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Context-Aware Mobile Phone Based
City Guide

By: Ayenew Yifru Argaw

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Department of Computer Science

Context-Aware Mobile Phone Based City Guide

By:

Ayeneu Yifru Argaw

Approved By:

Members of the Examination Board:

1. Dejene Ejigu (Ph. D.), Advisor _____
2. Yaregal Assabie (Ph.D.), Examiner _____
3. _____
4. _____

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Dedication

To my mother Zeneb Adamu.

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List of Acronyms

PDA - Personal Digital Assistant

GPS - Global Positioning System

A-GPS- Assisted Global Positioning System

LBS – Location Based Service

IEEE – International Electrical and Electronic Engineers

LMU – Location Measurement Unit

SIM – Subscriber Identity Module

AOA – Angle Of Arrival

BS – Base Station

GSM – Global System for Mobile Communication

MS – Mobile Station

TOA – Time Of Arrival

MLC – Mobile Location Center

UHF – Ultra High Frequency

VHF – Very High Frequency

LOS – Line Of Sight

NLOS – Non Line Of Sight

RDF/OWL – Resource Description Framework/Web Ontology Language

CA-LBS – Context Aware Location Based Service

J2ME – Java 2 Micro Edition

HTTP – Hyper Text Transfer Protocol

RSSI – Received Signal Strength Indication

CLDC – Connected Limited Device Configuration

MIDP – Mobile Information Device Profile

Abstract

In order to provide a context aware location based service to a mobile phone user, the first thing is to know the exact location and context of the user. To know the exact location of the user there are different positioning techniques. Some of these techniques need support of Telecom provider and other methods require an embedded GPS. But the cost of most smart cell phone that has GPS is expensive and economically not affordable for most people in the country.

To overcome this problem we propose the context-aware LBS architecture that reads and process the location and context information of a user using ordinary cell phones. The architecture is composed of the client mobile device and the context aware LBS server. The client mobile device end consists of components responsible for reading the location and context data from the client cell phone. The context aware LBS server side consists of components responsible for processing the location and context data that comes from client cell phone and make decisions based on different information stored in the server. The LBS system uses mathematical model of lateration methods based on the signal strength and cell-ID received from telephone cell tower which all types of mobile phones can read.

To evaluate the validity of the proposed architecture, we developed a prototype that implements the core components of the proposed architecture. The implementation has been evaluated with a sample services areas between localities in Addis Ababa named as Arat Kilo and Sidist Kilo. Results from the experiment show the proposed architecture is promising to provide a context aware city guide services for users including those using ordinary (non-smart) phones without GPS.

Keywords

Location Based Service, Context-Aware, Trilateration, Cell-ID, Received Signal Strength Indication

1. Introduction

1.1. Background

The general trend of computing is progressing towards the vision of Ubiquitous Computing, in which devices are seamlessly integrated into the life of everyday users, and services are readily available to users anywhere they go at any time. In contrast to the traditional computing paradigm, in which the computing environment is often static and well-defined, in Ubiquitous Computing, however, the underlying environment is open and dynamic [3].

One field in the wide range of pervasive computing is the so-called context-aware (or sentient) systems. Context-aware systems are able to adapt their operations to the current context without explicit user intervention and thus aim at increasing usability and effectiveness by taking environmental context into account. Particularly when it comes to using mobile devices, it is desirable that programs and services react specifically to their current location, time and other environment attributes and adapt their behavior according to the changing circumstances as context data may change rapidly. The needed context information may be retrieved in a variety of ways, such as applying sensors, network information, and device status, browsing user profiles and using other sources [4].

Contexts have their own advantages in ubiquitous computing to reduce the interaction of the user with the system [4, 5]. Since a mobile device suffers from several limitations such as small screen and network connection with low bandwidth, it is important to select the suitable quantity and quality of information that is presented to the user [59, 60]. Using the context information lets the system to decide about the suggested information to its users which is more satisfactory for them [7].

According to Geer D. and Motorola Inc. [2], the rapid development of information technology, the need of various types of information service emerges. Among them the location sensitive applications are of the utmost importance. LBS are a service that is offered to the users considering current geographical position. This service is implemented for wide purposes like advertising business, navigation purpose, traffic analysis and routing purpose. To provide location based services to the user, the first step is calculating the current geographic position of the user.

For example, the U.S. Federal Communications Commission has made Enhanced 911 (E911) a mandatory requirement for wireless communications services such as cellular telephone, wideband (broadband) personal communications services, and geographic area specialized mobile radio [2, 8]. In this rule, any public safety answering point (PSAP) attendants of wireless communications networks must be able to know a 911 caller's phone number for return calls and the location of the caller, so that calls can be routed to an appropriate PSAP and related emergency assistance attendants [52].

All kinds of LBSs require mechanisms to determine the current position of a mobile target, which can be done either in a terminal-based, terminal-assisted or network-based fashion. Looking at positioning methods that are available nowadays mobile phones or mobile network providers, there are many alternatives like e.g. Observed Time Difference of Arrival, Time Difference of Arrival, AOA, Cell-ID, GPS or Assisted GPS (A-GPS) [6] and Database Correlation. Observed Time Difference of Arrival involves time difference measurements being made in the handset, and a mechanism to pseudo-synchronize the network. The handset makes an observation of the time difference of arrival of signals from two or more different base stations [9]. The location is then estimated by the best intersection of the multiple hyperbolic curves the mobile station accesses [10, 11].

Since most of the mobile phones do not yet have a built-in GPS receiver, the most widely available positioning method today is Cell-ID. It is referred to as a method to derive the position of a mobile station based on the coordinates of the serving base transceiver station(s) [6]. Cell-ID positioning offers only very low accuracy but wide area coverage and very low power consumption. GPS is favorable because of its high accuracy, but it is the most power-consuming positioning method and current mobile phone batteries last only a few hours when the GPS receiver is turned on [6]. In addition to this, some of the positioning systems are suitable for outdoor positioning with a better accuracy than the other but doesn't work for indoor positioning and others are suitable for both indoor and outdoor positioning but in low level of accuracy. From the above means of positioning system GPS and GSM (Cell-ID) tower based positioning are suitable for mobile devices (like cell phones, tablet PC or PDA). Since other positioning methods need some modification either in the SIM card of the client cell phone or in the GSM tower.

Mobile guides constitute a special class of mobile computer system [54]. Usually mobile guides are closely related to the user's physical location and objects in the user's immediate surroundings [1]. Also, they are often used while the user is moving from one physical location to another.

To provide better location based service (city guide) to the user knowing current position of mobile device either using GPS or GSM towers is not enough; in addition context information is required to provide a comfortable service to mobile phone users.

1.2. Motivation

Since location based service is one of the application areas that are implemented on the mobile phone. Location based services are crucial for large cities like Addis Ababa, and such applications can be realized using the country's network infrastructure and users mobile phone. To provide a better location based service to the users, it is necessary to link spatial processing to other domain of applications, one of such applications context-aware (proactive) service. In many countries this proactive location based service has been implemented to overcome user navigation difficulties in big cities. Most of the applications already in use in many countries are implemented for smart phones, tablets and PDA.

But directly implementing these applications in countries like Ethiopia is totally impossible because of the cost of the devices and existing network infrastructure. So the main motivation for this study is to deliver proactive location based service to the users by considering the users cell phone and the infrastructure.

Beside this main motivation we are also motivated to provide location based advertising to the companies especially for recreation centers and hotels in the city. And we use this system for disaster prevention mechanism for fire brigade and other social service activities (like ambulance and police services). In addition, we expand the system to other main tourist destination cities though out the country.

1.3. Statement of the problem

Currently, most people living in cities and even those living in country sides have a mobile phone for the purpose of communication. Beside this, mobile devices have so many services to give to the user by linking it to different application domains. From these application domains the cell phone users use this device for navigation and other purposes by linking the cell phones to GIS (Geographic Information System) applications. Such applications are implemented in many countries for city guide and providing a tourism service for the users. Such applications, however, are not widely available in countries like Ethiopia.

Like many big cities, Addis Ababa, the capital of Ethiopia, also needs mobile based city guide. However, most of the mobile based city guide applications are implemented in different countries for smart phone (which has built-in GPS inside) and PDA's. Like "Time Out" in London and New York, and "Tokyo Walker" and "Magitti" in Tokyo for city guide and leisure activities respectively, and others [5]. It is not possible to directly implement these applications in our country because these cell phones are not economically affordable by most people.

To address this problem, this study focuses on the design of context aware mobile based system that detects the geographical positions using cell phone that either has built-in GPS inside or not, combined with user context. Mobile phones without built-in GPS use signal strength and cell-ID measurement techniques from active and neighboring GSM towers. Using this method location determination problem for ordinary cell phones is resolved. Figure 1.1 shows how a signal strength and cell-ID of active and neighboring cells are used to detect location of a mobile station without GPS technology (i.e. using LMU of GSM towers).

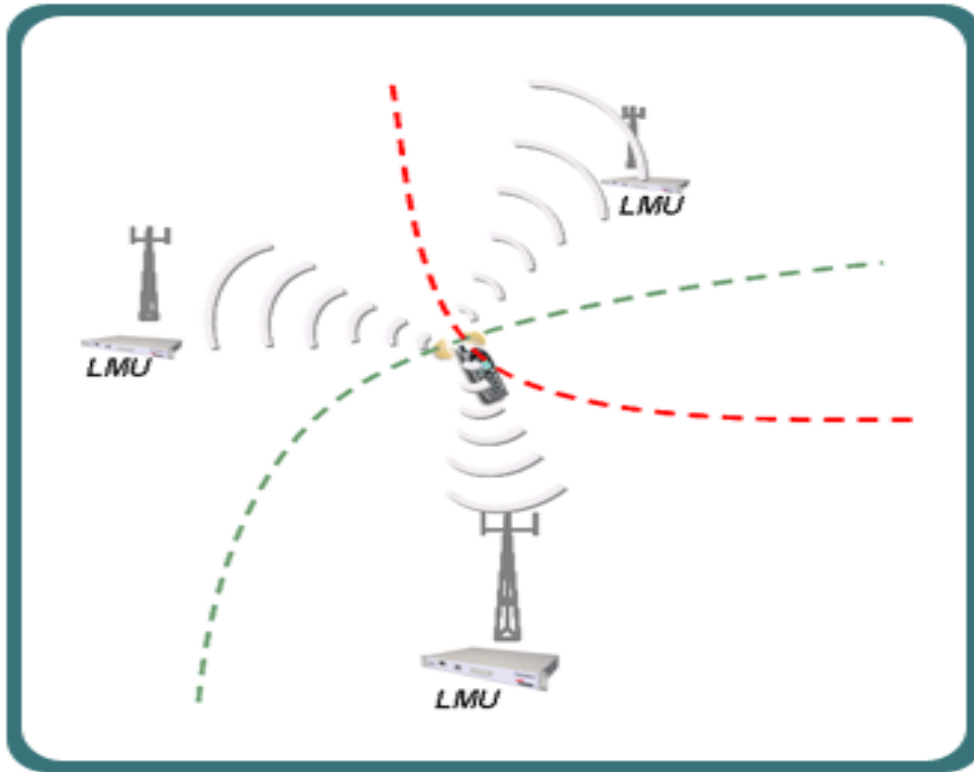


Figure 1.1 Trilateration technique for location determination in cell phone using Cell-ID

Research questions to be addressed are:

- Can we determine geographic coordinates of user location using ordinary mobile phone without built in GPS?
- Can we provide location aware services like listing names of governmental and non-governmental organizations, café and restaurants, recreation centers, cinema and theater halls, and other service areas near to the user ordered by considering the current context of user and distance of the service areas from the current geographical position of the user?
- Can we provide such service on a simple java enabled mobile phones?

1.4 Application of the Study

As we have mentioned in the motivation, location based services provide different applications to the user. This context aware mobile based city guide can be used in the following application areas directly or with slight modification. This study is applicable to provide a better tour service

for the tourist in the city. When a tourists visits different areas of the city, this system gives a nearby museum, historical places and other tourist destination places.

This study is also applicable to report where the accident (car, fire, etc) happens to the police office, fire brigade or Red Cross society. In addition, this study is also useful to give better location based advertising for different organizations or companies considering user profile and interest. Since advertising is one of a means to reach customers, so many organizations can use this system as one way of advertising their business to the customers by considering current locations of users.

This service can be also extended to country wide applications (especially cities that have large number of foreign and local tourists).

1.5. Objectives and Scope

1.5.1. Objectives

The general objective of this research work is to design and develop a generic model for context aware mobile phone based city guide service.

The specific objectives of the research work are to:

- Review the current research in context aware computing, location based service, positioning of mobile devices, and mobile phone based city guide.
- Identify appropriate user context.
- Collect and organize spatial and non-spatial data about different corners of the city.
- Collect and use spatial information of GSM towers in the city to calculate geographic position of the user.
- Design and develop a tool for positioning the cell phones without GPS technology.
- Develop a mobile phone based interface to send context and location information to the server.
- Develop a system that accepts context and location information from the user and then send replay information to the user via Internet connection.
- Develop a prototype for the proposed system, and
- Demonstrate and evaluate the performance of the system.

1.5.2. Scope

Context aware mobile phone based city guide include different service to the users. However, this research work focuses on the following:

- Determining current location and particular context of the user by using their cell phone and provide text based information from the server about main service areas around the user based on user context and location information.
- Provides route, distance estimation and other related services to the user.

1.6. Methodology

In order to achieve the general and specific objectives mentioned before, we employed different methods in three consecutive phases of this work. In the first phase, review of the relevant literature was conducted to gain deeper understanding of the research domain. To have a better and solid understanding of the problem domain, reading of books, journals and research articles relevant to the research topic were undertaken. The major activities carried out in this phase were the following:

- Major researches in the area of location based service and pervasive computing have been studied.
- Context-aware computing and related issues in pervasive environments in general and context-aware location based systems in particular have been investigated.
- Existing context management and processing models were studied with an emphasis on location based service.

The completion of this phase resulted in a clear and deep understanding of the problem and its surroundings as well as the requirements for the solution to be proposed.

The second phase of this work was to develop a model for context-aware location based system based on the inputs from the first phase. The major activities undertaken in this phase were the following:

- Identifying the requirements of the model to be developed based on the study made in the first phase.

- Development of the model as per the outlined requirements. This involved:
 - ❖ Identifying the various components of the model.
 - ❖ Defining the internal details of each component.
 - ❖ Defining the means and scope of communication among the components.

The third and last phase of this work is to design and develop a prototype so as to demonstrate the validity of the proposed context-aware location based system architecture. Both the preceding phases provided valuable inputs to this phase. The following major activities were conducted in this phase:

- Specifying the requirements of the prototype.
- Studying tools, technologies and protocols needed for implementing the prototype.
- Developing design of the prototype as per the specified requirements.
- Implementation and testing of the prototype design.

1.7. Thesis Organization

The rest of this thesis paper is organized into four chapters. Chapter Two presents introductory background on context-aware computing paradigm, location based system, signal propagation path loss models for outdoor and indoor environment and related works in the context aware location based service in different scenarios. This chapter is a foundation for the subsequent chapters. Chapter Three focuses on presenting the proposed architecture for context aware location based system. Next to this implementation environment and experimental results are discussed. Finally, this thesis is concluded by highlighting the method we used in this work and introducing the possible future works.

2. Literature Review and Related Works

2.1. Introduction

In this chapter we tried to revise different research papers that emphasis on “Context-Aware Location Based System Using Cell Phones”. Mainly, these papers are classified into different field of studies like position techniques, context organization and user interface development in mobile devices. This chapter deals with state of art in positioning techniques currently used in location based service, literatures related to signal propagation path loss models in mobile communication, topics related to context capturing, organization and processing and finally, revise some related works that has direct relation with this thesis.

2.2. Positioning Techniques

The crucial thing in any LBS systems is determining the current geographic position of the user. Positioning techniques are a way of determining the current location of the users. There are a number of positioning techniques [2, 44, 45, 46, 52, 55, 56] that could be used by mobile operators seeking to provide LBS. Some of these techniques are presented in the following subsections:

2.2.1. Global System for Mobile Communication (GSM) (Cell-ID)

One of the available parameter of GSM networks is “Cell-ID”. This value is present in the mobile handset’s Subscriber Identity Module (SIM) card and the GSM network itself. The Cell-ID value can be converted to a location estimate using details of mobile network cell coverage present in the server database or in the cell phone text file [6, 36, 38, 43].

The Cell-ID value alone may not necessarily be an accurate way to determine the location of a particular mobile handset. In urban environments, the accuracy is typically around 2 km; although this can improve in city centers to around 500 m. But the accuracy can be 5 km or worse in suburban and rural environments which have fewer base stations [2, 13]. According to Alex Varshavsky et al. [36], the Cell-IDs values alone are enough to determine location of mobile station.

2.2.2. Uplink Time Difference of Arrival

The uplink positioning method is based on measuring the Time of Arrival (TOA) of a known signal sent from the mobile and received at three or more measurement units. The uplink TDOA mechanism requires three or more network Location Measurement Units (LMUs) to measure the arrival time of a signal sent from a mobile handset (see Figure 2.1). The difference in arrival time of the mobile signal at different network LMUs is used by the network's Serving Mobile Location Center (SMLC) to determine the handset's location. A benefit of the uplink TDOA positioning mechanism is that it can be used with existing GSM handsets [2, 12].

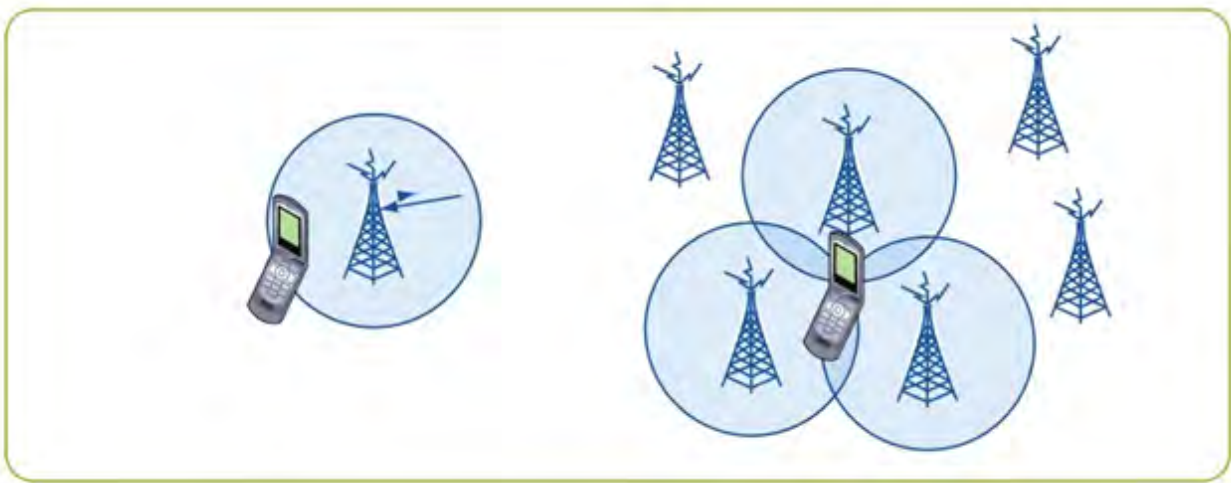


Figure 2.1 Positioning using Time of Arrival

2.2.3. Angle of Arrival (AOA)

Signal angle of arrival (AOA) information, measured at the base station (BS) using an antenna array, can be used for positioning. Assume two dimensional Euclidian geometry, two AOA measurements of BTs are sufficient for unique location calculation. This is illustrated in Figure 2.2, where the user location is determined as the point of intersection of two lines drawn from BSs. It is seen that AOA technique requires line of sight between the MS and the BSs for accurate results.

Since AOA method needs line-of-sight propagation conditions to obtain correct location estimates, it is clearly not the method of choice in dense urban areas where line of sight to two or

more BSs is seldom present [2, 15]. So this method of location determination is not suitable for our proposed system.

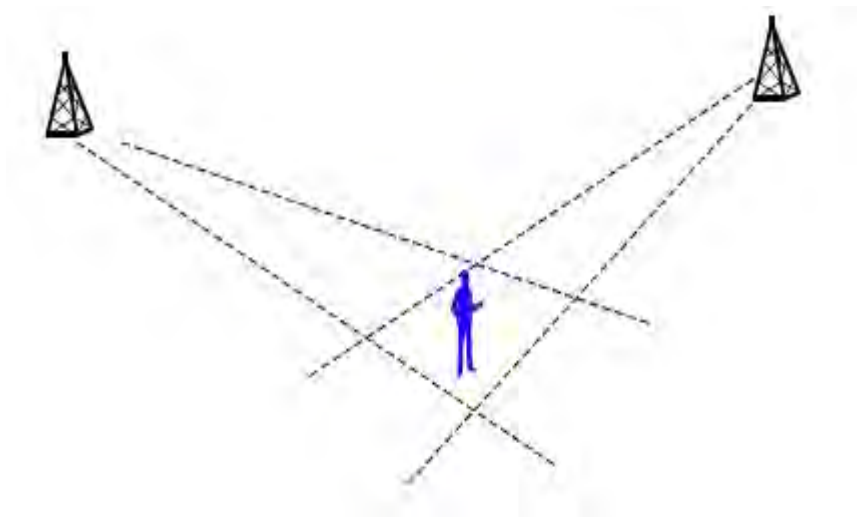


Figure 2.2 Positioning using AOA

2.2.4. Database Correlation Method

It is a generic location method that can be applied to either indoor or outdoor environment for any cellular network [2, 14, 26, 30]. In this positioning approach the signal information of locations seen by mobile station (MS) is stored in the database. The database should contain signal information samples, called fingerprints; with a resolution relative comparable to the accuracy that can be achieved with the method, and this resolution may vary in different environments. When the MS needs to be located, the necessary measurements are performed and transmitted to the location server. The location server then calculates the MS location by comparing the transmitted fingerprint and the fingerprints that are already stored in the database. Since collecting fingerprints for large city in order to construct a database for location is expensive and time consuming. Therefore, this approach is not technically and economically feasible for this study.

2.2.5. Observed Time Difference of Arrival (OTDA)

This positioning technique requires a handset to measure the arrival time of signals sent from three or more base stations [2].

- In “network assisted” mode, the handset reports this information back to the server. The server uses these radio timing measurements to determine the handset location. As you can see in the Figure 2.3, the mobile device measure the arrival time of signals from three towers and send it to the server for further processing.
- In “handset-based” mode, the mobile handset itself makes use of timing measurement information to deduce the current location.

This technique requires modification to a standard GSM handset in order for radio timing measurements to be carried out, and for estimating the current location of a mobile device (in “handset-based” mode). This approach is not suitable for location determination in our proposed system, because this technique requires modification in the GSM handset and this change is not possible for us.



Figure 2.3 Positioning using OTDA

2.2.6. Global Positioning System (GPS)

GPS provides a means to determine position, velocity, and time around the globe. The satellites constellation are developed and maintained by the U.S. Department of Defense. Civilian access was guaranteed through an agreement with the Department of Transportation. GPS satellites transmit two carrier frequencies. Typically, only one is used by civilian receivers. Each satellite’s

direct-sequence spread-spectrum (DS-SS) signal is modulated by a 50 bit-per-second navigation message that includes accurate time and coefficients (ephemeris) to an equation that describes the satellite's position as a function of time. The receiver (more precisely, its antenna) position determination is based on TOA.

The four main conventional GPS receiver functions are:

- ❖ Measuring distance from the satellites to the receiver by determining the pseudo ranges (code phases);
- ❖ Extracting the time of arrival of the signal from the contents of the satellite transmitted message;
- ❖ Computing the position of the satellites by evaluating the ephemeris data at the indicated time of arrival;
- ❖ Calculating the position of the receiving antenna and the clock bias of the receiver by using the above data items.

The accuracy of autonomous GPS is around 5-50m and easily affected by the weather condition and building (especially in the cities) [38, 44]. To improve the accuracy of autonomous GPS two techniques were used. The first one is differential GPS (DGPS) and the other is assisted-GPS (especially for the mobile phone) [2]. DGPS is a means of improving the accuracy of your receiver by adding well-known local reference stations to enhance the information available from the satellites [17].

2.2.7. Assisted Global Positioning System (A-GPS)

A-GPS is a handset-based mobile locating method fundamentally based on GPS locating technology but functionally distributed between the mobile and a centralized server (see Figure 2.4). Mobiles must be specially equipped to receive GPS signals from multiple GPS satellites in order to make measurements of the signals from GPS satellites and relay this information or their calculated position through the mobile network to the SMLC (Serving Mobile Location Center) or other related software run on server.

In cases where the mobile does not compute its own location from GPS data, the SMLC uses GPS data relayed from the target mobile to compute the mobile's position. Once determined, the

position can be sent to a gateway mobile location center (GMLC) for distribution to the application that originated the location request. A-GPS is a supplemental form of GPS whereby GPS satellite position data is sent from the MLC through the mobile network to the mobile to assist the mobile in determining which GPS satellites it should attempt to acquire. This supplemental data is intended to:

- Speed the mobile's satellite signal acquisition process.
- Increase the mobile's ability to receive signals from the target GPS satellites.

A-GPS is intended to reduce latency and improve other location performance when a mobile's view of GPS satellites is obscured. That can occur when the caller is in a building, in a vehicle, or in an "urban canyon." Although A-GPS does improve overall locating performance, accuracy, latency, and yield performance can be subject to degradation if a mobile's view of GPS satellites is obscured [2, 10, 44].

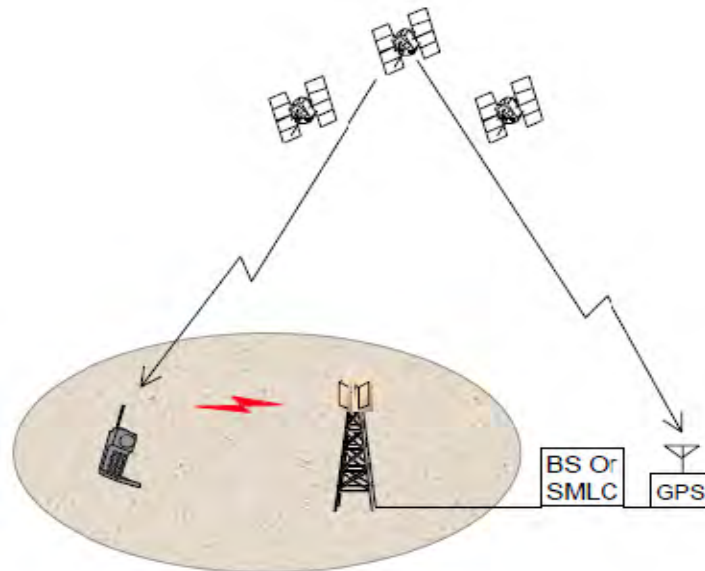


Figure 2.4 Positioning using A-GPS

In general, each positioning techniques has advantages and disadvantages, accuracy level and suitable areas of application. From the above positioning techniques the first five approaches doesn't require a GPS so it is applicable on any mobile phones. But most of the positioning techniques need minor modification either on the BS or MS (Mobile Station). After analyzing the issues in each positioning technique we choose Cell-ID positioning technique suitable for our context aware location based service.

According to Anthony Clarkson et. al. [44], different application areas need different level of accuracy in geographic positions of the users. The following table (Table 2.1) compares different positioning techniques with coverage (urban and rural areas), accuracy and cost [44].

Table 2.1 Comparison of positioning techniques

Method	Coverage(Urban/ Rural)	Accuracy	Cost
Cell-ID	Good/good	Cell radius	Server in network
Cell-ID(RSSI)	Good/good	30-200m	Server in network; software in handset
GPS	Moderate/good	5-50m	Hardware in handset
A-GPS	Moderate/good	5-50m	Hardware in handset; reference receivers in network
Angle of Arrival	Good/moderate	50-300m	Directional antenna and servers in network
Time of Arrival	Good/low	50-200m	Server in network
Observed Time Difference on Arrival	Moderate/low	50-200m	Server in network

2.3. Signal Propagation Path Loss Model

Path loss refers to electromagnetic wave attenuation between transmitter and receiver in the communication system. Path loss might be due to effects such as diffraction, refraction, reflection, free space loss, coupling loss and absorption between the signal generator and receiver.

Path loss models are important for predicting area coverage, interference analysis, frequency assignments and cell parameters which are basic elements for network planning and location calculation processes in mobile radio systems [55]. The propagation models can be divided into three types of models, namely the empirical, semi-deterministic and deterministic models. Empirical models are based on measurement data, statistical properties and few other parameters. Examples of this model category are Okumura and Hata models. Semi-deterministic models are based on empirical models and deterministic aspects, examples being the Cost-231 and Walfish-Ikegami models. Deterministic models on the other hand are site-specific, requires enormous number of geometry information about the city (building specially for indoor positioning), computational effort and more accurate model than empirical and semi-deterministic models. Several deterministic techniques for propagation modeling can be identified. For indoor applications, especially, the Finite Difference Time Domain (FDTD) and the geometrical optics (GO) techniques are the most common once.

2.3.1. Empirical Models

a. Empirical Hata Model

Hata model is the most popular model that extensively used in Europe and North America [39, 40, 41]. The model was developed by Y. Okumura and M. Hata [18] and based on measurements in urban and suburban areas on Japan in 1968. Validity range of the model is frequency (f_c) between 150MHz and 1500 MHz, Tower height (h_b) between 30 and 200m, receiver height (h_m) between 1 and 10m and Tower and Receiver distance (r) between 1 and 10km.

Hata's Equations are classified into three models [18]:

- Rural: open space, no tall trees or building in path
- Suburban area: Village Highway scattered with trees and house with some obstacles near the mobile but not very congested.
- Urban area: Built up city or large town with large building and houses.

Details of the above three Hata models are presented in chapter three.

b. Egli Model

The Egli Model is a terrain model for radio frequency propagation. Egli model was first introduced by John Egli in 1957 [19]. This prediction model is applicable at frequency from 40MHz to 1000MHz and linking range is less than 60 km. It was derived from real-world data on Ultra High Frequency (UHF) and Very High Frequency (VHF) television transmissions in several large cities. It predicts the total path loss for a point-to-point link. Egli observed that there was a tendency for the median signal strength in a small area to follow an inverse fourth-power law with range from the transmitter, so the model is based on plane-earth propagation.

Egli's model for the median (i.e. 50%) path loss is based on:

$$E_{50} = \frac{h_t h_r f}{95d^2} \sqrt{P_t} \quad 2.1$$

Where

- E =field intensity in microvolt per meter
- h_t =transmitting antenna height in feet
- h_r =receiving antenna height in feet
- f =transmission frequency' in megacycles
- d =distance from transmitter in miles
- P_t = effective radiated power in watts.

From equation 2.1, it is noted that this model predicts that the average field intensity will decrease with the distance at a rate $1/d^2$. The decrement rate is not depending on the effective height of the radio base station antenna or other factors if all these factors remain the same throughout the whole distance of measurement.

2.3.2. Semi-deterministic Models

a. Cost-231 Model

The COST-Hata-Model is the most often cited of the COST 231 models. It is a radio propagation model that extends the Hata Model to cover a more elaborated range of frequencies. COST (COoperation européenne dans le domaine de la recherche Scientifique et Technique) is a

European Union Forum for cooperative scientific research which has developed this model accordingly to various experiments and researches.

The COST-231 Hata model is designed to be used in the frequency band from 1500 MHz to 2000 MHz. It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has seen it widely used for path loss prediction at this frequency band. The basic equation for path loss in dB is [20]

$$PL = 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(h_b) - ah_m + (44.9 - 6.55 \log_{10}(h_b)) \log_{10} d + cm \quad 2.2$$

Where, f is the frequency in MHz, d is the distance between base and receiver antennas in km, and h_b is the base station antenna height above ground level in meters. The parameter cm is defined as 0 dB for suburban or open environments and 3 dB for urban environments. The parameter ah_m is defined for urban environments as [21]

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.97 \quad 2.3$$

And for suburban or rural (flat) environments,

$$ah_m = (1.1 \log_{10} f - 0.7)h_r - (1.56 \log_{10} f - 0.8) \quad 2.4$$

Where, h_r is the receiver antenna height above ground level. Observation in equation (2.2) to (2.4) reveals that the path loss exponent of the predictions made by COST-231 Hata model for urban environment is given by,

$$PL = 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(h_b) - (3.20(\log_{10}(11.75h_r))^2 - 4.97) + (44.9 - 6.55 \log_{10}(h_b)) \log_{10} d + cm \quad 2.5$$

b. Walfish-Ikegami Model

This model has been shown to be a good fit to measured propagation data for frequencies in the range of 800 to 2000 MHz and path distances in the range up to 5 km. The Walfish Ikegami model distinguishes between LOS and NLOS propagation situations [20].

In a LOS situation where the base antenna height is greater than 30 meters ($h_b \geq 30$) and there is no obstruction in the direct path between the transmitter and the receiver, the WIM path loss model for LOS is:

$$PL = 42.64 + 26\text{Log}_{10}(d) + 20\text{Log}_{10}(f) \quad 2.6$$

Where d is distance in Kilo meter and f is frequency in MHz.

The NLOS model is the most complex but it has the ability to represent more environments. In the absence of data, building height in meters may be estimated by three times the number of floors, plus 3m if the roof is pitched instead of flat. The model works best for base antennas well above roof height [20]. Because of the complexity of the model we skip the detail formula of the model for this paper.

2.3.3. Signal Propagation for Indoor Environment

Signal propagation within a building is strongly influenced by the local features, i.e. the layout of the particular building under consideration and the building construction material used for the walls, floors and ceilings [42, 43, 55].

Indoor mobile radio signal differs from normal mobile radio signal in two important aspects: the interference environment and the fading rate [42, 43]. The interference environment is often caused by spurious emissions from electronic equipment such as computers, and the level can sometimes be much greater than that measured outside. Moreover, there are substantial variations in signal strength from place to place within a building. The fast fading rate makes it inappropriate to calculate system performance by averaging over the fading. There are different models used to calculate propagation loss in the indoor environment [20, 27].

International Telecommunication Union Radiocommunication Sector (ITU-R) [28] recommends different coefficients for path losses that happen in indoor positioning techniques because of the factors that are stated in the previous paragraph. Those recommendations from ITU-R are found in Appendix A¹. Floor penetration loss factors, L_f (dB) with the number of floors penetrated,

¹ See Appendix A for constants set by ITU-R

shadow fading statistics, standard deviation (dB) and Power loss coefficients (N), for indoor transmission loss calculation are written in Appendix A Table 3, 4 and 5 respectively.

2.4. Context and Context-Aware System

2.4.1. Definition

Context is an important concept in ubiquitous and pervasive computing and it plays crucial roles in mobile computing area. The term context has been defined several times by several researchers [7, 22, 57]. We use a Dey definition throughout this paper, he define context as follow [22]:

“Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.”

Dey also defines *“the system to be context-aware if it uses context to provide relevant information and/or services to the user, in which the relevancy depends on the user’s task [22].”*

The context could be divided into categories where different researchers have tried to present a comprehensive one in different application domain. Generally, the context may be classified into four main categories including computing/system (such as size of display, input method, network and communication cost and quality), user (such as people nearby, user’s profile, socio-cultural situation), physical (such as location, lighting, temperature) and time (such as time of day, week, month). As well, the context history could also be useful for certain applications. Other classifications also suggested by researchers from their application fields points of view.

2.4.2. Context Model

A context model is needed to define and store context data in a machine easily accessible and processable format. Since developing flexible and useable context model that cover different application domains of contexts is a challenging task. Strang and Linnhoff-Popien [23] summarized the most relevant context modeling approaches, which are based on the data structures used for representing and exchanging contextual information in the respective system.

Key-Value model: - These models represent the simplest data structure for context modeling. They are frequently used in various service frameworks, where the key-value pairs are used to describe the capabilities of a service. Service discovery is then applied by using matching algorithms which use these key-value pairs.

Markup scheme model: - These models use a hierarchical data structure consisting of markup tags with attributes and content. Typical representatives of this kind of context modeling approach are profiles [51, 16]. Examples of this model are Composite Capabilities / Preferences Profile (CC/PP), User Agent Profile (UAProf) and Comprehensive Structured Context Profiles (CSCP). See Figure 2.5 for a CSCP profile example.

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:cscp="context-aware.org/CSCP/CSCPPProfileSyntax#"
  xmlns:dev="context-aware.org/CSCP/DeviceProfileSyntax#"
  xmlns:net="context-aware.org/CSCP/NetworkProfileSyntax#"
  xmlns="context-aware.org/CSCP/SessionProfileSyntax#">
  <LocationProfile rdf:ID="Location">
    <cscp:defaults rdf:resource=
      "http://localContext/CSCPPProfile/previous#Location"/>
    <Position><dev:UserPosition>
      <dev:latitude>9.00216</dev:latitude>
      </dev:longitude>38.75001</dev:longitude></dev:UserPosition>
    </Position>
  </LocationProfile>
</rdf:RDF>
```

Figure 2.5 CSCP profile example

Graphical models: - The Unified Modeling Language (UML) is also a suitable method for modeling context [48]. Various approaches exist where contextual aspects are modeled in by

using UML. Another modeling approach includes an extension to the Object-Role Modeling² (ORM) [49, 50].

Object oriented models: - Modeling context by using object-oriented techniques offers to use the full power of object orientation (i.e., encapsulation, reusability, inheritance). Existing approaches use various objects to represent different context types (such as user profile, location, etc.), and encapsulate the details of context processing and representation. Access the context and the context processing logic is provided by well-defined interfaces.

Logic based models: - Logic-based models have a high degree of formality. Typically, facts, expressions and rules are used to define a context model. A logic based system is then used to manage the aforementioned terms and allows adding, updating or removing new facts. The inference (also called reasoning) process can be used to derive new facts based on existing rules in the systems. The contextual information needs to be represented in a formal way as facts. The figure has shown below (Figure 2.6) is an example for logic based model using Semantic Web Rule Language³ (SWRL).

$$\begin{aligned}
 &Hotels_and_Restaurants(?x) \wedge Hotels_and_Restaurants(?y) \wedge Description(?x, ?y) \\
 &\rightarrow Services(?x, ?y) \\
 &Location(?x) \wedge Location(?y) \wedge Latitude(?x, ?y) \wedge Longitude(?x, ?y) \rightarrow \\
 &Location_Id(?x, ?y) \\
 &Resident_Type(?x) \wedge Home_address(?x, true) \rightarrow Addis_Resident(?x) \\
 &Working_Hours(?x, ?y) \wedge sameAs(?x, ?y) \rightarrow Services(?x, ?y)
 \end{aligned}$$

Figure 2.6 Example for logic based context model.

Ontology based model: - Ontologies represent a description of the concepts and relationships. Therefore, ontologies are a very promising instrument for modeling contextual information due to their high and formal expressiveness and the possibilities for applying ontology reasoning

² www.orm.net

³ www.w3.org/Submission/SWRL

techniques. Various context-aware frameworks use ontologies as underlying context models [47, 57]. See example for context model using ontology (RDF/OWL) in Figure 2.7.

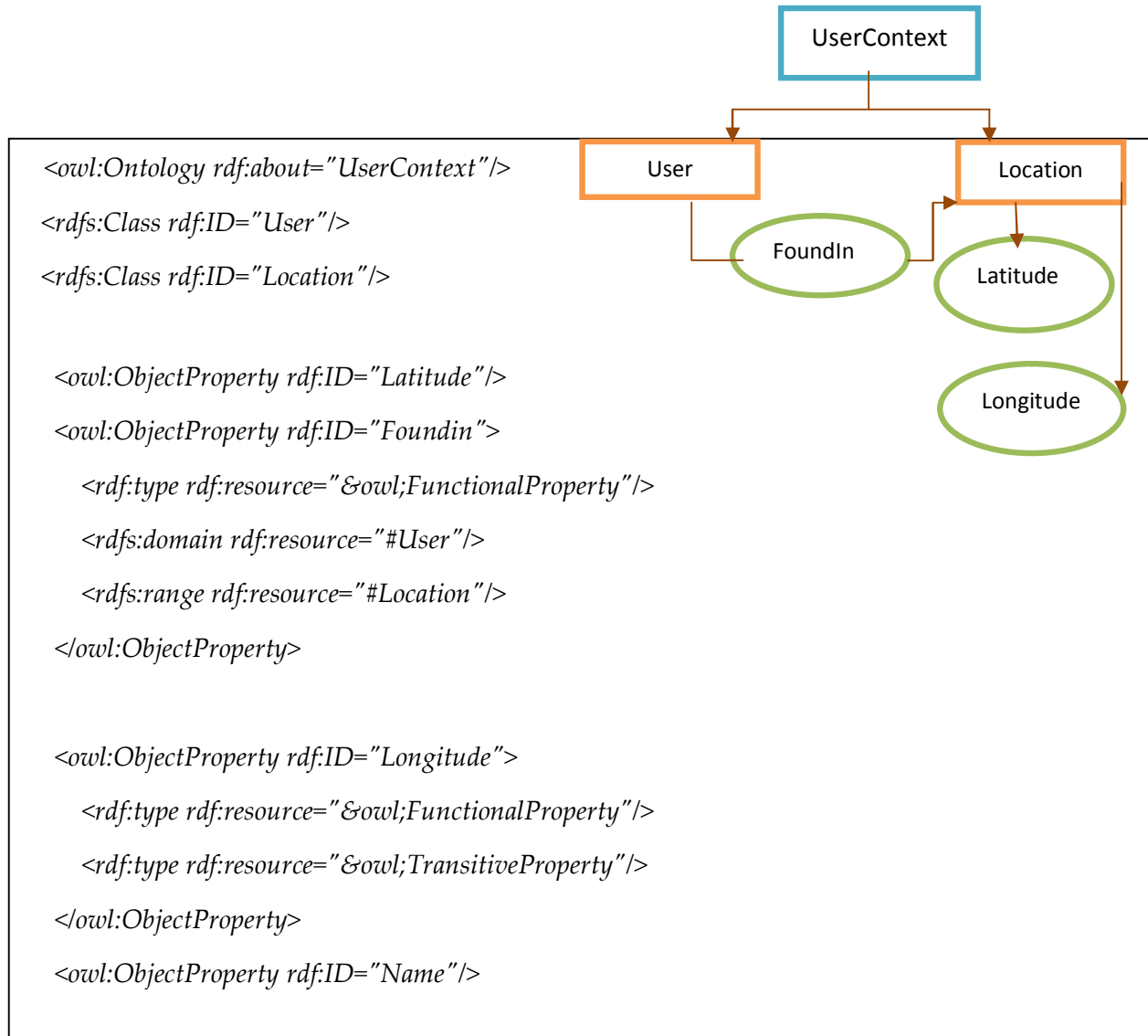


Figure 2.7 RDF/OWL ontology example for location context model

2.5. Related Works

In this section, works related to location based context-aware services are reviewed. Many researchers [7, 22, 24, 25, 30, 61] coined this issue for cities in different corners of the globe. Each paper uses different method to address context organization and service delivery in mobile phone (most of them uses smart phones), Pocket PC and PDA. Some of this works will be presented in the following subsections as they are related to our proposed system.

2.5.1. Context-Aware Tourist Guide Systems

The World Tourism Organization defines tourists as “*people who travel to and stay in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited*[25].” Based on this definition, tourists are new for the environment and it need some guide that show different tourist destination and service areas in the place. Coined these problems of the tourists, so many papers are conducted in many researchers in different countries [7, 24, 30, 53]. From those papers let us see two of them in this section.

2.5.1.1. Building a Context-aware Mobile Tourist Guide System Based on a Service Oriented Architecture

The aim of the study has been to introduce service oriented architecture for context aware tourist guide in the city. The core component of Service Oriented Architecture (SOA) is services. Services in SOA are reusable, share a formal contract, abstract underlying logic, and are loosely coupled, autonomous, stateless, and discoverable.

The main focus of this study is to create a personal tourist guide (PTG) for every tourist based on the services that tourist needs. As shown in Figure 2.8 the architecture has four main parts; PTG, context, service catalog and service provider. PTG is a module to collect and manage context information, operate GIS (Geographic Information System) operation, organize rule to make decisions and bridge the phone to the server system.

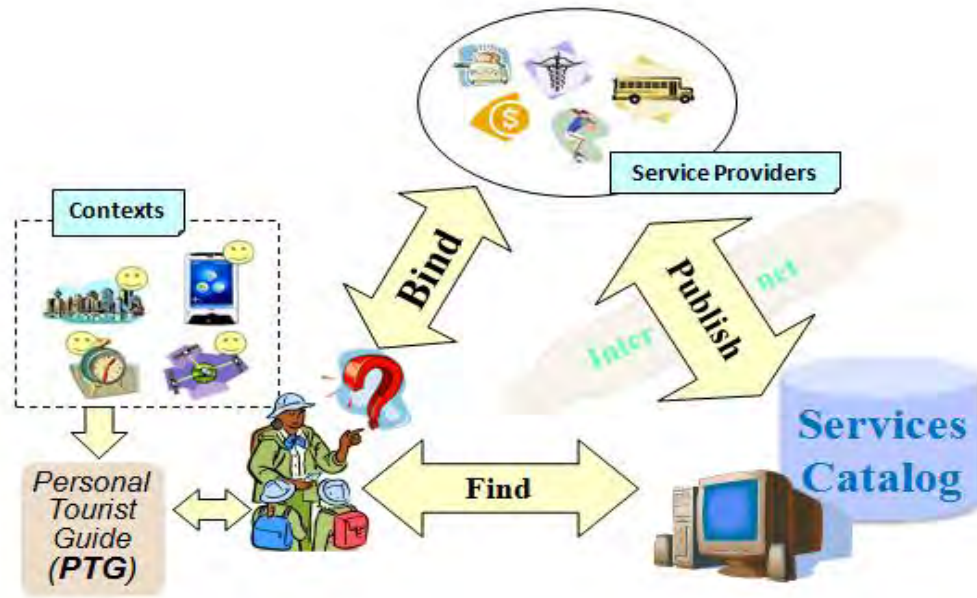


Figure 2.8 Architecture for context-aware system using SOA

The system was evaluated using a light evaluation version of PTG in Window operating system based pocket PC. The components of context used are location (collected by the GPS receiver), time (collected by the timer of pocket PC), and user (collected by a questionnaire and adapted by feedbacks of application). The information collected by context elements are stored and managed in context manager component of PTG.

This work related to our proposed system in one way. Like our proposed system the user context information is collected by user mobile device (either PDA or Smart Phone). Unlike our proposed system most of context and location information processing is carried out in the user mobile device.

2.5.1.2. Context-Aware Recommendations in the Mobile Tourist Application COMPASS

This study integrates the concept of recommender system with a context aware system to provide a better context aware system to the tourist. Context and interests (recommender) can be used as hard or soft criteria in the selection of relevant services to the tourist. Hard criteria are used to limit the set of available information and/or services. Soft criteria are used to order the set of selected services or to present a relevance score to the user for each selected service.

The study is based on **WASP** (Web Architectures for Services Provisioning) platform and adds the **COMPASS** on it. The following figure (Figure 2.9) shows how **COMPASS** application integrated with **WASP** platform. The third party (3G network, context and business) services are services provided by other parties. Next to that the **WASP** platform interlinks the **COMPASS** application with third party services. The interaction manager is responsible to identify and create a link between client mobile devices and server side applications. And **POI** (Point Of Interest) retriever receives a request from interaction manager when the changes happen in the client context and link to the recommendation service to sort data based on soft criteria. Beside this **COMPASS** application has an external map service to draw map based on the information comes from interaction manger.

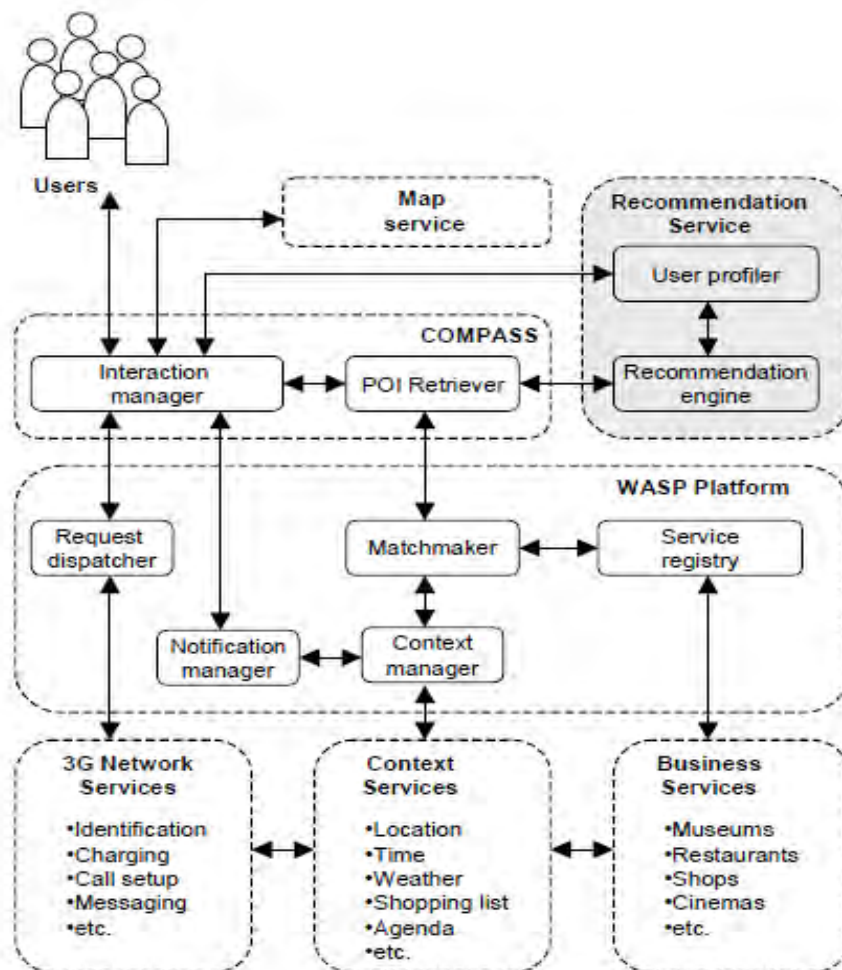


Figure 2.9 The overall architecture of WASP platform and the COMPASS application

This work resembles our work in two aspects. The first one is location context is collected in two ways (GPS or mobile network) just like us. The other similarity is that most of the information processing is carried on the server computer system. Unlike our study the study is only applicable for smart phones, PDA or pocket PC's.

2.5.2. Context Aware Location Based Service

2.5.2.1. Magitti Mobile Leisure Guide

Magitti delivers timely and personally relevant recommendations about nearby venues for pursuing activities in an urban environment [5]. Magitti is designed for young people live in the city interested in all kinds of leisure activities, emphasizing spontaneity rather than sightseeing. The study use machine learning techniques to make a chain of predictions that target information to user interests.

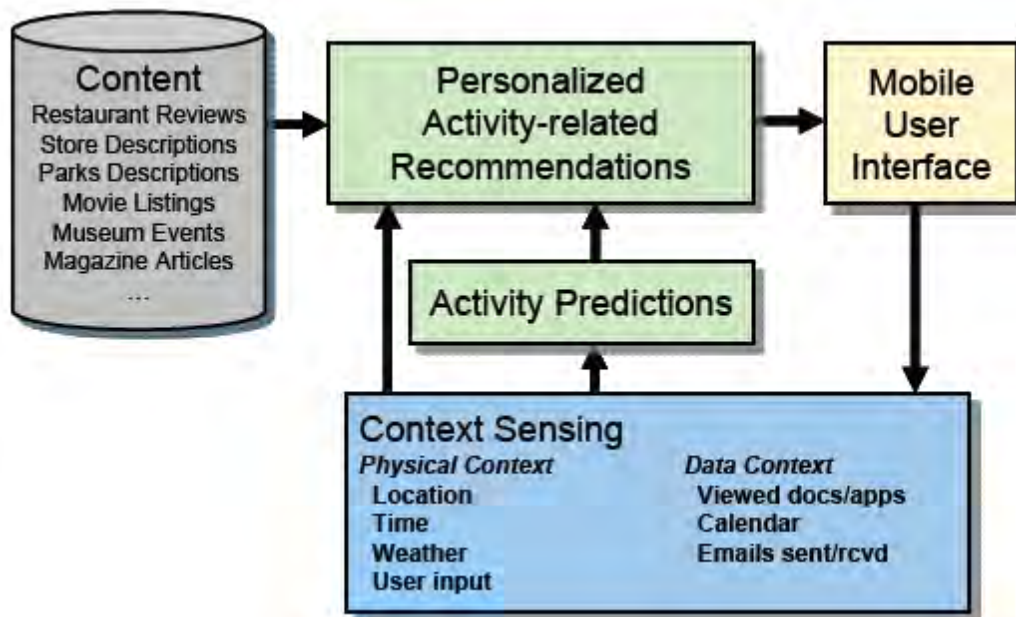


Figure 2.10 Magitti general architecture

The above diagram shows the general architecture for Magitti, this study uses client-server architecture. In this system the context sensing is carried on in user mobile phone and sends the information to the server. Activity predictions module predicts user activity for now and coming

two hours based on the data comes from context sensing module and user existing pattern. The last module combine context information with activities that are comes from activity predictions modules and retrieves information from the database and sent the result to the user mobile device.

This work resembles our work in few points. Like our work it prefers client server architecture and the mobile device is active in collecting context information and displaying the result to the user and other tasks are carried on in the server. Unlike our work the system was designed for smart phones and PDA.

2.5.2.2. Location-Aware Information Delivery with ComMotion

ComMotion provides a location-aware service to the user in a multi-modal (text, audio and map) user interface [61]. The system uses user location information (by using built in GPS), user context and subscription of users to different services like headline news, weather reports and current movie listings. These data is collected from the client side mobile device.

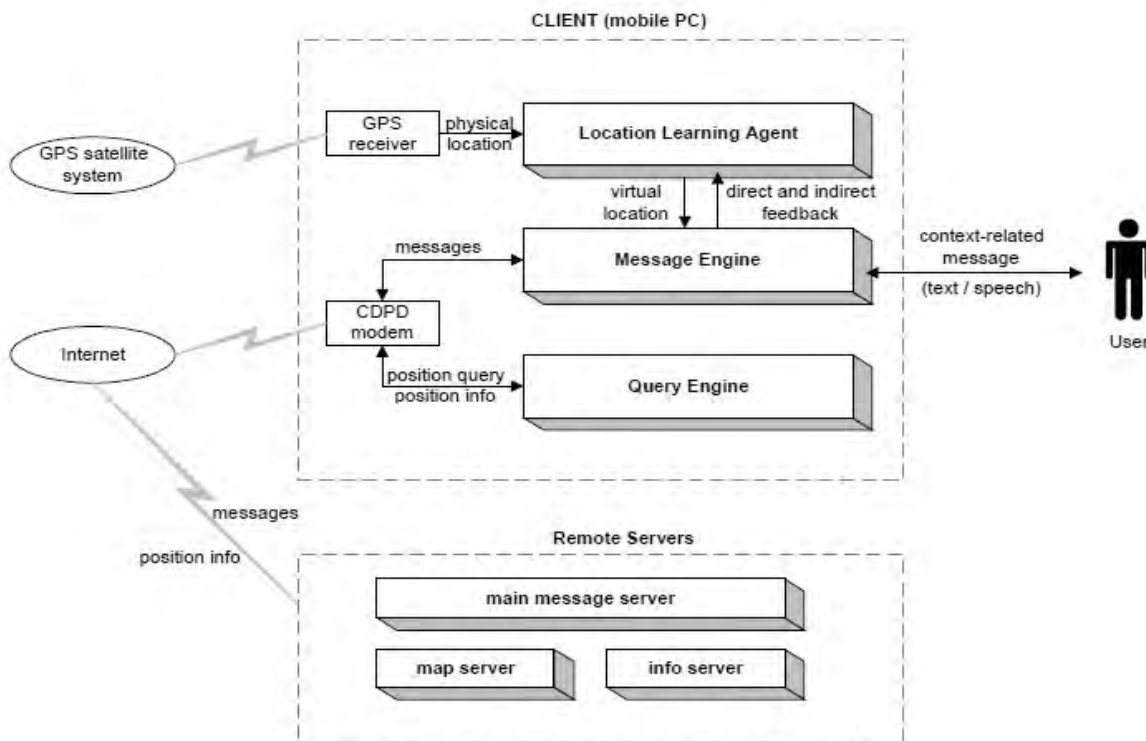


Figure 2.11 The architecture of comMotion showing the three main modules of the client application and its connection to the remote servers

As you can see in Figure 2.11, the system has two main parts implemented on the client mobile device and the server. The system uses GPS technology to acquire the user location and Cellular Digital Packet Data (CDPD) modem for TCP/IP socket for client and server communication. In addition to this, the client mobile device has message and query engines.

On the other hand, the server module has three main components i.e. main message, map and info servers. These modules processes data comes from a mobile device and delivers message, map and other information to client device.

This system related to our work in two points. Like our system it uses client server architecture and it focuses solely in the outdoor environment. Unlike our work this system uses GPS positioning technology to acquire user location; because of this all location related tasks are carried out in the mobile device. In addition to location technology, the system also provide multi-modal user interface to the user.

2.5.3. Summary

All related works reviewed deal with how context are captured, analyzed and processed; and context-aware applications are implemented and used in mobile devices (smart phones, PDA and pocket PC). All the works have limitation that they depend on smart devices capable of capturing their geographic location using GPS systems. In situations like in Ethiopia, where most people use non-smart phones, we have to look for another approach that provide location services in ordinary mobile phones that are in the hands of most people. This is the gap this research work tries to address. The work aims at providing such location based context aware service to all users including those using non smart phones.

3. The Proposed Context Aware Location Based Service

3.1. Introduction

In this chapter, we have presented the architecture of the proposed Context Aware Location Based Service (CA-LBS) to be implemented on mobile phone and server computer. The system is designed to work in any cell phone that supports J2ME, CLDC 1.0 or 1.1 and Mobile Information Device Profile (MIDP) 2.0 or 2.1. The architecture contains components on both the client and on the server side.

The proposed system has two main categories of components in general: Client side and server side. Implemented on mobile phone, the client side components are used to capture location, context and other settings of a user whereas the server side components are dedicated to process the data sent from the client side and responds with the available services at the user current location.

3.2. CA-LBS Architecture

The proposed architecture shown in Figure 3.1, contains the two major categories of components found at the client mobile device and Context Aware LBS server. Each of the categories is composed of several sub-components that are needed to carryout different tasks in the course of giving context aware location based service.

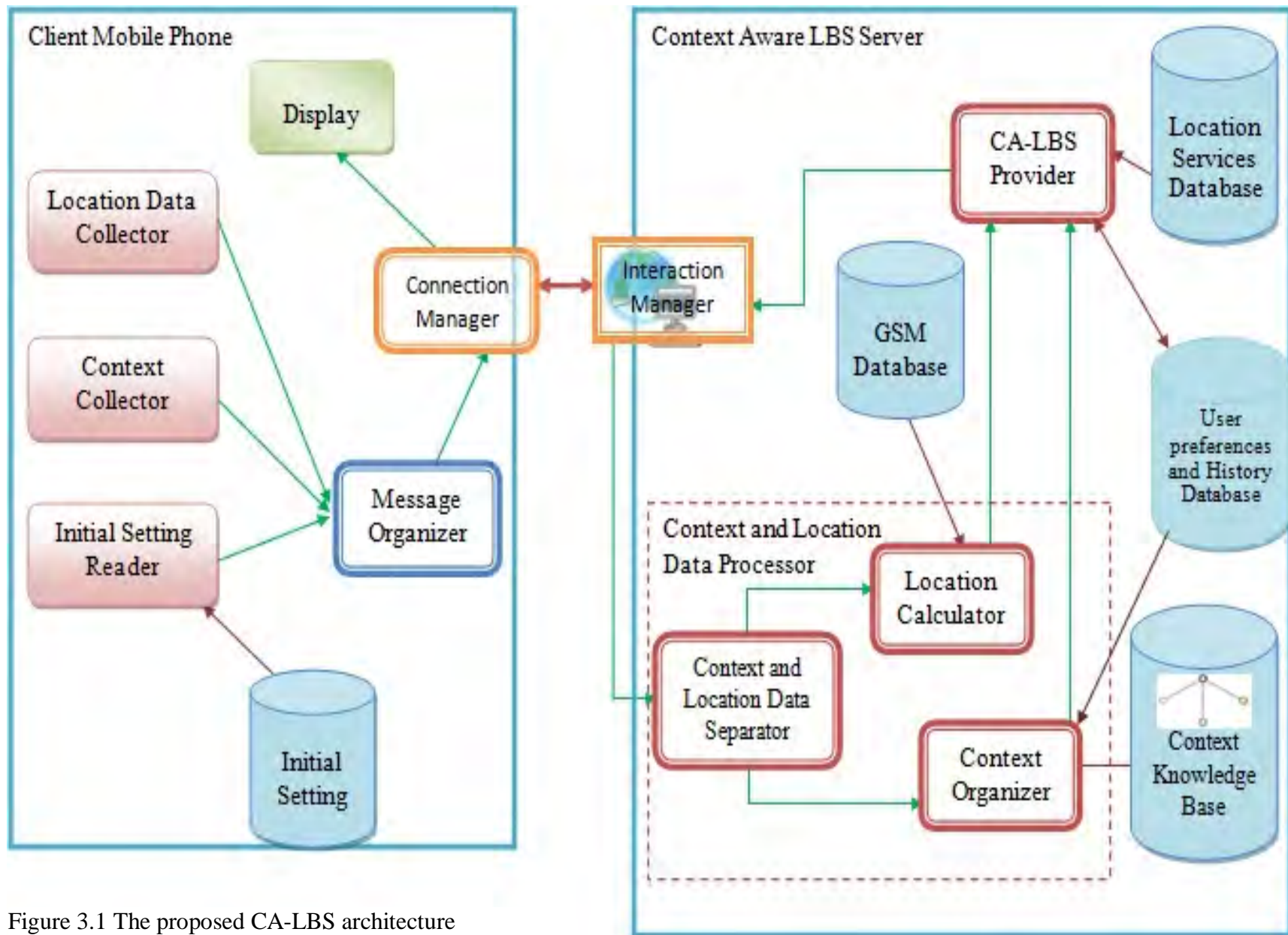


Figure 3.1 The proposed CA-LBS architecture

The core components in proposed CA-LBS architecture and their corresponding purposes are described in Table 3.1.

Table 3.1 Major components in the proposed architecture

Component Name	Purpose
Location Data Collector	Reads and organizes the parameters (cell-ID and signal strength) of active GSM and neighboring GSMs or access other position detection services in the user cell phone.
Context Collector	Extracts user contexts, like calendar, time, user settings and other found on the user phone
Initial Setting Reader	Reads and organizes initial settings of the user found on the user mobile phone.
Message Organizer	Receives the data coming from other client module, organize it and then send the data to the Connection Manager module.
Context and Location Data Separator	Accepts the data sent from the Interaction Manager module, differentiate a context and location information and then sends the data to the respective modules that process each data.
Location Calculator	Used to calculate the current location of the user cell phone based on the location data (i.e. cell-ID and signal strength of active GSM towers) coming from Context and Location Data Separator module.
Context Organizer	Organizes the user context data based on the existing data in the context knowledge base.
CA-LBS Provider	Provides location based service to the user based on the context and location information that comes from different module of CA-LBS server.

3.3. Reading Location and Context Data

3.3.1. Location Data Collector

Reading location data using location sensors is the first task in any location based service (LBS) [38]. However, since the processing capacity of cell phones is limited and to be energy aware, the client mobile phone reads necessary location information and the server carries out the remaining complex mathematical computation to determine the exact location of the user. The algorithm shown by Figure 3.2 is used to read location data at the client side.

Algorithm 1: To read cell-ID and signal strength of GSM

Input: Initial-stamp and Interval.

Output: Cell-ID and signal strength of neighboring GSM towers.

1. Initialize the initial time-stamp as current time
 $Interval \leftarrow 60seconds$
 $Initial-stamp \leftarrow current-time$
 $t-stamp \leftarrow Initial-stamp$
2. Create an array of string to hold cell-ID and signal strength of a GSM towers
 $bts-cell \leftarrow 0$
 $bts-signal \leftarrow 0$
3. Read the BTS tower and set as GSM (cell-ID and signal strength)
 $bts-cell \leftarrow cell-ID$
 $bts-signal \leftarrow signal\ strength$
4. Do while $t-stamp \leq Initial-stamp + interval$ or number of cell-IDs ≥ 3
 $Read\ cell-ID\ and\ signal\ strength$
 $Assign\ to\ bts-cell\ and\ bts-signal\ variable$
 $t-stamp \leftarrow t-stamp + 1$
 if $cell-ID \neq bts-cell$
 $cell-IDs \leftarrow cell-IDs + 1$
5. Merge the cell-ID with signal-strength
 $cell-value \leftarrow cell-ID\ concatenate\ with\ signal-strength$
6. Send cell-value to the server
7. end

Figure 3.2 Algorithm to read cell-ID and signal strength of GSM

Each GSM tower has one or more cells (microwaves); telecom companies use this approach for different reasons like reducing installation cost, security issues, limitation of suitable places to fix the towers, number of users in the area and others. Each cell has unique cell-ID and the Cell-Filter module determines whether a given cells are found on a single GSM tower or not.

The task of this module is to determine whether the cell-IDs are found on the same tower or not. To do so, the module first accepts the cell-ID from Location Data Collector module and then check to see the cell-ID in the tower database to read the geographic coordinates. If the coordinates of a given cell-ID is not found in the temporary variable list then Cell-Filter module adds as a new coordinate point otherwise it discards the point. On the other hand, if the cell-ID is not found in the database then the module checks the pattern of the cell-ID from the server at the telecom company⁴ and set a coordinate position for new cell-ID if it fulfills conditions and updates the database with new cell-ID value. Otherwise, the module discards the new cell-ID which does not fulfill the criteria.

Since the accuracy of location determination algorithm is directly dependent on the GSM cell-IDs that are read from different towers in particular location and time, detecting GSM tower of active and neighboring cells is crucial to calculate the location of users with a better accuracy.

3.3.2. Context Collector

This component of the system is responsible to read the context of the user from their cell phone. The module read calendar and calendar settings (i.e. meeting, memo, anniversary and to-do lists), address books, time and other essential settings of the client mobile phone that shows the context of the user.

In addition, this module also reads phone properties like screen size and other information which are helpful to select appropriate way of positioning (use GPS or not) and are used to decide how to display information on the cell phone. So knowing the cell phone properties is crucial to provide a better location based service (specifically in accessing user's location and way of displaying information to the users) based upon the cell phone capabilities.

⁴ In our case Ethio Telecom is the only telecom company. So we check the patterns of cell-ID found in the GSM towers.

3.3.3. Initial Setting Reader

The main tasks of this component of the proposed system are to read the initial settings and transfer the data to the Message Organizer module in the client mobile phone. In this module, the users have the right to select their interest from different options found in the interface of the system in their phone. The options that are selected by the user describe their residence type in the city, current place of interest to visit, and other settings that shows the context and interest of the users. These initial settings are helpful to the server for updating user preferences and history databases.

3.3.4. Message Organizer

The task of this component of the proposed system is decoding the data that comes from other modules in the client mobile phone. This task is useful to properly utilize the bandwidth of mobile internet connection and reduce the communication cost to transfer data. The module sends the decoded data to the connection manager in the client mobile phone.

3.3.5. Connection Manager

The main task of this module is to establish communication between the client mobile device and the server. This module accepts data from message organizer and sends a request to the server; similarly the module receives information sent from the server then sends the information to the display module in client phone.

3.4. Context and Location Data Processor

This component is found in the CA-LBS server. It has three sub-components: Context and Location Data Separator, Location Calculator and Context Organizer modules. The detail tasks of each sub-component are described in the following subsections.

3.4.1. Context and Location Data Separator

Since the data was sent from the mobile phone in coded and combined form to reduce the size of data transmitted to the server as well as to reduce the network traffic and communication cost,

the server must have a module that accepts and process the coded data sent from the client mobile phone.

It accepts the data from the Interaction Manager and decodes the data sent from client cell phone. In addition, it makes a distinction between the context and location data and then sends the data to Context Organizer and Location Calculator modules for further processing respectively.

3.4.2. Location Calculator

This component, as its name indicates, is responsible for calculation of the geographic position of the user. It has subcomponents to perform the location calculation easily and in efficient manner. The next subsections describe details of each module:

3.4.2.1. Processing Received Signal Strength Indication (RSSI)

In order to calculate the location of unknown mobile station using GSM cell-ID with acceptable accuracy for the services, receiving and processing the signal strength [42, 43] of each GSM stations is required. As we describe in Algorithm 1, the cell phone captures and sends both the cell-ID and signal strength of tower(s) to the server. So the received signal strength must be processed in the CA-LBS server to identify the position of the user with an acceptable accuracy level.

For this study we use HATA⁵ [18] model to calculate the radius of the BTS (GSM) tower with respect to the RSSI in the cell phone. This method uses various models and formulas for different areas like Urban, Semi-urban and open space (rural) areas. So for this study we use HATA model for urban areas. The major propagation related factors that have to be taken into consideration are the effect of irregular terrain and the influence on the signal of trees, buildings and other natural and man-made obstacles. This model considers all these major propagation factors that hinder the signal in the city.

According to Walter Debus [32], received signal strength of any electronic system is mathematically computed by using equation 3.1.

⁵ After comparing the Hata model with other signal propagation path loss models we had gotten a better accuracy level for our dataset. See the experiment result section of the paper for the detail.

$$R = P_t + G_{tot} - L \quad 3.1$$

Propagation loss is the difference value between the radiated power in the sender end and the received power in the receiver side. So from equation 3.1, we compute propagation loss (L) as follow:

$$L = P_t + G_{tot} - R \quad 3.2$$

Where:

- R is received signal strength in DeciBell (dB)
- L is propagation loss in dB
- P_t is transmitter power in dB
- G_{tot} is total gain in dB (computed as (Ag-Cl))
- Ag is total antenna gain in dB
- Cl is total connection loss in dB

The transmitter power (P_t), total antenna gain (Ag), and total connection loss (Cl) of GSM tower are constants. The only variable value in this equation is the received signal strength (R) which is easily accessed in any electronic device by running a code that is supported by particular device we need.

According to Masaharu Hata [18], propagation loss is computed using equation 3.3:

$$L(dB) = 69.55 + 26.16 \log_{10} f_{MHz} - 13.82 \log_{10} h_1 - a(h_2) + (44.9 - 6.55 \log_{10} h_1) \log_{10} d_{km} - K \quad 3.3$$

Where:

- h_1 (30-200) and h_2 (1-20) are base station and mobile antenna heights in meters respectively,
- d_{km} (0-20) is the link distance in kilometers, and
- f_{MHz} (150-1800) is the center frequency in megahertz.

The term $a(h_2)$ is an antenna height-gain correction factor that depends upon the environment. It is zero for $h_2=0$.

According to Okumura's prediction method, the suburban correction factor K (dB), which is the difference between the median field strength in the urban area and that in the suburban and open space areas.

Table 3.2 HATA model formulas for $a(h_2)$ and K

Type of Area	$a(h_2)$	K
Open	$(1.1 \log_{10} f_{MHz} - 0.7)h_2 - (1.56 \log_{10} f_{MHz} - 0.8)$	$4.78(\log_{10} f_{MHz})^2 - 18.33 \log_{10} f_{MHz} + 40.94$
Suburban		$2 \left[\log_{10} \left(\frac{f_{MHz}}{28} \right) \right]^2 + 5.4$
Medium-small city		0
Large city ($f_{MHz} > 300$)	$3.2(\log_{10} 11.75h_2)^2 - 4.97$	0
Large city ($f_{MHz} < 300$)	$8.29(\log_{10} 1.54h_2)^2 - 1.10$	0

As shown by Table 3.2, the formula changes based on the nature of the area we need to compute the signal propagation loss. So for this study we used the HATA equations for large city with frequency greater than 300 MHz (i.e. $a(h_2) = 3.2(\log_{10} 11.75h_2)^2 - 4.97$ and $K=0$ respectively).

When we replace the equation $a(h_2)$ and the value of K in Table 3.2 to Equation 3.3 we get the formula given by equation 3.4 to compute propagation loss in the large city:

$$L(dB) = 69.55 + 26.16 \log_{10} f_{MHz} - 13.82 \log_{10} h_1 - (3.2(\log_{10} 11.75h_2)^2 - 4.97) + (44.9 - 6.55 \log_{10} h_1) \log_{10} d_{km} \quad 3.4$$

Equation 3.3 and Equation 3.2 are used to drive Equation 3.5

$$d_{hata} = \text{anti log}_{10} \left(\frac{P_t + G_{tot} - R - 69.55 - 26.16 \log_{10} f_{MHz} + 13.82 \log_{10} h_1 + a(h_2) + K}{44.9 - 6.55 \log_{10}(h_1)} \right) \quad 3.5$$

By using Equation 3.5, we compute the radius of the given cell with respect to the signal strength (R) received by a mobile station.

In Equation 3.5, most of the variables are constants based on the location of GSM towers. However, the frequency of the GSM tower is in defined range and the received signal strength in

the user cell phone changes frequently. The value of the frequency of the GSM is obtained from the service provider (in our case from Ethio Telecom).

3.4.2.2. Computing User Location

As described in section 3.4.2.1, the radius of each cell tower is computed using HATA path loss model. Then the position of users is computed by using different lateration algorithms. These algorithms are dependent on the radius, geographic location and number of GSM tower(s) communicating to the cell phone. Trilateration, bilateration and unilateration algorithms are used to calculate the position of the user cell phone if the numbers of accessible towers are three or more, two and one respectively. All the algorithms we have used to compute the user location works only in two dimensional (2D) environment, by assuming the effect of altitude for this study insignificant.

Algorithm: To choose computing user location algorithm

Inputs: - received cell-ID and signal strength of BTS

Output: - Selected algorithm for computing user location

1. Accept cell-ID and signal strength information
BTS ← cell-ID
2. Calculate the size of BTS array variable
length ← BTS.length
3. If length ≥ 3 then
Goto trilateration
4. Else if length = 2 then
Go to bilateration
5. Else if length = 1 then
Go to unilateration
6. Else
Display "Your position is not reachable at this moment"
7. Exit

Figure 3.3 Algorithm to choose appropriate position technique for computing user location

The algorithm given by Figure 3.3 is used to decide what kind of positioning technique is used to compute the current position of the user based on the number of GSM towers. The next sections describe positioning algorithms that are found in the previous page (i.e. unilateration, bilateration and trilateration).

3.4.2.2.1. Unilateration Algorithm

When the cell phone detects only a single GSM then the geographic position of the GSM tower is used as a location of mobile station. This approach is used when the first two options are not true because of the limitation of reachable GSM towers. It is very simple and doesn't need any mathematical computation.

But the accuracy of this method is dependent on the radius of the GSM tower. Because we assign the location of GSM to the mobile station the mobile station may found in anywhere within the radius of the GSM tower.

3.4.2.2.2. Bilateration Algorithm

In this algorithm we consider the following assumptions:-

1. The cell phone sends the data of two neighboring GSM towers.
2. The radiuses of both GSMs are computed by using HATA propagation path loss model for urban areas (Equation 3.5).

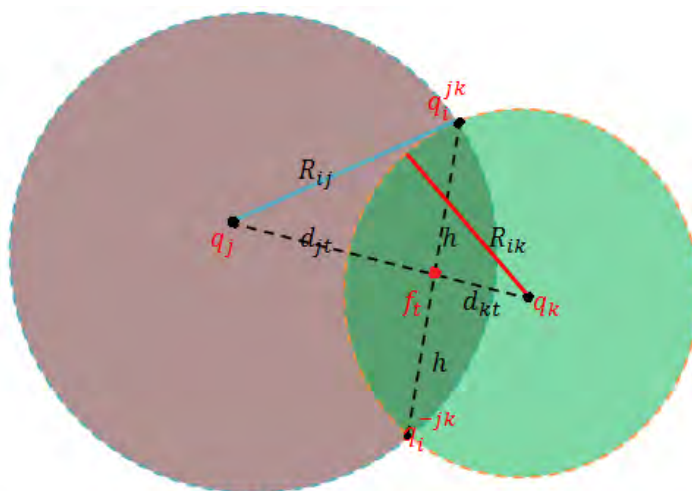


Figure 3.4 Locating users by using two reachable GSM towers

As shown in Figure 3.4, two circles interlink each other at two points (g_i^{jk} and g_i^{-jk}). The intersection area of two circles is a possible place for mobile station and hence we follow the following steps to compute the two intersection points.

We first compute the value of h:

$$R_{ij}^2 = h^2 + d_{jt}^2 \quad 3.6$$

$$R_{ik}^2 = h^2 + d_{kt}^2 \quad 3.7$$

The distance d_{jt} can be obtained by solving for h^2 in equations 3.6 and 3.7.

$$R_{ij}^2 - d_{jt}^2 = R_{ik}^2 - d_{kt}^2 \quad 3.8$$

Let $d = \sqrt{(x_j - x_k)^2 + (y_j - y_k)^2} = d_{jt} + d_{kt}$ and it is easy to calculate d_{jt}

$$d_{kt} = d - d_{jt} \quad 3.9$$

When we replace equation 3.9 into equation 3.8 we get:

$$R_{ij}^2 - d_{jt}^2 = R_{ik}^2 - (d - d_{jt})^2 \quad 3.10$$

$$R_{ij}^2 = R_{ik}^2 - d^2 + 2 \cdot d \cdot d_{jt} \quad 3.11$$

$$d_{jt} = \frac{R_{ij}^2 - R_{ik}^2 + d^2}{2d} \quad 3.12$$

Where the position $f_t = [x_t, y_t]^T$ is obtained as follows:

$$f_t = q_j + \frac{d_{jt}}{d}(q_k - q_j) \quad 3.13$$

Finally, we compute the value of x and y as follow:

$$x = x_t \pm \frac{h}{d}(y_k - y_j) \quad 3.14$$

$$y = y_t \pm \frac{h}{d}(x_k - x_j) \quad 3.15$$

Since h is easily computed by using equation 3.6 or 3.7.

Algorithm: To compute the unknown location of a user using bilateration

Inputs: - radius of two BTS towers

latitude and longitude of both BTS towers

Outputs: - the intersection points of two circles

1. Compute the value of d

$$d \leftarrow [(x_j - x_k)^2 + (y_j - y_k)^2]^{1/2}$$

2. Compute the value of d_{jt} and d_{kt}

$$d_{jt} \leftarrow \frac{R_{ij}^2 - R_{ik}^2 + d^2}{2d}$$

$$d_{kt} \leftarrow d - d_{jt}$$

3. Compute the value of h by replacing equation 3.12 into equation 3.6 or 3.7.
4. Compute the location of f_t using equation 3.13.
5. Compute the value of x and y using equation 3.14 and 3.15
6. Return x and y
7. End

Figure 3.5 Algorithm to compute user location using bilateration.

This algorithm fails if and only if one of the circles is enclosed by the other one. In this case the error happens in computing the intersections points of the two circles [31, 34, 35]. This situation may happen rarely because of the variations in frequency, obstacles and height of GSMs towers found in the city.

3.4.2.2.3. Trilateration Algorithm

Trilateration is a method of computing an unknown position of a mobile station by using three known reference points [37, 43, 55]. So this approach is used in our study to compute the position of the user by using three or more Base Transceiver Stations (BTSs) or GSM towers that are neighboring the user. We used this approach to reduce the location error estimation of the cell phone user.

In ideal case three circles intersect in a single point but this situation rarely happens among three circles with different radius and center. In this case the computation is easy and efficient [34]. When the situation is not true (i.e. circles are intersect more than one point), then the computation of a mobile station is done by different algorithms. Least Square (LS), Least Median Square (LMS) and Linear Least Median Square (LLMS) are mostly used once [34].

We consider the following assumptions to use the trilateration algorithm for calculating a position of a mobile station:-

1. The cell phone sends the data of three or more neighboring GSMs.
2. When the number of neighboring GSM is more than three, then select the nearest three neighboring GSMs based on the received signal strength of each GSM tower in the cell phone.
3. The radius of a base station is calculated based on the HATA propagation path loss model for urban areas (i.e. Equation 3.5).

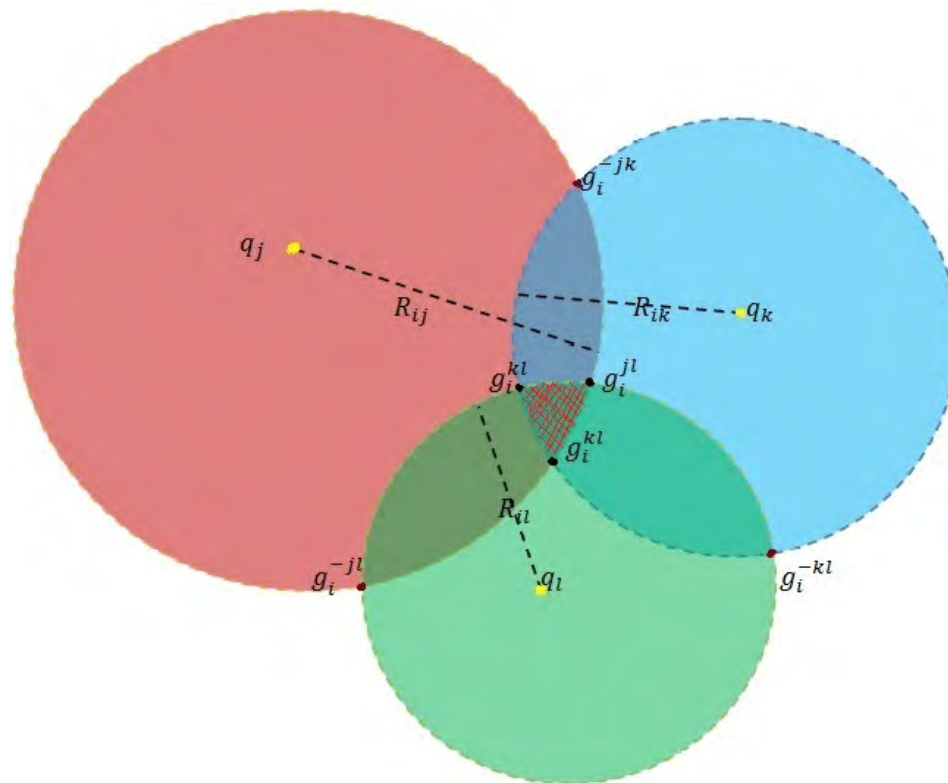


Figure 3.6 Intersection of three circles

In Figure 3.6 three circles q_j, q_k and q_l with different radius (R_{ij}, R_{ik} and R_{il}) and center $(q_{jx}, q_{jy}), (q_{kx}, q_{ky})$ and (q_{lx}, q_{ly}) respectively have an intersection area between points g_i^{kl}, g_i^{jl} and g_i^{jk} . The computation is carried out by using a bilateration concept to compute intersection points of two circles among the three iteratively. Intersection points are g_i^{kl} and g_i^{-kl}, g_i^{jl} and $g_i^{-jl},$ and g_i^{jk} and g_i^{-jk} between circles q_k and q_l , q_j and q_l and q_j and q_k respectively. The following algorithm shows a detail implementation of trilateration algorithm using a bilateration concept.

Algorithm: To compute the unknown location of a user using trilateration

Inputs: the computed radius of three or more BTS towers
location (latitude and longitude) of each BTS towers

Output: geographic coordinate of a mobile station (MS)

1. Select three BTS towers based on the radius each BTS (chooses the smallest three radiuses).
2. Read location (latitude and longitude) of each GSM towers (q_{jx}, q_{kx} and q_{lx} and $q_{jy}, q_{ky},$ and q_{ly} are latitude and longitude values for GSM tower q_j, q_k and q_l respectively)
3. Compute the intersection points of two circles iteratively using bilateration algorithm

initialize $val \leftarrow 0, ite \leftarrow 0, q_j \leftarrow q_0, q_k \leftarrow q_1, q_l \leftarrow q_2$

do

ite $\leftarrow val$

if ($val+1 \leftarrow 3$)

bilateration (q_{ite-2}, q_{ite})

else

bilateration (q_{ite+1}, q_{ite})

val++;

return $g_0^{ite+1 ite}$ and $g_0^{-ite+1 ite}$

while ($ite < 3$)

Continued....

4. Assign the first two circles intersection point as a reference point
 $ref \leftarrow g_i^{jk}$ $ref2 \leftarrow g_i^{-jk}$ [Assign g_i^{jk} and g_i^{-jk} as a reference point]
5. Compute the distance between reference points to other intersection points and assign to array variable.

do

initialize $i \leftarrow 0$

$distance \leftarrow \sum (ref_x - g_x^{i+1})^2 + (ref_y - g_y^{i+1})^2$

$distance \leftarrow \sqrt{distance}$

$distance2 \leftarrow \sum (ref2_x - g_x^{i+1})^2 + (ref2_y - g_y^{i+1})^2$

$distance2 \leftarrow \sqrt{distance2}$

$i++$;

while $i < 4$

6. Compute the sum of the two distances and compare it

$distance \leftarrow \sum_0^{end} distance$

$distance2 \leftarrow \sum_0^{end} distance2$

compare ($distance$, $distance2$)

if $distance > distance2$

return $ref2$

while end of the array

compare consecutive array values and return the least one

else

return ref

while end of the array

compare consecutive array values and return the least one

7. Read the location (xy coordinate of three points).
8. Compute the average x and y of three points.
9. Return average(x) and average(y)
10. Exit

Figure 3.7 Algorithm: To compute the unknown location of a user using trilateration

As shown in Figure 3.6 three transmitters (GSMs) with different radius (i.e. received signal strength of each tower) are detected and the geographic coordinate of each transmitter is well known. In Figure 3.6, trilateration algorithm uses the results of three bilateration calculations. The results of each bilateration algorithm are compared to the remaining bilateration results to compute the mean square among points. Finally, we choose the smaller between two mean squares.

3.4.3. Context Organizer

In order to accomplish the main task, context organizer communicates with the following modules and databases in the system to read context and other preferences of a user:

- ❖ Context and location data separator module: to access context data that was sent from the client mobile phone. In addition to context data, user initial settings that were sent from the client mobile phone also accessed from this module.
- ❖ Context knowledge base: store terms (concepts), properties of concepts, relationship between concepts and constraints on the properties of concepts in the context aware LBS.
- ❖ User preferences and history: this database holds user preferences (profile) and user information about visited sites.

The core task of this module is making reasonable decision and transfer the decision to the next module in the system. To do this, the module reads the data and use rules that govern the decision process by context model. The context model uses rule based approach to context processing.

3.4.4. CA-LBS (Location Based Service) Provider

This module accepts the processed data and rules and location information from context organizer and location calculator modules respectively. It uses both hard and soft criteria for selection purpose. Hard criteria (i.e. user current location, user context, history and preferences of user stored in the database) are selection rules that must be true to select data from the location database in the server. Soft criteria (category of service area and the distance gap between the service area and user current location) are used to sort or group the selected information that are sends to the mobile device.

The module selects data from location service database using hard criteria used as a selection condition and sort the data based on soft criteria. Beside this, the module updates user preferences and history database automatically with new data in each selection operation.

3.4.5. Interaction Manager

This module is responsible to instantiate the communication between the client mobile device and the server. The module receives request from the client module and sends the data to the respected module in the server. Similarly, the module receives information from the CA-LBS provider module and sends to the client mobile device.

4. Implementation and Validation

The previous chapter presented the detail of the proposed context-aware mobile based city guide architecture. This chapter discusses the prototype implementation of the architecture by presenting the objectives of the prototype, tools and technologies used, setup of the prototype, the implementation details and evaluation results and demonstration to validate the proposed system.

4.1. Overview

The prototype developed in this study is principally aimed at providing proof of the concepts presented in the detailed explanation of the proposed context aware location based service (CA-LBS) architecture, discussed in the previous chapter. To achieve this principal goal, the majority of the components in the architecture have been implemented as per the theoretical specifications formulated for each component.

The prototype implementation uses sample services areas between localities in Addis Ababa named as Arat Kilo and Sidist Kilo. Some of the data are collected manually (especially geographic position of GSM towers) using GPS enabled cell phone⁶ and other data is obtained from the city municipality (Land Urban Management Office). The prototype implementation lets the user to see recreation centers, museum, governmental and non-governmental organizations and other known places around them with defined range (radius) set by the service provider (this range may be changed based on the user needs and feedbacks), and the information is based on the current location, context and other preferences and history of the user.

Scenario:

- It is obvious that so many tourist and local residents come to Addis Ababa for different reasons. Mainly, tourists and other foreigners come to Addis Ababa to visit historical and tourist destination sites and for other businesses. For all of them Addis Ababa is a path for the destination areas or the destination by itself. So any of them stay in the city for a few days or months depend on the reasons they are come.

⁶ See table 2 in appendix

- Beside this, local residents also come to Addis for a variety of reasons like referral for their medical problems, training and meetings, vacancies and others. In addition to this, city residents also move from one side of the city to the other because of many reasons just like local residents.
- Mr. John is a tourist who comes to Ethiopia and he stayed few days in Addis Ababa.
- Ato Hassan is a governmental worker in country side he frequently comes to Addis for meetings and training carried at the head office.
- Ato Temtim is a business man in the city; he meets different individuals for his day to day business in different parts of the city.

4.2. Tools and Technologies Used for Implementation

Several tools and technologies were utilized for the purpose of developing the prototype implementation. The following is list of programming, communication, database management, context representation, context reasoning and operating environment used in the prototype implementation.

- Java 2 Micro Edition (J2ME) Software Development Kit (SDK) version 3.0 for CLDC (Connected Limited Device Configuration) of the MIDP (Mobile Information Device Profile) is used for developing the mobile version of the prototype.
- Light Weight User Interface Toolkit (LWUIT) version 1.5 is used for developing interfaces and themes for mobile device edition of the prototype.
- Nokia SDK 2.0 for Java used as emulator for a Nokia mobile device for testing the code before deploying to a real device.
- Nokia E5 with Symbian Operating System version 9.0, series 60 releases 3.2 and IEEE⁷ 802.11 wireless LAN and Geographic Positioning System (GPS) capability is used as a mobile device.
- NetBeans Integrated Development Environment (IDE) version 7.0.1 is used for developing the server side of the prototype. This version of NetBeans uses Java 2 Standard Edition (J2SE) specification version 7 with Java Development Kit (JDK) version 7.

⁷ Institute of Electrical and Electronics Engineers

- MySQL database server version 5.5 is used for persistent data management (for both spatial and non-spatial data) on the server.
- Java Servlet application program interface (API) version 3.0 is used for bridging the mobile version and the server side of the prototype.
- Apache Tomcat version 7.0.30 or Glassfish Server version 3.1.1 is used as a web container for Java Servlets.
- Protégé Ontology Editor⁸ Version 3.4.8 is used for developing location and user ontology.
- Semantic Web Rule Language⁹ (SWRL) is used for implementing the ontology and user-defined reasoning rules.
- Microsoft Windows 7 (64 bits) operating system is used for the context refinement server.
- IEEE 802.11 wireless LAN (Wi-Fi) is used as a communication infrastructure between the mobile device and the LBS server.

4.3. Setting up the Prototype

To support scenarios in the previous section (section 4.1), a prototype is implemented as an application with the client-side on the mobile device (Nokia E5 or Nokia java emulator) and the server-side on context aware LBS server (Windows 7). The two sides communicate through a Wi-Fi LAN. On the client mobile device, the location and context data collectors and initial setting reader are implemented as a J2ME classes while the message organizer is implemented as J2ME threads that bind themselves to a certain port to communicate with the services on the server through a standard Hyper Text Transfer Protocol (HTTP).

On the context aware LBS server side, the positioning techniques (unilateration, bilateration and trilateration), the context and location data separator, LBS provider and the information sender are implemented as Java Servlets. The context knowledgebase and the location ontology are implemented as RDF schema and OWL ontology document respectively. The location, GSM and user preferences and history database are implemented as MySQL relational databases (for both

⁸ <http://www.protégé.stanford.edu>

⁹ <http://www.w3.org/Submission/SWRL/>

spatial and non-spatial). The detail of implementation for the major components is outlined in the following section.

4.4. Implementation Details

In the previous section, we have seen the general prototype setup we have used to test this application both on the mobile side and the server side.

4.4.1. Modules on the Client Mobile Device

The Location Data Collector: It is implemented as a J2ME java class and embedded on a main MIDlet class. It incorporates all the major means of location identification techniques found in the cell phone model. Basically, this class collects cell-ID and signal strength of neighboring cells. Moreover, this java class identifies the cell-IDs that are found in the same GSM towers.

The Context Data collector: It is implemented as a J2ME java class and accessed from a main MIDlet class. This class performs reading of different settings from the phone including calendar settings and information, alarms and meetings and other contexts that are needed for location based service.

The Initial Setting Reader: It is implemented as a J2ME MIDlet class and embedded on a main MIDlet class. This MIDlet class reads the values that are set during the first access or any changes that are made in the user profile. This MIDlet also provides a user interface to the users to set or update their profile.

The Message Organizer: It is implemented as a J2ME java class and embedded on the main MIDlet class. This class establishes a HTTP connection to the server to send/receive necessary information from phone to server and vice-versa. In addition to this class, coded data comes from the above modules in a client mobile device to reduce the communication cost of the server.

4.4.2. Modules on the Context-Aware LBS Server

The Context and Location Data Separator Module: It is a Java Servlet class that communicates with the context organizer module of the J2ME MIDlet client mobile device. This module receives and sends HTTP messages from the server to a mobile device.

The Location Calculator Module: It is implemented as a Java class and used to compute the location of the mobile device based on the location information that comes from the context and location data separator module. This module reads location information from GSM database and use appropriate algorithm to compute the location. Finally, this module sends the result to LBS provider module.

The LBS Provider Module: It is implemented as a Java Servlet class that merges the context and location information that comes from different module in the system and organizes the final information that is sent to the client mobile phone. This module communicates with other modules to establish a communication for sending a result to the mobile user. Beside this, the module updates the user preferences and history database with the current information that are sent to the user.

The Context Organizer Module: This module is implemented as a Java Servlet class. This class is the main reasoning module in the system, it communicates with different modules and databases to receive/send or read/write data respectively. Mainly this module reads location context ontology from context knowledgebase, user history and preferences from user history and preferences database and the current context of a user from the context that is sent from the user cell phone.

After reading all this information the module makes decision based on the rules that are generated by SWRL (Semantic Web Rule Language). The context model that is found in this module did final context organization and decision making process to the user context information. Finally, the module sends the rules to the LBS provider module.

The Location Context Ontology: This is where all the terms (concepts), properties of concepts, relationship between concepts and constraints on the properties of concepts in the context aware LBS are modeled. It is implemented as a protégé OWL ontology document. Figure 4.1 shows the class hierarchy of the concepts modeled by the ontology.

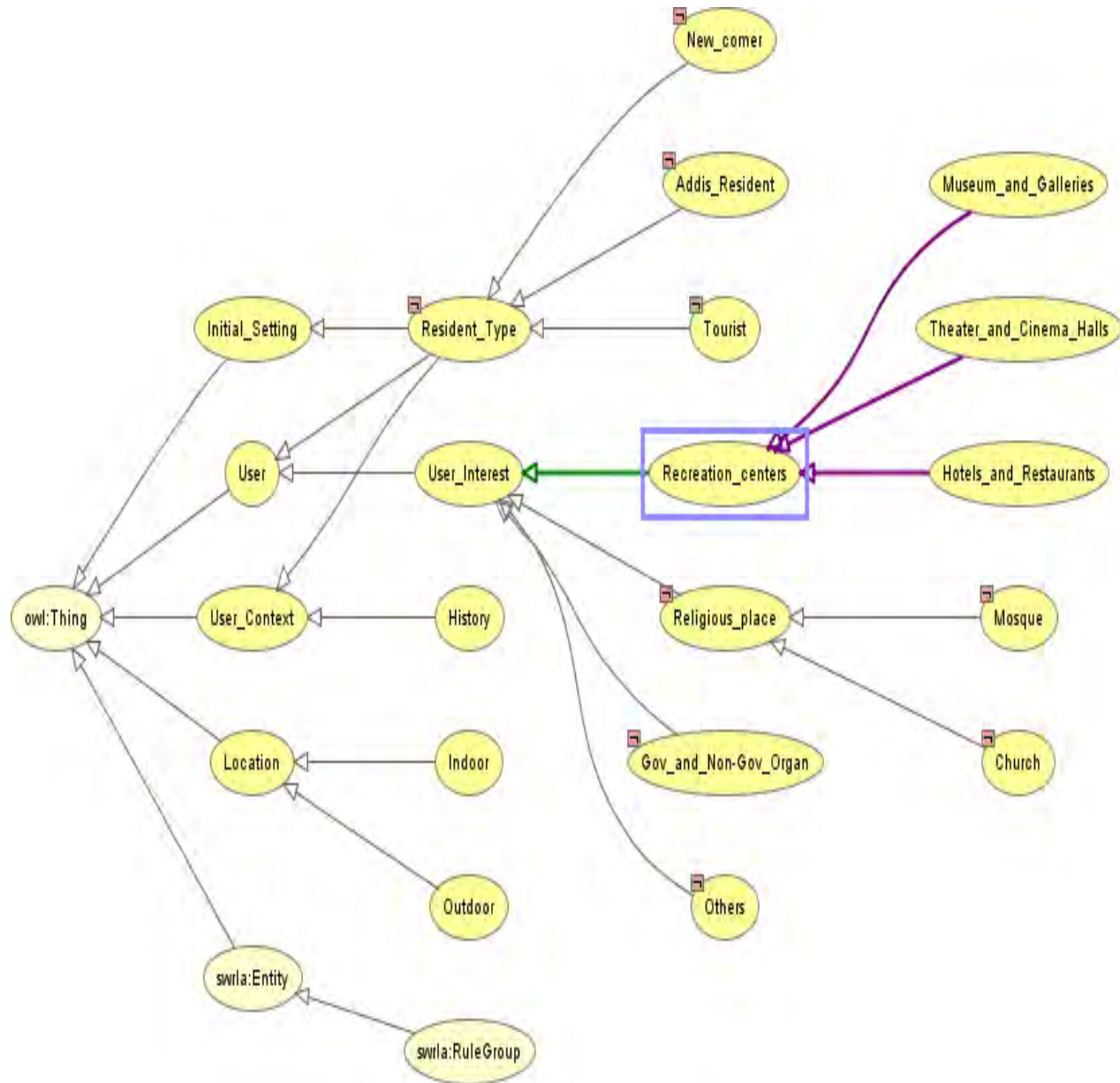


Figure 4.1 Class hierarchies for the proposed context aware location based service ontology

4.5. Experimental Results

Experiments on this study are carried out by checking the appropriateness of different path loss propagation models (mainly Hata, COST231 and Egli models) for our dataset (both GSM and location information) and choose the best one for our study. To do this we use Roskilde [33] constants for GSM tower properties and mobile station in the large cities and apply those constants to equations (2.2 and 3.5). The constant values that are used in this study are the following:

- ❖ G_{tot} (total gain)=12dBm
- ❖ GSM_height=30 m
- ❖ mobileStation_height=1.5 m
- ❖ Maximum power (Pt) = 21 dBm and
- ❖ Frequency =1900MHz.

By using these constants and the received signal strength of each tower we compute both Hata and Cost231 path loss propagation models. The following diagram shows the comparison between Hata and COST231 models.

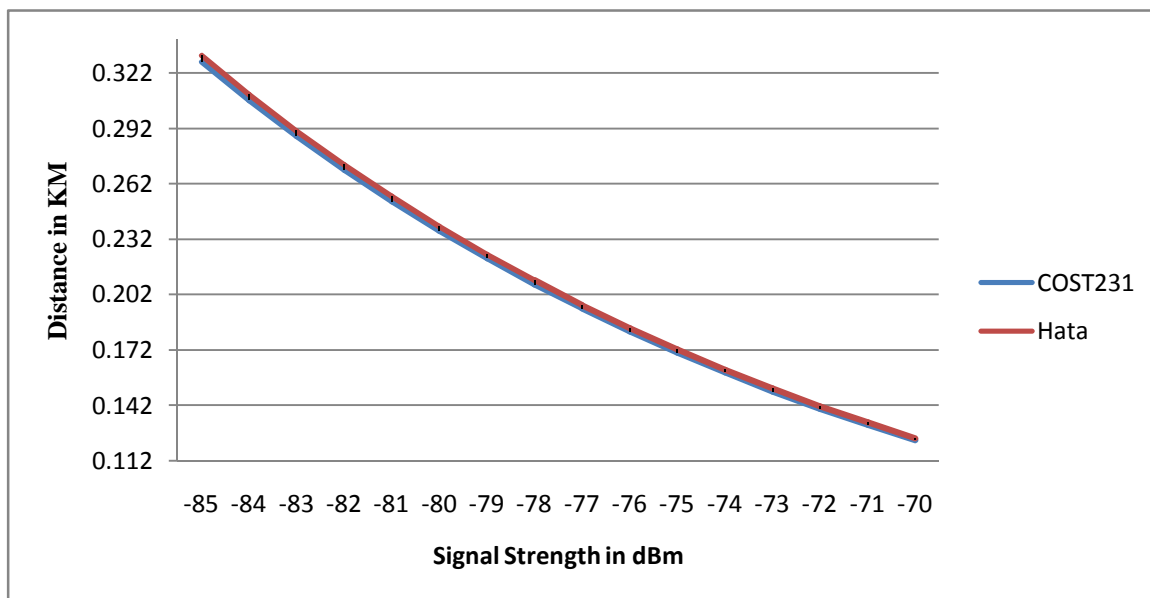


Figure 4.2 Comparison of Hata and COST231 path loss propagation models.

Figure 4.2 shows the radius of a GSM tower in Km with respect to received signal strength in cell phone using Hata and COST231 models. Their result is slightly differing from one model to another (the detail result of the models is found in the appendix¹⁰). The table has the radius of GSM tower in all valid received signal strengths in the cell phone using two path loss propagation models.

By using the results of the two models we compute the position of a mobile station using two techniques (i.e. bilateration and trilateration). The result show Hata path loss propagation model is better than COST231 in predicting the position of a mobile station. So we choose the Hata model for this study for computing the radius of GSM towers.

The other experiment we did in the prototype implementation is the location accuracy of the three techniques (unilateration, bilateration and trilateration) that are used in this study. Figure 4.3 shows the comparison of three positioning algorithms we used in our study dataset.

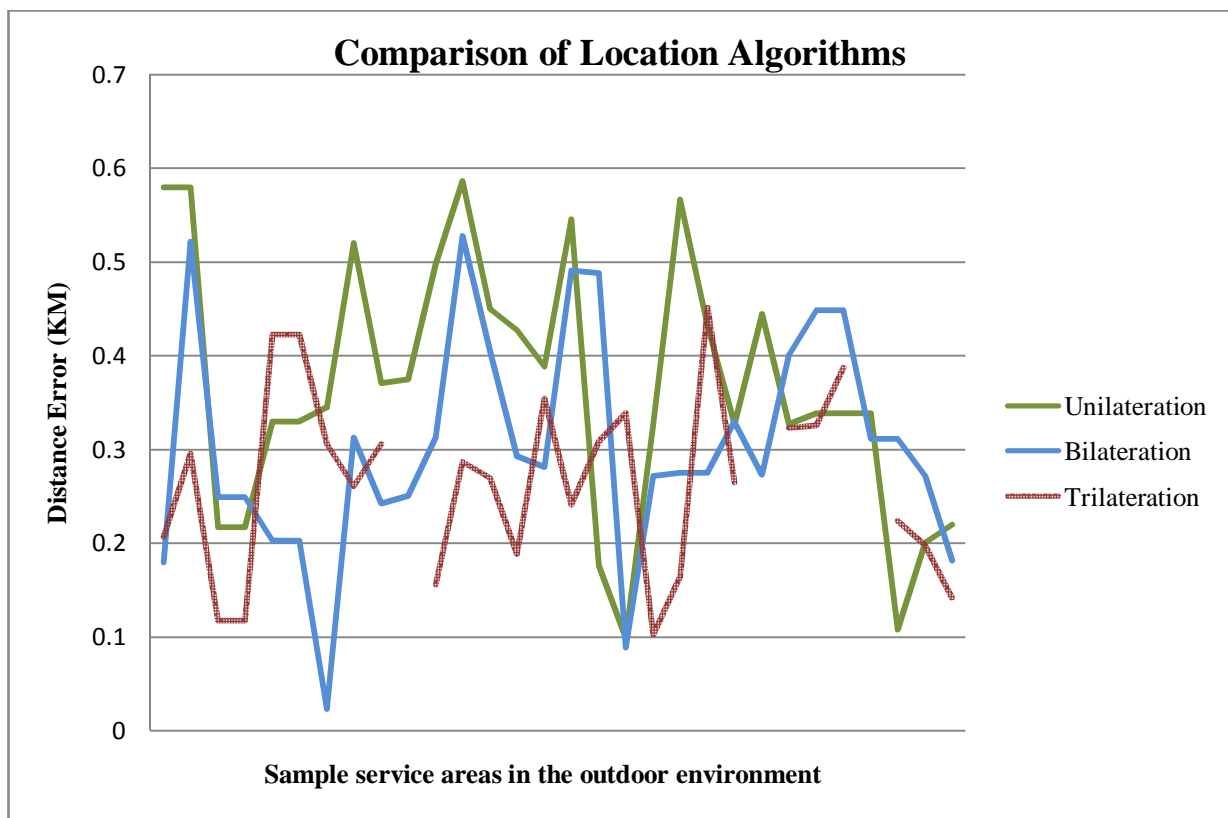


Figure 4.3 Comparisons of Location Algorithms.

¹⁰ See table 1 in appendix

Figure 4.3 shows clearly the location error in three methods of location calculation algorithms and their existence in the sample dataset. As you see in Figure 4.3 the line is not broken both in unilateration and bilateration algorithms because we got at least two GSM towers in any sample dataset in the experiment so the algorithms compute the result properly. But in the case of trilateration algorithm the line is broken in few points because some of sample datasets doesn't have three or more neighboring GSM towers. Hence, in our sample dataset more than 85% of points we had collected using cell phone for this experiment have three or more neighboring GSM towers cell-ID and signal strength.

The figure shown below illustrates the average distance error of points in bilateration and trilateration algorithms. As you see in the figure bilateration algorithm are more error prone than trilateration algorithm. But trilateration algorithm is not working in all dataset used in this experiment since some of our datasets have only two neighboring GSM towers information.

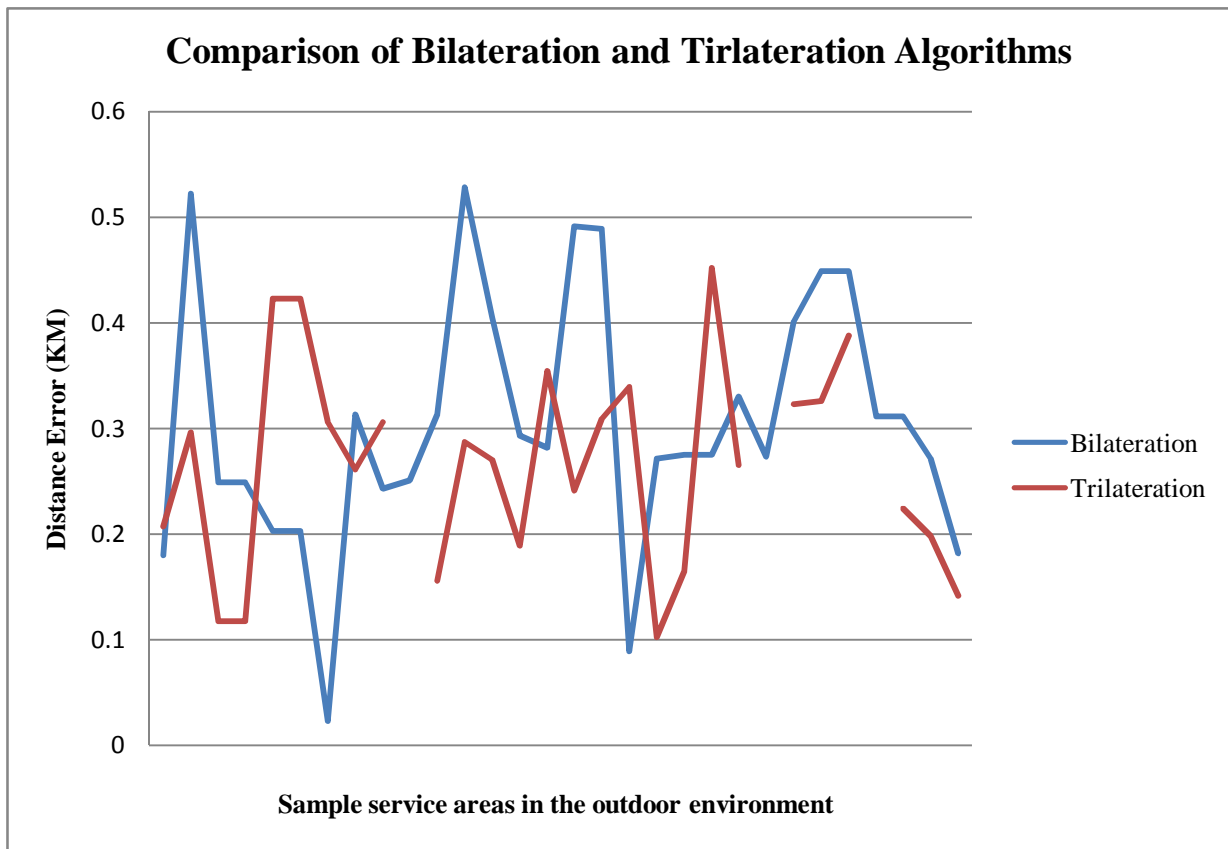


Figure 4.4 Distance error comparison between bilateration and trilateration algorithms.

Table 4.1 The standard deviation, mean and median error of the three location calculator algorithms used in this study.

Position Algorithm	Unilateration	Bilateration	Trilateration
Mean	0.367	0.30438	0.266
Median	0.342	0.27855	0.27
Standard Deviation	0.138	0.12078	0.098

The above table describes the mean, median point and standard deviation of errors of localization algorithms on sample points that are taken in the outdoor environment. As you can see in the table mean of trilateration algorithm is the least one from the rest two algorithms. It shows the average error of trilateration algorithm in our sample dataset is less than the remaining algorithms. The median and standard deviation of the trilateration algorithm is also the least one compared to the remaining two algorithms.

In rare cases of our sample datasets in the experiment we have received signal strength of a cell-ID in a given GSM tower less than -94dBm. The radius of a tower with signal strength less than -94dBm is greater than the average distance between two GSM towers in our dataset. This causes an expected error in the process of location calculation in bilateration and trilateration positioning algorithms as we can stated in the previous chapter¹¹. To overcome this problem we eliminate the GSM cell-ID that have a signal strength less than -94dBm and compute the distance with the remaining GSM towers information.

We have also done simulation experiments for indoor positioning¹² by using constants set by International Telecommunication Union Radiocommunication Sector (ITU-R) [28] for floor penetration loss factor and shadow fading statistics¹³.

¹¹ See section 3.4.2.2.2 for the detail of it.

¹² Indoor positioning in this study is focusing on dataset of Signal strength of a GSM towers that are collected inside buildings.

¹³ See table 3 and table 4 in the appendix for the detail of it.

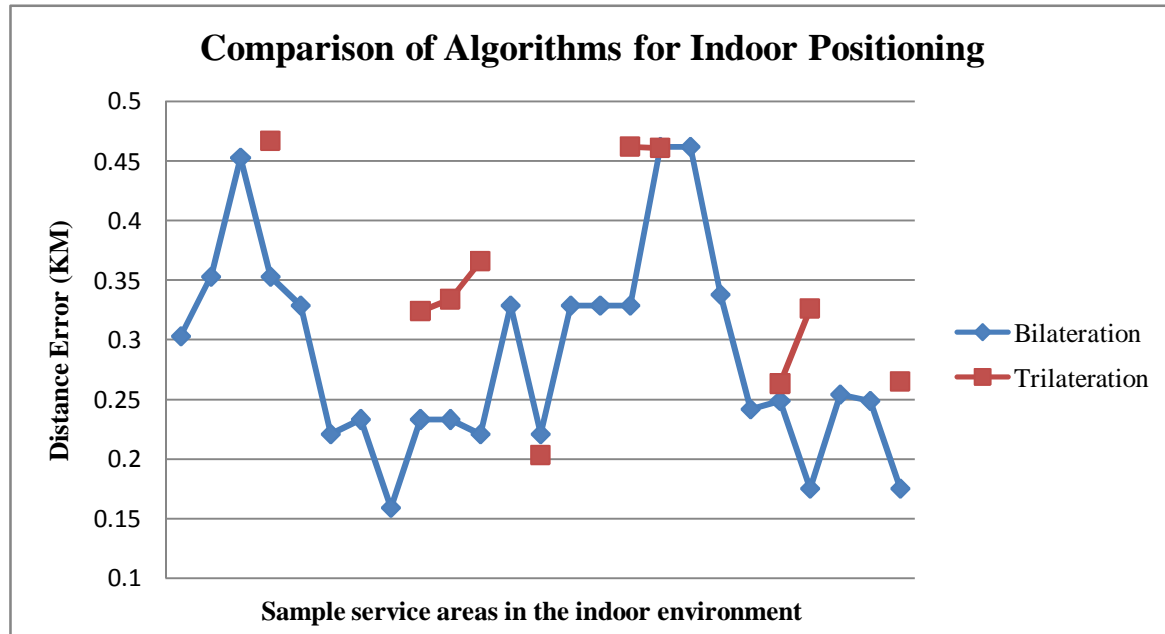


Figure 4.5 Comparison of Bilateralation and Trilateration algorithms for indoor environment

The above figure shows the result of bilateralation and trilateration location algorithms using the simulated dataset in the indoor environment. The experiment results show that bilateralation positioning algorithm is better than trilateration algorithm both in existence of data values and average distance error.

Table 4.2 Standard deviation, mean and median of localization algorithms on sample dataset in the indoor environment

Positioning Algorithms	Bilateralation	Trilateration
Mean	0.28936	0.3471
Median	0.254	0.33
Standard Deviation	0.0862	0.0922

The table has mean, median and standard deviation errors of bilateralation and trilateration algorithms. In the table the mean, median and standard deviation of bilateralation algorithm is less than trilateration¹⁴ algorithm. The table shows, unlike outdoor environment, bilateralation algorithm is suitable approach to determine position of a mobile station in the indoor environment.

¹⁴ Mean, Median and Standard Deviation in the above table is computed only on the valid results of a trilateration algorithm.

4.6. Demonstration

The previous section describes accuracy of path loss propagation models and location algorithms used in this study for both indoor and outdoor environment. The experiment is carried out to select a better way to determine current geographic position. In that process we did different experiments and gets results on a given dataset both for indoor and outdoor environment.

After choosing a better method for path loss propagation and location calculation and get the users position with a better accuracy. Then we proceed to demonstrate the final result by adding appropriate user context to test the context processing capability of the proposed system.

Figure 4.6 shows the interface of the proposed context aware LBS system in the client mobile phone. By this interface clients easily communicate with the service provider and get location information related to their current context.



Figure 4.6 Interface of context-aware LBS in client mobile phone.

For the demonstration purpose, we use different categories of service areas and information and context of users. By changing the test dataset especially on the context of users other than location information of user since location related tests are completed in the previous section of this chapter.

The results we get from the system is good in determining the context of users by checking their history, initial setting and preferences stored in the database and current context of a client that are sent from client cell phone. Beside this the system also checks context knowledgebase and location context ontology to make a decision about user context.



Figure 4.7 List of service areas and detail of it.

Figure 4.7 illustrates one sample case of a user accessing the system in first time during working hours. As shown in the figure, the system sends the location information to the user as a text and the user may also get details of each service area by pressing on it as shown in the figure.

5. Conclusion and Future Works

The approach we used in this study to determining the user location is cell-ID (received signal strength) positioning. In this approach we access cell-ID and RSSI of each GSM towers and compute a user location using lateration techniques. Experimental results show that our positioning algorithm and approach is a reasonable alternative for devices without embedded GPS.

The experimental results shows trilateration algorithm is a best approach to determine the location of a mobile station in outdoor and bilateration algorithm is better in the indoor environment respectively. The system is used without any change for the areas that have equivalent (similar) number of GSM tower in the given area (i.e. the GSM density of a given area is equivalent to our testing GSM density). Beside this, the context of a user also treated in this study and the experimental results in this regard also show the system performance is as expected in theoretical explanation. The study gives a promising result to provide context based LBS to the user using non-smart cell phones.

In this study we are also faces some limitations that affect the testing scenario and application development. These are some of the limitation we have faced in this study:

- Lack of collaboration from telecom organization in the country that have suitable information for the study.
- Lack of accuracy in geospatial data we obtained from relevant City Administration Offices.

Because of the above limitations in the study we limit our test dataset on services areas between localities in Addis Ababa named as Arat Kilo and Sidist Kilo.

As a future work, we propose the following works as additional investigation and implementation.

- Implementation of this study in other non-smart mobile phone models that are currently manufactured, used and penetrate the market share in the country (like Techno, Tana, Smadle, and other cell phone models).

- Linking the service with Google Earth and other services to provide a better and map based application to the user.
- Implement the Android version (especially for Samsung phones) of the application for Android cell phone models used by the user.

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Appendix

A. Tables of constants and computed results used in the study

Table 1. Comparison of Hata and COST231 path loss propagation models with received signal strength in the range of -70 to -105 dBm.

Received Signal Strength (dBm)	Distance in Km (Cost231 Model)	Distance in Km (Hata Model)
-70	0.122928549	0.124201126
-71	0.13123262	0.132591162
-72	0.140097648	0.141547962
-73	0.149561527	0.151109812
-74	0.159664709	0.161317584
-75	0.170450382	0.172214912
-76	0.181964649	0.183848376
-77	0.194256727	0.196267705
-78	0.207379161	0.209525984
-79	0.221388041	0.223679886
-80	0.236343249	0.238789913
-81	0.252308712	0.254920653
-82	0.269352674	0.272141056
-83	0.287547989	0.290524733
-84	0.306972435	0.310150264
-85	0.327709042	0.331101539
-86	0.349846448	0.353468115
-87	0.37347928	0.377345599
-88	0.398708558	0.402836054
-89	0.425642125	0.430048441
-90	0.454395108	0.45909908
-91	0.485090413	0.490112148
-92	0.517859248	0.523220211
-93	0.552841683	0.55856479
-94	0.590187253	0.596296967
-95	0.630055591	0.636578029
-96	0.672617116	0.679580158
-97	0.718053757	0.725487166
-98	0.766559735	0.774495286
-99	0.81834239	0.826814003
-100	0.873623067	0.882666955

-101	0.932638065	0.942292886
-102	0.995639646	1.005946669
-103	1.06289711	1.073900394
-104	1.134697951	1.146444529
-105	1.211349084	1.223889167

Table 2. Sample GSM towers and their geographic position, Cell-IDs and name of the location¹⁵.

Cell-ID	Latitude	Longitude	Site Name
42181	9.04424	38.75814	6 kilo University
42182			
42183			
42184			
42185			
42303	9.04859444	38.76324444	FBE Campus
42304			
42306			
42307			
42312			
42551	9.04086	38.7611	Technology Campus
42553			
42554			
42555			
42556			
42283	9.036	38.766	Art School
42284			
42285			
42286			
42101	9.04214	38.7667	Ethio Telecom North District
42102			
42103			
42105			
42082	9.0271	38.76258	National Palace (Main gate)
42083			
42084			
42085			
42086			
42087			

¹⁵ Since Cell-IDs of each tower is not the exact once but Cell-IDs that were mostly accessed in the time of data collection.

Table 3. Floor penetration loss factors, L_f (dB) with n being the number of floors penetrated, for indoor transmission loss calculation ($n \geq 1$).

Frequency	Residential	Office	Commercial
900 MHz	–	9 (1 floor) 19 (2 floors) 24 (3 floors)	–
1.8-2 GHz	$4n$	$15 + 4(n - 1)$	$6 + 3(n - 1)$
2.4 GHz	$10^{(1)}$ (apartment) 5 (house)	14	–
3.5 GHz	–	18 (1 floor) 26 (2 floors)	–
5.2 GHz	$13^{(1)}$ (apartment) $7^{(2)}$ (house)	16 (1 floor)	–
5.8 GHz	–	22 (1 floor) 28 (2 floors)	–

⁽¹⁾ Per concrete wall.

⁽²⁾ Wooden mortar.

For the various frequency bands where the power loss coefficient is not stated for residential buildings, the value given for office buildings could be used.

Table 4. Shadow fading statistics, standard deviation (dB), for indoor transmission loss calculation.

Frequency (GHz)	Residential	Office	Commercial
1.8-2	8	10	10
3.5	–	8	–
5.2	–	12	–
5.8	–	17	–

Table 5 Power loss coefficients, N , for indoor transmission loss calculation

Frequency	Residential	Office	Commercial
900 MHz	–	33	20
1.2-1.3 GHz	–	32	22
1.8-2 GHz	28	30	22
2.4 GHz	28	30	–
3.5 GHz	–	27	–
4 GHz	–	28	22
5.2 GHz	30 (apartment) 28 (house) ⁽²⁾	31	–
5.8 GHz	–	24	–
60 GHz ⁽¹⁾	–	22	17
70 GHz ⁽¹⁾	–	22	–

⁽¹⁾ 60 GHz and 70 GHz values assume propagation within a single room or space, and do not include any allowance for transmission through walls. Gaseous absorption around 60 GHz is also significant for distances greater than about 100 m which may influence frequency reuse distances.

⁽²⁾ Apartment: Single or double storey dwellings for several households. In general most walls separating rooms are concrete walls.

House: Single or double storey dwellings for a household. In general most walls separating rooms are wooden walls.

B. J2ME MIDlet for Location Sensing on Mobile Device

```
public String[] getcell()
{
    int i=0;
    long counter=0, finals=0;
    Date date,date2;
    String value="";
    int val_new=0;
    String [] cell=new String[6];
    String [] rssi=new String[6];
    String [] cell_su=new String[6];
    String [] cell_f=new String[6];
    String [] rssi_f=new String[6];
    String int_cell=System.getProperty("com.nokia.mid.cellid");
    String int_rssi=System.getProperty("com.nokia.mid.networksignal");

    try
    {
        date=new Date();
        counter=date.getTime();
        counter=counter+60000;
        cell_f[i]=int_cell;
        rssi_f[i]=int_rssi;
        while(i<2)
        {
            date2=new Date();
            finals=date2.getTime();
            if ("0".equals(int_cell))
            {
                int_cell=System.getProperty("com.nokia.mid.cellid");
                int_rssi=System.getProperty("com.nokia.mid.networksignal");
            }
            else
            {
                cell[i]=System.getProperty("com.nokia.mid.cellid");
                rssi[i]=System.getProperty("com.nokia.mid.networksignal");

                if ("0".equals(cell[i]))
                {
```

```

        cell[i]=int_cell;
        rssi[i]=int_rssi;
    }

    if (int_cell.equals(cell[i]))
    {
        cell[i]=int_cell;
        rssi[i]=int_rssi;
    }
else
{
    if (i==0)
    {
        cell_f[i+1]=cell[i];
        rssi_f[i+1]=rssi[i];
        i++;
    }
    else if (i!=0 && cell[i].compareTo(cell[i-
1])!=0&&cell[i].compareTo(int_cell)!=0)
    {
        cell_f[i+1]=cell[i];
        rssi_f[i+1]=rssi[i];
        i++;
    }
}

if (finals>counter)
    break;
}

System.arraycopy(rssi_f, 0, cell_f, 3, 3);
int fi=0,f=0;
while (fi<cell_f.length)
{
    if (cell_f[fi]!=null)
    {
        cell_su[f]=cell_f[fi];
        fi++;
    }
}

```

```
    else
    {
        if (fi==0)
        {
            //cell_su[f]=cell_f[fi+2];
            fi +=6;
        }
        else if (fi==1)
        {
            cell_su[f]=cell_f[fi+2];
            fi +=3;
        }
        else
        {
            cell_su[f]=cell_f[fi+1];
            fi +=2;
        }
    }
    f++;
}
do//for (int val_new=0;val_new<cell_su.length;val_new++)
{
    value=value.concat(cell_su[val_new]);
    val_new++;
}while (val_new<cell_su.length);
}catch(Exception e)
{
    System.out.println("Connection is not established"+e.getMessage());
}
return cell_su;
//return value;
}
```

C. Java Servlet Class for the Context Organizer Module

protected void doPost(HttpServletRequest request, HttpServletResponse response) throws ServletException, IOException {

```

    DataInputStream in=new DataInputStream((InputStream)request.getInputStream());
    PrintWriter out=response.getWriter();
    DataAccess data=new DataAccess();
    String idd[]=new String[20];
    String ig[]=new String[20];
    String cell_values[]=new String[6];
    String user_profile[]=new String[8];
    int i=0,j=0,t=0;
    int ch=0;
    double position[]=new double[2];
    System.out.println("Ayuyazi in JSP");
    try
    {
        String chh=new String();

        while((chh=in.readUTF())!=null)
        {
            ig[ch]=chh;
            System.out.println(ig[ch]);
            ch++;
            idd=ig;
        }
    }catch(NullPointerException e)
    {
        System.out.println(e.getMessage()+"Error happen in reading a file from connection");
    }catch (EOFException e)
    {
        System.out.println(e.getMessage()+"\t error happen here");
    }

    int idd_che=0, cell=0,data_val=0;
    while (idd_che<idd.length)
    {
        if (idd[idd_che]==null)
            break;

```

```

byte idd_byte[]=idd[idd_che].getBytes();
if (idd_byte[0]>=65 || idd_byte[0]==48)
{
    user_profile[data_val]=idd[idd_che];
    System.out.println("Users Input Data" + user_profile[data_val]);
    idd_che++;
    data_val++;
}
else
{
    cell_values[cell]=idd[idd_che];
    System.out.println("Computed cell Id" + cell_values[cell]);
    idd_che++;
    cell++;
}
}

try
{
    if (ch>1)
    {
        if (cell==2)
        {
            position=unilateral(cell_values);
            System.out.println("Unilateration technique is used");
        }
        else if (cell==4)
        {

            System.out.println("Bilateration technique is used");
            position=bilateral(cell_values);
        }
        else
        {
            System.out.println("Trilateration technique is used");
            position=trilateration(cell_values);
        }

        String comp[]=data.readData(position, idd);
        int res=0;

```

```
        while (res<comp.length)
        {
            out.println(comp[res]);
            res++;
            if (comp[res]==null)
                break;
        }
    }
else
{
    String tempo=idd[0];
    String comp[]=data.readDetail(tempo);

    out.println(comp[0]);
}
in.close();
out.close();
}
catch (SecurityException sec)
{
    System.out.println("Security Error "+sec.getMessage());
}
    catch(Exception e)
    {
        System.out.println("Error Message one\t"+e.getMessage());
    }
}
```

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all source of materials used for the thesis have been duly acknowledged.

Declared by:

Name: _____

Signature: _____

Date: _____

Confirmed by advisor:

Name: _____

Signature: _____

Date: _____

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