar tamamen mobil telefona bağımlıdır. Pozisyonu bulabilmek için GSM sinyalini kullanan birçok farklı çözüm vardır. Bu çözümler arasında en bilinenleri: hücre kimlik numarası yöntemi, varış açısı yöntemi ve zaman farkı yöntemleri sayılabilir.

Bu tezde hücre kimlik numarası ve alınan sinyal gücü yöntemi kullanıldı. GSM RF sinyalini ölçmek, alınan sinyal gücünü ve hücre numarasını verisine ulaşılabilesinin kolaylığı nedeniyle Android işletim sistemi yüklü bir telefon tercih edilmiştir. Daha hassas ve doğru pozisyon elde etmek için Kalman filtresi ile veriler işlenmiştir.

Anahtar Sözcükleri : GSM, GSM Lokalizasyon, Rssi, Hücre Kimlik Numarası, Android, Kalman Filtresi

CONTENTS

	Page
THESIS EXAMINATION RESULT FORM	ii
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
ÖZ	v
CHAPTER ONE – INTRODUCTION	1
1.1 Localization Methods	1
1.2 GSM Localization Application Areas	2
1.3 GSM System Specifications	5
1.4 GSM Network	6
1.4.1 Mobile Station(MS)	7
1.4.2 Network Switching Subsystem(NSS)	7
1.4.2.1 Mobile Service Switching Centre(MSC)	8
1.4.2.2 Visitor Location Register(VLR)	8
1.4.2.3 Authentication Centre(AUC)	8
1.4.2.4 Equipment Identity Register Centre	8
1.4.3 Base Station Subsystem(BSS)	9
1.4.3.1 Base station Controller	9
1.4.3.2 Base Transceiver Station	9
1.4.3.3 Transcoder	9
1.4.4 Signalling System in GSM	10
CHAPTER TWO – GSM RADIO WAVE PROPAGATION	11
2.1 Introduction to Radio Wave Propagation	11
2.1.1 Diffraction	11
2.1.2 Scattering	11

2.1.3 Reflection.....	12
2.1.4 Shadowing (Normal fading)	12
2.1.5 Path loss and large-scale fading.....	12
2.1.6 Multipath propagation and small-scale fading	14
2.2 Propagation Models.....	15
2.2.1 Free Space Loss (FSL).....	15
2.2.2 Hata-Okumura	17
2.2.3 Cost-231.....	18
2.2.4 Lee's Model	19
2.2.5 Walfisch-Ikegami	19
CHAPTER THREE – LOCALIZATION TECHNIQUES.....	21
3.1 GPS(Global Positioning System)	21
3.1.1 Assisted GPS	22
3.2 Gsm Localization Technique Introduction.....	22
3.2.1 Cell-Id Method.....	22
3.2.2 TA(Timing Advance) Method.....	23
3.2.3 Received Signal Level Technique Method.....	24
3.2.4 AOA (Angle of Arrival) Method.....	24
3.2.5 TOA (Timing of Arrival) Method	25
3.2.6 TDOA (Time Difference of Arrival) Method.....	25
CHAPTER FOUR – GSM MEASUREMENT METHOD	27
4.1 Obtaining the position	27
4.1.1 Cell-Id	28
4.2 Localization Approach	28
4.2.1 Google Earth Software	28
4.3 Geometric Localization Techniques.....	29
4.3.1 Triangulation.....	29
4.3.2 Trilateration	30

4.3.3 Multilateration	32
4.4 Data Correction	33
4.4.1 Moving Average Filter	33
4.4.2 Kalman Filter	34
4.5 Observation Setup	35
4.5.1 Mobile Side.....	35
4.5.1.1 Windows Mobile 6.5.....	36
4.5.1.2 Android	36
4.5.2 PC Side	42
 CHAPTER FIVE – IMPLEMENTATION OF KALMAN FILTER TO LOCALIZATION PROBLEM ON GSM NETWORK	 43
5.1 Overview of this chapter	43
5.2 Obtaining data software.....	43
5.3 Math behind the algorithm	45
 CONCLUSION.....	 57
 REFERENCES.....	 59
 APPENDICES	 63
A- Figures.....	63
B- Sample Codes	67
C- Technical Spec	80

CHAPTER ONE

INTRODUCTION

1.1 Localization Methods

Localization or localisation is a term the meaning of which can change depending on usage in a context. If we use it in a medical article, it means the determination of the place of any process or lesion of particular part or organ of the body. In Banking and Economics, localization is used as the antonym of globalization. Global banking sector mostly uses localization as a slogan in their advertisements. Software localization, adjusting for a certain location adapting software or hardware especially for other nations and cultures, The software designed for international market should be localized generally, a program coming language add-on file after default language also known as navigation and positioning in engineering. Our localization problem is about determination of the place where something is. In engineering disciplines, localization can be categorized according to area of use. In wireless sensor network, Localization has been a huge research area for wireless network sensor. Using directional antenna, getting data from sensor nodes (Wen & Jian, 2007). Robot localization used to mapping a robot and it has a pivotal role in mobile robot navigation (Cheng, Wu, & Zhang, 2011). Sound localization pays attention to acoustic signal. A person or microphone array can hear different soundwaves and approximately estimate where the source is (Mungamuru & Aarabi, 2004). Satellite localization is a navigation technique which utilizes satellites in space. It will be discussed in the following GPS (Global Positioning System) headline.

Local Positioning is one of the most interesting features of the next generation of wireless systems. In recent years, usage of 3G has been growing gradually and new technologies such as LTE are ready to go and 4G (Fourth generation) will become standard. With very high data transferring rate, it is predicted that usage of wireless systems will increase. Thus, mobile positioning navigation solution will be necessary. In this study, we argue that GSM Localization as a solution for determining the location of a mobile user using wireless GSM signals.

1.2 GSM Localization Application Areas

Location based applications are completely crucial for network operators to compete in the wireless localization marketplace. Location based services offer many opportunities. Location based services currently using commercial applications which are performed using location determination equipment and services can be used such as commercial vehicle tracking and management, alerts, advertising, city trip services and mobile yellow pages internally used for navigating itself to find out current position data for information services. In Emergency situation and lawful intercept, location services allow sending the location of the user's mobile telephone to public safety point. This application is based on discovering and transferring device location information to emergency facilities or services.

Nowadays, cell phone localization is an essential project and is currently used. For example, E-911 in America or E-112 in Europe was deployed to save people's lives (Van Rheeden, & Gupta, 1998). It is estimated that about 70 percent of 911 calls are placed from wireless phones, and that percentage is getting to increase. According to current FCC (Federal Communications Commission), Phase II rules carriers use handset based technologies to locate 67 percent of calls within 50 meters and 95 percent of calls within 150 meters and use network based technologies to locate 67 percent of calls within 100 meters and 95 percent of calls within 300 meters (Wang, Green, & Malkawi, 2002).

In Turkey, Aselsan&Netaş consorsium created Turkish single emergency call number project 112. For pilot implentation, they chose Antalya province and its backup database Isparta province. In 2009, single emergency number project was started in Turkey as a MATRA project by the Ministry of Internal Affairs (Küçükılıç & Şut, 2011). The aim of this project was to access to all public safety emergency numbers with a single number. In this project, 112 Emergency call center is the common call center for call-takers and the ambulance service, Fire brigade, Police, Gendarmerie, Forest fire, Coast guards and Civil defence dispatchers. All this units use the same software, database and public safety radio communication system.

Accessing this system can be via fixed network by using Türk Telekom or via Mobile operators (Turkcell, Avea). For fixed phones, the system shows number and location and for mobile phones, number and coordinates of location. Mobile telephone subscriber once registered mobile operator, operator access database with a web-link. Thus, by accessing telephone area, location data can be achieved from unique cell phone number. The goal of this project was to decrease localization errors and to find caller's location in 1000 meters for 95% of calls and in 250 meters for 67% of calls.

There are two techniques for the above the cellphone localization system. There are network based systems and handset based systems. Although both techniques try to answer the localization problem, there are a few differences between these two techniques. Network based systems advantages are that they can be applied to all manner of phones, whether old or new generation phones, and even those that are not GPS-enabled. Locating mobile phones in any environment such as indoor, urban, suburban, rural, etc. This technique can be adapted to government systems more easily. Disadvantages of network based systems are worry about sharing location data with 3rd persons or foundations and legacy problems.

Nowadays, handset based solutions generally contain GPS or A-GPS questioning. Nevertheless, most of mobile phones do not have this complicated equipment. This is the disadvantage of handset based techniques. This approach depends on well equipped system and doesn't work on old phones. Even if there is a GPS on a mobile handset, emergency response time takes too long.

Friend Finder application by Telenity is one of the examples for using GSM localization. If one of the friends on buddylist is near, application gives a message to user's location to each other. The application also allows sharing location with their family members and colleagues who use the same network operator. Another usage of Peoplefinder application allows managing, following and communicating with their employees.

In addition to emergency issues, cell phone localization has a different area of usage today. Mobile users using Google cell-id database know current location and share with each other by using popular applications such as Google Latitude and Foursquare. All of these applications fingerprint user's location using their cell phone, keep their cell phone info and collect it in a database for later questioning (this data is actually kept in a server for later usage for everyone).

In our country, the popular application named En Yakın Nerede was made by Turkcell. The application giving actual geolocation data with some error also gives data such as nearest hospital and police station. This technology uses CGI (Cell Global Identity) with TA (Timing Advance). There are always tracing suspicions by third persons and private legacy is not satisfactory today.

In this thesis, we investigated the possibility using GSM (Global System for Mobile Communications) as a localization system. Local positioning (or localization) is one of the most important research subjects in wireless network. Although primary function for the GSM Cellular system is voice call, GSM is able to be used for localization sub-mission. GPS (Global Positioning System) which is easily implemented and evaluated is a practical and cost effective and simple solution for localization problem. However, it does not work in indoor positioning such as concrete buildings or city valley (e.g. city downtown with many buildings) whereas Gsm does. Gsm signals can be used not only indoor but also for outdoor challenges. GPS technology uses satellites which orbit at 20.000 kilometers above the surface of the Earth. The purpose of these satellites are only radio navigation. A Receiver in mobile station can obtain latitude and longitude is determined with under 10 meters. However, the smallest part of the market has this device in their mobile device up-to-date. Another handicap for this system is that GPS devices must be seen clean sky. These difficulties make Gsm attractive for local positioning problem.

This thesis is organised as follows. Section 2 is about propagation of radio signals and current path loss models. Section 3 briefly reviews different estimation techniques, namely TOA TA, RSS, AOA based approaches. In Section 4, the data

correction methods will be examined and geometric localization techniques such as trilateration, triangulation and multilateration will be discussed. In section 5, the problem is defined and our RSSI based system model is outlined.

1.3 GSM System Specifications

A fundamental concept of GSM networks is based on cells (Küpper, 2005). The operating area of a cellular network is divided into cells; each of these cells are connected with one base station. The base station configurations generally assume they have a hexagonal form. Cells are drawn in hexagonal shaped cells and have no gaps or over laps between them. It causes no interruptions to the communication of a mobile subscriber moving from one cell to another. However, in a real world, there are huge living gaps and dead reckoning points where no coverage is provided to the mobile subscriber.

Mobility is one of the magic words for GSM cellular systems. Mobility function is provided by the wireless radio interface between base stations and mobile units.

Transmission speed of primitive GSM systems like first generation (1G) analog system is sufficient for only speech communication. Firstly, 1G was introduced for mobile cellular technology. 1G indicates that it originated in the 1980s wireless analog technology standards. After that, 2G wireless digital standards was used instead of 1G. 2G networks first commercially began on the GSM standart. 2G Gsm standards was first used in 1991 practically. Using system in European country works with 900 MHz and 1.8 GHz frequencies. 2.5G EDGE(Enhanced Data Rates for GSM Evolution) technology is a huge step that bridges 2G to 3G wireless technology. EDGE supports data transmission speed up to 384 kbps. By the year 2003, EDGE was deployed on GSM Networks (Halonen, Romero, & Melero, 2003). 2G and 3G had been defined as standards by the ITU (International Telecommunication Union) while 2.5G was created only for the purpose of the marketing which has not been defined officially (Dahlman, Parkvall, & Skold, 2011). 3G technologies have provided faster data transmission speeds and more advanced

networks services. The third generation of mobile phone standards is 3G. UMTS-HSPA is being designed to offer speed of at least 144kbps to 2 Mbps initially and besides, it offers experience to users in fast-moving vehicles and 3G support up to 10 Mbps by 2005. The 3.5G is a standard similar to 2.5G, the reference to 3.5G is not officially recognized as a GSM standard. In spite of the fact that 3G widely developed, GSM is still the world's extensive mobile communication standard and its specification is ceaselessly updated by 3rd Generation Partnership Project (ETSI Standard TS 45.001, 2012). Moreover, modern cellular systems (GSM, GPRS, UMTS) perform hand-over, location, paging functions. A handover is the change active base station on the fly without interrupting an active call.

ETSI (The Telecom Standardization authority in Europe) decided to use mix type of WCDMA and TD/CDMA air interface on planned universal mobile telecommunications system (UMTS). (Mistry, 1998)

Currently, HSPA (High Speed Packet Access) is the most widely deployed mobile broadband technology in the GSM family. HSPA builds on third generation (3G). Sometimes HSPA is the terminology used for HSDPA and HSUPA (Mishra, 2007). HSPA technology needs to extend operator investment in network before next step to LTE (Long Term Evolution) which is called fourth generation.

1.4 GSM Network

A GSM network can be categorized into three groups. (Figure): The Mobile Station (MS), Base Station Subsystem (BSS) and Network Switching Subsystem (NSS) (Sauter, 2011). These three subsystems consist of different elements. Network elements and their assignments are explained below.

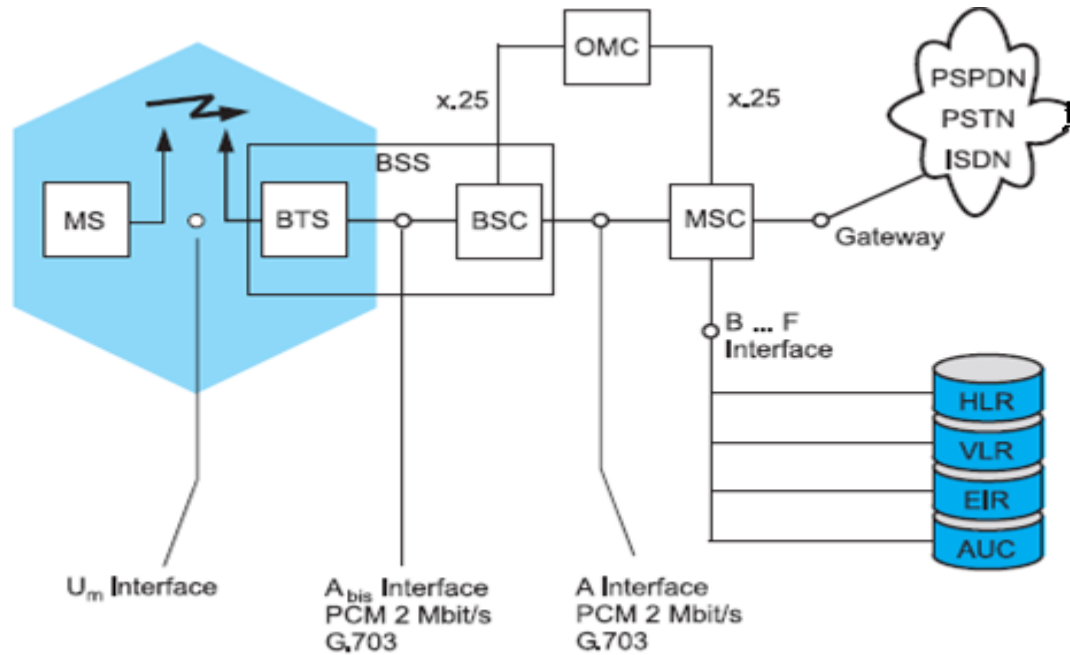


Figure 1.1 GSM Network Components: MS, BSS and NSS (Wandel & Goltermann communication test solutions pocket guide)

1.4.1 Mobile Station (MS)

Conventionally, the mobile station has two main parts: mobile terminal equipment and subscriber identity data. Terminal equipment is a device called ME (Mobile Equipment) and subscriber's data securely stores the subscriber key (IMSI) in a removable module called SIM (Subscriber Identity Module) (Mishra, 2007). The SIM is small memory device mounted on a card. The SIM keeps user specific identification data. To realize this purpose, SIM cards have a 64 Kilobyte memory nowadays. Therefore, mobile station (MS) consists of mobile equipment and SIM. The SIM card can be unmounted from mobile equipment and another one can be installed.

1.4.2 Network Switching Subsystem (NSS)

The Network Switching Subsystem (NSS) involves the network elements. The MSC contains the databases of the network. These databases are VLR, HLR, AC and EIR. Additionally, there is OMC (Operation and Maintenance Center) which assists

the network operator. OMC produces alarm about system health and sends log files and reports to the maintaining operation center.

1.4.2.1 Mobile Service Switching Centre

The MSC's main purpose is controlling calls in the network. It associates the origin and route of a call (mobile station or fixed line). An MSC performs as a bridge between a mobile network and public telephone line network, which is called a Gateway MSC. MSC has several important tasks such as: call control, initiation of paging, charging data collection.

1.4.2.2 Visitor Location Register (VLR)

The Visitor Location Register connects with MSC to pass authentication or call setup level. VLR is a database which keeps some information about users. In the database, SIM security info for authentication, subscriber's accessible services and currently subscriber's service area of the MSC and VLR data are held by VLR. Furthermore, attach or switch-off process can be managed in VLR and it is used before register. The VLR database is held temporarily and data (such as Temporary Mobile Subscriber Identity) is transferred into new service area to HLR.

1.4.2.3 Authentication Centre (AUC)

The Authentication Center is responsible for generating the necessary crypto variables for authentication and encryption on the network. All mobile devices have to go through this authentication process to access the network.

1.4.2.4 Equipment Identity Register Centre (EIR)

The EIR is used for security purpose databases. By storing information about mobile equipment, unique IMEI (International Mobile Equipment Identity) number,

it can verify that the equipment is approved. IMEI is written on mobile phone memory by factory and it is the unique number of each mobile phone terminal.

1.4.3 Base Station Subsystem (BSS)

The Base Station Subsystem is reliable for managing the radio network and the brain of this system is MSC. Commonly, one MSC contains several BSSs. A BSS may cover a considerably large geographical area consisting of many cells (Saunders & Zavala, 2007). The BSS consists of the base station controller (BSC), base transceiver station (BTS) and transcoder (TC).

1.4.3.1 Base Station Controller

BSC is in charge of controlling sources and operating-maintain function (Sauter, 2011). Main duties of BSC are: controlling radio connections (between TC, BTS and OMC), management of radio sources, realizing radio frequency management, saving cell data, calculating locating algorithm, managing hand-over process.

1.4.3.2 Base Transceiver Station

The BTS is the network element responsible for maintaining the air interface and minimizing the transmission problems (the air interface is very sensitive for disturbances which is argued in radio wave propagation chapter). This task is accomplished with some 120 parameters. These parameters define exactly what kind of BTS is in questions.

The BTS parameters handle the following major items: hand-overs, paging organization, radio power level control, and BTS identification.

1.4.3.3 Transcoder

Transcoder is the equipment which transforms between Gsm transmission format and general public telecommunications systems transmission format. In Gsm system,

because of air transmission difficulties, acceptable transmission data rate is 16 Kbit/s. Other telecom systems work with 64 Kbit/s transmission rate. Transcoder realizes transforming 16Kbit/s to 64 Kbit/s and vice-versa. It is usually located near the MSC.

1.4.4 Signalling Systems in GSM

There are two types of channels on GSM. These are Physical channels and Logical Channels. Generally GSM consists of 8 TRU and every time, slot serves at one time. Physical channels use one time slot on one carrier frequency. Additional TRU can be added for the purpose of cell coverage area. Information carrying physical channels can be named Logical channels (Kumar, Kumar & Malik 2012).

GSM network is based on SS7 [signalling system no7] (Mishra, 2007). When number A calls number B, connected santral number asks another santral step by step until finding the real santral. When digital cycle continues, creating a virtual channel, a santral to another in this way never uses traffic channel and whole process is forwarded in control channel. Thus, traffic channel is used economically. If number B is accessible, A traffic channel is assigned and communication is established.

GSM system needs extra solid security mechanisms beside the call routing and location updating process. To prevent listening of broadcast by third party persons and pirate broadcasting station, data must be encrypted and control mechanisms such as Temporary Mobile Subscriber Identities must absolutely be insluded into the network system. In Gsm, there are a few interfaces according to their use in SS7 signal signalling links are named depending on link type ("A" through "F") . For example, Ai is the Air interface between MS and BTS. For example, Abis is the interface between BTS and BSC.

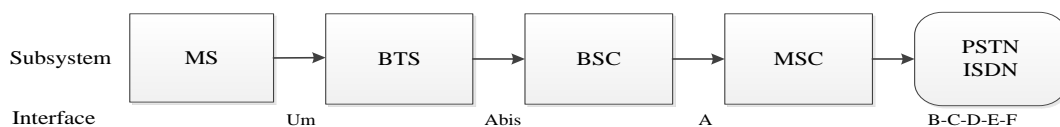


Figure 1.2 GSM Interfaces (Wandel & Goltermann)

CHAPTER TWO

GSM RADIO WAVE PROPAGATION

2.1 Introduction to Radio Wave Propagation

Radio propagation is the attenuation of radio waves when they are transmitted from one point on the earth. As a result of electromagnetic radiation, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering (Eberspacher, Vögel, Bettstetter, & Hartmann, 2009).

2.1.1 Diffraction

Obstacles with sharp edges will cause the signal to diffract over the edge. The following figure represents what happens when a radio wave faces an obstacle. The diffraction angle depends on the wavelength in relation to the size of obstacle, and is greater the longer the wavelength (Calais, 1999).

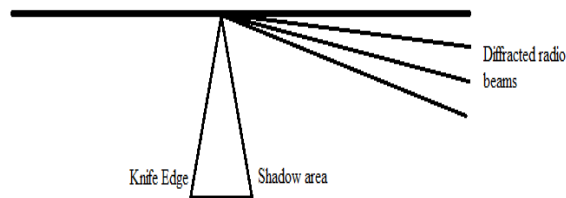


Figure 2.1 Diffraction of a radio wave

2.1.2 Scattering

When radio waves hit the edge, an object scattering occurs (Saunders & Zavala, 2007). Radio waves can be distorted while propagating. Signal can be reflected such as high building and comes together from reflected objects. This effect is mostly described as a multipath fading or signal dispersion. As a result of this phenomena, signal distortion occurs. The distortion degrades the recovery ability of signal on the receiver side.

2.1.3 Reflection

Reflection occurs when radio signals hit an object that acts as conductor plane or dielectric material (Saunders & Zavala, 2007). GSM signals behave like light reflects from mirror. When the signal reflects fully from the plane, at the receiving electrical field value can be fading or reach maximum value.

2.1.4 Shadowing (Normal Fading)

Concrete buildings and high hills between MS and BTS cause signal attenuation (Saunders & Zavala, 2007). For this reason, in receiver side come into some place which has no signal or relatively lower signal. To minimize this handicap, base stations are built up higher hills, towers and buildings.

Received signal strength oscillates around a mean rate because of path loss effects while changing the mobile position resulting would be call drop or getting noise in the speech signal.

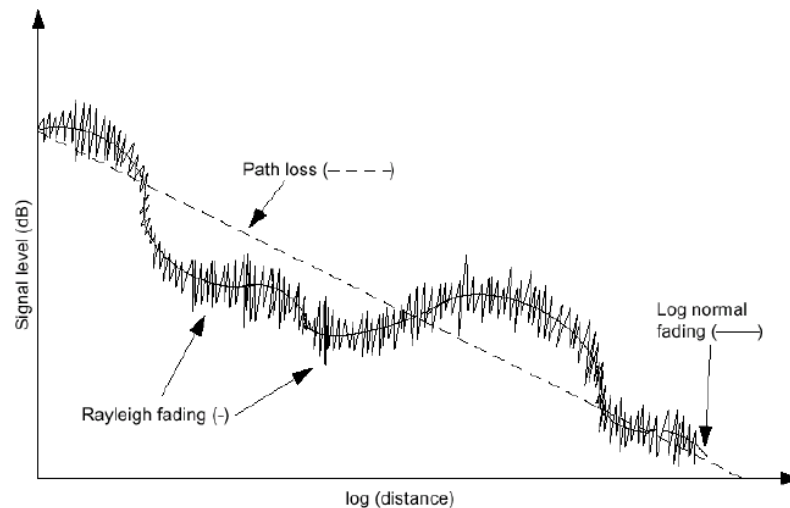


Figure 2.2 Representing of a radio signal fading

2.1.5 Path loss and large-scale fading

Propagation Models are used for the purpose of mean signal strength between transmitter antenna to receiver antenna to predict. This useful deterministic method

used by Rf engineers to calculate the link budget. Large scale propagation models are used to characterize depending on territorial signal strength plans. RF Signal map coverage planner basically uses GIS (Geographic information System) programs such as MapInfo, Global Mapper or ArcGIS. Territorial elevation files take into consideration DEM (Digital Elevation model) data files over large transmitter to receiver distances (several hundred meters to a few kilometers) radio coverage area fixes.

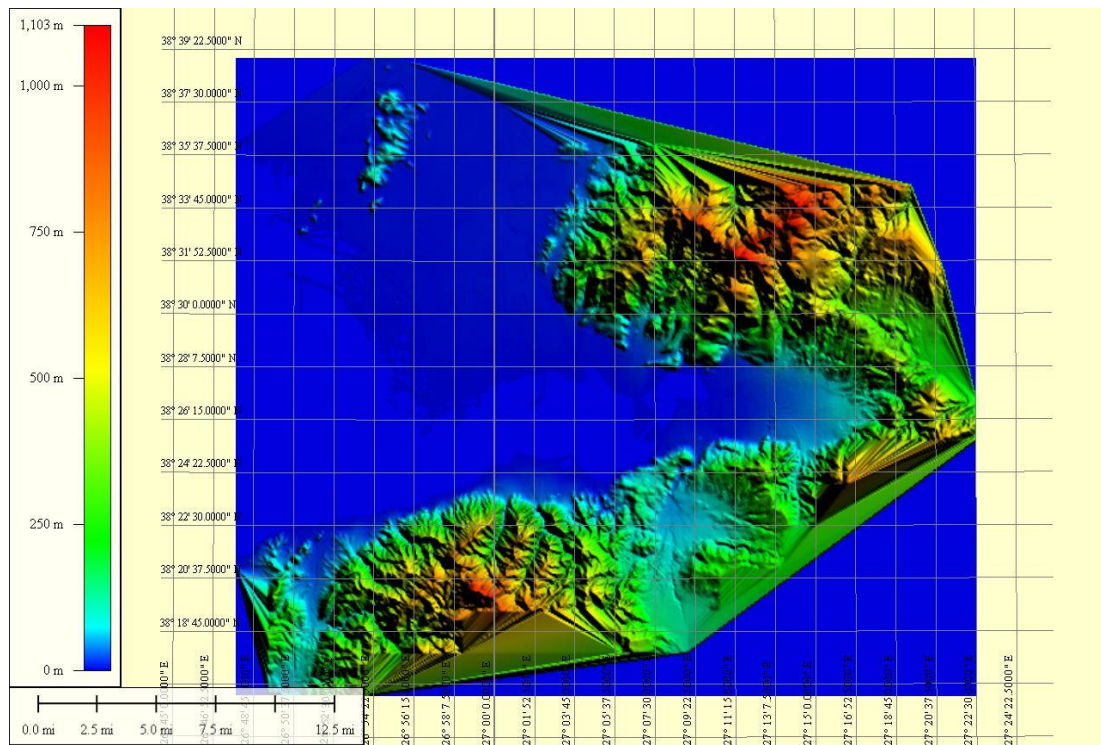


Figure 2.3 DEM (Digital Elevation Model) for İzmir City (Taken from Global Mapper)

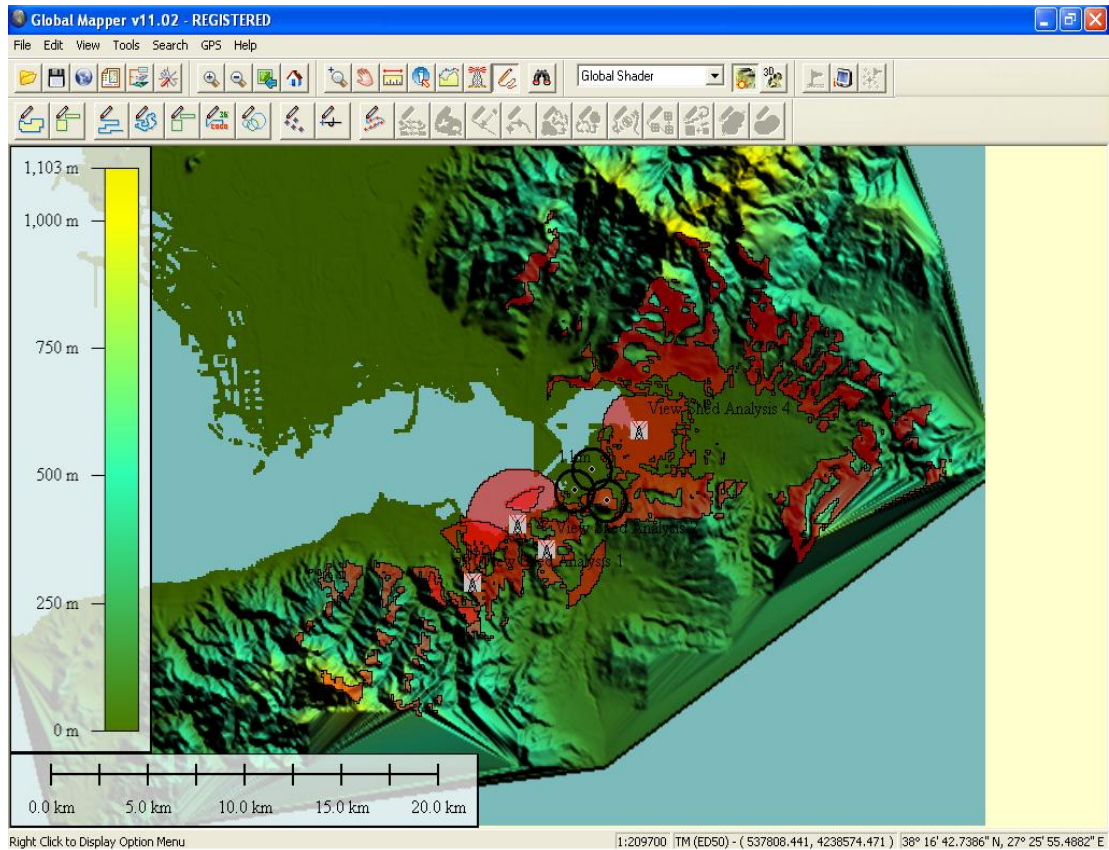


Figure 2.4 Terrain analysis (Taken from Global Mapper)

2.1.6 Multipath Propagation and Small-Scale Fading

This phenomenon is the consequence of reflection, scattering and diffraction of the radio signals. When a signal is received from multiple paths e.g. from reflections on rough walls etc. it may be phase shifted from the original signal received at LOS (Line of Sight).

Occurring signals from the multipath is added to the LOS signal resulting in either constructive or destructive addition effect to receiver point. Figure shows the extreme cases of this effect. The first path(A) represents the LOS and the echo paths (B) and (C) represents other signal paths.

Multipath signals also cause radio signal distortion as well as additional signal propagation loss.

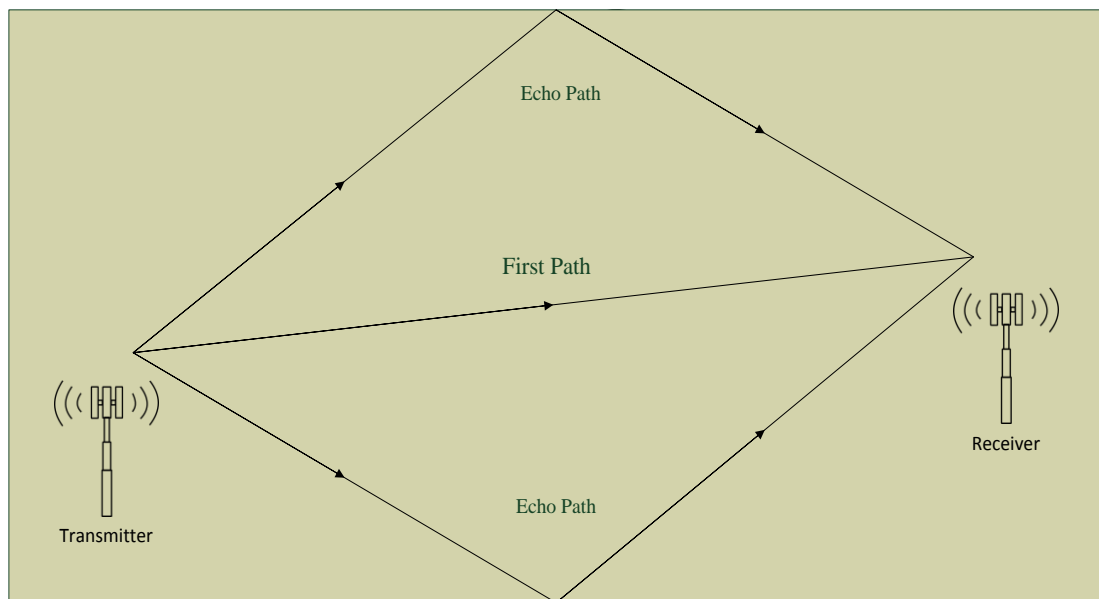


Figure 2.5 An example of multipath

The Path Profile/Los tool allows getting a vertical profile along a user specified path using loaded elevation datasets. User specified region Line of sight calculations can be done by using GIS based Computer programs such as Global Mapper.

2.2 Propagation Models

The Gsm network coverage highly depends on natural factors like geography such as mountains, etc. and like landscape (urban, suburban and rural). Therefore, to know radio propagation conditions for different areas, radio planners can use the existing standard ITU models or they can use their creating for own propagation models, either. There are two major type methods in propagation models: statistical and empirical methods.

2.2.1 Free Space Loss (FSL)

The free space propagation model is used to predict received signal strength between unobstructed line-of-sight between transmitter and receiver (Doble, 1996). The free space model predicts received power decrease as a function of the Transmitter-Receiver separation distance.(power law function) (Feng & Look, 2002)

Receiving signal power is reducing from radiating antenna depending on d^2 which is given by the Frii's free space equation:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad (2.1)$$

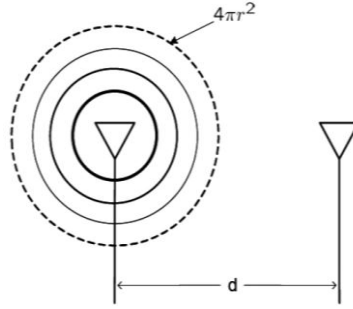


Figure 2.6 Isotropic Antenna

This formula is proved by using isotropic antenna. An Isotropic antenna is a fictional antenna that radiates power to every direction on the plane. Because power radiates in a uniform manner, we can represent that as a sphere. The surface of this power sphere is:

$$A = 4\pi R^2 \quad (2.2)$$

The power density S at any point at a distance R from the antenna can be expressed as:

$$S = P * G / A \quad (2.3)$$

Where P is the power transmitted by antenna, and G is the antenna gain. Thus, the received power P_r at a distance R is:

$$P_r = P * G_t * G_r * (\lambda / 4\pi R)^2 \quad (2.4)$$

On converting this to decibels we have:

$$P_r(dB) = P(dB) + G_t(dB) + 20\log(\lambda / 4\pi) - 20\log d \quad (2.5)$$

Last two terms in equation

The free space path loss for GSM 900

$$PL_{db} = 32.4 + 20\log(f[Mhz]) + 20\log(d[Km]) \quad (2.6)$$

Where f is the frequency in Megahertz and d is the distance in kilometers. The proposed approach works by taking into consideration that the mobile user is not

moving in GSM cell serving area. Free-space attenuation calculation standards are described by International Telecommunications Union (ITU-R P.525).

2.2.2 Hata-Okumura

The Okumura model is a propagation model which is appropriate to use in urban environment (Kumar, Kumar, & Malik, (2012). It is a well-known classical empirical model. This empirical model has some properties. These properties are: The frequency coverage is approximately 200 MHz and 1900 MHz. Distance of this model must be between 1km to 100km and Base station heights ranging from 30m to 1000m (Parsons, 2000). Hata's formulation is created from the provided graphical path-loss data by Okumura and Hata. Hata works between the same frequency, which is 150-1500 MHz. Consequently, The Hata model covers the Okumura model's frequency. This formula simplifies the calculation of path loss. It is not based on empirical curves for the different parameters. The Hata-Okumura consists of the combination of both of the above models.

The standart formula for empirical path loss [dB] in urban areas under the Hata-Okumura model is given by:

$$PL(db) = A + B \log(d) \quad (2.7)$$

A is fixed loss depends on frequency f .

d is distance in Km.

These parameters are given by empirical formula.

$$A = 69.5 + 26.16 \log(f) - 13.82 \log(h_b) - a(h_m) \quad (2.8)$$

$$B = 44.9 - 6.55 \log(h_b) \quad (2.9)$$

Where,

f is frequency measured in MHz fixed loss depends on frequency f .

h_b is height of base station antenna in meters.

h_m is height of mobile station antenna in meters.

$a(h_m)$ correlation factor in dBm.

For effective mobile antenna height $a(h_m)$ is given by

$$a(h_m) = [1.1 \log(f) - 0.7] h_m - [1.56 \log(f) - 0.8] \quad (2.10)$$

The path loss model for highway is given by

For without noise factor

$$PL(db) = PL(db)_{urban} - 2 \left[\log \left(\frac{f}{28} \right) \right]^2 - 5.4 \quad (2.11)$$

For with noise factor

$$PL(db) = PL(db)_{urban} - 2 \left[\log \left(\frac{f}{28} \right) \right]^2 \quad (2.12)$$

2.2.3 Cost-231

The COST231 is extension model of the Hata model the frequency range of which is 1500 MHz to 2000 MHz. This model is limited to the following range of these parameters: (Parsons, 2000)

Carrier Frequency $f_c=1500-2000$ MHz

BS antenna height $H_b=30-200$ m

MS antenna height $H_m=1-10$ m

T-R distance $d=1-20$ km

The path loss according to the COST231-Hata model is given by:

$$Lp(dB) = A + B \log(d) + C \quad (2.13)$$

where:

$$A = 46.3 + 33.9 \log(f_c) - 13.82 \log(h_b) - a(h_m) \quad (2.14)$$

$$B = 44.9 - 6.55 \log(h_b) \quad (2.15)$$

$C = 0$ for medium sized city and suburban areas

$C = 3$ for metropolitan centers and $a(h_m)$ is as given by original Hata model. The COST231-Hata model does take into consideration roof heights, streets widths parameters. Although Cost 231-Hata models are feasible for 30 meter and higher antenna heights, beside this, if around building height is shorter than base station, antenna may be used with shorter antennas. However, this model is inappropriate for prediction with transmission distances below 1 kilometer and it is highly dependent on surface of the local territory.

2.2.4 Lee's Model

Lee's model is based on empirical data which is learnt through observation (Saunders & Zavala, 2007). The empirical data is taken at 900 MHz. The equations for Lee's methods are:

$$P_L = 10n \log d - 20 \log h_b - P_0 - 10 \log h_m + 29 \quad (2.16)$$

Where,

$$P_L = \text{loss (dB)} \quad (2.17)$$

n is a distance correction factor that varies between 4.35 for open areas, 3.84 for suburban areas and can take different values depend on urban environments.

P_0 is an additional term derived from measurement that is -49 in open areas, -61.7 in suburban areas and differing values for urban environments.

d is distance in kilometers.

f is frequency measured in MHz fixed loss depends on frequency f .

h_b is height of base station antenna in meters.

h_m is height of mobile station antenna in meters.

2.2.5 Walfish-Ikegami Model

Walfish-Ikegami is a propagation model which can be used in micro-cellular propagation (Saunders & Zavala, 2007). Generally, it is used for micro-cells in urban environment. On the contrary, other propagation models used in macro-cells, Walfish-Ikegami are fit for limited coverage cells. Walfish-Ikegami is a method for point to area predictions for terrestrial services in the frequency range of 800 MHz to 2000 MHz. It can be used for heights up to 50m, and for a distance up to 5 km. There are two different formulas for this path loss model. These are Line of Sight (LOS) and Non-Line of Sight (NLOS).

The Path-loss formula for LOS condition is:

$$P_L = 42.6 + 26 \log d + 20 \log f \quad (2.18)$$

For the N-LOS formulas:

$$P_L = 32.4 + 20 \log d + 20 \log f + L_{RDS} + L_{MS} \quad (2.19)$$

While, the rooftop to street diffraction loss values are highly dependent on the street shape, street width and operation frequency. The multi screen diffraction losses are dependent on the distance and frequency.

Where,

f is frequency measured in MHz.

d is distance in kilometers

L_{RDS} is rooftop street diffraction and scatter loss

L_{MS} correlation factor in dBm is multiscreen diffraction loss

h_m is height of mobile station antenna in meters.

CHAPTER THREE

LOCALIZATION TECHNIQUES

3.1 GPS (Global Positioning System)

GPS is a navigation technique which is used since the 1980s by U.S. Department of Defense. Although it is a military project, most users use this for civilian purposes. GPS satellites transmit two carrier frequencies which are military and civilian frequency. Civilian use frequency is 1575.42 Mhz. Military signal frequency is 1227.6 Mhz. Difference between these two carrier frequencies is that military accuracy is higher than civilian usage frequency (Calais,1999). GPS Navigation System is a living operation system and consists of 24 satellites. Satellites' orbit takes 12 hours to complete around the world. A GPS operates by receiving signals from these satellites positioned around the earth. GPS provides satellite signals that can be calculated in a receiver. These signals are based on timing atomic time difference of each satellite. The basic idea behind is to determine the range to a given satellite via time of flight of an RF signal. Enabling the receiver to compute position, exact coordinates on the world can be known. Position is determined by the travel time of a signal from four or more satellites to the receiver. Four GPS satellites are enough to compute positions in 3D space. Although GPS has many advantages for outdoor application, it is impossible to use it in indoor application.

To determine the location of GPS Satellites, two types of data are required. These data are almanac and ephemeris data continuously transmitted by GPS satellites and GPS receiver collects and saves this data. Almanac data contains information about the status of GPS satellites and orbital information. If the GPS receiver is new or has a new location before located part in the world, it can take 15 minutes or less to get a fix. GPS receivers need a fixing point additional data called ephemeris. This data gives very precise information about the current orbit of each satellite. This information is about GPS working principle and explains how to obtain a GPS Location procedures process. However, it is not a relevant subject in this thesis.

3.1.1 Assisted GPS (A-GPS)

GPS navigation system has a weakness such as obligation to see the satellites or occurrence time consuming process which was argued before. This weakness can be improved by assisted GPS. Assisted GPS improves first time to first fix. Assisted GPS enhances the performance of conventional GPS using cell network. The server on the GSM side supplies an almanac and ephemeris data (Feng & Look, 2002). A smartphone has to download this data by using data connection method 3G or Wi-fi network. Thus, GPS receiver does not have to wait to receive these data from satellite download.

3.2 GSM Localization Technique Introduction

There are some solution approach proposals for GSM localization. These solutions use different specifications of radio signals. Such as RSSI (Receiving Signal Strength Indicate) which uses principles of radio wave attenuation, ToA (Time of arrival) and Tdoa (Time difference of arrival) method which uses signal propagation or AoA (Angle of Arrival) uses signal arriving angle property (Gezici & Poor, 2009). Although there is not any universal standard for GSM localization, Time of arrival, Enhanced observed time difference and Assisted GPS approaches for location determination are included in standardization (Rappaport, 2002). U-TDOA (Uplink Time difference) method has been formally standardized by the 3GPP (third generation partnership project) which is official development and standardization initiative of GSM and UMTS Network. In this chapter, we investigated current localization techniques.

3.2.1 Cell-id Method

The Mobile station consists of terminal equipment and SIM card which are register subscriber data. Cell-id is the most basic positioning mechanism for a GSM network. (Seybold, 2005) According to ITU, whole GSM networks have to Cell-id, LAC, MNC and MCC. ITU assigns a Mobile Country Code (MCC) to each country

and a Mobile Network Code (MNC) for each country. MNC is assigned uniquely to each cellular network operator. In addition, every cellphone operator has to design LAC (Location Area Code) for their network and responsible a numeric identification to each sector cell (Cell-id). (Meneses & Moreira, 2006). Whenever a mobile terminal is connected to the network, it is associated to one of these sector cells. This positioning info is based on the cell identification. Gsm operators can translate cell-id number to absolute geolocation points on a map. By considering the coordinates of the cell center and radius, localization can be realized. However, Gsm operators are not generally made publicly available due to privacy causes.

3.2.2 TA (*Timing Advance*)*Method*

The Timing Advance (TA) information transmitted in the BCCH (Broadcast Control Channel) corresponds with a propagation delay of a transmitted signal (Bajada, 2003). The Mobile station is a combination of terminal equipment and subscriber data. RxLev (Received Signal Level)TA is an unrefined measurement data based on network side because of time slot only access from the carriers. TA data can be measured from subtracting the time of reception of the beginning of downlink frame from the time of reception of the beginning of the corresponding uplink frame (Küpper, 2005). Thus, we obtained TA value which is expressed as from 0 to 63. Each value determines the distance from the BTS up to 35 km with a 550 meter step.

The data burst from the MS arrive at the BTS at the exact time. The resolution is one GSM bit, which has duration of 3.69 microseconds. Because of round trip time delay twice as distance. We divided two and found 1.85 microseconds, regarding as speed of light is 300 million meter/second.

$$x = v * \tau \quad (3.1)$$

$$x_{ROUND} = 300000000(m/s) * 1.85(\mu s) \quad (3.2)$$

A Round trip found approximetaly 550 meter. TA is given in figure 3.1

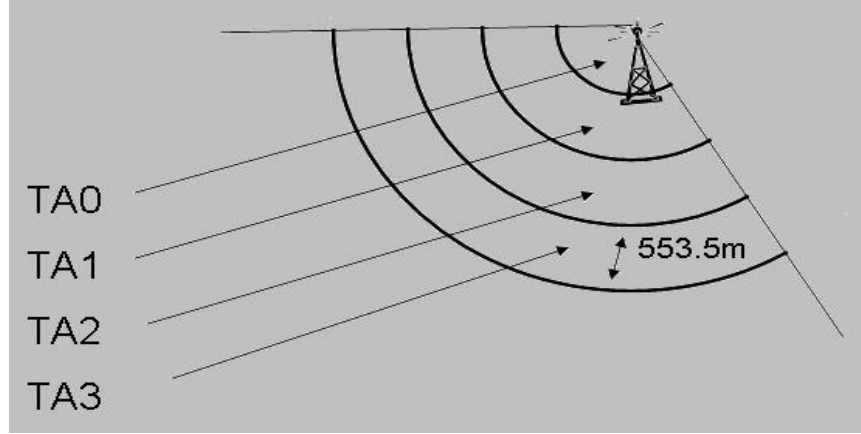


Figure 3.1 The distance of a timing advance (www.gsmdummies.com)

3.2.3 Received Signal Level Localization Technique

The Mobile station is a combination of terminal equipment and subscriber data. RxLev (Received Signal Level) represents the power of BCCH received by MS from a network. (Gezici & Poor 2009) (Klozar, 2011). The RxLev value depends on the length and propagation path. The free space path loss formulas were proved before.

$$Pl_{fs} = \left(\frac{4\pi df}{c} \right) \quad (3.3)$$

Where d is the propagation distance in [m], f is the signal frequency in [Hz], c is the speed of light ($3 \cdot 10^8$ m/s). The character of propagation environment influences path losses, therefore using the feasible propagation model is mandatory (Parsons, 2000).

3.2.4 AOA (Angle of Arrival) Method

This method is used in angulations technique which has to do with angle measurements. (Rappaport, 2002). An advantage of this localization method required minimum two BTS to find an intersection, which can be useful out of town. The main disadvantage is that AOA method requires active antennas deployment to measure signal arriving angle at every site. Each BTS has to be developed with an array of antennas that included special equipped smart antennas. However, smart antennas are not commonly used on the market because of its prices. Aoa equation is:

$$AOA_{TR} = \tan^{-1} \frac{(x_T - x_R)_E}{(x_T - x_R)_N} \quad (3.4)$$

3.2.5 TOA (Timing of Arrival) Method

ToA technique uses the signal travel time from the transmitter to the receiver. There must be at least three BTS (Klozar, 2011). When the distances from three different BTS are known, the location can be found at the intersection of the three circles. Circles' radiuses are created being the distance calculated.

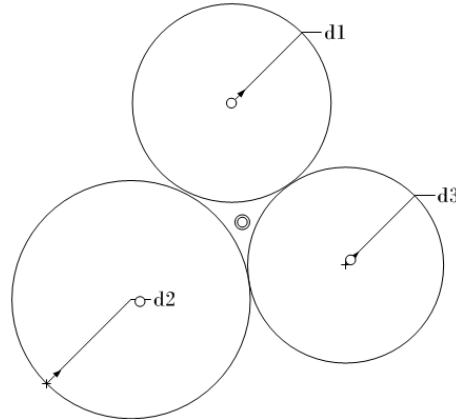


Figure 3.2 Expression of timing of arrival

The time the signal travel time between the MS and BTS is used by LMU Unit (Location Measurement Unit). The most significant thing in this method is precision of the clock in the LMU's. One microsecond timing error would result in a 300m error of the position. All LMUs are equipped with atomic GPS time to synchronize the clocks.

This localization method needs comprehensive changes in the network. In order to measure the time, each BTS needs to be GPS equipped LMU (ETSI spec, 2012).

3.2.6 TDOA (Time Difference of Arrival) Method

This geometrical technique is grouped in lateration approaches (trilateration-multilateration). TDoA is similar to ToA which is working principle based on using travel time difference between transmitter and receiver in order to measure the distances (Dannert, 2012).

TDOA is a network based system. The biggest advantage of this system is that there are not any changes on user side. Beside this, it can be used with any mobile phone, even non-GPS enabled phones, and it works in any environment. These benefits are putting forward this method. This technique is currently used in United States (AT&T Telecom) by TruePosition® Corporation in their Phase 2. In this system; a wireless subscriber can make a phone call for specific number such as 112 in Europe. Every BTS site is at a different distance from the caller so that cellphone signal arrives with a little time difference synchronized atomic clock in LMU unit. Caller's timing data differences are compared and computed to generate location data. Then the caller's latitude and longitude are sent to dispatcher. This localization technique requires at least three different BTS (Güvenç & Chong, 2009)

TDOA requires investment to resolve time differences very precisely. An electronic card called LMU (Location Measurement Unit) must be assembled at each of BTS to adapt current GSM infrastructure.

$$TDOA_{21} = TOA_2 - TOA_1 \quad (3.5)$$

$$\sqrt{(x-x_i)^2 + (y-y_i)^2} - \sqrt{(x-x_o)^2 + (y-y_o)^2} \quad (3.6)$$

$$\begin{aligned} d_{32} &= \sqrt{(x_{A_3} - x_M)^2 + (y_{A_3} - y_M)^2} - \sqrt{(x_{A_2} - x_M)^2 + (y_{A_2} - y_M)^2} \\ d_{31} &= \sqrt{(x_{A_3} - x_M)^2 + (y_{A_3} - y_M)^2} - \sqrt{(x_{A_1} - x_M)^2 + (y_{A_1} - y_M)^2} \\ d_{21} &= \sqrt{(x_{A_2} - x_M)^2 + (y_{A_2} - y_M)^2} - \sqrt{(x_{A_1} - x_M)^2 + (y_{A_1} - y_M)^2} \end{aligned} \quad (3.7)$$

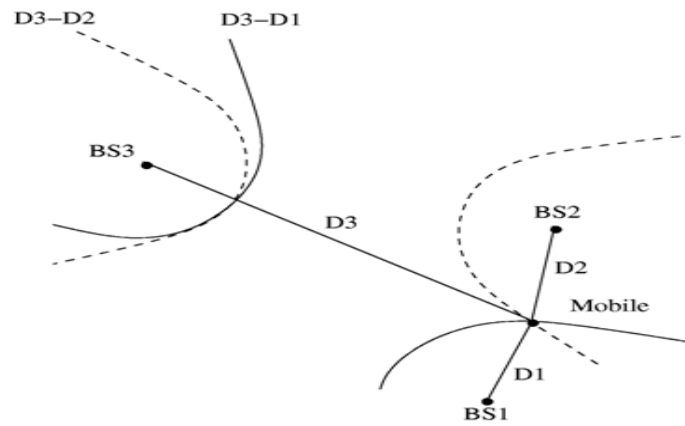


Figure 3.3 Hyperbolic trilateration technique with three BSs based on TDOA estimation

CHAPTER FOUR

GSM MEASUREMENT METHODS

4.1 Obtaining the position

Some parameters in Gsm signalling channel continually flow bi-directional mobile device to operator.(during location update, GSM handover or paging). According to measurement report, mobile phone chose strongest cell around and the cell reselection parameter continually changed. This test contained these parameters: ARFCN (Absolute Radio Frequency Channel Number), LAC (Location Area Code), RAC (Routing Area Code), MNC (Mobile Network Code), MCC (Mobile Country Code), RSSI (Receiving Signal Strength Indicator), RX Quality (Signal Quality), TMSI (Temporary Mobile Subscriber Identity), BAND, Channel in use (TCH-Traffic Channel, BCCH-Broadcast Control Channel, CCCH-Common Control Channel), Rx- Sensivity (BER-Bit Error Rate).

Obtaining the position consists of mobile equipment and mobile network signalling. This process will proceed with these steps: When the mobile phone is first powered on, it registers to the network and becomes part of the network system. Each cell phone on the network is connected to broadcast control channels (BCCH). Each BTS broadcasts this basic information (such as cellid). BCCH continuously sends information from BTS to Mobile equipment A Mobile equipment in an Idle Mode first looks for the channel that received strongest cell on the network, then connects the strongest and synchronizes with probably nearby cell (Aatique, 1997).

Mobile equipment continues monitoring other broadcast channels if there is a powerful power measurement; then, it will connect to the other bts bcch channel. This process is part of the regular hand-over process. Mobile equipment regularly continues during hand-over process and it continues power report testing. Thus, every Mobile device has such info. Consequently, Localization can be calculated mobile based.

4.1.1 Cell-id

Many GSM Operators have to know where which cell is. For this purpose, operators have cell database where cells are located. Each of these cells has different cell-id number. Thus, knowing cell identification number, database inquiry serving cell can be made so that a mobile station can obtain position roughly. Cell-id is the most widely used positioning mechanism for a GSM network.

4.2 Localization Approach

BTS location is given degrees coordinates (latitude, longitude) from database so that visual presentation is performed in the UTM coordinates. In order to translate to coordinates vice versa, we used Matlab M-files. Measured receiving rssi level value determines the propagation distance in each BTS using appropriate path-loss model.

Detractive environment can cause signal to be distorted. Because of this ambiguity, mobile phone's location position can be predicted inaccurately and its error margin highly depends on territorial surface and used path-loss model. The localization error is 165m and the typical error of this technique was about 300m in an urban environment.

Due to the nature of Rx Level technique, the curve arcs sometimes do not intersect in a single point. Reflections and interferences can cause fluctuation of measured Rx Level value. We represent three localization approaches for prediction of the MS position with ambiguous localization data. We figure out coordinates outputs by using Google Earth and City Surf program.

4.2.1 Google Earth

The Google earth is a comprehensive interface program for representing digital maps. Google earth can show 10 meters and less inaccurate satellite images. Some capital cities have more accurate images and other regions have low-resolution level

photo images. Published resolution levels completely depend on Google's responsibility. Google earth is consisted by taken satellite images at different times. Google Earth program can use both geographical degrees and UTM coordinates formats. Advantages of this program are: flight simulation section, GPS data using, data input, zoom in and zoom out, and shifting, coordinate data translate. Disadvantages are being no raster and vector data. The program can understand programming language called KML (Key-hole Markup Language). KML was developed by Google. This language look pretty much like XML (Extensible Markup language). It can be described as XML which includes latitude and longitude data. KML files can be written in notepad easily. Google Earth views the location on the map by reading the KML file.

4.3 Geometric Localization Techniques

In order to determine the position of the mobile station, many techniques can be performed. These techniques are based on geometrical calculation given measurement points. Calculation performed on 2-d Cartesian coordinate system.

In this section, three different positioning algorithms based on geometrical solution will be proposed.

4.3.1 Triangulation

In 2-d space, position of a point coordinates are taken from cellphone using known cell position. This process requires the intersection of two known coordinates in space and is commonly known as triangulation. Triangulation uses the measurement of absolute angles (Küpper, 2005).

4.3.2 Trilateration

Trilateration is based on the principle of determining absolute or relative locations. This process works with circle in 2-d space and spheres in 3-d space (Küpper, 2005).

Trilateration is a mathematical-geometrical method calculation process which can be obtained from two or three known site positions. Contrary to triangulation, it does not use measurement of angles. Trilateration has practical applications in radiolocation and navigation, including global positioning system (GPS) and cellular network positioning.

Radio wave travels at the speed of light because it is a kind of electromagnetic energy. The receiver can calculate by timing how long it takes the signal to arrive. In GPS systems, every satellite in space has synchronous atomic clock to measure this timing difference. This geometric method solution widely uses radio navigation systems such as GPS.

In order to make this calculation, the GPS receiver has to know the exact location of at least three satellites above observer and also the distance between ground and each of those satellites.

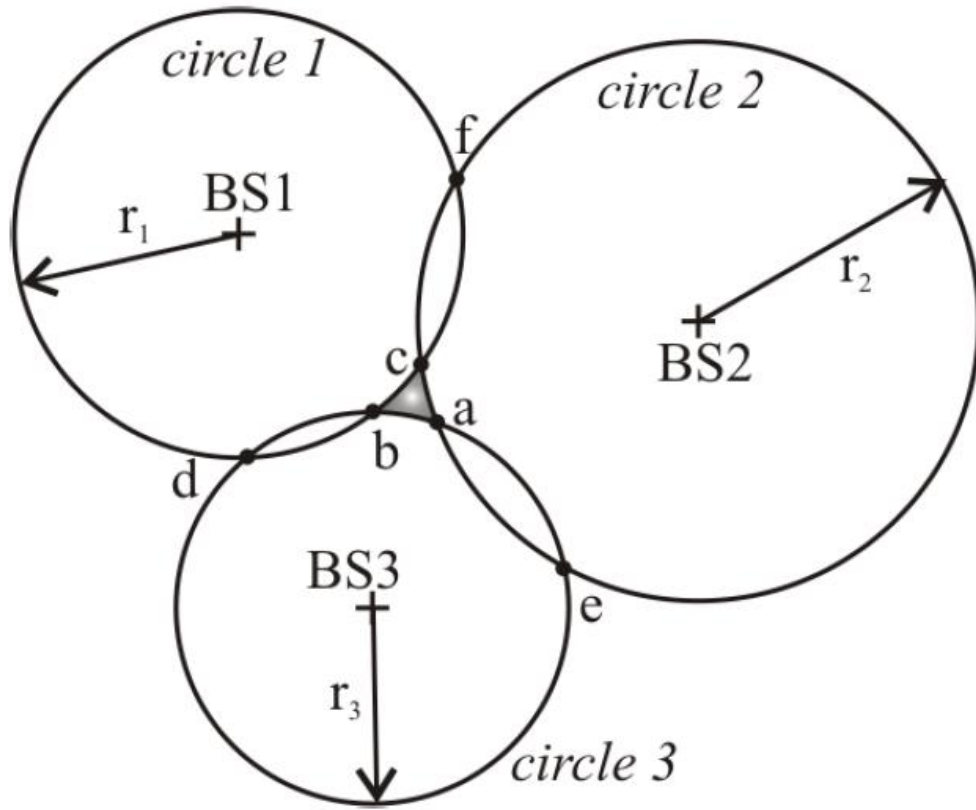


Figure 4.1 Trilateration technique with three BSs. Region of possible formed by Intersection of circles. (Brida, Machaj & Benikovsky, 2011)

In Cellular network positioning, signal source is bidirectional between BTS and mobile phone. Otherwise, GPS receiver can calculate the distance by observing and recording the time of a signals journey from satellites to receiver. If there are three or more sites around the mobile phone, by using signal arriving delay, location position can be obtained with error margin. Reasons of error margin were such as scattering, reflection e.g. as argued before. Mathematical expression of trilateration is:

$$(x - x_1)^2 + (y - y_1)^2 = d_1^2 \quad (4.1)$$

$$(x - x_2)^2 + (y - y_2)^2 = d_2^2 \quad (4.2)$$

$$(x - x_3)^2 + (y - y_3)^2 = d_3^2 \quad (4.3)$$

To simplify this quadretic equation, equation 4.3 is substituted into equation 4.1 and 4.2. Thus, we obtain two linear equations.

$$2(x_2 - x_1)x + 2(y_2 - y_1)y = (d_1^2 - d_2^2) - (x_1^2 - x_2^2) - (y_1^2 - y_2^2) \quad (4.4)$$

$$2(x_3 - x_1)x + 2(y_3 - y_1)y = (d_1^2 - d_3^2) - (x_1^2 - x_3^2) - (y_1^2 - y_3^2) \quad (4.5)$$

The X and Y coordinates are found by solving equation and using Cramer's rule. This determinant will be solved using Matlab. The program code is given chapter 5.

4.3.3 Multilateration

Multilateration is commonly used in civil and military navigation system applications. Such as the trilateration, the multilateration demands three BTS for positioning in 2-d space. One TDOA value can be calculated with comparing two BTS. Thus, mobile phone is located onto a hyperbola. Considering a third BTS existence, second value of TDOA is obtained and second hyperbola is created. The intersection point of these two hyperbolas gives one precise position point. In 3-d space, this technique requires fourth BTS in order to find the 3-d position.

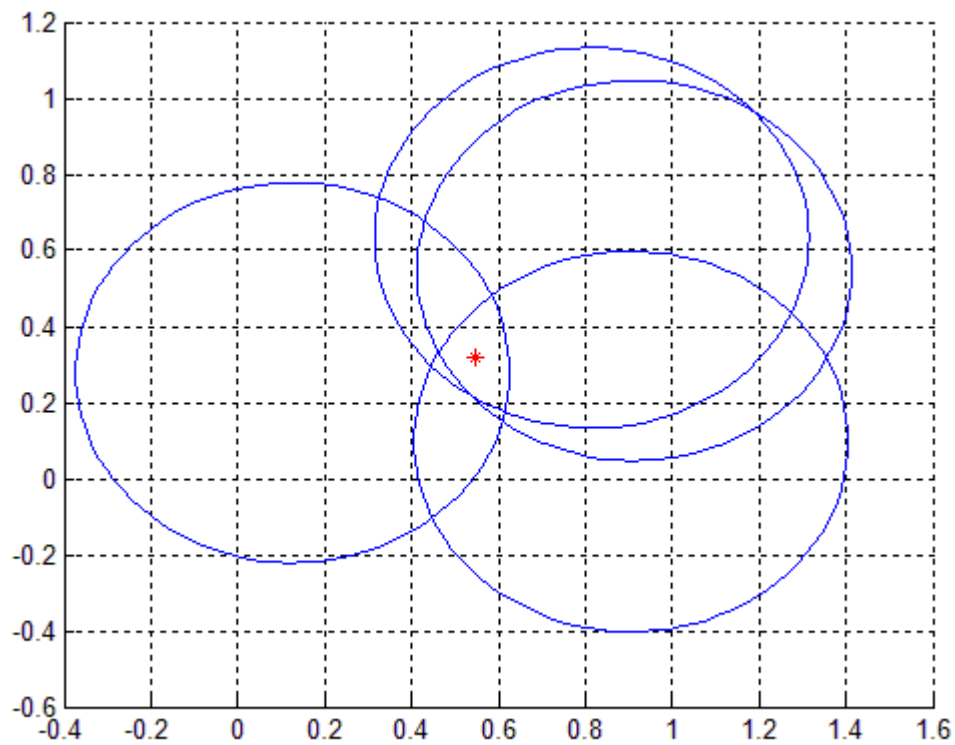


Figure 4.2 Multilateration technique in use based on circular lateration-circle intersection

4.4 Data Correction

In localization system, data receiving with noise lay on Gsm Rf signal property. That's why we used a data correction method in algorithm such as moving average filter for smoothing and Kalman filter algorithm to obtain new clean data based on the previous one.

4.4.1 Moving Average Filter

Receiving rssi data is considered to fluctuate because of reflection, scattering or multi-path propagation effect phenomena. Therefore, moving average filter is used to remove this noisy signal or at least reduce the effect.

Moving Average is a simple smoothing prediction technology. The basic idea behind this forecasting algorithm is that according to one by one series of time so that calculating the average of certain number values to obtain the numerical trend.

For example $n=3$;

$$x = \left(\frac{x_{k-1} + x_k + x_{k+1}}{3} \right), \quad y = \left(\frac{y_{k-1} + y_k + y_{k+1}}{3} \right) \quad (4.6)$$

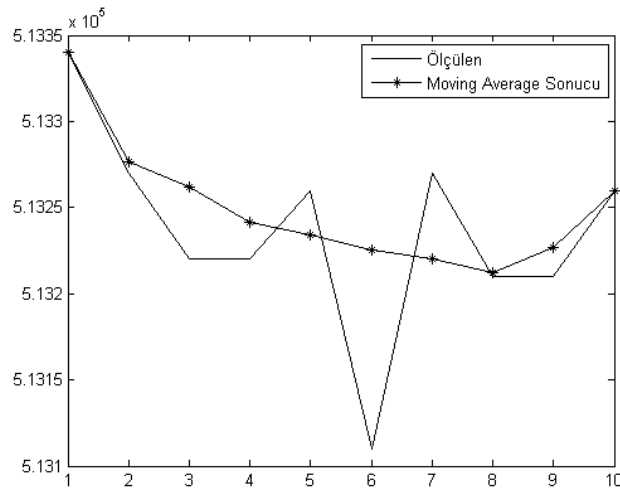


Figure 4.3 A typical output of Moving Average filter for ten location x data (latitude only).

4.4.2 Kalman Filter Approach

The Kalman Filter is a discrete time, finite dimension, time invariant linear system filter which provides solution to linear optimum filtering problem. The most significant feature of Kalman filter is a linear dynamic system condition variance (least square average) predictor (Haykin, 2011).

The Kalman Filter is a predictor type optimal estimation algorithm. It is set of mathematical equations that are implemented for minimizing to error. It reduces the estimated error covariance when some presumed conditions are met. The KF process can be formed into two parts statistically: time update equations and measurement update equations as shown in figure 4.3.

To error covariance is obtained based on predictor estimates for the next time step. The time update equations are responsible for projecting forward (in time) the current state and the predicted state estimate is known as the a priori state estimate because it does not include observation information from the current time-step.

The measurement update equations are responsible for the feedback in incorporating a new measurement estimate based on theory (that is the current a priori prediction is combined with current observation information to refine the state estimate) to obtain an improved practical (Welch & Bishop, 2009).

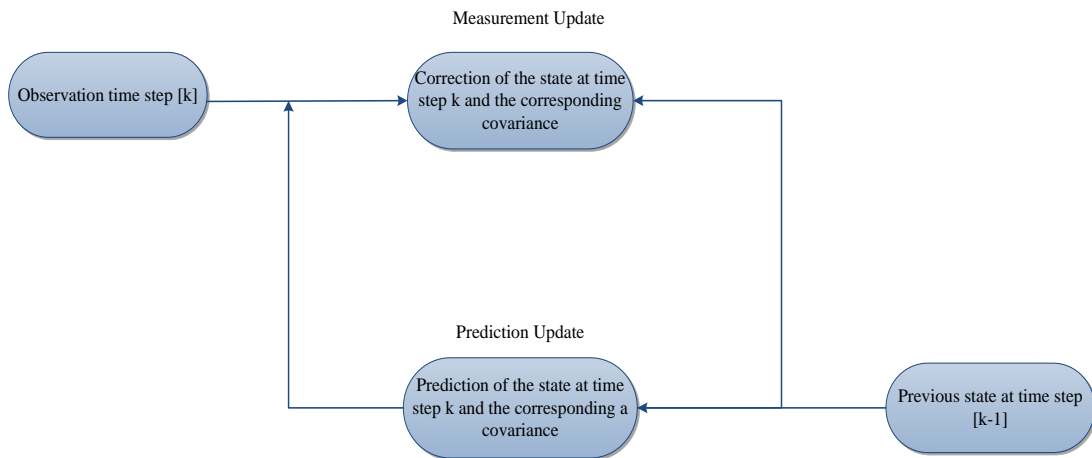


Figure 4.4 Prediction-Correction Process Model of Kalman Filter

4.5 Observation Setup

The network based methods have some advantages over a mobile. Unfortunately, most cell operators are unwilling to share this data with commercial concern. We designed the database cell-id to obtain which mobile phone in serving area works with. Database consists of every unique cell-id number and each of this location data (latitude, longitude and point of view). Querying the unique cell-id data, we obtain location of a mobile phone connected cell location point. All this process works in Matlab background with Matlab m-file called veritabani.m and database called cell_id.

Observation setup consists of a smartphone with Android operating system, a laptop with a Matlab packet program which was installed before. In smartphone, we started android program which was written by us. Every Android smartphone can run this program. The aim of this program is, to retrieve the connected cell-id and rssi level and its neighborhood Cell-Id using smartphone cell core and sending these data via Bluetooth. We create a virtual com port via Bluetooth, so that data can be sent by using this data tunnel. When receiving these data, It can be processed in algorithms such as trilateration, and calculating Kalman process. Finally, the result is shown in Google Earth program.

4.5.1 Mobile Side

Despite the higher resolution of the Base station analyzer, we decided on a HTC HD2 smartphone for making measurement. Rather than choosing a Gsm modem, which would result in comparable measurement results, a setup using mobile phones commercially available on the end-user market, was built. The reason for this was that we wanted to make use of real phones from the beginning onwards. Due to the ambiguous support of Android programming being easily and widely available on the market of smartphones, this option was pursued.

Although, HTC HD2 is a Windows Mobile smartphone, it supports Android, too. One of the reasons of using this smartphone is to obtain the Gsm network data, especially neighbor cell-id data and its rssi level. Default operating system, Windows Mobile 6.5 ROM is not sufficient to get this data. Therefore, we formatted its operating system to Android operating system instead of its default Windows ROM.

4.5.1.1 Windows Mobile 6.5

HTC HD2 smartphone comes with default Windows Mobile 6.5 operating system. The Windows Mobile 6.5 has developer platforms .NET and Visual Studio. The Windows Mobile 6.5 Developer toolkit adds documentation, sample code and header files, emulator and tools to Visual Studio to develop applications for Windows. Firstly, our program is written on Windows Mobile operating system to get serving cell id and its signal strength. We get the serving cell's id and signal strength by using Ril (Radio Interface Layer). However, it seen later to get neighbor cell id and its signal strength impossible in Windows Mobile Radio Interface Layer.

4.5.1.2 Android

Android is a new, open source and attractive mobile platform based on Linux kernel. There are too many libraries, toolkits and learning specifications about this. It may also become important in non-mobile platform. In order to learn rssi values of neighbor cells, we used android operating system. Because neighbor cell data is OEM dependent, Windows Mobile doesn't put forward this data. In contrast to Windows Mobile, Android can serve this data publicly (by using Android TelephonyManager) due to API Level3 which is appearing since April 30, 2009.

Android contains lots of APIs and its classes. These APIs provide info about cellphone. Most widely used APIs are: Activity Manager, Package Manager, Windows Manager, Telephony Manager, Location Manager, Etc. Android TelephonyManager API provides information about android telephony system by using classes. Class provides accessing the information about the telephony service

on the device. Applications can use the methods in this class to determine telephony services and states as well as to listen to the different telephony events. TelephonyManager classes can serve information about phone such as state of call, to get operator name, cell location, neighboring cell info, signal strength, etc.

The aim of specific classes are defined as cell location info is abstract class that represents the location of device. Neighboring cell information includes received signal strength and its cell id and signal strength contains phone signal strength related information. We send data using bluetooth.

Android is a user friendly programming language and asking any program can not be deployed without user permission. Permissions can be given based on xml file must allow to their manifest file. In our work, we allow access to fine location, bluetooth opening permission and read phone state permission.

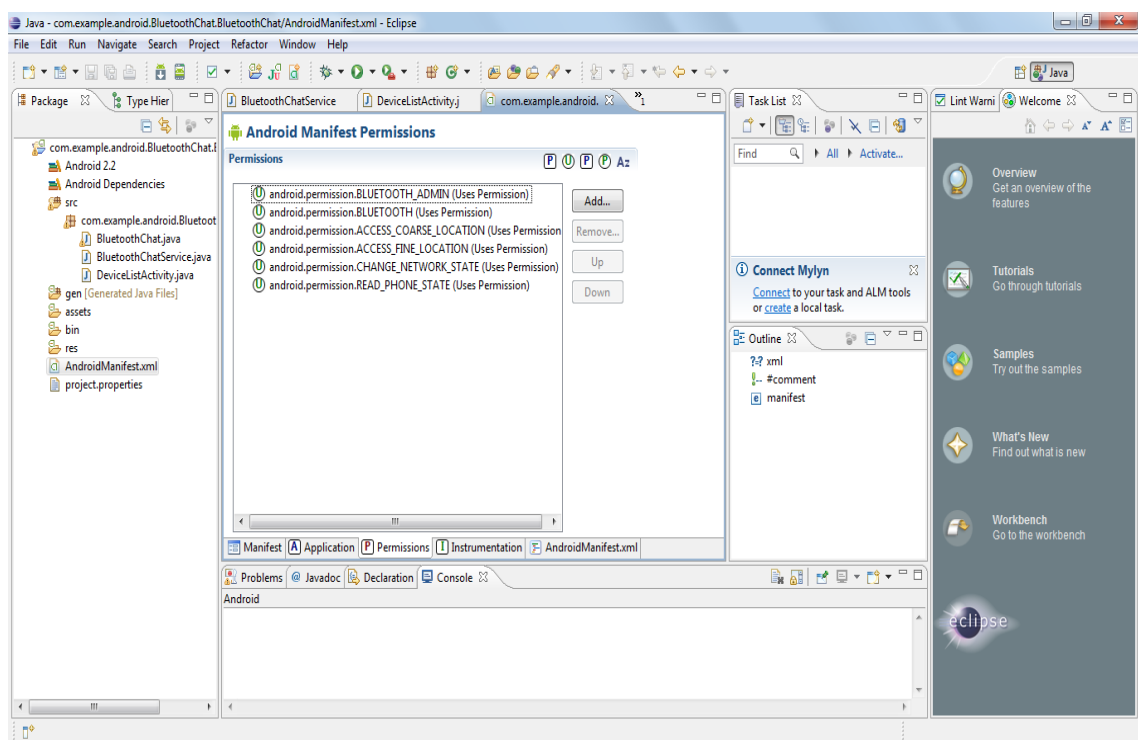


Figure 4.5 A view of android programming interface eclipse platform - Android manifest.xml

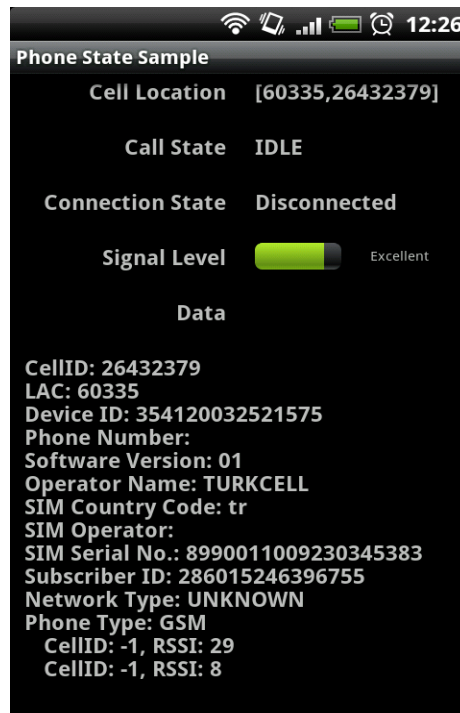


Figure 4.6 Reading phone data with Android program

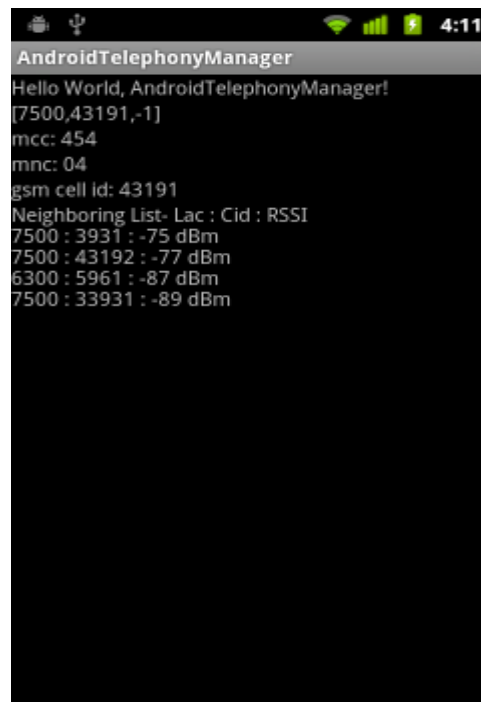


Figure 4.7 Screenshot of sample Android telephony manager class in Android platform



Figure 4.8 Scanning to find the paired Device. We build our application based on BluetoothChat example.

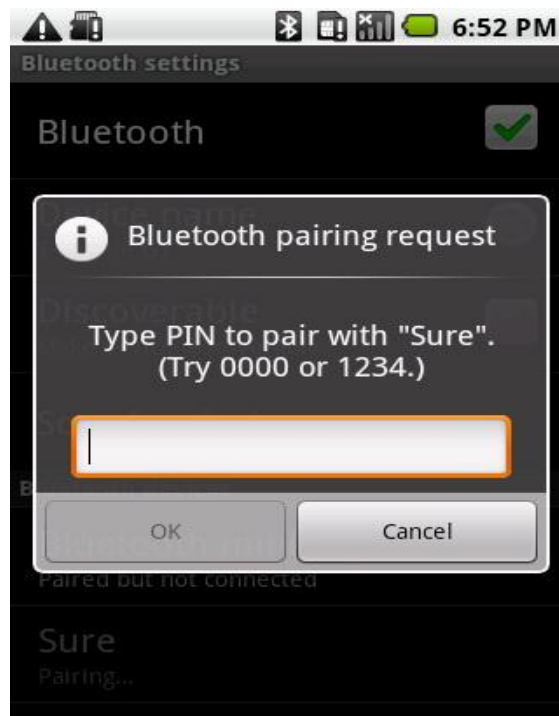


Figure 4.9 To pair two different device via Bluetooth asking permission in program



Figure 4.10 When tapping send button our application sending data to pc via virtual serial port

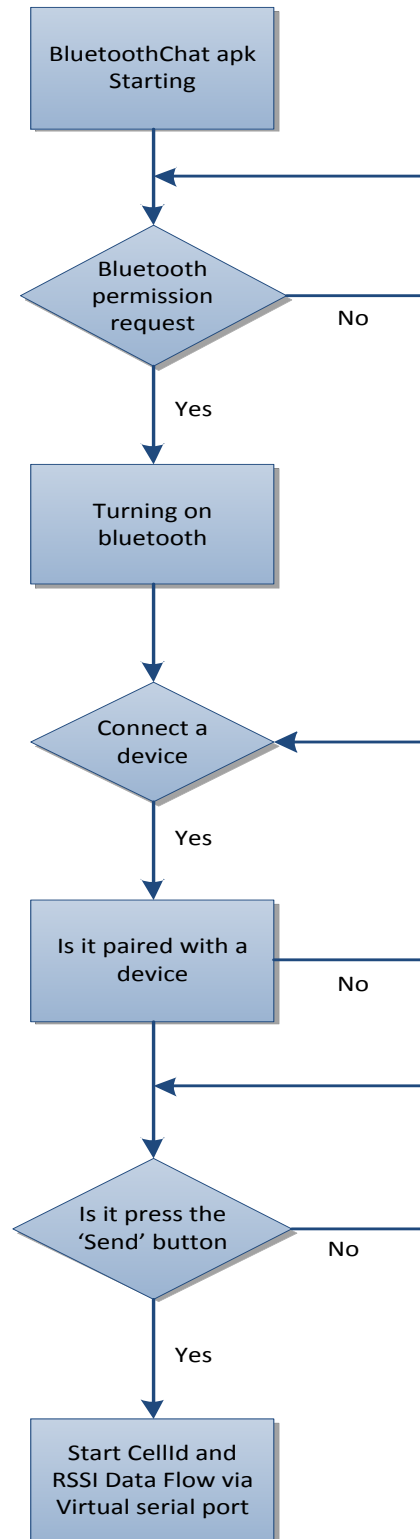


Figure 4.11 Algorithm of our developed program in Android (On the mobile side running).

4.5.2 PC Side

On the Pc side, we used Matlab packet program to get data from mobile phone and to process it in algorithm. Gsm data come to Android smartphone and are sent to Pc algorithm via Bluetooth. Receiving data are connected Cell-id, connected BTS's Cell-id number and its rssi level, neighbor BTS's cell identities and its rssi levels.

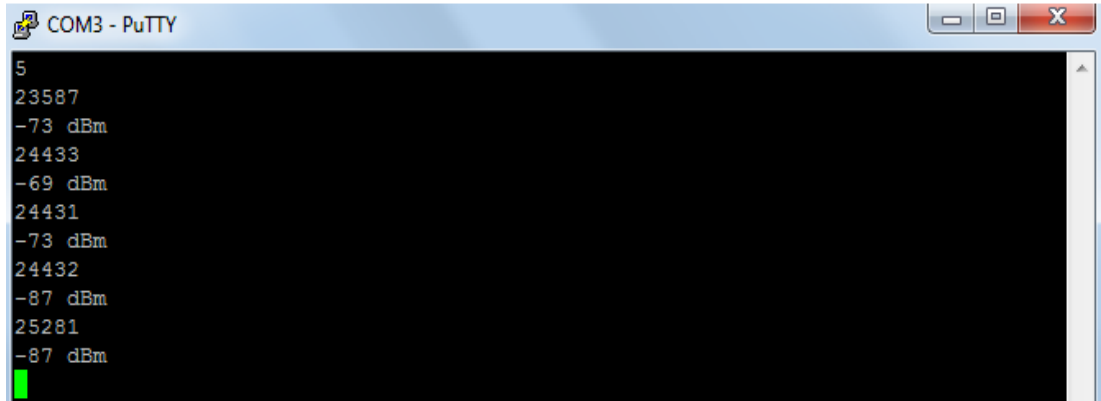


Figure 4.12 Sending serial data from mobile device to pc. As a serial monitor Putty in use

First number represents number of the BTS which are continuously communicate mobile station. After this number, connected cell identification and its receiving signal strenght. After that neighbor cell identification and its receiving cell-id come respectively. Each BTS has a receiving signal strenght and it is shown in the figure 4.12.

We create a database in Matlab and Android smartphone supplies its geolocation data to Matlab. After obtaining latitude and longitude, we use rssi path-loss algorithm for drawing circles and will find its circle intersection unique point. Codes are written in MatLab programming language. To control and access easily, the main program consists of sub-files called MATLAB m files.

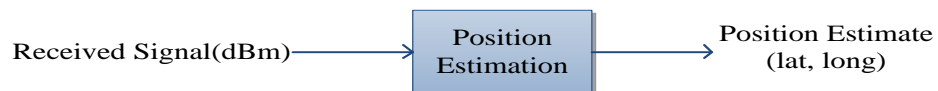


Figure 4.13 Main part of the code when receive RF signal input the algorithm, we translate into location data

CHAPTER FIVE

IMPLEMENTATION OF KALMAN FILTER TO LOCALIZATION PROBLEM ON GSM NETWORK

5.1 Overview of this chapter

As mentioned in the first chapter, the idea of this project is to obtain mobile users location with possible minimum error using data correction method. This localization problem will be modeled as a process and represented in the time domain. To realize this goal, certain parameters have to be taken into consideration. This chapter gives a logical account of the design process involved in the implementation of the MATLAB program.

5.2 Obtaining Data Software

This implementation is the essence of the project and its software is designed to make it in real-time data. The software starts with creating a virtual com port. Once the Database is created, android software is launched on the mobile side tapping by manually. Thus, data which is used on the following algorithm are sent via Bluetooth. To realize that, after opening the Matlab Command window, COM3 Port of our PC (Created by Virtual Serial Port Software By using BlueSoleil Bluetooth driver) is opened. Virtual COM Port drivers cause the bluetooth device to appear as an additional COM port available to the PC. This means COM3 port will be available COM11 vice versa. In this way, we are acting as if there are real standard serial port tunnels between mobile device PC. This method is also called null modem. When the send button is tapped, data flows with a endless loop. Once data is loaded to Pc, it will query to database which was created before. Knowing associated cell-id number and its received signal strength, we obtain the latitude and longitude. Latitude and longitude are converted to UTM coordinates because it is easy to work in cartesian coordinates. After that, we calculate the unique circle intersection point and the kalman filter will be processed. Kalman filter is used to reduce previously talked noisy signal effect. Finally, we plot the real position and its

error covariance and predict data on the graph. Beside this, Google earth will progress to show in a map.

The initialization sequence and the algorithm are as follows;

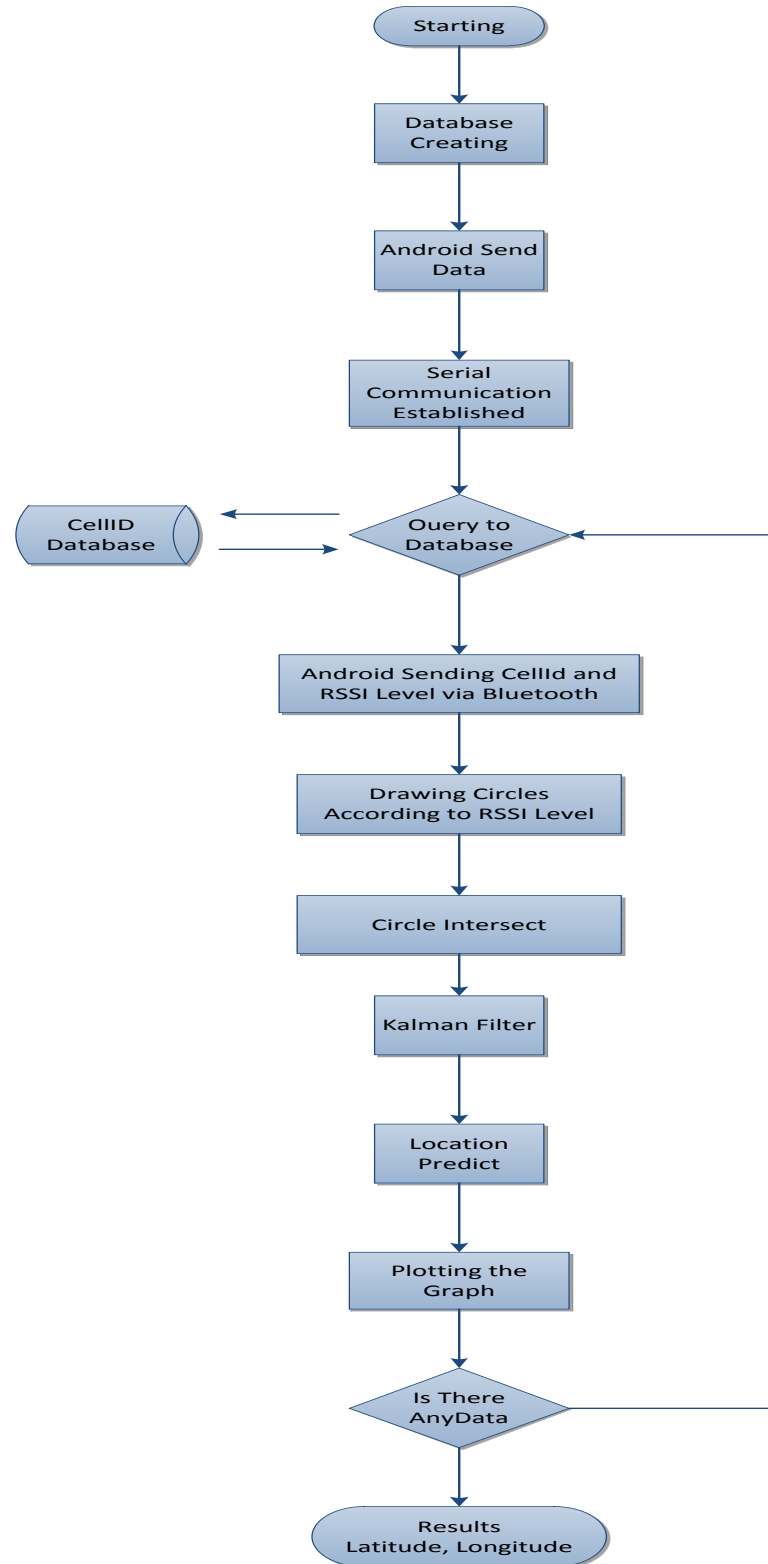


Figure 5.1 Algorithm of running program in MATLAB

5.3 Math behind the algorithm

After getting rssi data and location data. We calculate distance in Matlab. Taking advantage of path loss model formulas we write as:

$$RxLevel = T_x - PL_{[dB]} \quad (5.1)$$

We can write this equation for convenience:

$$PL_{[dB]} = P_T[dBm] + G_t[dbi] + G_r[dbi] - P_r[dBm] \quad (5.2)$$

$$d_{Km} = 10^{[r_{ss}-52-32.4 \cdot 20 \cdot \log(f)]/20} \quad (5.3)$$

To optimize process transmitter frequency can be tuned to specific test frequency. In our theoretical work, as a rooftop antenna was used omni antenna. To obtain a more realistic result, antenna accepted Kathrein 736350. The antenna is vertically polarized directional and has a vertical beam width of 13 degrees. Antenna gain is 8dBi in 900 Mhz, so that maximum EIRP is 51 dBm. We have to consider loss in the cable connecting the antenna with Bts. Since we know that P_t is defined as the power fed into the transmitter antenna we can write:

$$P_t = P_a - L_{cable}(L_{feeder} + L_{combiner}) \quad (5.4)$$

Where P_t transmitted power and P_a is the output power from the Bts antenna output. We assume 43 dBm (19.95 watt). L_{cable} is the cable loss. L_{cable} consists of feeder and combiner loss. We accepted combiner loss is 4 dB and Feeder loss is 3 dB. Substituting this, we get Bts transmitting power.

G_i represents the gain of the transmit antenna in questions. For calculations with sector antennas, only the maximum gain has been used in calculations. (G_i accepted 16 dBm)

G_r represents the gain of the mobile device antenna. Since there is no external antenna used, we take the gain to be 1.

P_r represents the received power level at the antenna minus the receiver antenna gain. We assume that there is no cable loss at the receiving side.

We consider shadowing effect and fading on the receiver side. On the rxlevel signal comes with different effect including reflection, scattering and distortion. Observing among other things the standard deviations, it will take into with an appropriate path loss model calculation equation. (Deblauwe, 2008)

Finally, we calculate distance from the Path loss formulas. If Path loss is calculated we draw circle and find intersection via geometric method. Point this unique point continually changing with noise such as small fading or shadowing effect which talked before. The unique point will enter Kalman filter to find best predicted point and give best guess of user location.

The initialization sequence and the code are as follows;

Veritabani.m is the first working subfile and file creating and providing query cellid database to our main program. This code read a cell tower from a kml files and creates a database which is useful for use.

Veritabani.m

```
map_structure = kml_shapefile('VFcell.kml')
load cell_id.mat;
%data=num2cell(data);
%data=cell2str(data)
[map_structure.cid] = deal(data)
for i = 1:length(map_structure)
map_structure(i).cid = data(i);
end
map_structure=rmfield(map_structure,'Geometry')
```

```

map_structure=rmfield(map_structure,'Id')
map_structure=rmfield(map_structure,'altitude')
cellData = struct2cell(map_structure);
reply = input('Cell_id giriniz:', 's');
reply=str2num(reply);
i=1;
for i = 1:length(map_structure)
Index = isequal(reply,map_structure(i).cid);
if(Index==1)
    i
    enlem=map_structure(i).Y(1,:)
    boylam=map_structure(i).X(1,:)
else
    i=i+1;
end
end
end

```

Android.m creates a virtual comport to trap coming data from android pre-installed smartphone. Android.m m-file is given below.

Android.m

```

s = serial('COM3','BAUD',9600);           % Create serial object (PORT Dependent)
fopen(s)                                   % Open the serial port for r/w
adim=fscanf(s,'%d');
x=1:adim;
n=length(x)
for i=1:n;                                % Creating for loop
    cid(i) = fscanf(s,'%d');               % Getting cell-id data
    rss(i) = fscanf(s,'%d');               % Getting rssi data
end;
fclose(s);                                % Close the serial port
delete(s);                                % Destroy the serial port
delete(instrfind)

```


After that, The data are classified line by line. Codes are processed respectively and first coming data parsing repeatedly. First coming data parsing as a connected cellid and searching in a database to find its location as a latitude and longitude. Second data as a its rssi level and it will be calculated after this m-file. In the main program, Path loss is calculated by given data from mobile smartphone.

```
f=900;
c=300000000;
G=[enlem; boylam]';
[c,idx]=unique(G(:,2));
rss=rss(idx);
%rss=unique(rss);
%rss=(-1)*rss;
rss=abs(rss);
l=length(rss);
```

Latitude and longitude are kept in database in degree format (like 38.3174, 27.1281) so that it has to be changed to utm coordinate to be used in cartesian coordinate. This function is used for this purpose.

```
[a,b,utmzone]=deg2utm(enlem,boylam);
```

To convert it degree again after determining the mobile phone location in UTM coordinate use this code part;

```
[lat0,lng0]=utm2deg(x0,y0,utmzone)
```

We can handle the trilateration in this way, also we carry circle centers if there is no intersection. By this way, we achieve the position roughly.

```
if (l==1);%
Rm=Rm(1:1:l);
m=length(Rm)
x0=sum(a)/m;
```

```

y0=sum(b)/m;
R0=sum(Rm)/m;
indx=1
elseif (l==2)
X=a(:);
Y=b(:);
R=Rm(:);
cx1=X(1,:);
cx2=X(2,:);
cy1=Y(1,:);
cy2=Y(2,:);
R7=R(1,:);
R8=R(2,:);
x1= cx1+(cx2-cx1)*(min(R7,R8)/(R7+R8))
y1= cy1+(cy2-cy1)*(min(R7,R8)/(R7+R8))
x0=x1;
y0=y1;
elseif (l>=3)
[x0,y0] = pozisyonlama(a,b,Rm)
indx=2
end

```

Decided which algorithm is fit. We call pozisyonlama.m subfile.

Pozisyonlama.m

Circle intersect find the best point of intersection of 3 or more circles in the plane.

```

function [x0,y0] = pozisyonlama(X,Y,R)
[sirinyer,B] = geotiffread('D:\bilgisayarcsi\Desktop\Yeni klasör (3)\L18a14a.tif');
mapshow(sirinyer, B);
hold on
X = X(:);
Y = Y(:);

```

```

R = R(:);
cx1=X(1,:);
cx2=X(2,:);
cx3=X(3,:);
cy1=Y(1,:);
cy2=Y(2,:);
cy3=Y(3,:);
R7=R(1,:);
R8=R(2,:);
R9=R(3,:);
radius1=R7;
radius2=R8;
radius3=R9;
N=200;
H1=circle([cx1,cy1],R7,N);
H2=circle([cx2,cy2],R8,N);
H3=circle([cx3,cy3],R9,N);
R1=[radius1,radius2,radius3];
X=[cx1,cx2,cx3];
X=X';
Y=[cy1,cy2,cy3];
Y=Y';
R=[R7,R8,R9];
R=R';
x0= cx1+(cx3-cx1)*(min(R7,R9)/(R7+R9))
y0= cy1+(cy3-cy1)*(min(R7,R9)/(R7+R9))
x1= cx1+(cx2-cx1)*(min(R7,R8)/(R7+R8))
y1= cy1+(cy2-cy1)*(min(R7,R8)/(R7+R8))
x2= x1-x0
y2=y0-y1
x3=cx1+x2*(min(R8,R9)/max(R8,R9))
y3=cy1+y2*(min(R8,R9)/max(R8,R9))

```

```
hold on
```

```
plot(x0,y0,'r:+')
```

```
plot(x1,y1,'g:+')
```

```
plot(x3,y3,'y:+')
```

```
hold off
```

```
end
```

[x0,y0] are still in UTM coordinates system. Converting to degree latitude and longitude we use:

```
[lat0,lng0]=utm2deg(x0,y0,utmzone)
```

These lat0 and lng0 are used in following kalman function as kalman01 function input. Kalmanf.m is found in Matlab Central Fileexchange content is that:

Kalmanf.m

```
function y = kalman01(z)
```

```
% Initialize state transition matrix
```

```
dt=1;
```

```
A=[ 1 0 dt 0 0 0;...
```

```
    0 1 0 dt 0 0;...
```

```
    0 0 1 0 dt 0;...
```

```
    0 0 0 1 0 dt;...
```

```
    0 0 0 0 1 0 ;...
```

```
    0 0 0 0 0 1 ];
```

```
% Measurement matrix
```

```
H = [ 1 0 0 0 0 0; 0 1 0 0 0 0 ];
```

```
Q = eye(6);
```

```
R = 1000 * eye(2);
```

```
% Initial conditions
```

```
persistent x_est p_est
```

```
if isempty(x_est)
```

```
    x_est = zeros(6, 1);
```

```
    p_est = zeros(6, 6);
```

```
end
```

```

% Predicted state and covariance
x_prd = A * x_est;
p_prd = A * p_est * A' + Q;
% Estimation
S = H * p_prd' * H' + R;
B = H * p_prd';
klm_gain = (S \ B)';
% Estimated state and covariance
x_est = x_prd + klm_gain * (z - H * x_prd);
p_est = p_prd - klm_gain * H * p_prd;
% Compute the estimated measurements
y = H * x_est;
end
% Kalman filter loop
z=[lat0;lng0];          % Use Kalman filter to estimate the location
y = kalman01(z);

```

According to given data kalman output plotting trajectory to find the location with minimum error covariance. This codes plot the trajectory.

```

plot(z(1), z(2), 'bx-');
plot(y(1), y(2), 'go-');
drawnow; pause(.1)
grid;
hold off          % Plot the results
hold;             %plot_trajectory(z,y);

```

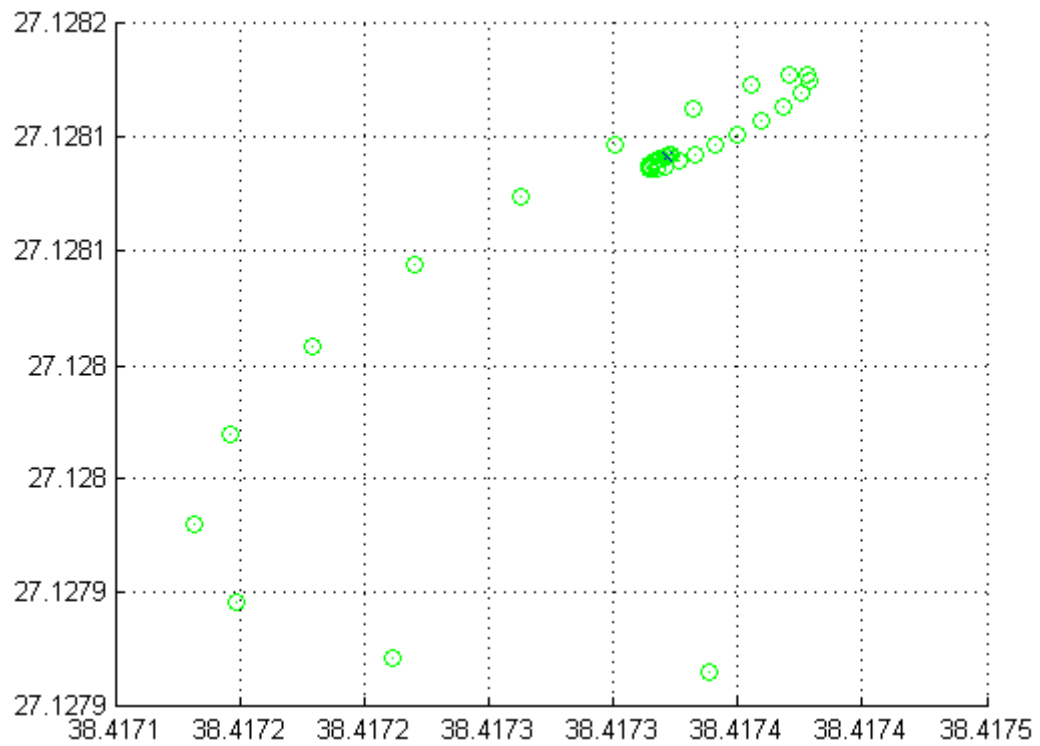


Figure 5.2 Plotting estimation trajectory

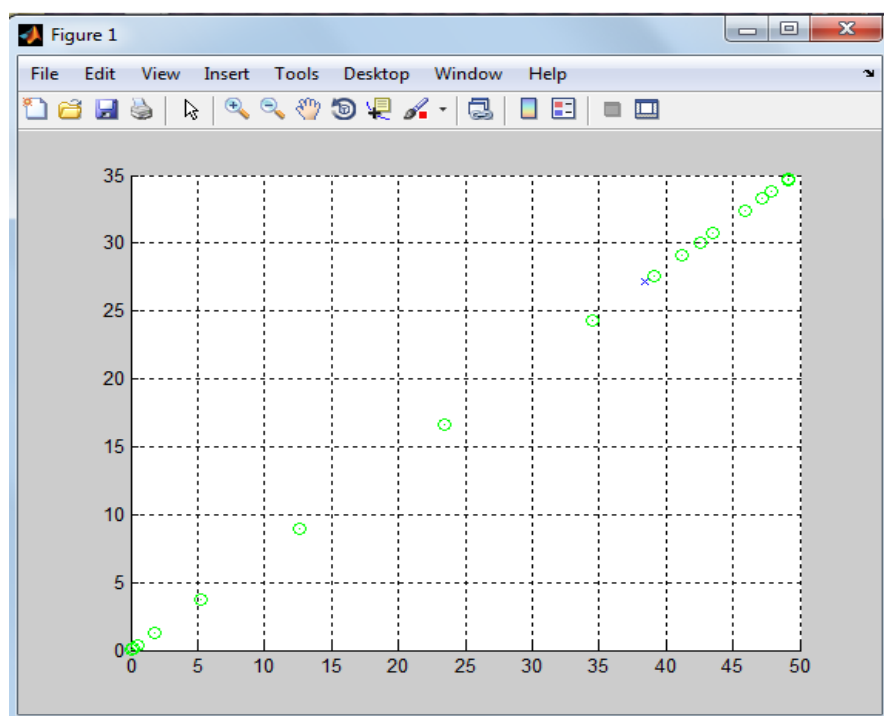


Figure 5.3 Kalman filter trajectory

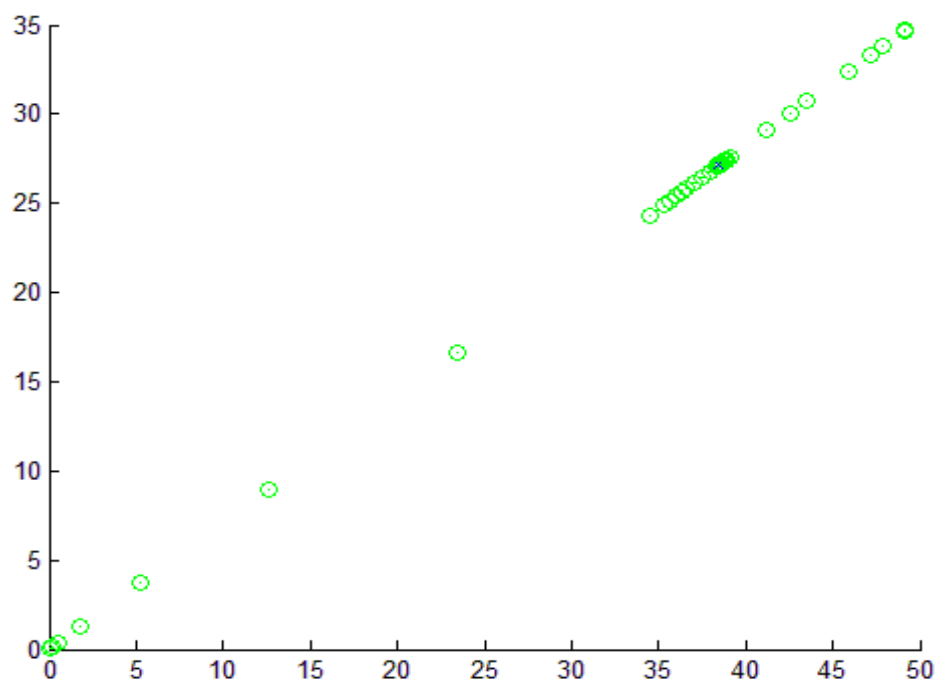


Figure 5.4 Initial state lat=0,long=0 in Kalman filter

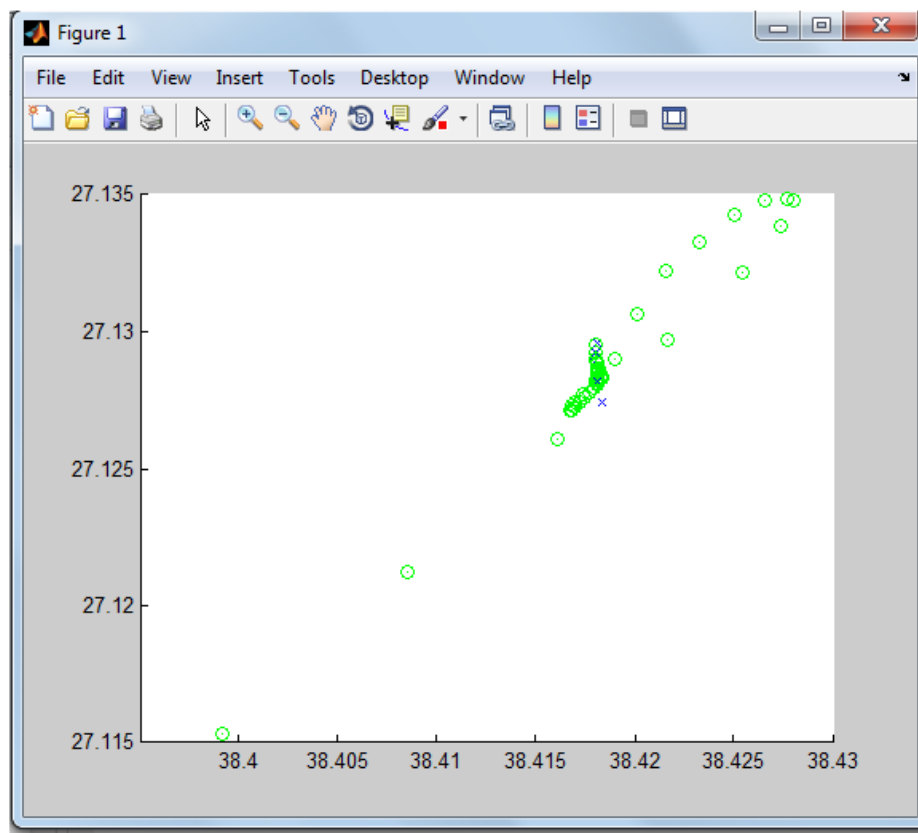


Figure 5.5 Our software testing with Kalman Filter



Figure 5.6 Real position of testing place and Estimated location experiment number1



Figure 5.7 Real position of testing place and Estimated location experiment number2

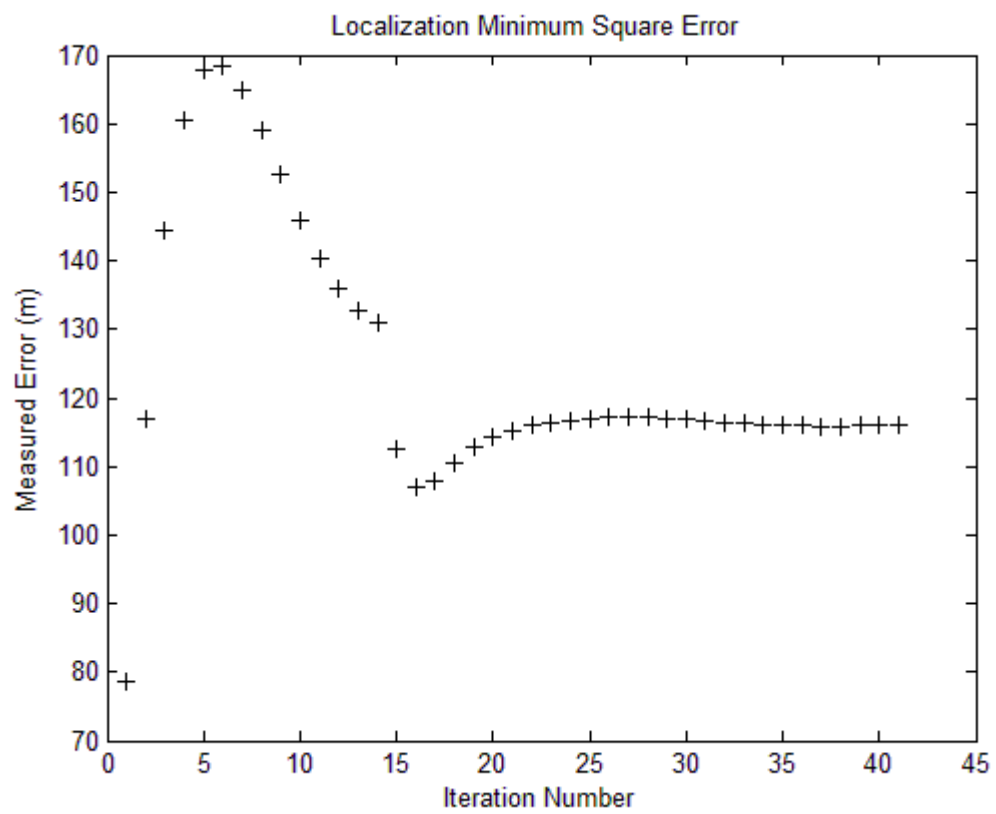


Figure 5.8 Mean square error

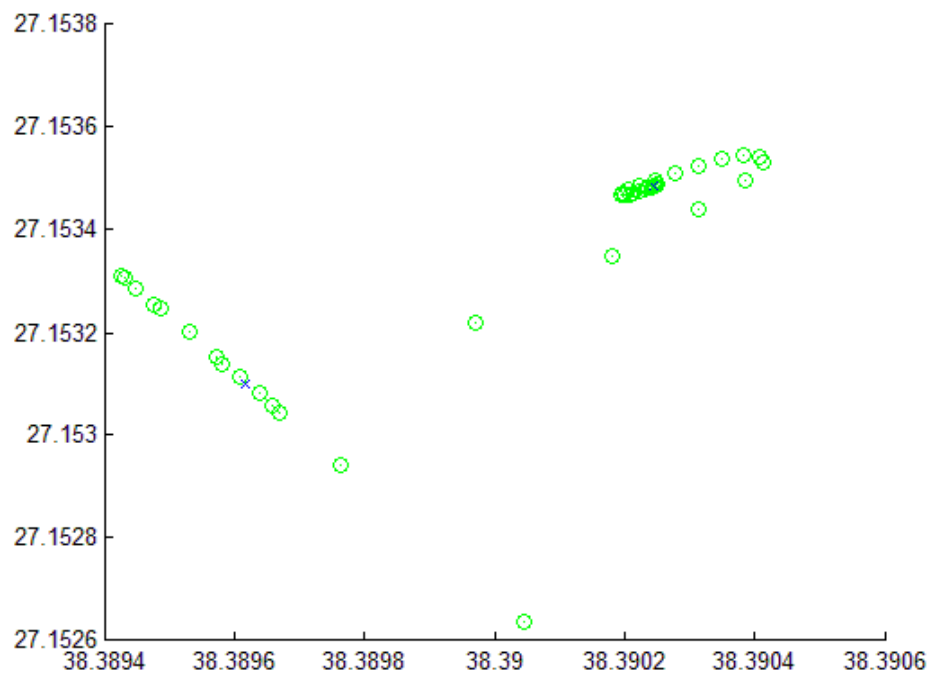


Figure 5.9 Plotting of location on the graph

CHAPTER SIX

CONCLUSION

The aim of the this thesis was to locate something in a GSM network at lower error rates comparing with other methods like Wi-Fi network based designs which bring several hundred meters error in urban area. There are two approaches for that design: network side design which is independent from user for emerging or commercial purposes or user side based design for personal localization usage. The system was realized practically as a measurement system which consists of a PC MATLAB installed before and Android Device HTC-HD2 for both approaches.

Software design was the most critical and important part of the project and accessing limited Network data on the GSM side was a too much time-consuming process. Especially, getting Base Station Site location with allocated cell identification number is a big step for creating database.

After the study, the proposed method was applied on several GSM networks and localization trials were realized in real-life conditions. In Chapter 5, application results and error rates were given. If we summary the results, better error rates were obtained with Kalman filter option compared with raw data. Similarly, better localization options were calculated than Wi-Fi network based approaches.

In the experimental trials which are given in chapter 5, different error rates, beginning from 50m to several hundred meters and as average 75-80m were reached. The reasons for the changes at the results are thought due to the changes propagation faults from diffraction, scattering and reflection of radio frequency in the urban areas. Because, in more open rural areas, less error rates were obtained.

In the measurement program design stage, we encountered a problem as handling mobile devices which had different radio and required OEM dependent code. Although Radio Layer Interface in Windows Mobile 6.5 gave connected BTS unique cell-id number, Radio Interface Layer could not give neighbor cell-id and its rx-level

data. That's why we developed a program in an android platform which can give all data we need. Advantage of this work is that Our Android code can be run in any Android device which is popular and getting increased usage in smartphones and it sends this valuable data via Bluetooth to any computer.

In this thesis study, only signal strengths and free space loss calculations were used to achieve positioning. At the same time, several radio frequency propagation models like Hata were applied to the calculations. Although several hundred meters of maximum error rates were obtained when proper number of GSM 2G and 2.5G base station systems are available, for more accurate positioning determination, GSM network assistance are required. If extra information such as BTS position and heights, channel number, TA and output power were supplied from the GSM network or operator must be taken into account. In this study, no network assistance was used. As the future work, for both network side operation and also personal usage, network based or assistant application can be developed.

Similar positioning system like GPS supplied systems in mobile phones and other equipments can supply more accurate positioning results, but in any emergency conditions, the method developed in this study may help by the usage of network side or personnel applications, when other methods could not be available or disabled.

REFERENCES

- Aatique, M. (1997). *Evaluation of TDOA Techniques for Position Location in CDMA Systems*.
- Bajada, J. (2003). Mobile positioning for location dependent services in GSM networks, *Computer science annual research workshop*, University of Malta.
- Brida P., Machaj J., & Benikovsky J. (2011). On the Accuracy of AGA positioning algorithm in multipath environment, *International Journal of the Physical Sciences*, 6, page 3409-3418.
- Calais E. (1999), Purdue University, *The Global Positioning System* Retrived December 1, 2012, from http://web.ics.purdue.edu/~ecalais/teaching/geodesy/GPS_observables.pdf
- Cheng L., Wu C. D., & Zhang Y. Z. (2011). Indoor Robot Localization Based on Wireless Sensor Network, *IEEE Transactions on Consumer electronics*, 57(3), 1099-1103.
- Dahlman E., Parkvall S., & Skold J. (2011). *4G: LTE/LTE-Advanced Mobile Broadband*, Academic Press
- Dannert A. S., (2012) *Positioning technologies and mechanisim for mobile device* , Retrieved December 8, 2012 from Seminar Module Paper SNET2 TU-Berlin [http://www.snet.tuberlin.de/fileadmin/fg220/courses/SS10/snetproject/positioning technologies_schmidt-dannert.pdf](http://www.snet.tuberlin.de/fileadmin/fg220/courses/SS10/snetproject/positioning_technologies_schmidt-dannert.pdf)
- Deblauwe N., & Biesen L. V. (2008). Cellular positioning from Received Signal Strength Measurements to the Algorithm, *IEEE Globecom 2008, December 2008 New Orleans, USA*.

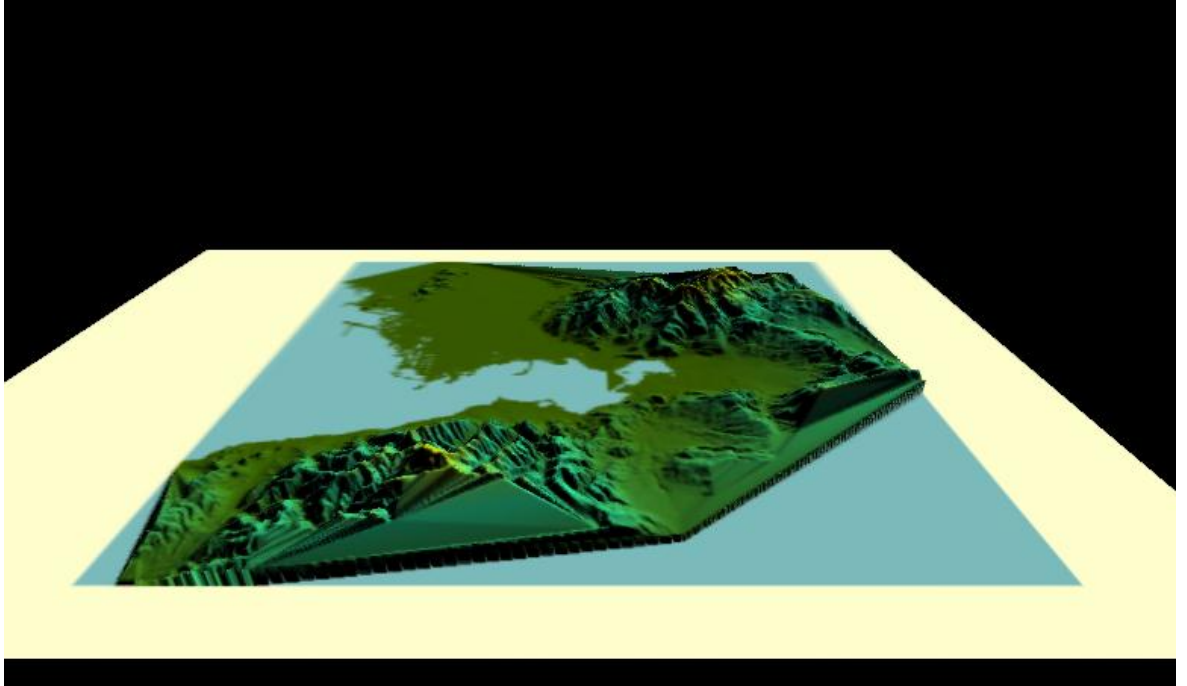
- Doble J. (1996). *Introduction to Radio Propagation for Fixed and Mobile Communications*, Artech- House Publishers.
- Eberspacher J., Vögel H. –J., Bettstetter C., & Hartmann C. (2009). *GSM-Architecture Protocols and Services*, 3rd edition, Wiley Publishing.
- ETSI Technical Specification Paper (2012). TS 45.001-Release 11, Physical layer on the radio path, 3GPP Standard.
- ETSI Technical Specification Paper (2012). TS 25.111-Release 11, Location measurement unit performance specification, 3GPP Standard
- Feng S, & Look C. (2002). *Intelligent transportation systems IEEE 5th International Conference*, page 926-931.
- Gezici S., & Poor V. H. (2009). Position estimation via ultra wide-band signals, *Proceedings of the IEEE* 97(2).
- Güvenç İ., & Chong C. C. (2009). A Survey on TOA Based Wireless Localization and NLOS Mitigation Techniques, *IEEE Communications Surveys & Tutorial*, 11(3).
- Halonen T., Romero J., & Melero J. (2003). *GSM, GPRS and EDGE Performance Evolution towards 3G/UMTS*, 2nd edition England: John Wiley & Sons
- Haykin S. (2001). *Kalman Filtering and Neural Network*, Wiley interscience publication, John Wiley & Sons.
- Klozar L. (2011). *Localization System in GSM and GPS Networks*, Unpublished Press.

- Kumar M., Kumar V., & Malik S. (2012). Performance and Analysis of Propagation Models for Predicting RSS for Efficient Handoff, *International Journal of Advanced Scientific and Technical Research* 2(1).
- Küçükkılıç T., & Şut E. (2011). 112 Acil yardım haberleşme sistemi, *Elektrik mühendisleri odası 6. iletişim günleri bildirileri*.
- Küpper A. (2005). *Location Based services Fundamentals & Operation*, John Wiley Press.
- Meneses F., & Moreira. A. (2006). Using GSM CellId Positioning for Place Discovering, *Pervasive Health Conference and Workshops*, (1-8)
- Mishra R. A. (2007). *Fundamentals of Cellular Network Planning and Optimisation 2G/2.5G/3G Evolution to 4G*, John Wiley & Sons.
- Mistri M. P. (1998) The Third generation cellular (3G): W-CDMA and TD-CDMA, *Northcon/98 Conference Proceedings*, p 35-39.
- Mungamuru B., & Aarabi P. (2004). *IEEE Transactions on systems, man and Cybernetics*, 34(3), 1526-1540.
- Parsons J. D. (2000). *The Mobile Radio Propagation Channel* (2nd Edition), John Wiley and Sons.
- Rappaport S. T. (2002). *Wireless Communications: Principles and Practices* (2nd edition), Prentice-Hall PTR.
- Saunders R. S., & Zavala A. A. (2007). *Antennas and Propagation for Wireless Communication Systems* (2nd edition), John Wiley and Sons.
- Sauter M. (2011). *From GSM to LTE: An Introduction to Mobile Networks and Mobile Broadband*, Wiley Publishing.

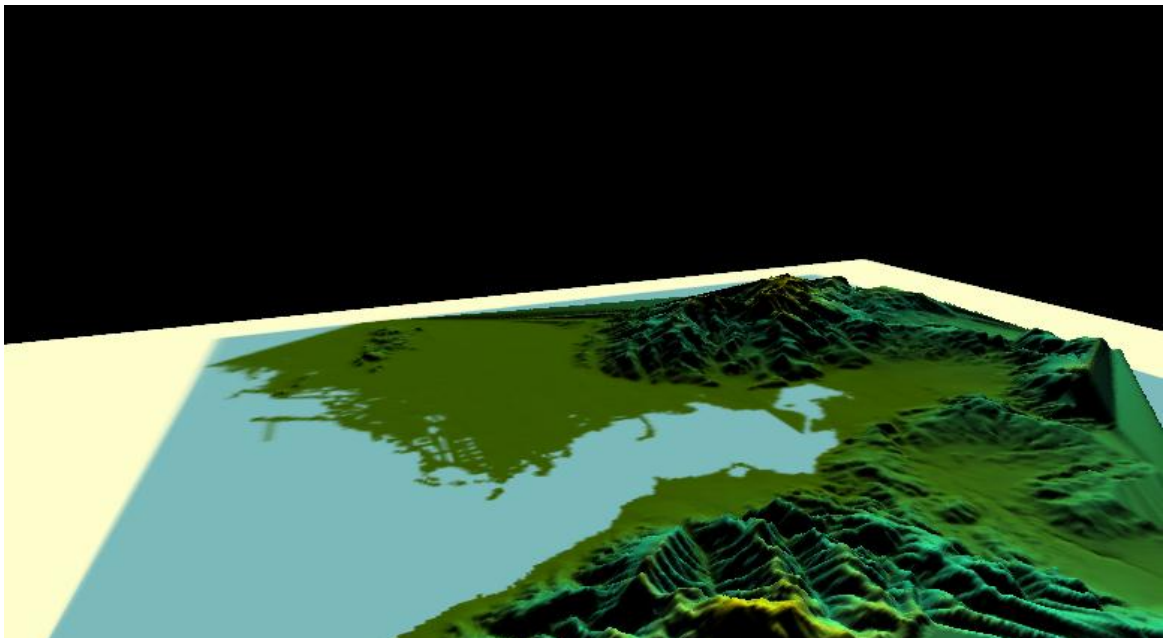
- Seybold S. J. (2005). *Introduction to RF propagation (2nd edition)*, Wiley & Sons.
- Van Rheeden. D. R., & Gupta S. C. (1998). A single base station position location approach for enhanced-911, *IEEE Vehicular Technology Conference*, 2555-2559.
- Wang P., Green M., & Malkawi M. (2002). E-911 Location Standards and Commercial Services, *Radio and Wireless Conference, RAWCON 2002 IEEE*, 9-12.
- Wen Y., & Jian M. (2007). Software defined radio localization using 802.11 networks advanced Information Networking and Applications, *AINA'07. 21st International Conference on 21-23 may 2007*.
- Welch G., & Bishop G. (2009). An Introduction to the Kalman Filter, Retrived November 1, 2012, from http://www.cs.unc.edu/~welch/media/pdf/kalman_intro.pdf

APPENDICES

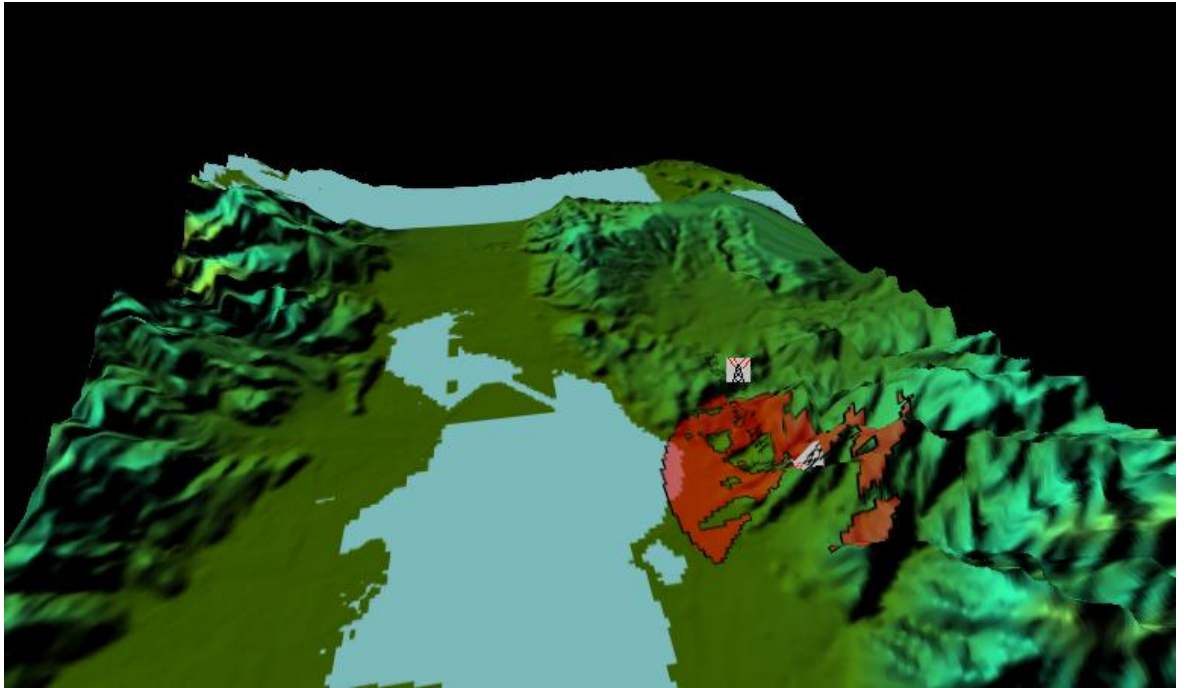
Appendix-A



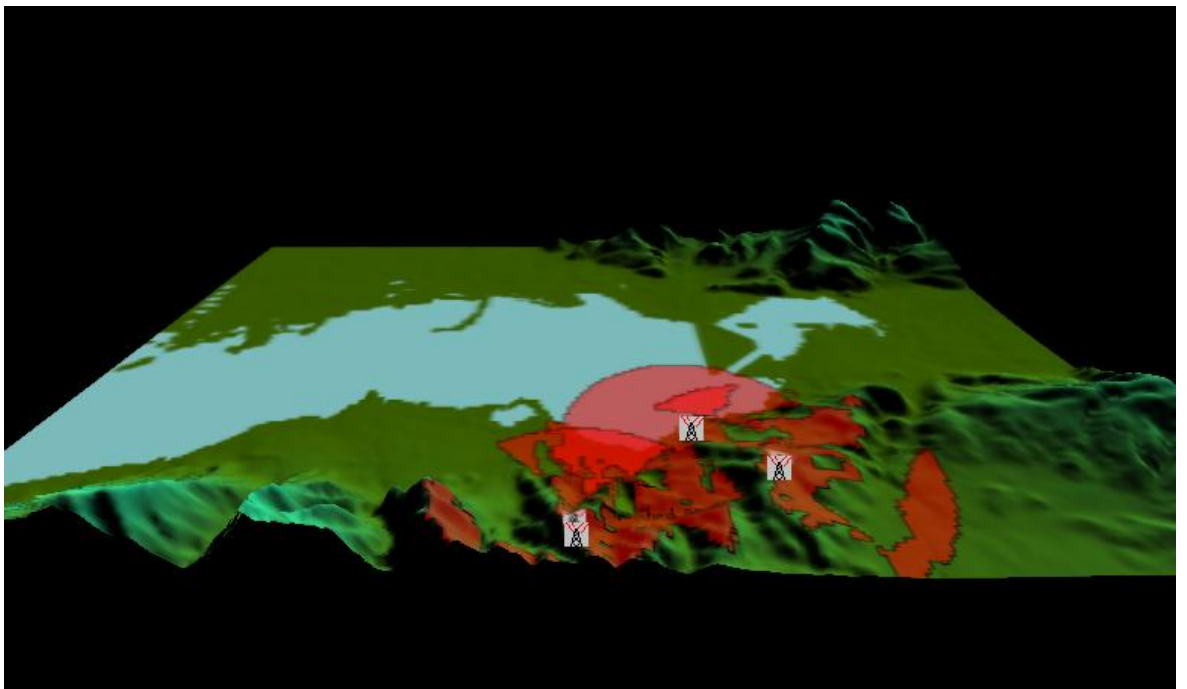
3-D Terrain analysis with DEM(Digital Elevation Model) Data (Taken from Global Mapper)



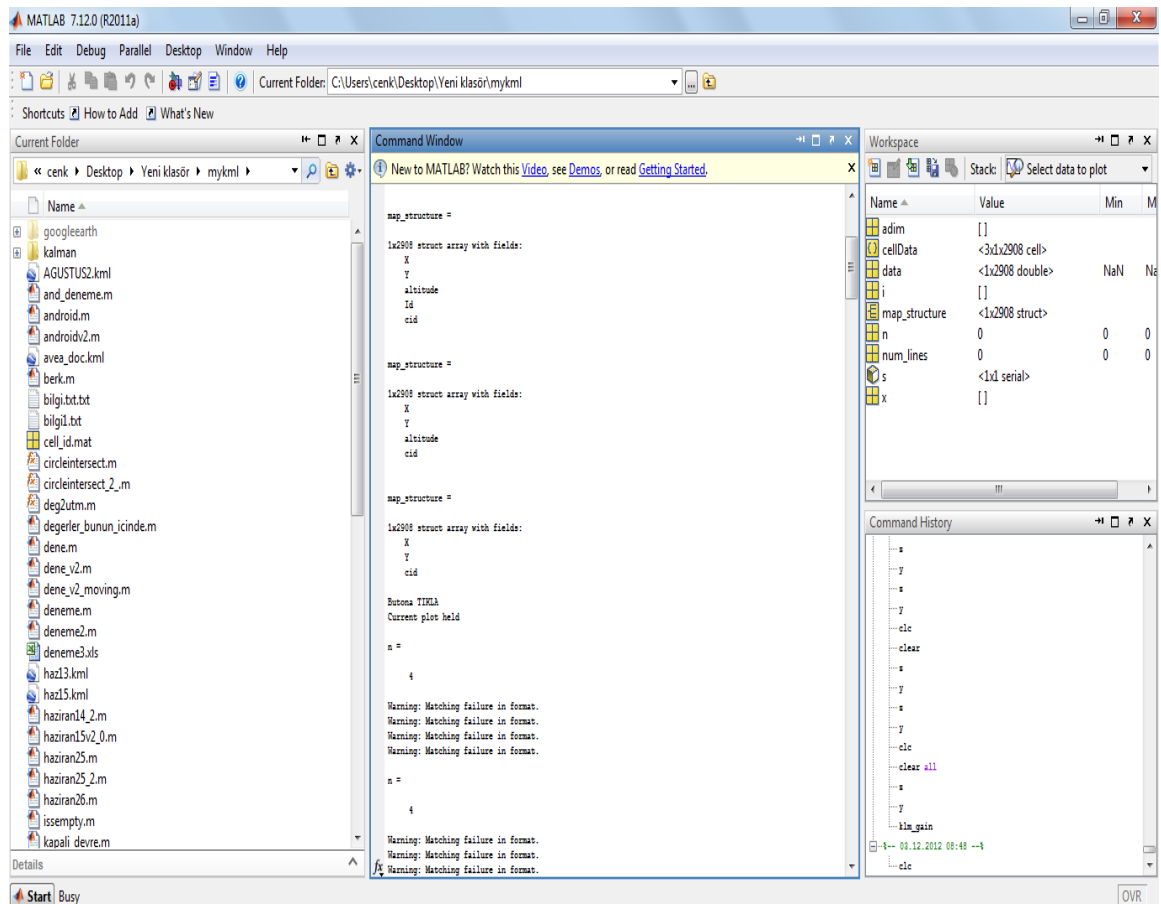
3-D Terrain analysis different angle (Taken from Global Mapper)



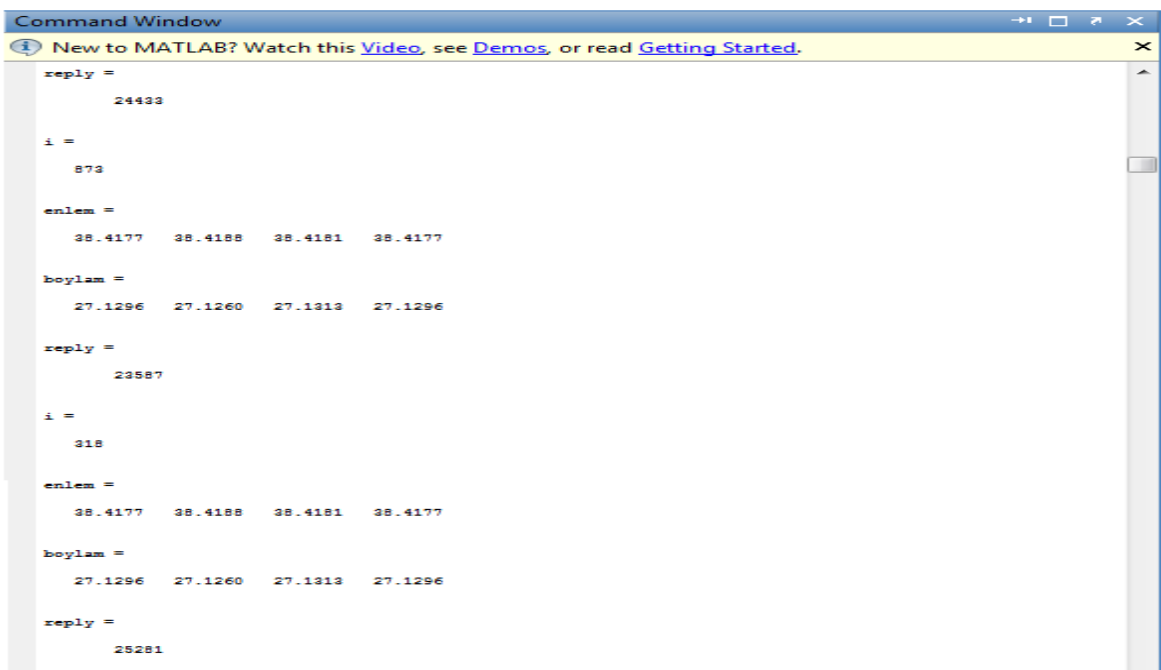
3-D Signal propagation from Bts (Taken from Global Mapper)



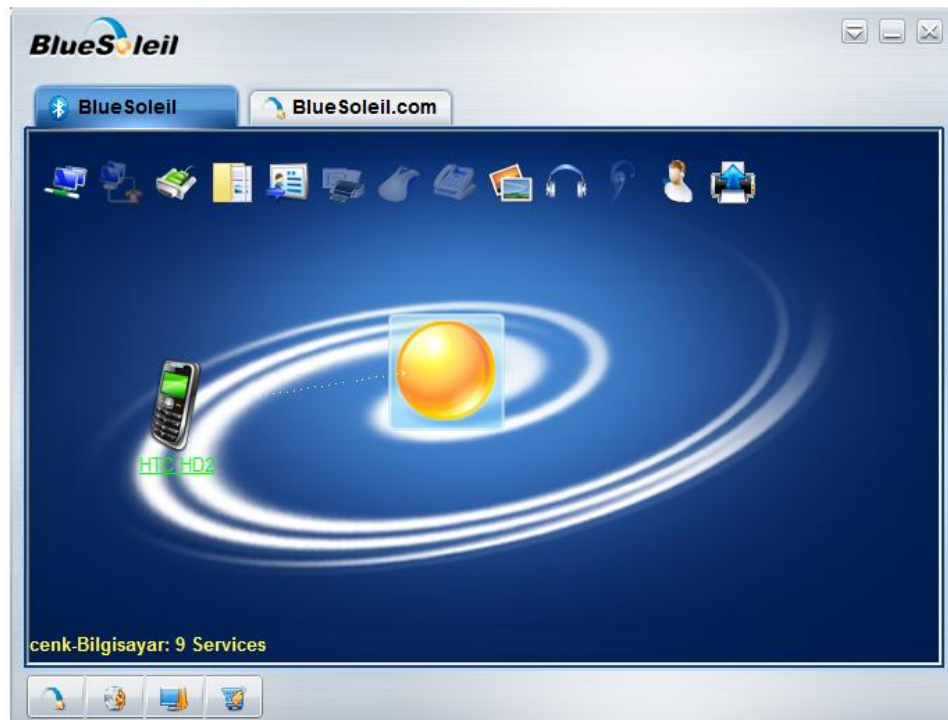
3-D Signal propagation from three Macro Bts (Taken from Global Mapper)



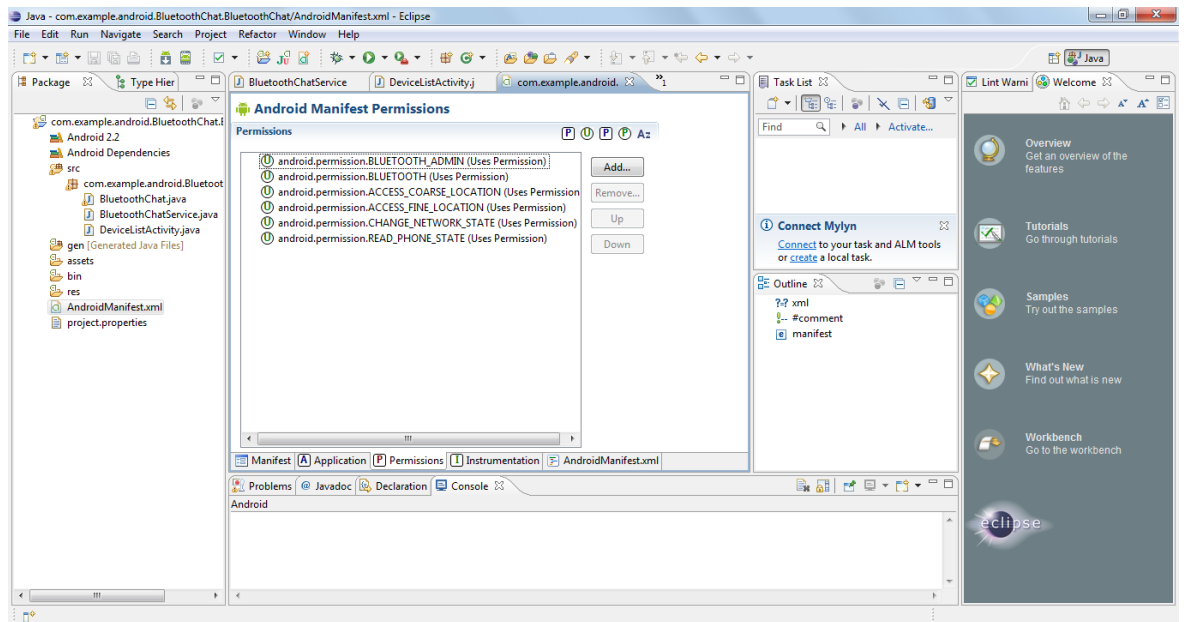
Screenshot of the Matlab program output



Screenshot of the Matlab program output-2



Screenshot of the Bluetooth pairing program (Used for driver bluetooth via COM port)



Screenshot of Java Eclipse Indigo Platform

Appendix-B

Android Main Program

```
/*
 * Copyright (C) 2009 The Android Open Source Project
 *
 * Licensed under the Apache License, Version 2.0 (the "License");
 * you may not use this file except in compliance with the License.
 * You may obtain a copy of the License at
 *
 *     http://www.apache.org/licenses/LICENSE-2.0
 *
 * Unless required by applicable law or agreed to in writing, software
 * distributed under the License is distributed on an "AS IS" BASIS,
 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
 * See the License for the specific language governing permissions and
 * limitations under the License.
 */

package com.example.android.BluetoothChat;

import java.util.List;

import android.app.Activity;
import android.bluetooth.BluetoothAdapter;
import android.bluetooth.BluetoothDevice;
import android.content.Intent;
import android.os.Bundle;
import android.os.Handler;
import android.os.Message;
import android.util.Log;
import android.view.KeyEvent;
import android.view.Menu;
import android.view.MenuInflater;
import android.view.MenuItem;
import android.view.View;
import android.view.Window;
import android.view.View.OnClickListener;
import android.view.inputmethod.EditorInfo;
import android.widget.AdapterView;
import android.widget.Button;
import android.widget.EditText;
import android.widget.ListView;
import android.widget.TextView;
import android.widget.Toast;

import android.telephony.PhoneStateListener;
import android.telephony.SignalStrength;
import android.content.Context;
import android.telephony.TelephonyManager;
import android.telephony.gsm.GsmCellLocation;
import android.telephony.NeighboringCellInfo;

/**
```

```

* This is the main Activity that displays the current chat session.
*/
public class BluetoothChat extends Activity {
    // Debugging
    private static final String TAG = "BluetoothChat";
    private static final boolean D = true;

    // Message types sent from the BluetoothChatService Handler
    public static final int MESSAGE_STATE_CHANGE = 1;
    public static final int MESSAGE_READ = 2;
    public static final int MESSAGE_WRITE = 3;
    public static final int MESSAGE_DEVICE_NAME = 4;
    public static final int MESSAGE_TOAST = 5;

    // Key names received from the BluetoothChatService Handler
    public static final String DEVICE_NAME = "device_name";
    public static final String TOAST = "toast";

    // Intent request codes
    private static final int REQUEST_CONNECT_DEVICE = 1;
    private static final int REQUEST_ENABLE_BT = 2;

    // Layout Views
    private TextView mTitle;
    private ListView mConversationView;
    private EditText mOutEditText;
    private Button mSendButton;

    // Name of the connected device
    private String mConnectedDeviceName = null;
    // Array adapter for the conversation thread
    private ArrayAdapter<String> mConversationArrayAdapter;
    // String buffer for outgoing messages
    private StringBuffer mOutStringBuffer;
    // Local Bluetooth adapter
    private BluetoothAdapter mBluetoothAdapter = null;
    // Member object for the chat services
    private BluetoothChatService mChatService = null;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);

        /*setContentView(R.layout.main);
        TextView textGsmCellLocation = (TextView)findViewById(R.id.gsmcelllocation);
        TextView textCID = (TextView)findViewById(R.id.cid);
        TextView textLAC = (TextView)findViewById(R.id.lac);
        */

        //retrieve a reference to an instance of TelephonyManager
        TelephonyManager telephonyManager =
        (TelephonyManager) getSystemService(Context.TELEPHONY_SERVICE);
        GsmCellLocation cellLocation = (GsmCellLocation)telephonyManager.getCellLocation();

        if(D) Log.e(TAG, "+++ ON CREATE +++");

```

```

// Set up the window layout
requestWindowFeature(Window.FEATURE_CUSTOM_TITLE);
setContentView(R.layout.main);
getWindow().setFeatureInt(Window.FEATURE_CUSTOM_TITLE, R.layout.custom_title);

// Set up the custom title
mTitle = (TextView) findViewById(R.id.title_left_text);
mTitle.setText(R.string.app_name);
mTitle = (TextView) findViewById(R.id.title_right_text);

// Get local Bluetooth adapter
mBluetoothAdapter = BluetoothAdapter.getDefaultAdapter();

// If the adapter is null, then Bluetooth is not supported
if (mBluetoothAdapter == null) {
    Toast.makeText(this, "Bluetooth is not available", Toast.LENGTH_LONG).show();
    finish();
    return;
}

@Override
public void onStart() {
    super.onStart();
    if(D) Log.e(TAG, "++ ON START ++");

    // If BT is not on, request that it be enabled.
    // setupChat() will then be called during onActivityResult
    if (!mBluetoothAdapter.isEnabled()) {
        Intent enableIntent = new Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
        startActivityForResult(enableIntent, REQUEST_ENABLE_BT);
    } // Otherwise, setup the chat session
    else {
        if (mChatService == null) setupChat();
    }
}

@Override
public synchronized void onResume() {
    super.onResume();
    if(D) Log.e(TAG, "+ ON RESUME +");

    // Performing this check in onResume() covers the case in which BT was
    // not enabled during onStart(), so we were paused to enable it...
    // onResume() will be called when ACTION_REQUEST_ENABLE activity returns.
    if (mChatService != null) {
        // Only if the state is STATE_NONE, do we know that we haven't started already
        if (mChatService.getState() == BluetoothChatService.STATE_NONE) {
            // Start the Bluetooth chat services
            mChatService.start();
        }
    }
}

private void button_soft(){

```

```

        //for(int b=0; b < 15; b++){ }

        //mSendButton.performClick();
    }
    private void butonsuz(){
        //for(int b=0; b < 15; b++){ }

        //mSendButton.performClick();
        //String message = ("cenk");
        //sendMessage(message);
        // Send a message using content of the edit text widget
        //TextView view = (TextView) findViewById(R.id.edit_text_out);
        //String message = view.getText().toString();

        TelephonyManager telephonyManager =
        (TelephonyManager) getSystemService(Context.TELEPHONY_SERVICE);
        GsmCellLocation cellLocation = (GsmCellLocation) telephonyManager.getCellLocation();
        String networkOperator = telephonyManager.getNetworkOperator();
        String mcc = networkOperator.substring(0, 3);
        String mnc = networkOperator.substring(3);
        final int cid = cellLocation.getCid();

        //int rssi = cellLocation.getRssi();
        //String signalLevelString = getSignalLevelString(pendra);
        //android.telephony.NeighboringCellInfo.getCid()

        //int rssi=cellLocation.getRssi();
        //int rssi = telephonyManager.getNeighboringCellInfo();
        // Send a message using content of the edit text widget
        // TextView view = (TextView) findViewById(R.id.edit_text_out);
        //telephonyManager.getNeighboringCellInfo();
        //String.valueOf(signalStrength.getGsmSignalStrength()
        //view.setText("Android");
        //setContentView(view);
        //String message = ("Android");
        telephonyManager.getNeighboringCellInfo();
        //String mystr = String.valueOf(cid);
        String mystr1= String.valueOf(mcc);
        String mystr2= String.valueOf(mnc);

        TelephonyManager telephonyInfo;
        PhoneStateListener phoneState = new PhoneStateListener() {
            public void onSignalStrengthChanged(int asu) {
                //deprecated on API 7 use onSignalStrengthsChanged instead
                //public void getSignalLevelString(int asu) {
                //private void getSignalLevelString(int asu) {

                String asu1 = String.valueOf(-113 + 2 * asu) + " dBm";
                String mystr = String.valueOf(cid);
                String mystr4 = String.valueOf(asu1);
                sendMessage(mystr+"\n"+"r");
                sendMessage(mystr4+"\n"+"r");//önce 63dbmden önce cid'i seriye basmak maksadıyla
                aşağı aldım
            }

            //API7

```

```

        // public void onSignalStrengthsChanged(SignalStrength asu) {
        // signalStrength = asu;
        // }
    };

    telephonyInfo = (TelephonyManager) getSystemService(Context.TELEPHONY_SERVICE);
    // API7
    // telephonyInfo.listen(phoneState,PhoneStateListener.LISTEN_SIGNAL_STRENGTHS);
    telephonyInfo.listen(phoneState,PhoneStateListener.LISTEN_SIGNAL_STRENGTH);

    List<NeighboringCellInfo> NeighboringList = telephonyManager.getNeighboringCellInfo();

    String stringNeighboring = "Neighboring List- Lac : Cid : RSSI\n";
    String my=String.valueOf(NeighboringList.size());
    sendMessage(my+"\n"+"r");
    for(int i=0; i < NeighboringList.size(); i++){

        String dBm;
        int rssi = NeighboringList.get(i).getRssi();
        if(rssi == NeighboringCellInfo.UNKNOWN_RSSI){
            dBm = "0";
        }else{
            dBm = String.valueOf(-113 + 2 * rssi) + " dBm";
        }
        stringNeighboring = stringNeighboring
            + String.valueOf(NeighboringList.get(i).getLac()) + " : "
            + String.valueOf(NeighboringList.get(i).getCid()) + " : "
            + dBm + "\n";
        String mystr3= String.valueOf(NeighboringList.get(i).getCid());

        //sendMessage(mystr3+dBm+"\n"+"r");
        sendMessage(mystr3+"\n"+"r");
        sendMessage(dBm+"\n"+"r");
    }
    //////////////////////////////////////7
    /*List<NeighboringCellInfo> NeighboringList = telephonyManager.getNeighboringCellInfo();

    String stringNeighboring = "Neighboring List- Lac : Cid : RSSI\n";
    for(int i=0; i < NeighboringList.size(); i++){

        String dBm;
        int rssi = NeighboringList.get(i).getRssi();
        if(rssi == NeighboringCellInfo.UNKNOWN_RSSI){
            dBm = "Unknown RSSI";
        }else{
            dBm = String.valueOf(-113 + 2 * rssi) + " dBm";
        }

        stringNeighboring = stringNeighboring
            + String.valueOf(NeighboringList.get(i).getLac()) + " : "
            + String.valueOf(NeighboringList.get(i).getCid()) + " : "
            + dBm + "\n";
        String mystr3= String.valueOf(NeighboringList.get(i).getCid());
        //sendMessage(mystr3+dBm+"\n"+"r");
        sendMessage(mystr3+"\n"+"r");
        sendMessage(dBm+"\n"+"r");
    }*/

```



```

// String message = view.getText().toString();

telephonyInfo.listen(phoneState,PhoneStateListener.LISTEN_NONE);

//sendMessage("f"+"n"+"r");
//sendMessage(mystr+"n"+"r");
/*
List<NeighboringCellInfo> NeighboringList = telephonyManager.getNeighboringCellInfo();

String stringNeighboring = "Neighboring List- Lac : Cid : RSSI\n";
for(int i=0; i < NeighboringList.size(); i++){

String dBm;
int rssi = NeighboringList.get(i).getRssi();
if(rssi == NeighboringCellInfo.UNKNOWN_RSSI){
dBm = "Unknown RSSI";
}else{
dBm = String.valueOf(-113 + 2 * rssi) + " dBm";
}
stringNeighboring = stringNeighboring
+ String.valueOf(NeighboringList.get(i).getLac()) + " : "
+ String.valueOf(NeighboringList.get(i).getCid()) + " : "
+ dBm + "\n";
String mystr3= String.valueOf(NeighboringList.get(i).getCid());
//sendMessage(mystr3+dBm+"n"+"r");
sendMessage(mystr3+"n"+"r");
sendMessage(dBm+"n"+"r");
}
*/
//private void sendmessage(String mystr1) {
// TODO Auto-generated method stub
}

private void setupChat() {
    Log.d(TAG, "setupChat()");

    // Initialize the array adapter for the conversation thread
    mConversationArrayAdapter = new ArrayAdapter<String>(this, R.layout.message);
    mConversationView = (ListView) findViewById(R.id.in);
    mConversationView.setAdapter(mConversationArrayAdapter);

    // Initialize the compose field with a listener for the return key
    mOutEditText = (EditText) findViewById(R.id.edit_text_out);
    mOutEditText.setOnEditorActionListener(mWriteListener);

    // Initialize the send button with a listener that for click events

    mSendButton = (Button) findViewById(R.id.button_send);
    mSendButton.setOnClickListener(new OnClickListener() {

        public void onClick(View v){

            while(true){
                butonsuz();
                try {

```

```

        Thread.sleep(3000);
    } catch (InterruptedException e) {
        // TODO Auto-generated catch block
        e.printStackTrace();
    }
}
});
// Initialize the BluetoothChatService to perform bluetooth connections
mChatService = new BluetoothChatService(this, mHandler);
// Initialize the buffer for outgoing messages
mOutStringBuffer = new StringBuffer("");
}
protected int getRssi() {
    // TODO Auto-generated method stub
    return 0;
}

@Override
public synchronized void onPause() {
    super.onPause();
    if(D) Log.e(TAG, "- ON PAUSE -");
}

@Override
public void onStop() {
    super.onStop();
    if(D) Log.e(TAG, "-- ON STOP --");
}

@Override
public void onDestroy() {
    super.onDestroy();
    // Stop the Bluetooth chat services
    if (mChatService != null) mChatService.stop();
    if(D) Log.e(TAG, "--- ON DESTROY ---");
}

private void ensureDiscoverable() {
    if(D) Log.d(TAG, "ensure discoverable");
    if (mBluetoothAdapter.getScanMode() !=
        BluetoothAdapter.SCAN_MODE_CONNECTABLE_DISCOVERABLE) {
        Intent discoverableIntent = new
Intent(BluetoothAdapter.ACTION_REQUEST_DISCOVERABLE);
        discoverableIntent.putExtra(BluetoothAdapter.EXTRA_DISCOVERABLE_DURATION,
300);
        startActivity(discoverableIntent);
    }
}
/**
 * Sends a message.
 * @param message A string of text to send.
 */
private void sendMessage(String message) // Check that we're actually connected before trying
anything
    if (mChatService.getState() != BluetoothChatService.STATE_CONNECTED) {
        Toast.makeText(this, R.string.not_connected, Toast.LENGTH_SHORT).show();
        return;
    }

```

```

    }

    // Check that there's actually something to send
    if (message.length() > 0) {
        // Get the message bytes and tell the BluetoothChatService to write
        byte[] send = message.getBytes();
        mChatService.write(send);

        // Reset out string buffer to zero and clear the edit text field
        mOutStringBuffer.setLength(0);
        mOutEditText.setText(mOutStringBuffer);
    }
}

// The action listener for the EditText widget, to listen for the return key
private TextView.OnEditorActionListener mWriteListener =
    new TextView.OnEditorActionListener() {
        public boolean onEditorAction(TextView view, int actionId, KeyEvent event) {
            // If the action is a key-up event on the return key, send the message
            if (actionId == EditorInfo.IME_NULL && event.getAction() == KeyEvent.ACTION_UP) {
                String message = view.getText().toString();
                sendMessage(message);
            }
            if(D) Log.i(TAG, "END onEditorAction");
            return true;
        }
    };

// The Handler that gets information back from the BluetoothChatService
private final Handler mHandler = new Handler() {
    @Override
    public void handleMessage(Message msg) {
        switch (msg.what) {
            case MESSAGE_STATE_CHANGE:
                if(D) Log.i(TAG, "MESSAGE_STATE_CHANGE: " + msg.arg1);
                switch (msg.arg1) {
                    case BluetoothChatService.STATE_CONNECTED:
                        mTitle.setText(R.string.title_connected_to);
                        mTitle.append(mConnectedDeviceName);
                        mConversationArrayAdapter.clear();
                        break;
                    case BluetoothChatService.STATE_CONNECTING:
                        mTitle.setText(R.string.title_connecting);
                        break;
                    case BluetoothChatService.STATE_LISTEN:
                    case BluetoothChatService.STATE_NONE:
                        mTitle.setText(R.string.title_not_connected);
                        break;
                }
                break;
            case MESSAGE_WRITE:
                byte[] writeBuf = (byte[]) msg.obj;
                // construct a string from the buffer
                String writeMessage = new String(writeBuf);
                mConversationArrayAdapter.add("HTC: " + writeMessage);
                break;
            case MESSAGE_READ:
                byte[] readBuf = (byte[]) msg.obj;

```

```

        // construct a string from the valid bytes in the buffer
        String readMessage = new String(readBuf, 0, msg.arg1);

        mConversationArrayAdapter.add(mConnectedDeviceName+": " + readMessage);
        //if(readMessage == X);
        setupChat();
        break;
    case MESSAGE_DEVICE_NAME:
        // save the connected device's name
        mConnectedDeviceName = msg.getData().getString(DEVICE_NAME);
        Toast.makeText(getApplicationContext(), "Connected to "
            + mConnectedDeviceName, Toast.LENGTH_SHORT).show();
        break;
    case MESSAGE_TOAST:
        Toast.makeText(getApplicationContext(), msg.getData().getString(TOAST),
            Toast.LENGTH_SHORT).show();
        break;
    }
}
};

public void onActivityResult(int requestCode, int resultCode, Intent data) {
    if(D) Log.d(TAG, "onActivityResult " + resultCode);
    switch (requestCode) {
        case REQUEST_CONNECT_DEVICE:
            // When DeviceListActivity returns with a device to connect
            if (resultCode == Activity.RESULT_OK) {
                // Get the device MAC address
                String address = data.getExtras()
                    .getString(DeviceListActivity.EXTRA_DEVICE_ADDRESS);
                // Get the BLuetoothDevice object
                BluetoothDevice device = mBluetoothAdapter.getRemoteDevice(address);
                // Attempt to connect to the device
                mChatService.connect(device);
            }
            break;
        case REQUEST_ENABLE_BT:
            // When the request to enable Bluetooth returns
            if (resultCode == Activity.RESULT_OK) {
                // Bluetooth is now enabled, so set up a chat session
                setupChat();
            } else {
                // User did not enable Bluetooth or an error occurred
                Log.d(TAG, "BT not enabled");
                Toast.makeText(this, R.string.bt_not_enabled_leaving, Toast.LENGTH_SHORT).show();
                finish();
            }
        }
    }
}

@Override
public boolean onCreateOptionsMenu(Menu menu) {
    MenuInflater inflater = getMenuInflater();
    inflater.inflate(R.menu.option_menu, menu);
    return true;
}

@Override

```

```

public boolean onOptionsItemSelected(MenuItem item) {
    switch (item.getItemId()) {
        case R.id.scan:
            // Launch the DeviceListActivity to see devices and do scan
            Intent serverIntent = new Intent(this, DeviceListActivity.class);
            startActivityForResult(serverIntent, REQUEST_CONNECT_DEVICE);
            return true;
        case R.id.discoverable:
            // Ensure this device is discoverable by others
            ensureDiscoverable();
            return true;
    }
    return false;
}
}

```

BluetoothChat Service

```
<?xml version="1.0" encoding="utf-8"?>
<!-- Copyright (C) 2009 The Android Open Source Project

Licensed under the Apache License, Version 2.0 (the "License");
you may not use this file except in compliance with the License.
You may obtain a copy of the License at

    http://www.apache.org/licenses/LICENSE-2.0

Unless required by applicable law or agreed to in writing, software
distributed under the License is distributed on an "AS IS" BASIS,
WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
See the License for the specific language governing permissions and
limitations under the License.
-->
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.example.android.BluetoothChat"
    android:versionCode="1"
    android:versionName="1.0">
    <uses-sdk minSdkVersion="6" />
    <uses-permission android:name="android.permission.BLUETOOTH_ADMIN" />
    <uses-permission android:name="android.permission.BLUETOOTH" />
    <uses-permission android:name="android.permission.ACCESS_COARSE_LOCATION" />
    <uses-permission android:name="android.permission.ACCESS_FINE_LOCATION" />
    <uses-permission android:name="android.permission.CHANGE_NETWORK_STATE" />
    <uses-permission android:name="android.permission.READ_PHONE_STATE" />

    <application android:label="@string/app_name"
        android:icon="@drawable/app_icon" >
        <activity android:name=".BluetoothChat"
            android:label="@string/app_name"
            android:configChanges="orientation|keyboardHidden">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
        <activity android:name=".DeviceListActivity"
            android:label="@string/select_device"
            android:theme="@android:style/Theme.Dialog"
            android:configChanges="orientation|keyboardHidden" />
    </application>
</manifest>
```

```
map_structure = kml_shapefile('VFcell.kml')
load cell_id.mat;
[map_structure.cid] = deal(data)
for i = 1:length(map_structure)
    map_structure(i).cid = data(i);
end
map_structure=rmfield(map_structure,'Geometry')%%%
map_structure=rmfield(map_structure,'Id')%%%
map_structure=rmfield(map_structure,'altitude')%%%
cellData = struct2cell(map_structure);
display('Butona TIKLA ');
num_lines=0;
figure;hold;grid;
s = serial('COM3','BAUD',9600); % Create serial object (PORT Dependent)
fopen(s) % Open the serial port for r/w
adim=fscanf(s,'%d');
x=1:adim;
n=length(x)
for i=1:n;
    cid(i) = fscanf(s,'%d');
    rss(i) = fscanf(s,'%d');
end;
while(s.BytesAvailable>0)

adim=fscanf(s,'%d');
x=1:adim;
n=length(x)
for i=1:n;
    cid(i) = fscanf(s,'%d');
    rss(i) = fscanf(s,'%d');
end
for k=1:adim;
%for k=1:n;
reply=cid(k)
i=1;
for i = 1:length(map_structure)
Index = isequal(reply,map_structure(i).cid);
if(Index==1)
    i
enlem(k)=map_structure(i).Y(1,:);
boylam(k)=map_structure(i).X(1,:)
else
    i=i+1;
end
end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%Propagasyon kaybı ile R(yari_cap hesaplandı)%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
f=900;
c=3000000000;
G=[enlem; boylam]';
[c,idx]=unique(G(:,2));
rss=rss(idx);
%rss=unique(rss);
rss=abs(rss); %rss=(-1)*rss;
l=length(rss);

for p=1:l;
    %d(p)=(rss(p)+43-46+8-5-32.4-20*log10(f))/20; Hata model for center frequency=900Mhz Hbts= 30 m
and Hmobile=1.55
    %Tx=20 Watt=43 dBm;
    %Gain of bts=8 dBm;
    %EIRP=51 dBm;
    %filter, cable and connector loss=5 dBm;
    d(p)=(rss(p)+46-126.42)/35.22;
    rss_d(p)=10^(d(p));
    Rm(p)=rss_d(p)*1000;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%YER TAHMİNİ YAPILIYOR%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
G=[enlem; boylam]';
[c,idx]=unique(G(:,2));
out=G(idx,:);
enlem=out(:,1)';
boylam=out(:,2)';
```

```

[a,b,utmzone]=deg2utm(enlem,boylam);
%d=sqrt((x(2)-x(1)).^2+(y(2)-y(1)).^2);
%if (d>R(1)+R(2));%too far
%d1=sqrt((x(2)-x(1)).^2+(y(2)-y(1)).^2);
%d2=sqrt((x(3)-x(1)).^2+(y(3)-y(1)).^2);
%d3=sqrt((x(3)-x(2)).^2+(y(3)-y(2)).^2);
%d4=sqrt((x(3)-x(2)).^2+(y(3)-y(2)).^2);

if (l==1);%
    Rm=Rm(1:1:1);
    m=length(Rm)
    x0=sum(a)/m;
    y0=sum(b)/m;
    R0=sum(Rm)/m;
    indx=1
elseif (l==2)
    X=a(:);
    Y=b(:);
    R=Rm(:);

    cx1=X(1,:);
    cx2=X(2,:);

    cy1=Y(1,:);
    cy2=Y(2,:);

    R7=R(1,:);
    R8=R(2,:);

    x1= cx1+(cx2-cx1)*(min(R7,R8)/(R7+R8));
    y1= cy1+(cy2-cy1)*(min(R7,R8)/(R7+R8));
    x0=x1;
    y0=y1;
elseif (l>=3)
    [x0,y0] = pozisyonlama(a,b,Rm);
    indx=2
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%GOOGLE_EARTH%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%[x1,y1] = circleintersect(x,y,R);
utmzone=utmzone(1,:);
[lat0,lng0]=utm2deg(x0,y0,utmzone);
z=100;
%output = ge_point(lng0,lat0,z);
num_lines = num_lines+1;
enl(num_lines)=lat0;
bylm(num_lines)=lng0;
test=[enl;bylm];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%KALMAN%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Kalman filter loop% Generate the location data
z=[lat0;lng0];
% Use Kalman filter to estimate the location
y = kalman01(z);
hold on
figure(1);
plot(z(1), z(2), 'bx-');
plot(y(1), y(2), 'go-');
drawnow; pause(.1)
grid;
hold off
hold;
X_real= 38.390752;
Y_real= 27.152573;
c=(X_real-y(1))*111000;
v=(Y_real-y(2))*111000;
hata=sqrt(c^2+v^2)
figure(2);
plot(num_lines,hata,'k+')
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
disp('Running');
hold;
end
fclose(s); % Close the serial port
delete(s);
delete(instrfind)

```


Appendix-C



736 350
OGB6-915N

Omnidirectional Antenna

Kathrein Scala's omnidirectional antennas for wireless, paging, SMR and mobile applications are extremely robust, using the finest fiberglass, brass, and aluminum. Applicable mounting hardware is fabricated from stainless steel. Many models may be mounted inverted. Higher gain antennas can be provided with downtilt, as well.

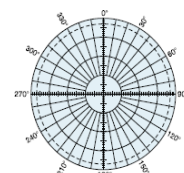
- Wireless
- Paging
- SMR
- Land Mobile
- ISM

Specifications:

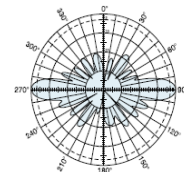
Frequency range	870-960 MHz
Gain	8 dBi
Impedance	50 ohms
VSWR	< 1.5:1
Intermodulation (2x20w)	IM3: -150dBc
Polarization	Vertical
Maximum input power	500 watts (at 50°C)
H-plane beamwidth	Omni
E-plane beamwidth	13 degrees (half-power)
Connector	N or 7-16 DIN female
Weight	12.1 lb (5.5 kg)
Height	60.7 inches (1543 mm)
Radome diameter	2 inches (51 mm)
Wind survival rating	120 mph (200 kph)
Wind load	at 93 mph (150kph)
Side	30 lbf (130 N)
Shipping dimensions	70 x 6 x 5 inches (1848 x 148 x 112 mm)
Shipping weight	14 lb (6.4 kg)
Mounting	For masts of 2 to 3.75 inch (50 to 94 mm) OD.

See reverse for order information.

* Mechanical design is based on environmental conditions as stipulated in TIA-222-G-2 (December 2009) and/or ETS 300 019-1-4 which include the static mechanical load imposed on an antenna by wind at maximum velocity. See the Engineering Section of the catalog for further details.



H-plane
Horizontal pattern
V-polarization



E-plane
Vertical pattern
V-polarization



Kathrein Inc., Scala Division Post Office Box 4580 Medford, OR 97501 (USA) Phone: (541) 779-6500 Fax: (541) 779-3991
Email: communications@kathrein.com Internet: www.kathrein-scala.com