LOCATION BASED SERVICES FOR LOW-END MOBILE PHONES

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June, 2014

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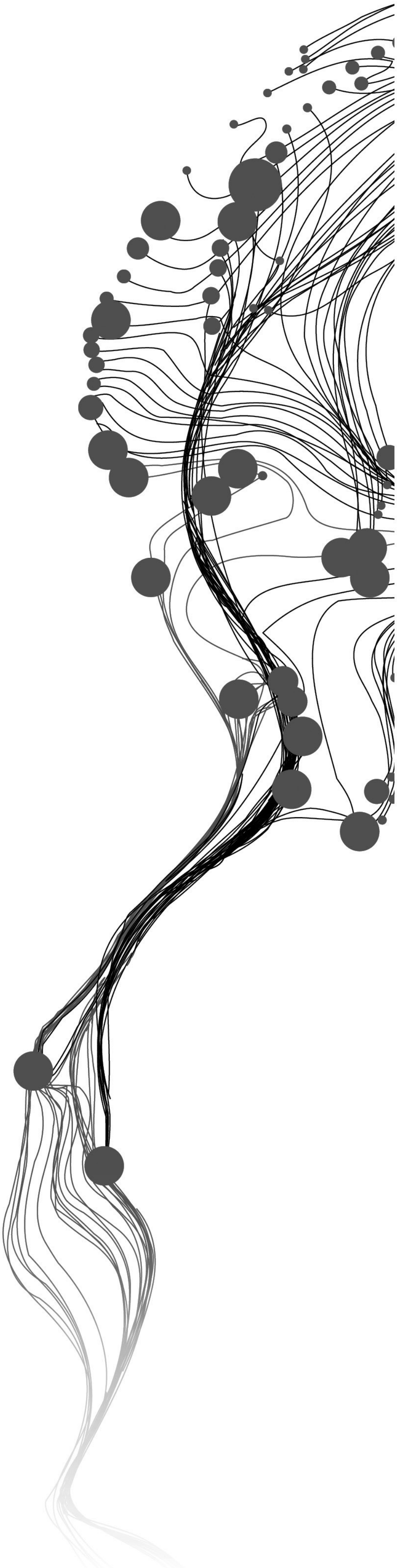

LOCATION BASED SERVICES FOR LOW-END MOBILE PHONES

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Thesis submitted to the Faculty of Geo-information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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This thesis is dedicated to my children Edom and Leul.

ABSTRACT

Location based services (LBSs) are services provided via mobile applications with the help of network connectivity and the ability to detect the location of the user so as to adapt the service to a particular geographic location. However, a significant number of mobile phones in the world, especially in developing countries, are used without built-in location sensor techniques and are unable to transfer their location information over the network. These phones are called "Low-end mobile phones" (LEMPs). Even though LEMPs cannot access all types of LBSs, it is possible to design LBSs based on USSD text channel. In this research project we have designed LBS which can be accessible from LEMPs. In order to design this services a series of methods are used. One of the basic component of this service is to enable the LEMPs to communicate with the application server over the network. Since these phones have no internet capability the communication can be built via the USSD text channel. Based on this text channel two location determination methods are designed. The first method allows the user to input their location using local names. And the second method is using the carrier billing records. The billing records are used in order to identify the geolocation of base station transceiver (BTS) with which the mobile phone is communicating. Because the BTS for each cell is in a fixed location, this can be buffered with maximum distance of the BTS antenna coverage. And later this area can be translated into a location of the mobile user and then the better approximate location can be achieved via interactive communication. This method can be practical when the service provider is working together with the mobile operators. Finally, in the USSD text channel it is not possible to display spatial information in graphic form, so to address this constraints, we propose to record all publicly known and/or natural landmark features of the area (which we need to display) in the database and display them in text form.

Keywords

Location Based Service, USSD Service, Low-end Mobile Phones, Positioning techniques, Interactive communication

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ACRONYMS

2G second generation mobile telephony

3G third generation mobile telephony

AOA Angle-of-arrival

AP Access point

A-GPS Assisted-Global Positioning System

API Application Program Interface

BTS Base Transceiver station

CBS Cell Broadcast Service

COWSO Community Owned Water Supply Organizations

CWPL Closest Water Point Locator

GPRS General Packet Radio Service

GPS Global Positioning System

GIS Geographic Information System

GSM Global System for Mobile

HTML Hypertext Markup Language

ITU International Telecommunications Union

LAI Location Area Identity

LBS Location Based Service

LMU Location Measurement Units

LEMP Low-End Mobile Phones

MCC Mobile Country Code

MNC Mobile Network Code

NGO Non Governmental Organization

PDA personal Digital Assistants

PSTN Public switched telephone network

RSS Received Signal Strength

SDDT Spatial Data Display as a Text

SDM Service Delivery Method

SEMA Sensors, Empowerment and Accountability

SMS Simple Message Service

TDOA Time-difference-of-arrival

URL Universal Resource Locator

USSD Unstructured Supplementary Service Data

ULD User Location Determination

VXML Voice Extensible Markup Language

WP Water Point

WPM Water Point Mapping

WPLD Water Point Location Determination

XML Extensible Markup Language

Chapter 1
Introduction

1.1 MOTIVATION AND PROBLEM STATEMENT

Today, mobile devices are widely used communication means. Due to their growing recognition and availability by people of different social status, connection and communication on the go is no more science fiction. In many rural places in Africa mobile phones are considered the first modern telecommunication infrastructure since in some areas mobile phones were introduced earlier than landlines phones. In Africa the number of mobile subscribers dramatically increased from 5% in 1999 to 57% in 2006 [1]. However, the International Telecommunications Union (ITU) reports that only 17.7% of the world mobile subscriptions are third generation (3G) mobile services subscribers [2]. Majority of mobile services subscribers with 2G services or lower reside in Africa.

Mobile phones brought the possibility to have easy access to information for business, social and political activities. This quickly made the mobile phones one of the basic instruments considered a must for all humans, as well as spurred the development of specialized applications, known as m-apps, short for "mobile applications" for business, education, health etc. The benefit of such applications is the delivery of information and services in a format suited to various forms of devices and types of users at a convenient place and time [3, 4]. These services include the so-called Location-based services (LBS).

LBS are services provided via m-apps with the help of network connectivity and the ability to detect the location of the user so as to adapt the service to a particular geographic location [5]. For instance, it may give answers to basic questions that might be asked by a traveler, such as "Where am I?", "What is around me?", "Where is the nearest hotel, hospital, pharmacy?", "What is the most convenient route?", and so on [6]. However, this conception of LBS requires core functionality (such as sensing one's current location, visualizing data etc.), which we cannot find in Low-end mobile phones (LEMPs). Accordingly, the current development trend of LBS targets phones with smart functionality and are not accessible for the clients who have simple mobile phones. Here, the term "LEMP" can be defined as mobile devices which are habitually dedicated to perform conventional tasks, such as telephony services, organization of addresses, contacts and notes, media playing, etc. [7]. Similarly smart mobile can be defined as mobile devices, which have additional sensors, such as an accelerometer, a digital compass, a GPS, microphones, cameras, near field communication, and other equipment. Moreover smart phones are mobile devices with a built-in operating system that enables the storage of third party applications [8] which can make use of the sensors.

But this does not mean that there is no m_app for LEMPs. There are a lot of simple mobile applications, which are not dependent on the location of an end user. These m_app are focus on the majority of people in Africa which have access to mobile phones but not too smart phones or computers. Therefore many banks and profit-oriented organizations are start to recognize they can be reaching millions of customers through mobile advertisement and service promotion. Like in countries such as Kenya and South Africa they have successfully deployed mobile banking platforms [2]. Similarly, in Nigeria and Ghana Pharmaceutical safety can be verified by texting a code on the drug's pack to a free SMS number to verify the authenticity of the drug [2].

However for LBS the minimal requirement is a device equipped with location sensing techniques that allows the detection of the current location of the user and can visualize the required data. For LEMPs the main challenge remains to be the absence of such location sensing functionality, lack of Internet connectivity, and the incapability to visualize spatial information on the screen.

1.2 RESEARCH IDENTIFICATION

The aim of this research project is to develop and implement an application that fills the identified gaps to make Low-end mobile phones LBS accessible. The gaps can be filled by designing a technique that can be functional from LEMPs and used by all type of mobile subscribers. This can enables all citizens to access and manipulate location based information or send complaints and get feedback on government malfunction in providing public services. In order to validate the designed method we developed a prototype. Which determines the closest water points to the user location. The prototype uses the water points, which are distributed over suburbs and rural areas. In this research the name "Water point" is used for those sources of water where water is drawn for various purposes such as drinking, washing and cooking.

1.2.1 Research objectives

The objective of this research project is to improve Location Based Services by extending the accessibility of these services from LEMPs. This general objective can be achieved by defining the following two groups of specific objectives:

1. To develop a method to handle the location information of a LEMP users.
   - 1.1. To understand how the contemporary LBS developers extract location information of the users from their mobile phones.
   - 1.2. To design a method to obtain user location information, in the absence of any built-in location sensors in LEMPs.
   - 1.3. To distinguish which mobile built-in features can support the users to access LBS.
   - 1.4. To develop a method to communicate between the LEMPs and Third party application, in the absence of internet capability in a LEMPs.
   - 1.5. To evaluate how much accuracy level can be identified from the proposed method.
2. To develop a method that enables spatial information display on a LEMP screen in the form of text.

1.2.2 Research questions

1. How can the LEMP's location be determined?
   - 1.1. How can the location of a mobile device be determined?
   - 1.2. How can the LEMP users' location information be identified, in the absence of any built-in location sensing techniques?
   - 1.3. Which features of mobile phones can support access to LBS?

1.4. How can the LEMP users transfer their location information for third party application servers, in the absence of internet capability?

1.5. What location accuracy is needed, under which circumstances, e.g., what accuracy is enough to find the nearest water points?

2. How can we display spatial information on a user's LEMP screen, as replay to their service request?

1.2.3 Innovation aimed at

Based on the USSD text channels, we designed methods which enables the users to access LBSs from their LEMPs.

1.3 PROJECT SET-UP

1.3.1 SEMA project overview

SEMA stands for Sensors, Empowerment and Accountability. It is an integrated research project between the University of Twente and the University of Dar-es-Salaam. The project is funded by the Netherlands Organization for Scientific research un- der the WOTRO-Global Science for Development Programme. Research under this project focuses on how ordinary citizens in Tanzania can directly exercise accountability on government's malfunction of public services in their areas [9].

As a part of this big project our contribution focuses on empowering the ordinary citizens, with limited access to expensive mobile phones. This application enabling them to access the LBS in order to complain and get feedback on malfunctioning of public services from their LEMP.

1.3.2 Method adopted and thesis structure

As shown in Figure 1.1 to achieve the proposed objectives and to answer the corresponding research questions, the following main steps are applied. The first step in this research project is to review the literature on how the current trends of LBS developers can retrieve the location information of a mobile phones. So identification of the basic feature as well as LBS requirements of LEMPs are reviewed and discussed in chapters two and three respectively.

Chapter four discusses the steps we followed in designing the prototype such as define service components, data generation, and building the application. Chapter five presents the outputs and evaluates the developed prototype. Finally, in chapter six the basic findings of the research is discussed, result from the prototype is concluded, and the possible recommendation is pointed out for future work.

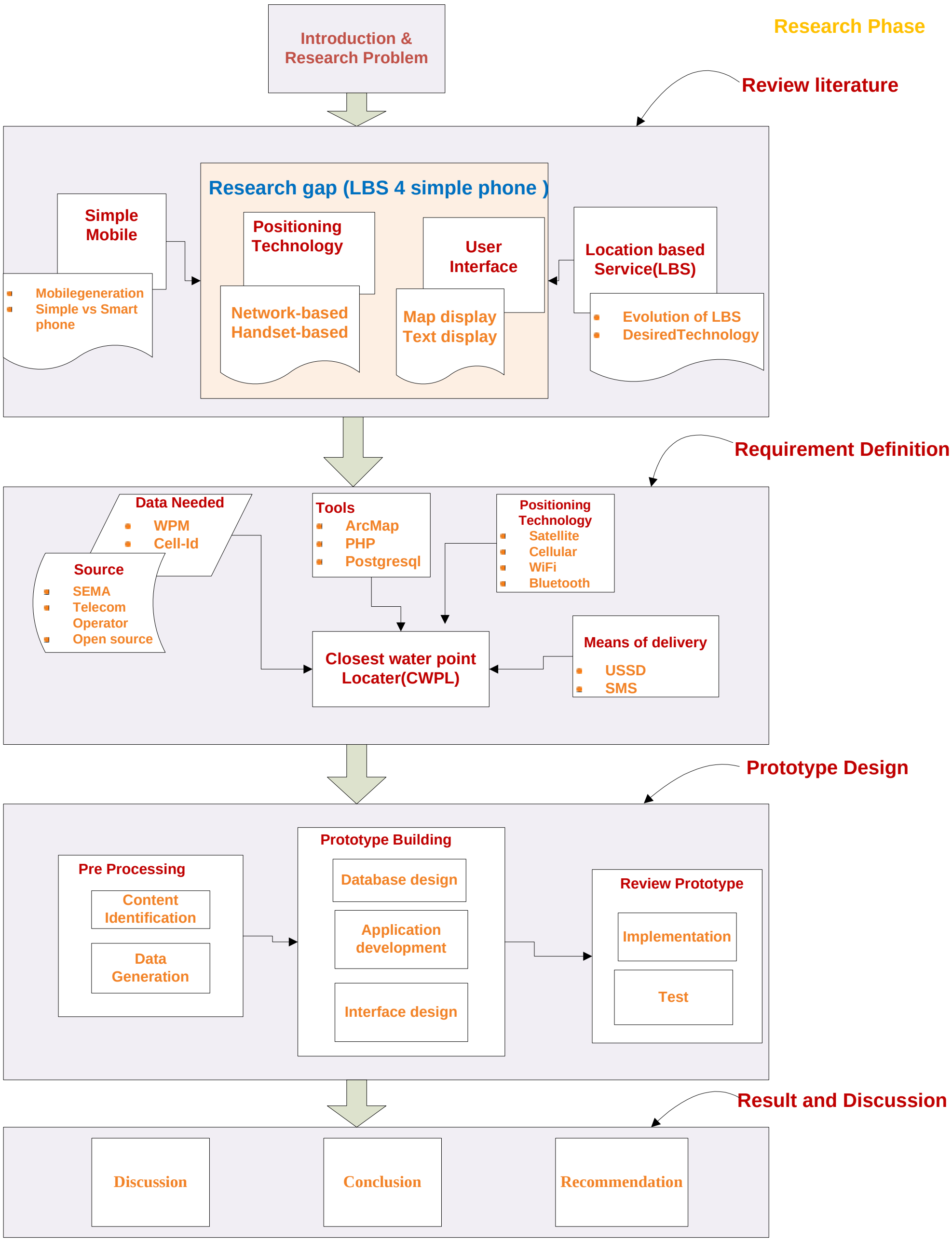

Figure 1.1: Research phases

1.3.3 Resources required

1. Data and its source:

   - Water point map of Tanzania
     Although there are water pumps all over the country, in Tanzania, many people spend a lot of time to fetch water even if it is not safe to drink. In 2007 SNV (Netherlands Development Organisation) Tanzania, WaterAid and six other international NGOs initiated a joint effort to monitor the functionality of water points (WP) in Tanzania and make timely repair of the broken ones. To see how many of the WPs are functional and how many of them need repairs, they developed Water Point Mapping (WPM) initiative [10].
   - Village level administrative boundary of Tanzania.
     Downloaded from open source.
   - Gazetteer (Geo-name) of Tanzania.
     Downloaded from open source.

2. Software:

   - Desktop ArcGIS.
   - Notepad++.
   - PostgreSQL with postGIS extension.

3. Programming language:

   - PHP
   - HTML

Chapter 2

Location based services (LBS)

2.1 INTRODUCTION TO LBS

In much of the literature location services and location based services are interchangeably used to describe the same service. But in this document we are using the term "location services" to refer to positioning technologies, which obtain the location of the user, and LBS to refer to the added value after identifying the position/location of the user, in other words services for mobile users that take the current position of the user into account when performing their task [11]. Therefore positioning technology is the heart of LBS. Since the 1970s location services are not a new phenomenon. However first the U.S. Department of Defense has been operating the global positioning system (GPS) for serving the positioning of people and objects just for the military purposes. But later in 1980 the U.S. government decided to provide this technology for other civil industries worldwide [12]. In addition specifically for the growth of LBS. Much literature agrees that the USA and European legislation for emergency relief played a major role in the development of LBS. Especially in 1995, the US Federal Communications Commission launched an emergency services initiative called enhanced 911 (e911). This initiative proposed that the US Congress institutes a legislative mandate forcing all mobile network operators to provide services to locate emergency 911 calls within 50m of their location [11, 13, 14]

Even though the beginning of LBS is associated to the GPS technology, later as mobile telephony became increasingly common as a hand held computing platform, location-tracking of mobile phones enabled LBSs to spread to all types of our daily life [15] using wireless networks like WiFi, Bluetooth and GSM. These can provide LBS without the involvement of GPS technology.

Nowadays LBS is the most common form of context-aware computing systems, which are becoming more popular with the growth of capabilities of modern mobile devices, positioning technologies and mobile internet to deliver to user value added information or service based on their location [12, 15, 16].

2.2 DESIRED TECHNOLOGIES

Many types of technologies are required for the provision of LBS, namely mobile devices, communication networks, localization techniques, and service and content providers [11]. In order to request mobile LBS, a user has to be equipped with a mobile device and their request is supposed to be transferred from the mobile terminal to the service provider or vise versa through communication networks. To answer the user's request, the service provider needs to identify the location of the user. The user location can be obtained either by using the mobile communication network (a mobile operators infrastructure) or by using the Global Positioning System (GPS) which depends on the user mobile devices built-in location sensor. Is not always service and content providers will be the same organization, service provider may just offers a number of different services to the user and is responsible for the service request processing. Like services offer the calculation of the position, finding a route etc. But content providers may store and maintain the necessary information. LBSs are not standalone services that could be run or managed by a single organization or technology, but, as shown in figure 2.1 [17] they need an intersection of technologies [3].

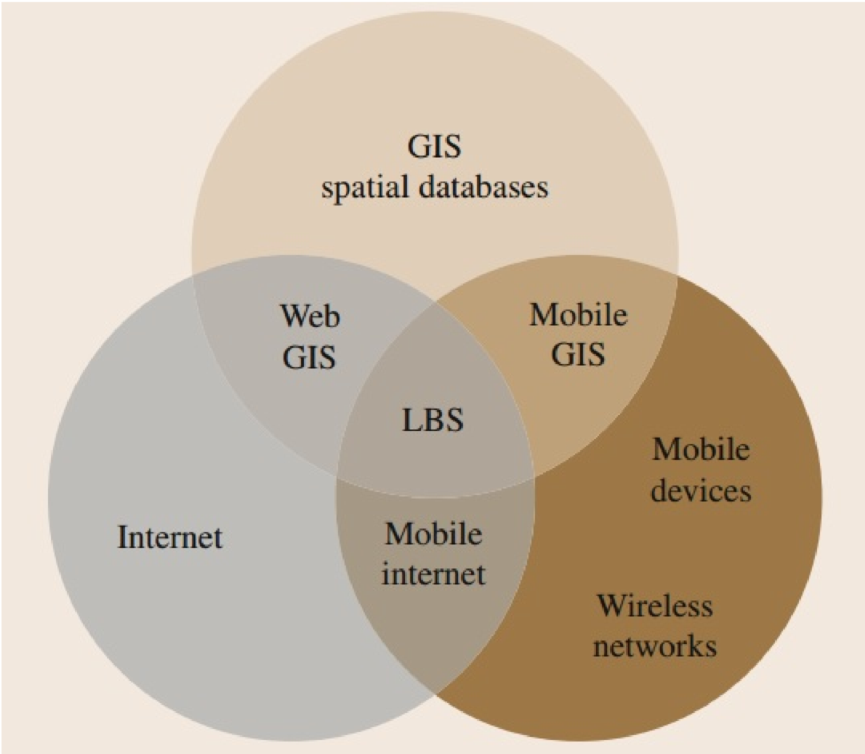

Figure 2.1: LBS as an intersection of technologies.

2.3 MOBILES PHONE CLASSIFICATION BASED ON CAPABILITY TO ACCESS LBS

Actually there are no clear cut between the type of mobiles classification yet, but we are trying to summarize the types of mobiles, based on their capabilities to access different available method of location aware services, see Table 2.1.

Table 2.1 Classification of mobile phone based on their capacity to access LBS.

Technology	Smart phone	feature Phone	LEMPs
Satellite based (GPS)	√	-	-
Accelerometers and Compasses	√	-	-
WiFi	√	√	-
Bluetooth	√	√	-
Cellular network	√	√	√
Capable of internet	√	√	-
Installing Third party application	√	√	-

As most of the current trends to develop LBS, one of the developer's precondition is, to check whether the user's device can identify its own location within the network. The next question is: can the device transfer its location over the internet for the third party[1] application. Because

[1]Third party is any organization which develops LBS that requires the location information of the user

internet is the transport network that allows users to interact with the applications anywhere at any time. Apart from those smart mobile phones there is also a significant number of mobile phones capable of transferring its location information for the third part for further queries to enable the user to access services, based on their current location. So this type of mobile phone that we are categorize as feature phone.

But our research targets mobile phones which have no support of GPS localization techniques, wifi & Bluetooth networks and any of augmented sensors in cell phones, e.g. accelerometers and compasses. Moreover, these are which have no capacity to install a third part application. Which is called Low-end mobile phone. Based on our knowledge this types of mobiles have not get any attention of the LBS developer yet.

2.4 TYPES OF INFORMATION DELIVERY MECHANISMS OF LBS

There are two types of information delivery methods of LBS. It is distinguished on the way how the LBS server delivers information or services to the customers i.e., push and pull. Push service is a communication initiated by the server. The server send the whereabouts of the user without the request of the user. This can be done based on prior subscription of the user on the service like to be informed when one of his friends is located in the same general area.

Unlike a Push service, a Pull service a communication initiated by the user when the user requesting to know where they are or where the nearest service center is. There are also services which integrate both push and pull functionality [12].

2.5 USER PRIVACY

LBS is not without drawback of privacy, since all types of LBS require the share of physical location of the user. By sending their locations, LBS users could endanger their security and privacy because, for example, an attacker could determine their location and track them. Actually when it comes to sharing the physical location of users, privacy is a serious concern, so according to the geolocation API, 'user agents must not send location information to websites without the express permission of the user.' In other words, a user must always opt in to share location information with a website [18].

Unlike to this, in LEMPs, the user location is determine based on the mobile operator's infrastructure so the user is not able to disable positioning from the handset. That why as a third party we have to deal with the mobile operators about the privacy of our user.

2.6 MOBILE PHONE POSITIONING TECHNOLOGY

Although this paper intends to enable citizens who live in lesser developed countries in Africa to use LBS from their simple mobiles, it is also worthwhile to see the technologies used by current LBS developers. Location determination mechanisms are methods and techniques used to calculate the user's geographic location by using different location determination equipment. In the following subsection we are describing two group of positioning technologies.

2.6.1 Handset-based technology

Handset-based technology is like Global positioning system (GPS) for outdoor and wifi and Bluetooth for indoor and this technology have to be built into each handset devices. GPS is allowing a user through their mobile device to determine the geographic position of themselves on the Earth's surface more precisely in few meters or even centimeter level [19]. Although currently there is no method as accurate as GPS, it has some disadvantages like it require the line-of-sight of at least four satellites to improve the position accuracy. This means that the GPS signal is completely lost inside the building or when the satellites are in shadow and the signal strength frequently drop by mobile devices [20–22] owing to tree cover and steep slopes. In addition to that if its setup is expired the set-up time can be quite long [23].

Based on the disadvantages of GPS system there is a need to find other alternatives such as WiFi and Bluetooth positioning system. With the existing infrastructure of WiFi it is also possible to positioning a device inside a building within 60-300 meter [16, 24]. WiFi provides wireless connectivity by emitting radio wave by its Access point (AP) which has to be taken as station. AP is a device that allows wireless devices to connect to a wired network using WiFi [25]. Positioning can be conducted only in places where several access points (AP) cover the whole area. The distance from the stations to the mobile device has to be calculated by converting measurements of the received signal strength (RSS) to a distance measurement with the accuracy of proximately 4 meter [26].

Bluetooth is also one of a wireless communication that uses radio technology and can be taken as one of candidate techniques for indoor positioning system [24, 27]. It is a short range, which is around 10 meters, [24] so it can be assumed that if a Bluetooth scan finds your mobile that means you are found within 10 meter of it.

2.6.2 Cellular positioning technology

Because of its high battery consumption of GPS and the less accessible of the WiFi networks in various cities. Many types of mobile phone application developers and governments are preferring to use the cellular positioning system [22]. Unlike, GPS and WiFi, cellular positioning works on all type of phone all over the world, with minimal energy consumption and some of the cellular positioning techniques can work without additional built-in localization equipments in mobile phone.

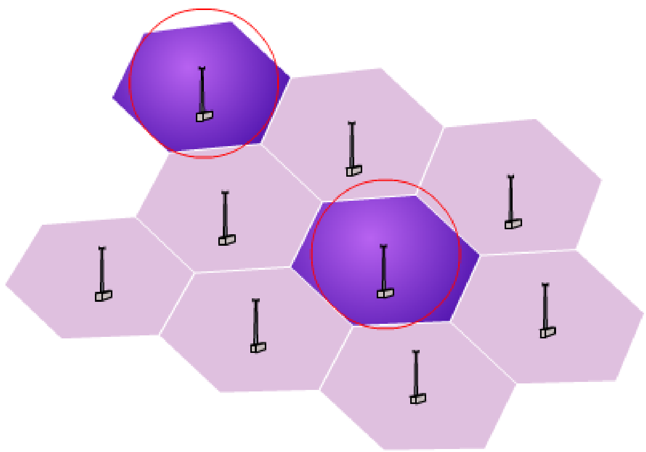

Figure 2.2: Omni-directional antenna Cell. The hexagon is just a convenient idealization that approximates the shape of a circle.

Cellular positioning works while Wireless phones can make and receive calls, because they are connected over the air to a nearby cell tower. Each base transceiver station (BTS) broadcasts both the Location Area Identity (LAI) and the Cell-ID to its cells [23]. A mobile phone is always receiving these broadcast messages; thus, it always knows its Cell-ID. Knowing its Cell-ID, a mobile phone can approximate its actual location using the geographical coordinates of the corresponding BTS [22]. Actually, the mobile phone can be everywhere within the cell (see Figure 2.2 [28]).

This id is sent to the location server of the application developer through the API which is installed on the mobile phone [29]. For example Google Maps for mobile, with its functionality of named 'My location' enables users to pinpoint their approximate location on a map even if their phone does not have a GPS chip. Since the phone knows the ID of the cell tower that it's currently using, it can send it to the Google location server. If the phone has GPS, the Maps application on the phone sends the GPS coordinates along with the Cell-ID to the Google location server. Or if the phone has no GPS the application on the phone queries the Google location server with the cell tower ID to translate that into a geographic location, i.e., lat/long coordinates [30]. In fact this all are applicable for the mobile which has internet capability and the capacity of installing the third party application. In the next chapter we will provide details of how cellular positioning works for the scenario of mobile phones without capability of internet and so unable to functioning with the third party software.

Chapter 3

LBS requirements for Low-end mobile phones (LEMPs)

LBSs cannot be accessed from all types of mobile Phones. In this chapter we are going to discuss technological requirements which can support the LEMP in order to access LBSs.

3.1 EVALUATING POTENTIAL LOCALIZATION TECHNIQUES FOR LEMPS

Even though Cellular positioning is the ideal method for the LEMP, some applications still require further approximation of the user location. Mobile operators can have the capability of improving their location services by adopting different positioning techniques.

Mobile operators deploy radio based technology to compute the users distance from the base station. In order to compute this distance there should be two ends. One is a fixed base station transceiver, which is located at the center of each cell in a mobile network. The second one is a mobile device in which we are interested to measure its location relative to the fixed one. The location computing process can be deployed either at the fixed end or at the mobile end.

Based on this there are different methods which can be used to improve the accuracy of the positioning of the user. Some of them needs the installation of equipment and the upgrade of related software in the base station as well as in the mobile phone. In the next subsection we briefly discuss some of the methods which are network-based, i.e. they do not require a mobile device upgrade to operate.

3.1.1 Angle-of-arrival (AOA)

In AOA, a mobile device's signal is received by multiple base stations. The base stations have additional equipment that determine the compass direction from which the user's signal is arriving, see Figure 3.1. The information from each base station is sent to the mobile switch, where it is analyzed and used to generate an approximate latitude and longitude for the mobile device [31].

3.1.2 Time-difference-of-arrival (TDOA)

In TDOA, a mobile position is determined by measuring the difference in the time arrival of a known signal sent from the mobile device and received by three or more base stations, (see Figure 3.1 [31]). Unlike to AOA, the time difference is measured. The position of the mobile device is then calculated by hyperbolic trilateration. But this method needs additional hardware (Location Measurement Units (LMUs)) to accurately measure the arrival time of the bursts [12,31].

3.1.3 Cell broadcast service (CBS)

CBS is a GSM standard in which nearby cell towers broadcast their locality name [29]. A phone can receive CBS messages from only one cell tower to which it is currently connected. This can

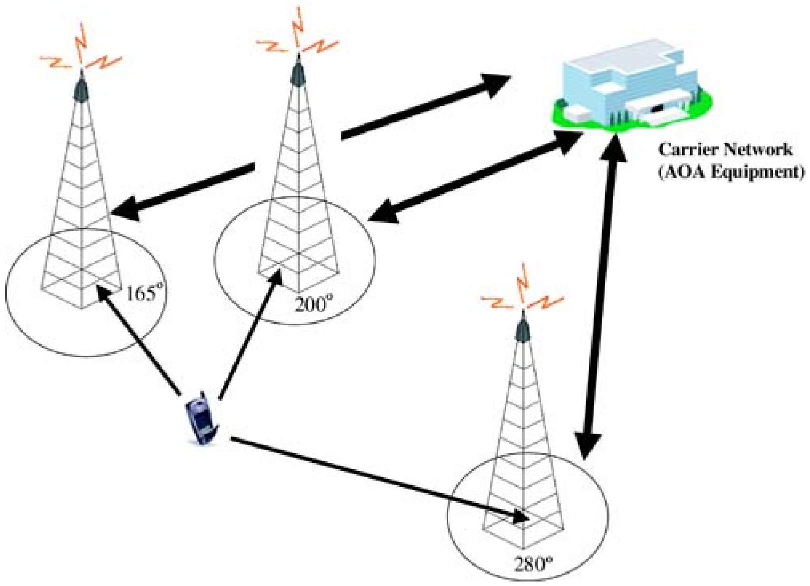

Figure 3.1: Angle of arrival (angle can be measured) AND Time of arrival (time can be measured).

help the user to easily identify the area name in which they are located. So using CBS can aid to improve the user's experience, when the users are asked to input their local area name.

3.1.4 Cell tower

A cellular network, which gives cell phones their name, is made up of cellular towers or base transceiver station (BTS) distributed across the country. A base station contains an equipment which facilitate wireless communication between the user phone and Telecoms infrastructure. The carrier divides the whole country into a cell [28]. A cell is a geographical area which is supported by the radio service of a single BTS. Cell sizes vary from place to place, based on the available traffic, generally small in urban area and large in rural area (see Table 3.1 [23]) and see Figure 4.2. Each cell has one tower located at the center. This tower can covers the region of a cell.

Table 3.1 cell size.

Cell Type	Dimension in km
Large macrocell	3-30
Small macrocell	1-3
Microcell	0.1-1
Picocell	0.01-0.1
Nanocell	0.01-0.001

Each base station is connected to a mobile switching center (MSC) which is connected to a Public switched telephone network (PSTN) [32]. Therefore once the geolocation of the BTS is identified, it is also possible to estimate the phone location.

Although all the above mobile positioning techniques do not request a mobile phone to upgrade and are applicable for all types of mobile phones, we still face challenges to use the first two methods for our prototype. As shown in Figure 3.1 the techniques require a mobile device to be in range of at least two or three base stations, but this is often not the case in rural or even some suburban areas.

3.2 COMMUNICATION CHANNELS

LEMPs have no internet capability, and as a result it is unable to establish communication between a third party application server. We have to find a method to build this communication. The best way is using the network's of text channels. The text channels is one of the best ways of using a cell phone to communicate with any application server. And it is applicable in all types of mobile phones and in all parts of the world [33–35]. There are two types of text channels: Short message service (SMS) and Unstructured Supplementary Services Data (USSD).

SMS is used for person-to-person messaging; however, it has been widely deployed outside this scope. It is now being used to send SMS notifications for new voice mail, email, and fax messages [35]. Usually SMS messages are a combination of letters and numbers but it is also possible to send black and white pictures with low quality [36].

Likewise, USSD was built as supplementary service in order to fulfill session-based real time data communication, and it is also possible to use it for chat services between the mobile end users [34, 37].

3.2.1 Why USSD

USSD is an ideal tool to develop a service incited by a mobile user to retrieve information from the dedicated USSD server regardless of the type of mobile phones used and it is cost effective for two-way communication [37]. Moreover, we are preferred the USSD over SMS massages because of its communication characteristics. Unlike SMS, USSD allows communication between mobile phone and a network based application server in real time and session based. This gives immediate replies to the users as if they are chatting with someone. "USSD is as similar to speaking to someone on a phone as SMS is to sending a letter" [38]. USSD is a protocol used by GSM cellular telephones to communicate with the service provider's computers. Although it is a type of messaging service, it is does not follow a store-and-forward oriented message transaction like SMS [37–39].

3.2.2 The development of USSD

USSD has two developmental phases. Since there is no session between the mobile and USSD application, in the first phase we are only able to send information from mobile phone to USSD application like with SMS service. Therefore the information delivery mechanism used here is Mobile-initiated services (Pull operation). In the second phase of its development USSD becomes capable of establishing a session that helps a two way communication between the mobile phone and USSD application. Therefore the information delivery mechanism used here is both mobile-initiated services and network-initiated services (pull and push operations) [40].

These contemporary stages of the USSD development allow us to develop our interactive communication based application.

3.2.3 USSD code

USSD codes are simple to use. They comprised of an asterisk (*), followed by a combination of digits (0 to 9) and a hash (#). Users can directly enter the USSD string and press the call key to send a message. The asterisk and hash codes are much like simple programming codes in that they signify the beginning and end of the request. The following is an example of one Mobile initiated USSD massage flow.

1. User enters a predetermined short code into a phone for example *103*389#.
2. The phone sends it to the mobile network operator.
3. It is received by a mobile network operator computer dedicated to USSD.
4. The answer is displayed from dedicated USSD computer.

The entire process takes a few seconds [41] see Figure 4.3.

3.2.4 Features of USSD

The design of the menu can vary from application to application and depends on service provider choices based on some technical constraints.

- FIRST PAGE
  The welcome message and the initial menu both can be displayed at the first page unless the service offers numerous services. Specifically if more than 9 items or more than 182 characters are included in the welcome message. It is necessary to separate the welcome message and the initial menu. The separation of the menu from the welcome page may require the user to send additional message to request the menu. Or how to link the menu can depend on the designer choice.

- Layout
  Since USSD is a text channel it does not allow any formatting and layout as well as embedding graphics such as logos. All information is based on pure text with the look & feel of a text message.

- Text length (system output)
  Depending on the language and on the platform there are limitation on the number of characters per message. The maximum are 182 characters per text page, except the first page that is restricted to 157 characters. Languages using special characters and being represented by 16-bit Unicode only allow half the characters, i.e. 91 for regular pages and 78 for the first page.

- Menu length
  Ideally it is advisable to have a very precise and a maximum of 5 options of menu. This can help the user to see the available option immediately. But in case more choices are required for the ease of usability it is recommended not to exceed 9 items.

- Dynamic hyperlinks
  As dynamic hyperlink is dependent on the type of platform it is recommended to design explicit hyperlinks (pre-defined hyperlinks like "next", "back" and "more") for the extended output. This will again depend on the limited resource, such as number of menus and number of text characters.

- Length of answer
  Some services may be difficult to set in the form of limited number of menus, so we will need to enter free text from the user or we may combine the menu with the free text. Therefore the maximum characters for answering is 133.

- Multi-slot input
  The USSD channel allows no multi-slot input. At a time only one answer is possible, while the services need more answers, it can be done in the form of sequence. To proceed from one output to the next one the user has to send a request. The default request code is "1" being represented as "1:OK".

- Time constraint
  Although USSD is seven times faster than SMS, it depends on the carrier and transmission distance. And on average from calling a service to displaying the first page of the application will delay form 3.5 seconds to 6 seconds and subsequent pages have an average delay from 0.5 seconds to 1.5 seconds.

- Resolution of display
  Since the resolution of the display is totally dependent on the types of platform and the USSD application is available for all GSM cell phones, we have to design by taking in to consideration of all type of mobile with small screen, low display resolution etc in order to increases readability and improves the usage of space.

- Standard navigation
  While the navigation is needed inside of a sequence processes we would manage it with the hyperlink but if it needs to get back to the last menu, for instance, when the caller chose a wrong path. Even better and more logical using the generic hyperlink back is offering the menu itself [33].

3.3 HIGH LEVEL COMMUNICATION ARCHITECTURE

In this section we are discussing about how our proposed application can communicate with the necessary external system interfaces to build a fully functional application. In this application the system interfaces are the LEMP's subscriber who needs our application, the telecoms operators (we called this in the document interchangeably as carrier operator) in which we are going to use one of their services (USSD), and our location based application (can be called server side application). Before going to discuss our communication it is better to see the trends of how the contemporary LBSs can communicate with their external system interface, as we found from many prior studies [13, 42, 43]. Figure 3.2 (a) [13] shows the high level system architecture for smart phones. And (b) shows the modified system architecture for LEMPs.

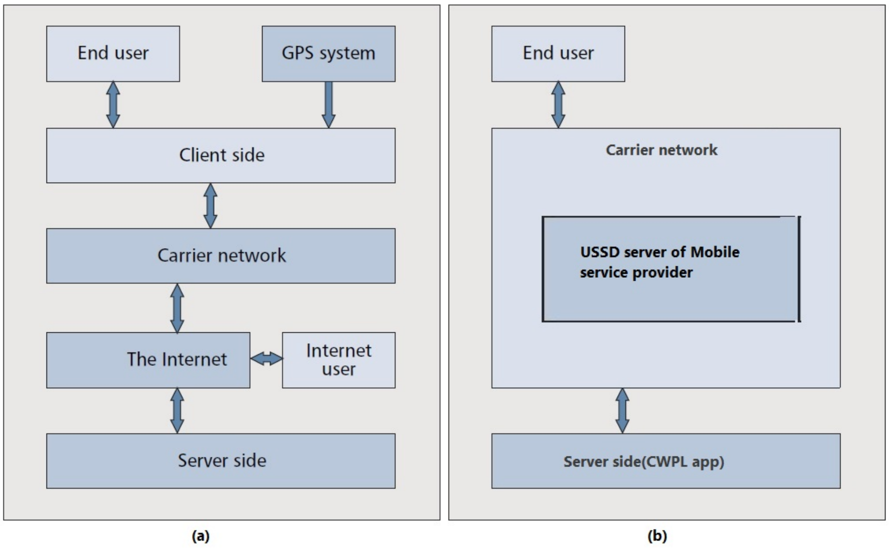

Figure 3.2: (a)High-level system architecture, (b) is CWPL's system architecture, it is modified to support the LEMPs.

Chapter 4

Closest water point locator (CWPL)

4.1 INTRODUCTION

This chapter discusses the prototype design and development of the application which is called closest water point locator (CWPL). CWPL is a location based service which is designed for the LEMP users to locating the closest functional water points. Section 4.2 discusses the service components which have been developed by this project in step by step scenarios. Section 4.3 discusses the pre-processing parts which have to be done before the design of the algorithms of the application and Section 4.4 discusses the prototype building of the application.

4.2 SERVICE COMPONENTS

CWPL has four main service components which are necessary to ensure the functioning of our application. Figure 4.1 shows these components, the necessary data and its source. They are:

- User location determination (ULD)
- Water point location determination (WPLD)
- Spatial data display as a text (SDDT)
- Service delivery method (SDM)

All components of this application are designed almost in standalone mode. This does not mean they are not dependent on each other but there is no going back and forth between the components, just the output of the former is used as input for the next component. In the next subsection we are going to discuss each components in detail.

4.2.1 User location determination (ULD)

ULD is designed to determine how we can place users location on map. This should be done from received service request messages. Since this method depends on mobile phones' capability and the users' geographic area of living, we have investigated many potential ways by taking into consideration of these situation. The following are most promising methods to obtain the user location.

1. Working collaboratively with the telecom operator to obtain the geolocation of the visited BTS[1].
2. Users look up their own closest cell tower from their mobile phone and send to our application.

[1] Base station is an equipment which facilitate wireless communication between the user phone and Telecoms infrastructure. See Section 2.6.2.

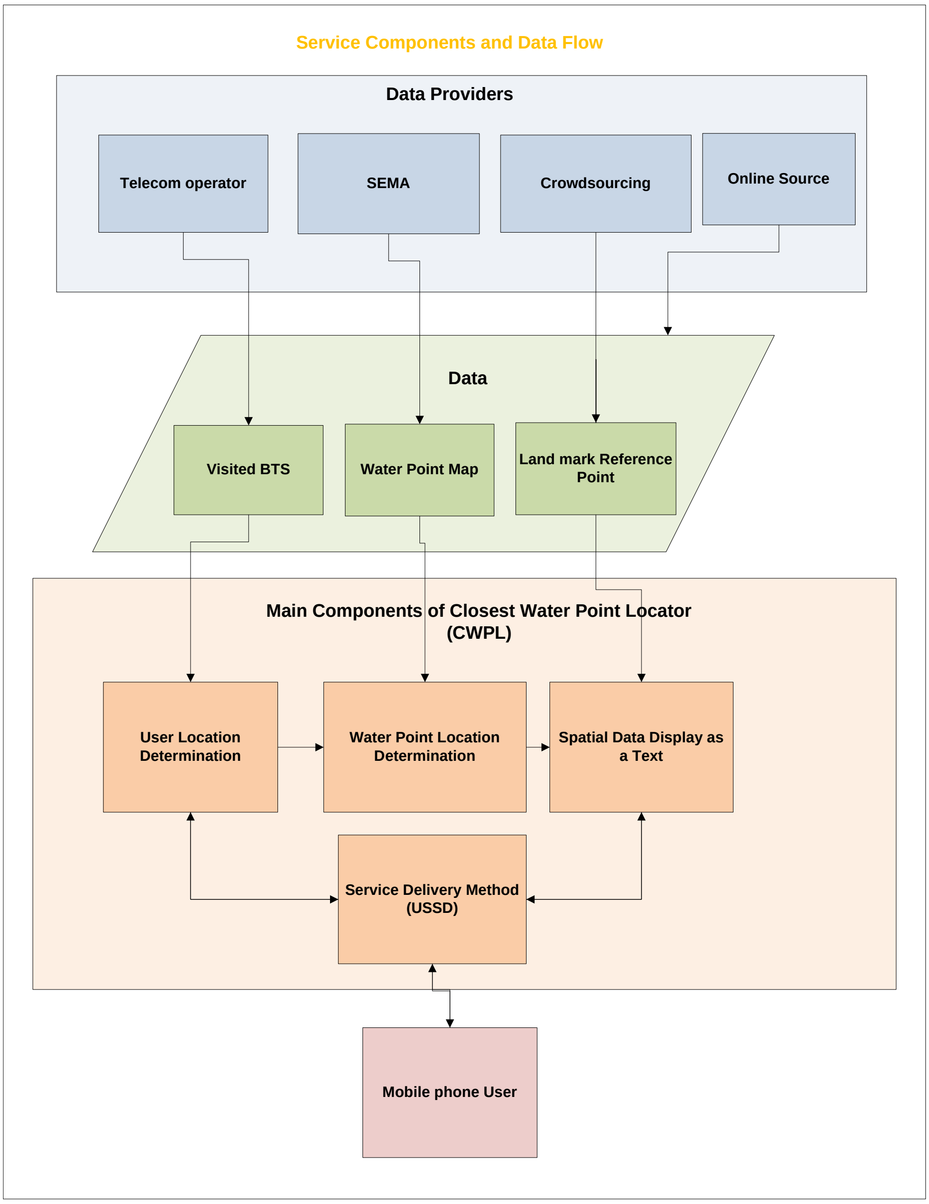

Figure 4.1: Schematic diagram of the service components and data flow.

3. Users ask their telecoms operators about their location and send for our application.

4. Users enter their Village name.

From these four candidate approaches, we adopted the first and the fourth approach, because the second and the third are complicated to implement and they require the familiarity and expertise of the users about how cell tower could be distributed over the area.

1. Working collaboratively with the telecoms operator This method requires to work with the telecoms operators in order to obtain the geolocation of the visited BTS. While the user sends a USSD message to request our service, their phone communicates with one of the nearby antennas. This event is recorded in the carrier's database as a billing event that can later be used to generate an invoice (see Table 4.1 [40]).

Table 4.1 Example of Mobile operator's (Deutsche telekom) billing data.

Beginn	Ende	Dienst	ein/ausgehend	Laenge	Breite	Richtung	Cell-Id_A
8/31/09 7:57	8/31/09 8:09	GPRS	ausgehend	13.39611111	52.529	30	45830
8/31/09 8:09	8/31/09 8:09	GPRS	ausgehend	13.38361111	52.53	240	59015
8/31/09 8:20		SMS	ausgehend	13.38361111	52.53	240	9215
8/31/09 9:12	8/31/09 9:12	Telefonie	ausgehend	13.37472222	52.530	120	1845

Since the carrier is from Germany the data is recorded in German. The records start with a beginning date and time, and, when the service is not instantaneous (e.g. SMS), an end date and time as well. The third column describes the type of service (e.g. GPRS internet access, SMS, or voice telephony), and the fourth indicates whether it was inbound or outbound. Columns five and six contain the longitude and latitude, respectively, of the antenna covering the cell used by the phone. If the antenna is directional, column seven contains its direction, as a bearing in degrees clockwise from north, otherwise the value is null. Column eight contains the cell's ID, and column nine contains the redirected cell-ID of the other party to the service but the last one is not included in the data we found.

We can use this record as one of our inputs. However due to privacy and commercial sensitivity, mobile phone belling records are not generally available for use [40]. Therefore in order to access these records at any cost we will involve in a two way agreement with the carrier for the sake of application development.

Knowing the geolocation of the visited BTS gives us a "rough estimation" of where the user location is. Depending on how many cell towers are in that area. The "rough estimation" could be as a few square kilometers to 30 square kilometers [21, 23], (see Figure 4.2 [44]).

However research from [21, 23] has shown that using the visited BTS alone as location determination is not viable, for LBSs which require high accuracy. Likewise our application "closest water point locator" needs a better accuracy than the possible accuracy one can get by using Cell-ID positioning method.

Therefore for further approximation of the user location we designed an interactive communication between the application and end users using the USSD messages.

In this method we are divided the roughly estimated area into smaller villages as many as the number of village names we find in the database. This village names are selected from

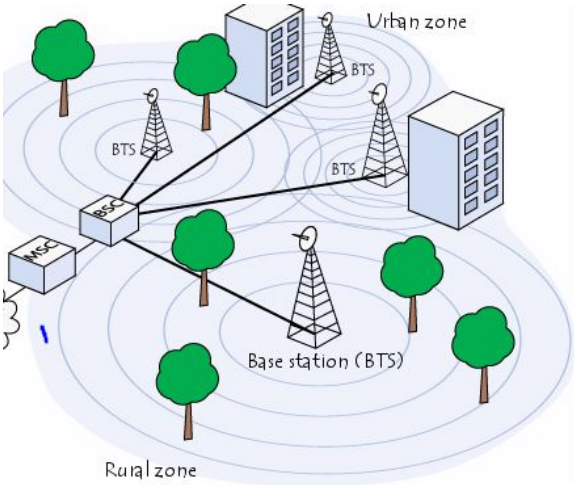

Figure 4.2: Base station tower distribution between urban and rural areas.

the areas which are potentially covered by the antenna which is within maximum of 30 kilometer radius[2].

These names are provided to the user as USSD menu, then the user can choose their village name, and the conversation is continues until we find the user's more proximate local name. Since most of these local names are referring the location of one or more water points, indirectly the position of the users can be determined based on the distribution of the water points. This implies wherever the actual location of the user is found within a chosen village, the application needs to know which group of water point is near to the user, is enough.

2. Users enter their village name.

   The second method uses interactive communication between the application and end user using the USSD messages without the aid of visited BTS. While the user sending a USSD message request to the application they are provided with the question whether they are know their nearest water point name or not. Since the database stores all water points along with their coordinates, the location is then also known. But if they do not know, they are asked to enter their village name. Then the application queries the local name from the database for further approximation.

4.2.2 Water point location determination (WPLD)

WPLD is the second component of the application which is analyzing the water point map to facilitate the decision making process of which water point is closest to the user current location.

The analysis part include checking the availability of water points. Availability can be measured in a combination of values such as its functionality and capacity level of the water points near to the user geolocation. The functionality is recorded in the database in three levels such as "functional", "non functional" and "need repair" but from the user point of view the application can take only the functional water points as the state of availability. The capability level, can be measured by balancing the number of sending users for that water point and the number of population in which the water point was constructed for. After we found the water point, which qualified the above criteria, its geolocation passed to the next component.

[2]this radius is the maximum cell size from prior studies [21, 23]

4.2.3 Spatial data display as a text (SDDT)

SDDT is the third component. After identifying the geolocation of both the user and the available functional water points, the next step is to return enough information for the user. This information includes the name of the water points and where those water points can be found. Since we cannot display the map of the routes on LEMPs screen, we have to guide our user by using text format. Explaining landmark features which are found near the water points can help the user to easily remember the selected water points.

The landmark features can be any publicly known ones (like hotel, school, playground, park) or natural ones (like mountain, hill, big tree, river, and so on). Recording all types of land mark features which are existing near to the water point can facilitate the process. In addition to the landmark, the text display also includes the estimated walking time to the water points, which can be produced based on the calculated distance between the geolocation of the user and the geolocation of the selected water points.

4.2.4 Service delivery method (SDM)

SDM is the fourth and the main component of the application. As we already discussed in Section 3.2 LBSs need to exchange information between the users and application running on the server. For LEMPs this can be done via one of the text channels, USSD. As part of the application development our role is modify all outputs based on the constraints of this text channels. Therefore all the communication we have in the application is built based on the USSD text channels, see Figure 4.3.

Figure 4.3: Sample USSD menu.

4.3 PROTOTYPE DESIGN : PRE-PROCESSING

4.3.1 Source database analysis

The source of the water point's database is in the form of a spreadsheet having 65,535 rows of data and 38 fields. Some of the following fields are selected in order to locate users and water points (names of water point, district, ward, village, sub village, and latitude and longitude). However, using village name as positioning of the user can creates a confusion between different places. Because as shown in Figure 4.4 many village names are used redundantly in different parts of the country. Therefore, in order to specifically identify the places it is required to use the district and ward names together. Likewise, sub village names help to more proximate the location of the user by dividing the large village area into smaller units. However, a significant number of villages have no sub village names, and as a result we used the gazetteer (Geo-name) of Tanzania in a village we can not find recorded local names.

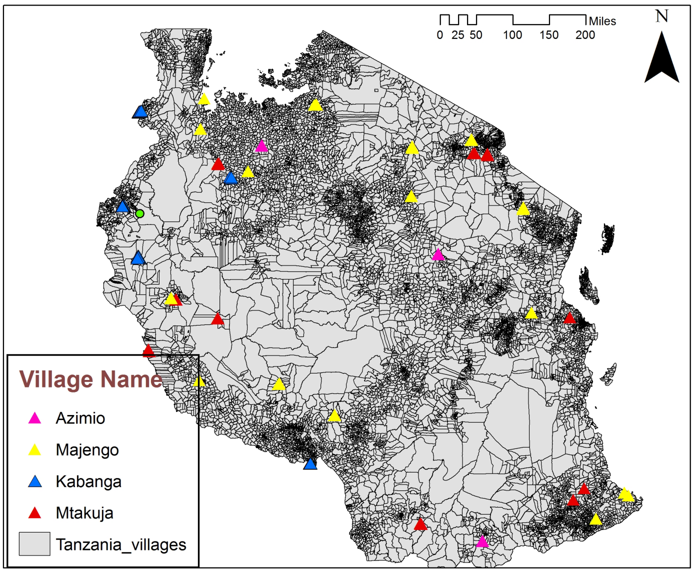

Figure 4.4: Geographically different places called with the same name.

4.3.2 Water points gazetteer generation

Before computing users location we are produced Short-form gazetteers, based on the distribution of the water points in the country. Short-form gazetteers means a gazetteer which contain a list of place-names together with their locations in latitude and longitude and/or other spatial referencing system. Like other Gazetteer editors, we are also gathering these facts from our officially collected water point map of the country. All water points have their own geolocation in latitude and longitude and place names of the local area. Therefore we are using this information in the process of user location determination to reference the geolocation of the user. As shown in Figure 4.7 on page 28 if the decision point at "is sub village name redundant" is yes. That implies one single local name is recorded for more than one water points in the database. To minimize the confusion of representing different coordinates with a single name, we tried to collect those points and form a polygon by using built-in postGIS database. And assigning the local names for that polygon. As shown in Figure 4.5 there are four polygons labeled from 1-4 in a village namely 'Isanjandgu'. For example the first village has seven dots, each dot is representing one water point and each water point has a local name. But all these seven water points have the same local name "Legeza Mwendo". We are connecting all points in order to form a polygon as well as assigning its local name for it. From now this local name is refereeing the polygon instead of refereeing more than one water point which is found in different coordinates.

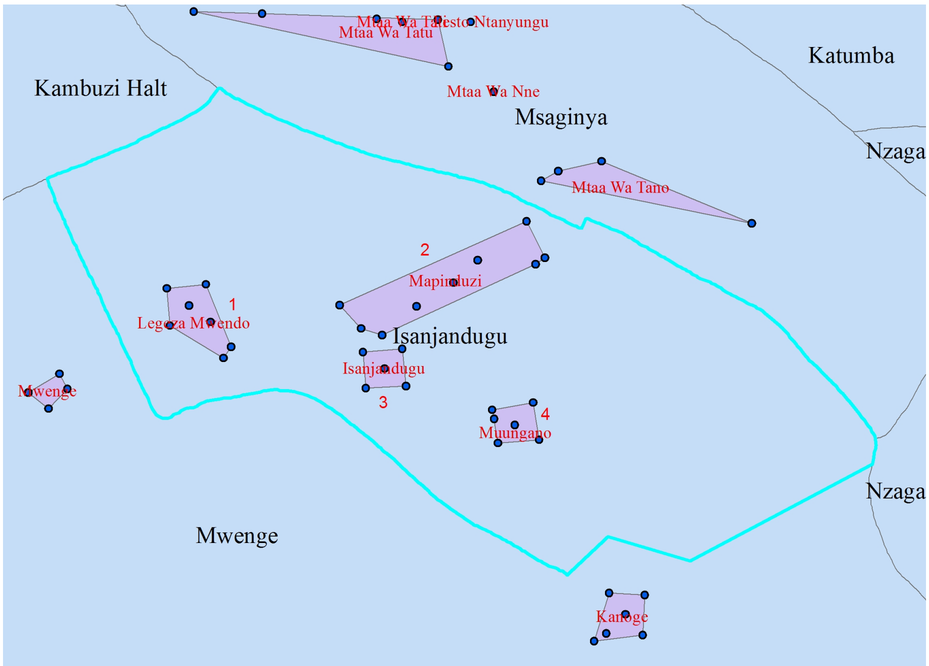

Figure 4.5: Water point gazetteer. Each dot represents the location of the water point and the polygon is labeled by the sub-village names of those water points.

4.4 PROTOTYPE BUILDING

4.4.1 Architecture of the application

In the following subsection we are discussing the concepts, procedural requirements and design of the application in much detail along with its inputs and intermediate outputs of the components. For the sake of understanding and to have the birds eye-view of the entire communication within the four components of the application, we are designing the conceptual model of the whole application together (a-d) and later we will discuss each part separately (see Figure 4.6). First consider the component of the application that determine the user location. This component has two parts: one is identifying the user village name which is labeled (1) and the second one is the approximate user location which is labeled (2) in the figure. We are dividing these components into two parts in order to show where the two methods of implementing this components are different. Therefore their difference is in the techniques we are using to identify the user village (1), but (2) and the rest of three components are the same for both methods.

The second component of the application is WPLD, which is shown (b). It has its own sub components, which can be processed to check the states of the water point and calculate the distance to the user. This again can be input for the third component, SDDT (c). Finally the fourth component SDM, is executed to decide how the output can be displayed on LEMPs screen (d).

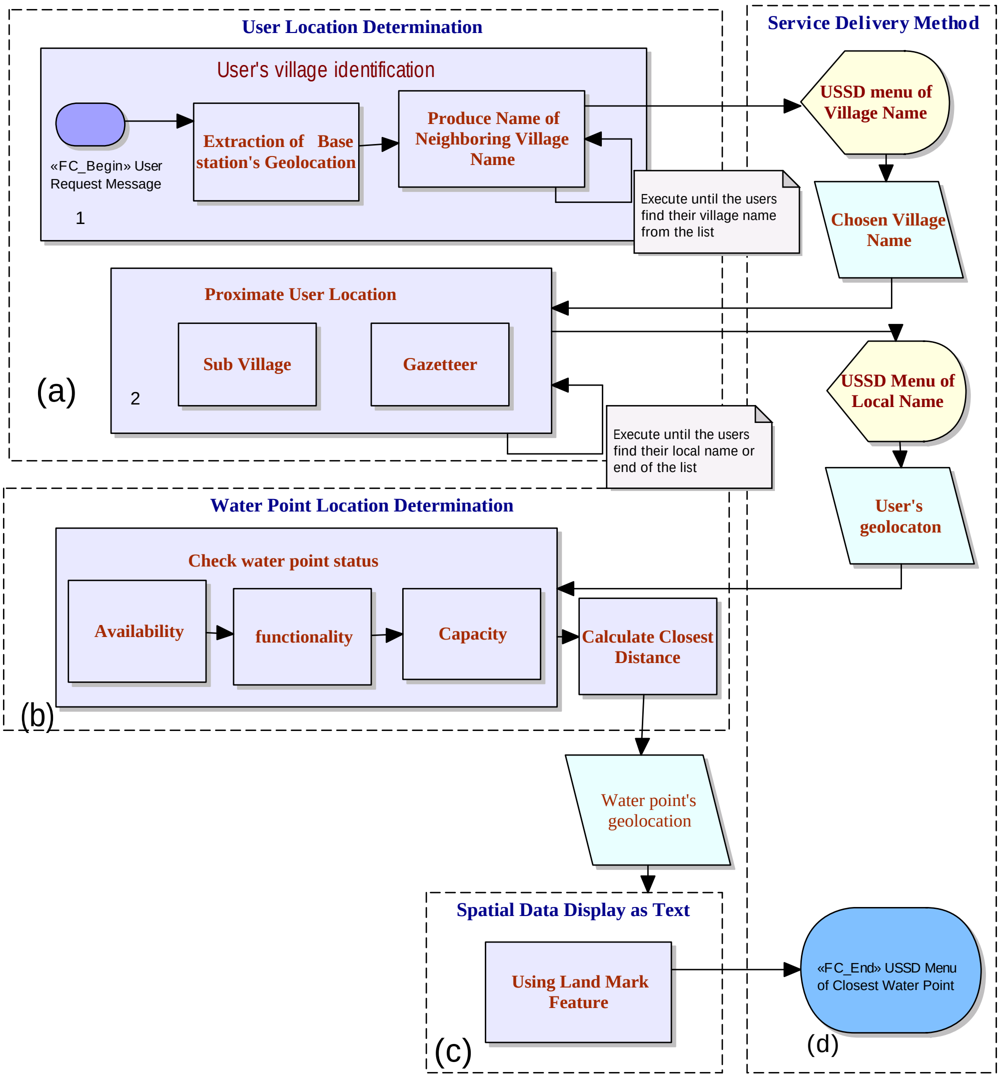

Figure 4.6: Conceptual model of closest water point locator, (a-d) are the four components of the application.

(a) User location determination (ULD)

Since the first component has two methods of implementation, we are going to discuss both algorithms with their respective input, process and intermediate output before proceeding to the next component. Figures 4.7 and 4.8 show the similarities and differences in terms of the conceptual diagram. Its implementation in the form of algorithms is described below.

1. Working collaboratively with the telecom operator

   Figure 4.7 shows the conceptual diagram of ULD based on the geolocation of the visited BTS. The application executes fifteen commands/methods. The methods are discussed in the form of verbose algorithm as follows. (a) shows the first part of the component that is covered from step one to step seven in the algorithm and (b) shows the second part of the component which is from step eight to step fifteen.

   Input:

   The component needs four types of data sets: Billing records of the carrier, administrative boundary of a country, Geo names (gazetteer) of the country and water point map of the country.

   Process:

step 1 Extract the geolocation of the cell tower from the user message, two attributes from the billing record of the carrier are needed, that is longitude and latitude (see Table 4.1 for the structure of the billing record of the carrier).

step 2 Buffer this point feature at the distance of 30 kilometers. [3]

step 3 Check if the village name exists more than once but in different districts. If yes, continue to step 4. If no pass to step 5

step 4 Display the district name followed with its village name. In this case the structure of the menu will change, see delivery method below.

step 5 Select each Village name under the buffering area and divide the selected village name into eight parts until the end of the selected list.

step 6 Display one group of village names at a time until the user finds its village name or until the end of the list. If the user cannot finds its village name in the list, go back, and execute the second method.

step 7 Receive the user's choice of the village name and check another sub administrative unit name under that village, or gazetteer name which are found in that village.

step 8 If any result is found from step 7, form a group of eight local name and display one group at a time until the user found its nearest local name or until the end of the list produced.

step 9 Check if the submitted local name is sub village name or gazetteer name. if it is gazetteer name pass to step 15 if not continue to the next step

step 10 Check if the sub village name exists more than once if it is true continue to the next step if not pass to step 15

step 11 Select the redundant local place's geolocation and form the convex-hall

step 12 Calculate the center of the convex-hull of polygon feature

step 13 Add the x-y coordinate to the center of the convex-hull polygon feature

step 14 Assign this coordinate as the user's geolocation

step 15 Pass the geolocation and the village name which is chosen by the user in the sixth step, to the next component.

[3] this distance is the radius of the Large Macro cell

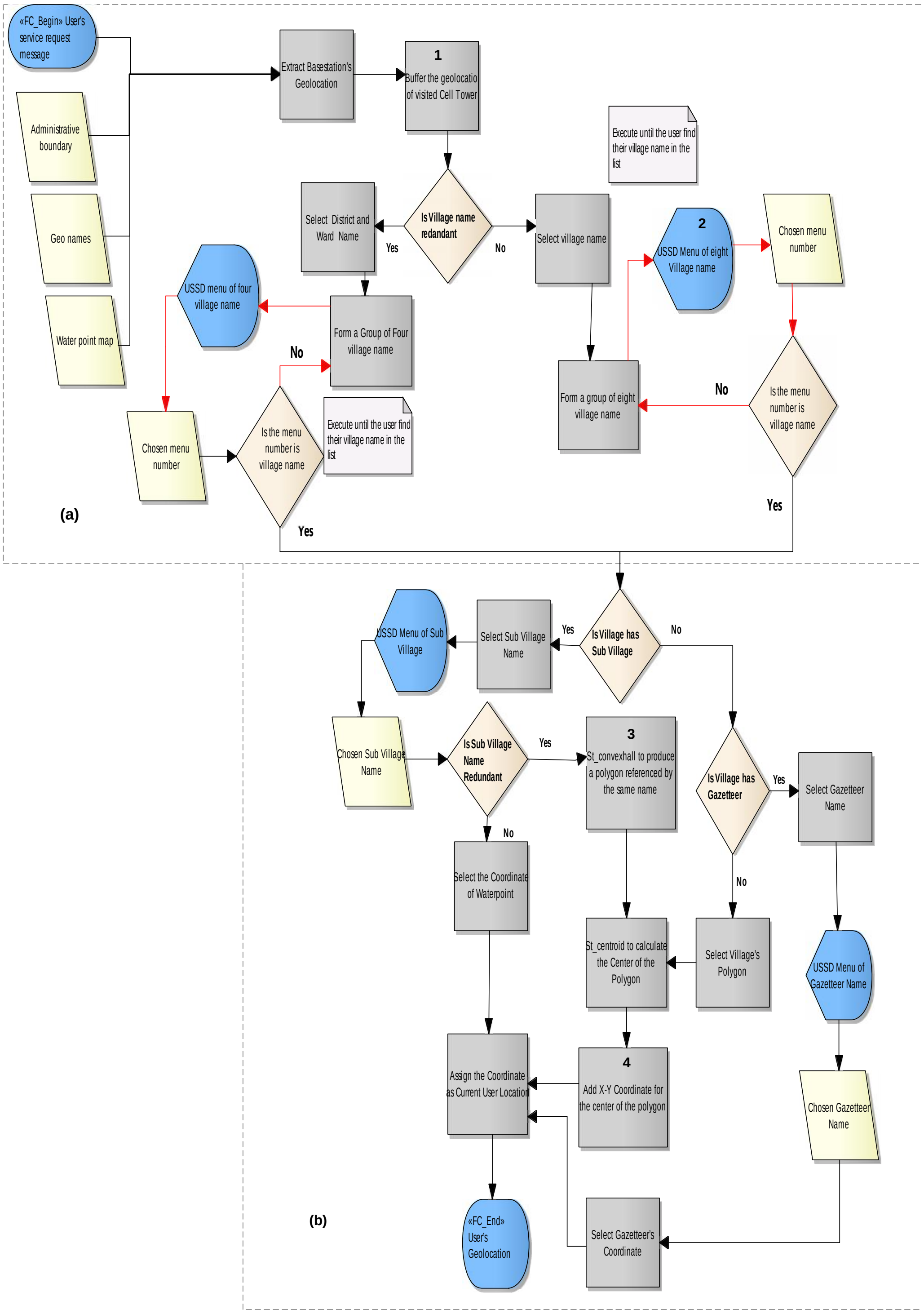

Figure 4.7: Conceptual model of user location determination using the carrier billing record (a) shows the difference between the two methods. Later for the second method it is replaced by Figure 4.8 and (b) is common for both methods and can be append for the second method. For numbers from 1-4, see its visualization in Figure 5.1, 5.2, 5.4 respectively.

Output: User's geolocation and the village name.

2. User enter their Village name

Figure 4.8 shows the conceptual diagram of ULD based on the user entered village name. In this method we require input from the user that is their village name or the name of the nearest water point name, if possible. Since these two methods have common features this conceptual diagram is not complete by itself. So we can append the second section or (b) from Figure 4.7 in to Figure 4.8 , to see its full function.

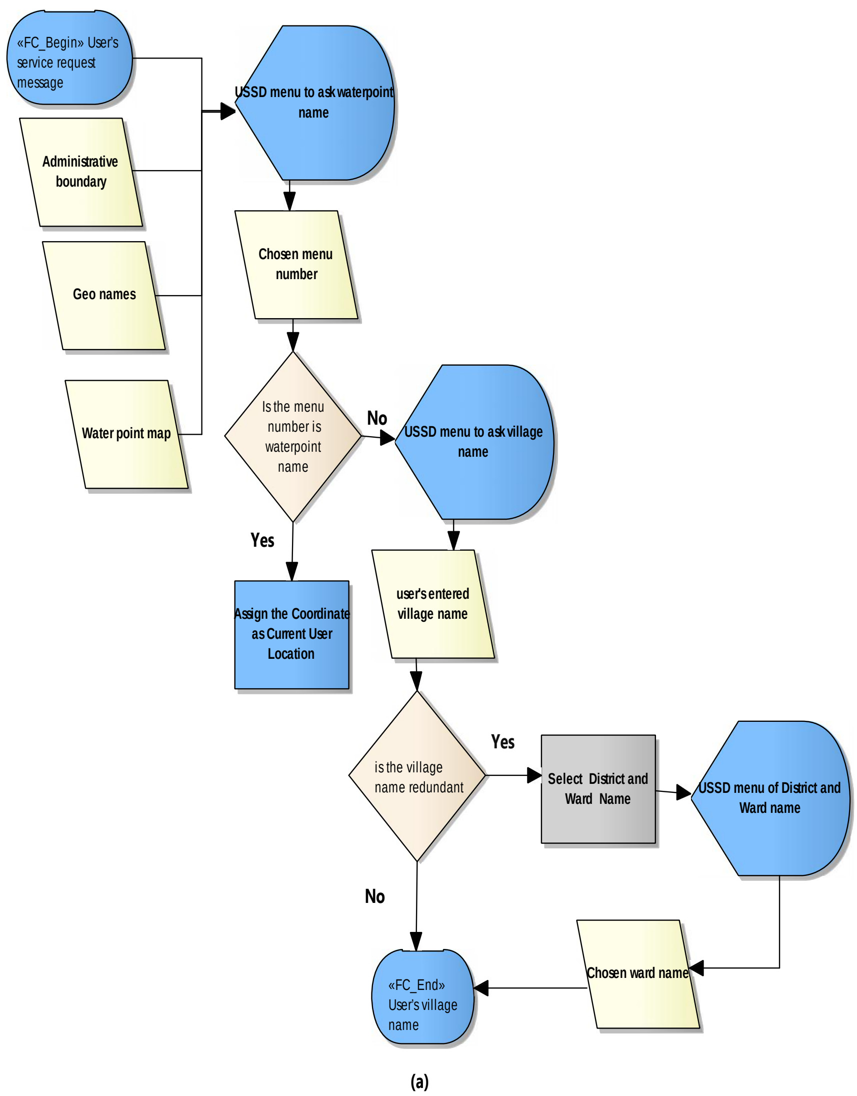

Figure 4.8: Conceptual model of user location determination through the interactive communication with the user.

Input:

Similar to the first method we have four types of data sets. Instead of the carrier belling record here we are going to use the user entered village name or the nearest water point name. While we are using this method the first five steps are done via interactive communication with the user. We can see the differences more in terms of the produced menu than in the algorithm, see Figure 5.6.

Process:

Unlike the first method, here the application starts with the interactive communication, because we cannot know the user location without the involvement of the user. The following five steps are doing the interactive communication until we find the user village name, then the next steps are common for both methods.

step 1 After receiving the user request message, display the first USSD menu with the question of whether they know the nearest water point name or not. If they know pass to step 2 if not pass to step 3.

step 2 Display the next USSD menu to allow them to enter the water point name. If they know pass to step 14, if not pass to step 3.

step 3 Display the next USSD menu to allow them to enter their village name.

step 4 Check whether that village name is redundant within different the country. If it is yes pass to step 5 if not pass to step 6.

step 5 Display the next USSD menu of district and ward name followed by village name.

step 6 From this step onwards both methods follow the same algorithm so we can adopt step 6 to step 14 from the first method. These steps are also depicted in Figure 4.7(b).

Output: User's geolocation and the village name.

(b) Water point location determination (WPLD)

As Figure 4.9 shows the determination of the geolocation of available water points. The application executes ten commands. They are discussed in the form of algorithm as follows.

Input:

Two type of data sets and the outputs from the first phase are needed. Such as water point map and administrative boundary of the country, and the geolocation of the user respectively.

Process:

step 1 Intersect the geolocation of the user over the water point map.

step 2 Select the village with its neighboring village.

step 3 Check if there are water points in the selected villages. If yes pass to step 4, if not pass to step 10

step 4 Check if the selected water points are functional, if yes pass to step 5, if not pass to step 10

step 5 Check if the selected water points have capacity to serve the user, if yes pass to step 7, if not pass to step 10

step 6 Calculate the distance between water point's and user's geolocation

step 7 Ordered the name of water points by their distance ascending.

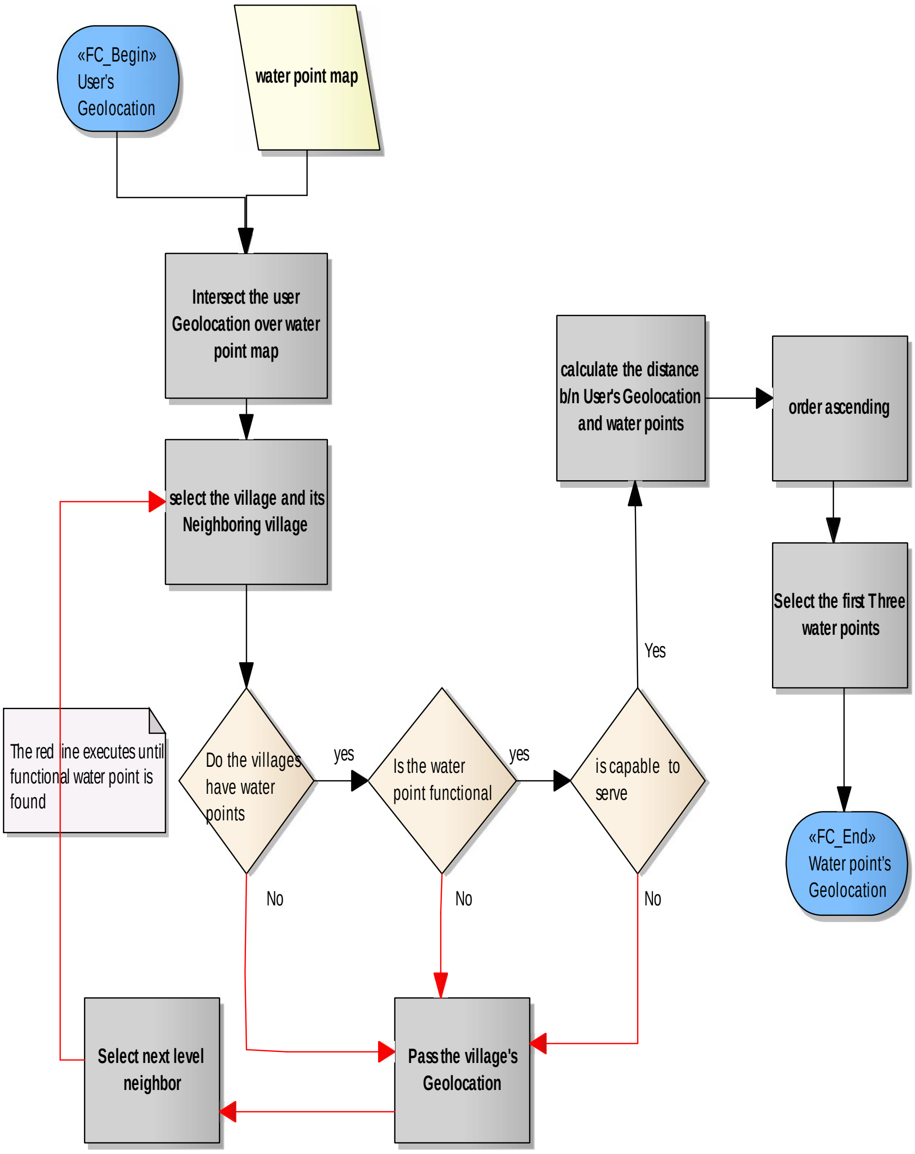

Figure 4.9: Conceptual model of water point location determination.

step 8 Select the calculated distance and change to walking time.

step 9 Select the first three water points and pass their geolocation and their walking time for next component.

step 10 Repeat the process from steps 2 to step 6 until the available water point is found.

(c) Spatial data display as a text (SDDT)

This component is implemented by associating the name of the water points found from the previous phase with the near by landmark features. In technical term the task of this application is concatenating the name of the water point with its near by land mark features. But there are many jobs which have to be done before reaching to this step. Because there are no landmark features data in the water point data set, we should collect this data a head. However in the water point database we have more than 65,000 water points and thousands of additional water points are going to be part of the database, so recording the land mark features for all of these water points is very tedious. Therefore we designed a crowdsourcing method which can reduce our costs significantly.

As part of the SEMA research project, we can use an application which is already done by the project. There is an Android application which has been developed to update the water point database. This application is going to be used by formally organized groups, namely Community Owned Water Supply Organizations (COWSOs). They will use the application to report the status of the water points. This can be done every one or two weeks. Therefore we can use this organization and their application in order to collect the landmark features.

The procedure which we are followed is:

step 1 Contacting the group who are working on developing an android application to orient the advantage of the landmark feature.

step 2 Modifying their database schema by adding additional table that can store the land mark features of the water points.

step 3 Modifying the user interface of already available android application, see Appendix A.1 & A.2

The display includes the measurement of distances between the user location and the selected water points. We are calculating the distance to provide three water points for the user in the order of the shortest distance first. And to give a suggestion for the user how long they can walk to get the water points. The walking time can be calculated based on the assumption of the average walker and without considering the time lagging if the walking is in a difficult situation [45]. The walking time used equals 2.5 miles per hour.

4.4.2 USSD application development

Even though the technical details of USSD are beyond the scope of this research, we seek to briefly discuss it for the reason to understanding the required processes from our side. In order to send data for our users (on their mobile phones), we need to have access to the USSD server of a carrier operator i.e. we need to have their account in order to configure our URL there. In addition to that we need to have the USSD code, see Section 3.2.3. This code is what we provide for our users to dial when they need our service.

To answer the user's request in our side we have developed an application which generates a USSD menu and sends back to the carrier's USSD server in the format and syntax that carrier's USSD server API supports like HTML, XML, VXML, etc. Then the server will direct that response to the user mobile. The back and forth sending continues until the session is timed out [46].

4.4.3 USSD menu design for display

This component is equivalent to a user interface design part in any software development environment. So like any other type of interface we designed our USSD menu, based on the user's experience and USSD's technical constraints. In the USSD channel all information is based on pure text with the look and feel of a text message. This mean it is not possible to include any graphics and layout [33]. As shown in Figure 4.10, USSD is a menu driven application. All communication between the user and the application platform is based on the predefined answers. The following lists are discussed the technical constraints (see Section 3.2.4) of the USSD channel and the techniques how we are modifying our application accordingly to get the best out of it.

- When our response is larger than 157 characters, we do not include any welcome statement in the first page of the message.
- The maximum number of character per message is limited to 182 and the menu length is restricted to 9, therefore we have to group the village names to displayed. Every group has eight village names, and developing an application that can loop until the end of the list or until the user can find its village name.
- USSD does not allows multiple input so all of our requests obtain one answer at a time. For example, users are asked their village name and local name separately.
- To support an easy replay, the menu item should be preceded by a number, therefore the users are not required to text the name of their village. Instead they just send the number.
- Output concatenation, USSD can not automatically concatenate one output to the next, the user must request the followed information. Therefore, for each menu we have designed a next option in the menu, where we are dividing the number of displayed village into eight as the maximum possible menu item can be nine.

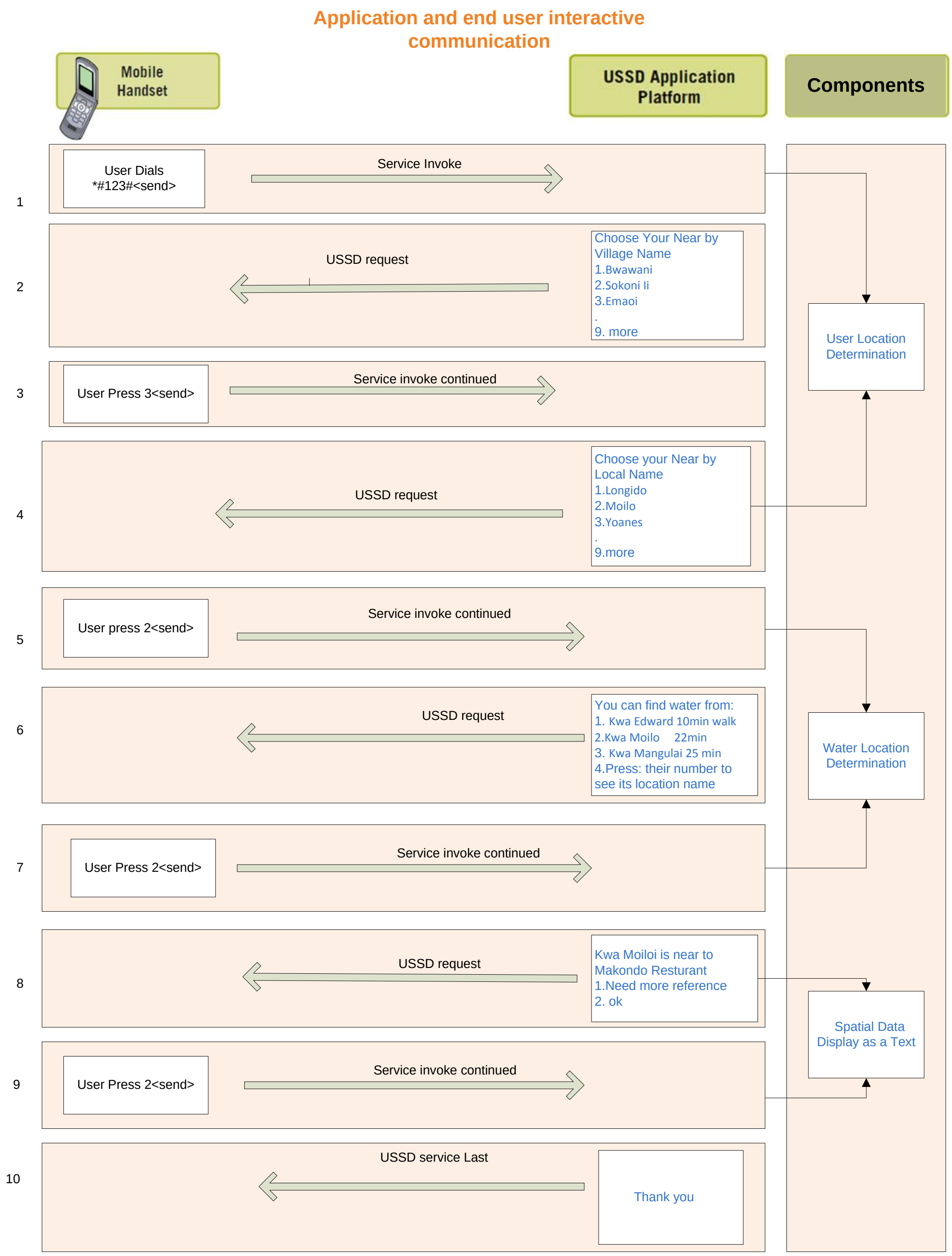

Figure 4.10: The overall USSD menu of the application along with its components in the application and example user choices.

Chapter 5

Prototype implementation and testing

5.1 VISUALIZE THE APPLICATION

This section is discuss the application by separating the entire process into its three components. Since the fourth component is a tool, we can see its effect on all of the three components. The visualization includes the steps of the application starting from the user service request message to the last USSD item of the communication. In order to create a clear imagination of how the system works, mock-ups of mobile phone displays are used instead of the actual prototype interface. For the latter, the reader is referred to Appendix B.

5.1.1 User location determination (ULD)

We have two methods for ULD and we are going to visualize them separately.

1. Working collaboratively with the telecom operator

   While the user send a service request message to our USSD application server, see Figure 5.6(a), the app starts to identify the user's surrounding villages by buffering the geolocation of visited BTS. The buffering distance is at the maximum coverage area of the omni-directional antennae. Figure 5.1 shows the produced buffered polygon by taking the following geolocation of visited BTS Longitude = 33.154 & Latitude=-2.943

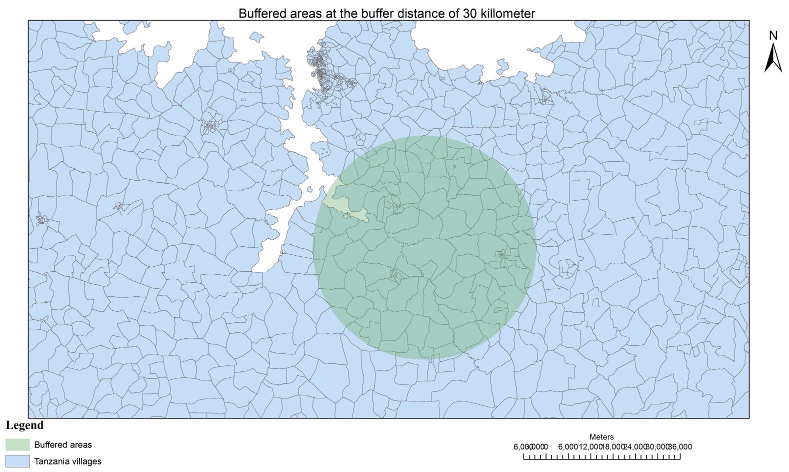

Figure 5.1: Buffered areas based on the maximum coverage areas of the visited base station transceiver.

Figure 5.2 shows how the village names are displayed in the form of the USSD menu. The display has nine menu options. The first eight are village names and the ninth menu item lets the users to request more village names until they find its village name on the menu. The length of menu can be less than nine if we find long village names. This is because the maximum number of alphanumeric character of the USSD message should not be more than 182.

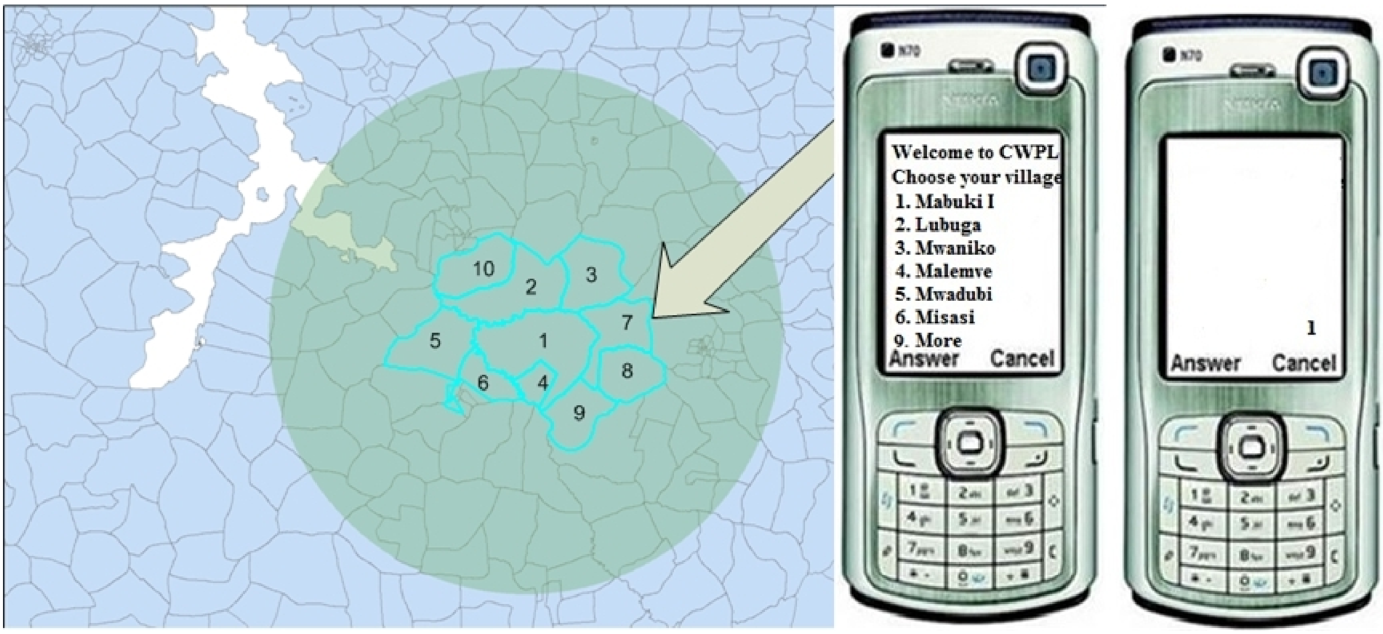

Figure 5.2: USSD menu of the first group of village names, which can be covered by the visited BTS, the circled polygon on the map.

The center of the buffered polygon is the geolocation of the visited BTS. The selected polygons which are found inside the buffered polygon are the first group of the USSD menu ordered according to their distance from the center.

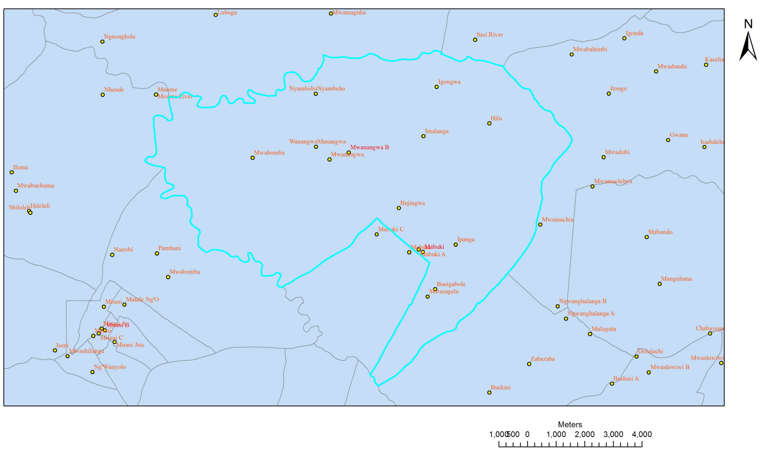

Figure 5.3: Chosen village name and its local names.

Since the name of the village displayed preceded by number, the users can easily reply by entering a number. But if the users are selects number 9, it means they cannot find their village name inside the menu. So the application will reply with the second USSD menu. This can continue until the users find their village name and/or until the whole buffered village names are displayed.

After receiving the users choice of the village name, the application query the available local names in that particular village, in order to better approximate the user location. Figure 5.3 shows the chosen village names and the available local names of that village. Determining the user location in terms of local names can improve the accuracy of the application. Because if the application does not find any recorded local names, under the chosen village name. It will be assigned to the center of the village as the location of the user based on the logic that, the user can be every where within that village. But instead of taking the whole polygon as the user location, local names more proximate to the actual user location by minimizing the total area of the village into pieces, see Figure 5.4.

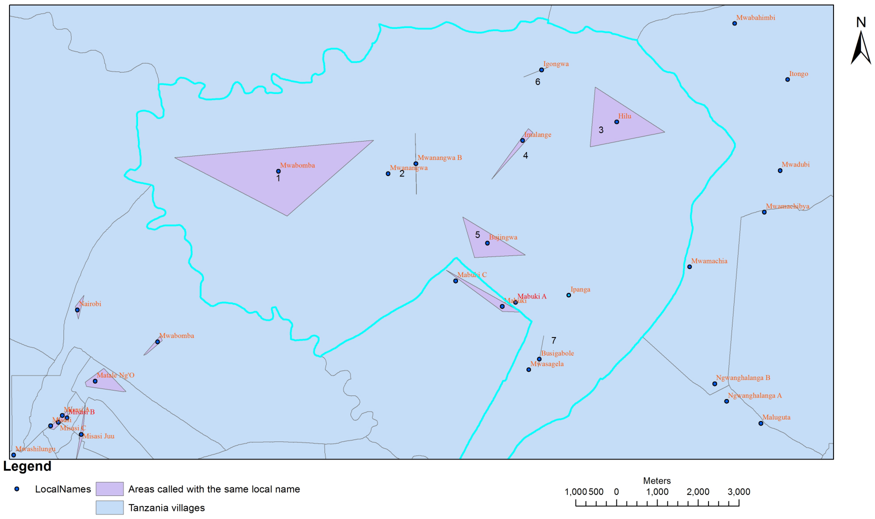

Figure 5.4: Approximating the user location in terms of local names. The number label from 1-7 is shows we have seven distinct local names.

Now the chosen village has fourteen local names (seven distinct) which are almost evenly distributed all over the village. This implies we can divide the larger polygon of the village into seven smaller parts in order to better approximate to the user location.

But now like we did with the village names, we cannot order the local names based on the proximity. Because the user can be everywhere in the village that mean all local names have equal priority to be displayed. Therefore we should display the local names randomly, see Figure 5.5. From the figure the user replies 3 and this number represents the local name called "Mwasagela" which is shown by a big arrow in the figure. That is the geolocation of the user.

Figure 5.5: USSD menu of the first group of randomly selected local names for the selected village in the map. The arrow shows the current user location.

2. Users enter their Village name.

   Since this method uses interactive communication, after receiving the first USSD request message from the user, see Figure 5.6 (a), we have to ask if they do know the nearest water point name or not (b). That is the first USSD menu of the output. From the figure their answer is no (c), so we have to ask them their village name with the second USSD menu (d) then the user entered their village name (e). Because the USSD does not allow us to use multi input, we have to ask one question at a time. If we are succeeding to receive the user's village name, the second step is to approximate the user location using a local name. If not we have to allow the user to start the process again by using the predefined hyperlink "More", see Section 3.2.4.

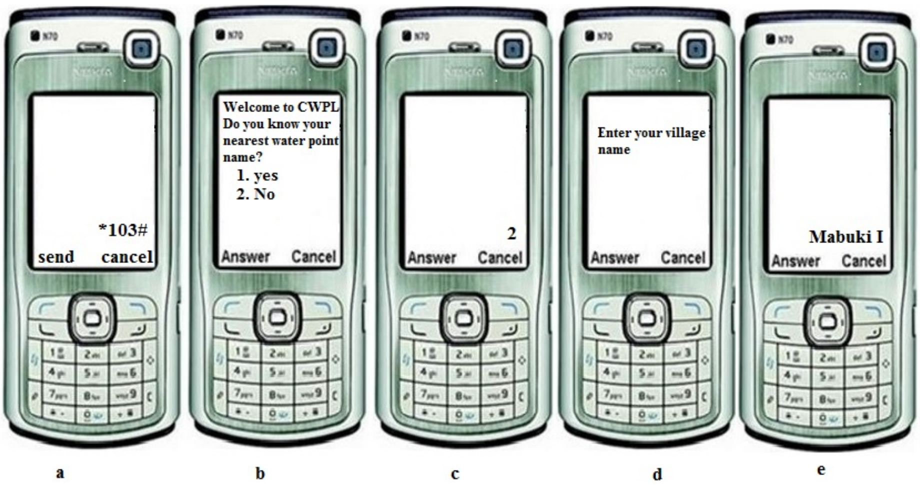

Figure 5.6: Interactive conversation between the user and application server, (a) Service request message from the user (b) welcome page together to check whether the user know their water point name or not (c) user reply (d) asking their village name (e) User's village name.

After we find the user's village name 'Mabuki I'. The rest of the process is the same as the first method. So we can continue to check the flow of the process with the produced figure from the first method, see Figure 5.3, 5.4, 5.5 respectively.

5.1.2 Water point location determination (WPLD)

As shown in Figure 5.4, the numbers from 1-7 show different groups of the local names which refer to more than one water point. Every corner of the polygons are representing the water points, for example if the user choose number 3 this local name can refer three water points.

After receiving the user's chosen local name the next step is checking the status of the water points. These processes select three functional and capable water points and displaying in ascending order with their distance from the chosen local name. And the distance is displayed in the form of walking time. Walking time can also improve the method of guiding the user to the water points. It enables them to guess how far the distance is, before deciding to which water points to go and to choose their means of transportation to get there.

In addition to distance the Capacity level is also measured in order to prevent the possible occurrence of overcrowding at the water points. Sometimes sending many users to the nearest water point might not be enough, until we are sure they can collect water from it.

Finally, we are producing the USSD menu, see Figure 5.7. The menu includes: the name of three selected water points preceded by number, walking time and an option to ask if they need references to distinguish between water points.

If their replay is from number 1-3, see the next subsection. If it is 4 the USSD application is ended by displaying Thank you message.

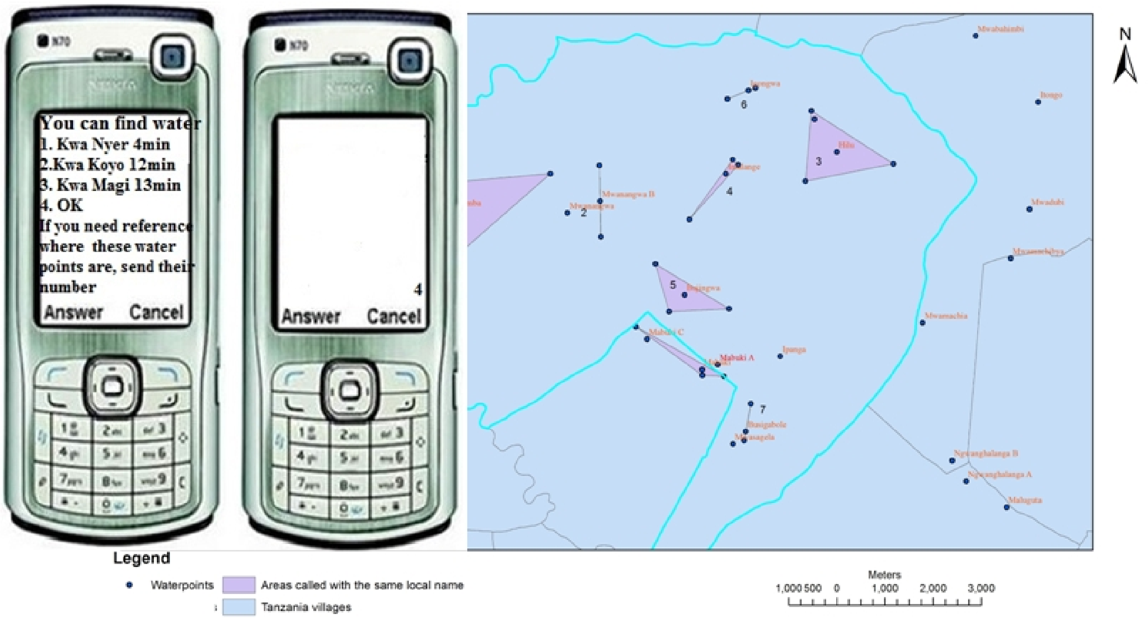

Figure 5.7: USSD menu of available closest water points for the people who are living in "Mwasagela", see number 7 in the map.

5.1.3 Spatial data display as a text (SDDT)

After receiving the name of three functional water points, the users will ask additional information how to get there, by sending number from 1-3 based on their choices of the water point. Then the application replays with the available location information which are recorded in our database under those particular water point, see Figure 5.8. The display should not more than 182 alphanumeric characters.

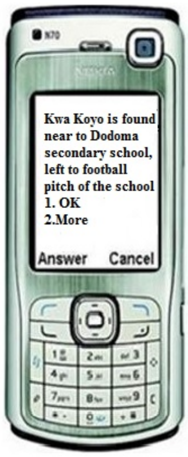

Figure 5.8: USSD menu of location information, explaining the spatial data using text in the absence of map.

5.2 EVALUATING THE APPLICATION

This section describes the strength and weakness of the application.

5.2.1 User location determination (ULD)

After the end of the first phase of our application we had the chance to demonstrate part of our application for the target[1]user of our application. This demonstration served to evaluate the usability of our prototype. As a result of this test we identified the strengths and weaknesses of the method in which the users enter their village name. The main strength is that once the users enter their village name correctly it is easy to identify user location within a maximum of two steps of interactive communication. A weakness is that the users are required to hit many keys on their mobile keyboard to enter their village name, which is error prone. Figure 5.9 shows an error message generated by the application during the demonstration.

The main strength of the second method is that the users are provided with village names to chose from the menu instead of require them to input. This reduces the user's problem of entering erroneous input as a result of hitting several key from LEMPs keyboard. A weakness is that more than two steps of interactive communication has to be done in order to identify the user's village name. As a result the message exchange may be timed out before the user gets the necessary services from the application.

In both methods, after the identification of the village name, a better approximation of the users location using the local name depends on the presence of as many local names in a database

[1]Target user is the mobile subscriber with simple mobile phone, who are living in urban and suburbs areas of Tanzania.

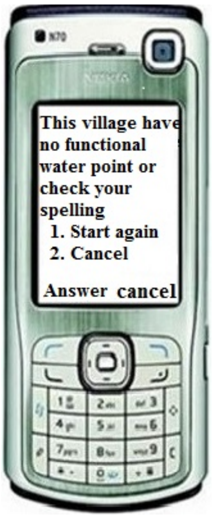

Figure 5.9: Error message generated by the application because of spelling error in user's input of Village name.

as possible. In addition their distribution of those local names over the village have an effect on the result i.e. if the local names are few and/or distribute unevenly, we will find less accurate results.

5.2.2 Water point location determination (WPLD)

Regarding the use of local names to determine the closest water point, we have the advantages over the disadvantage of inaccessibility of the positioning technology in LEMPs. As we are describing in many sections of this document, the location of the user (within the selected village) is determined via interactive communication between the user and the application. This includes asking the user about their nearest local name. But while the users are choosing their local name, they have the chance the chance to consider other situation of the local area, like the means of transportation and cost of water based on their prior experiences.

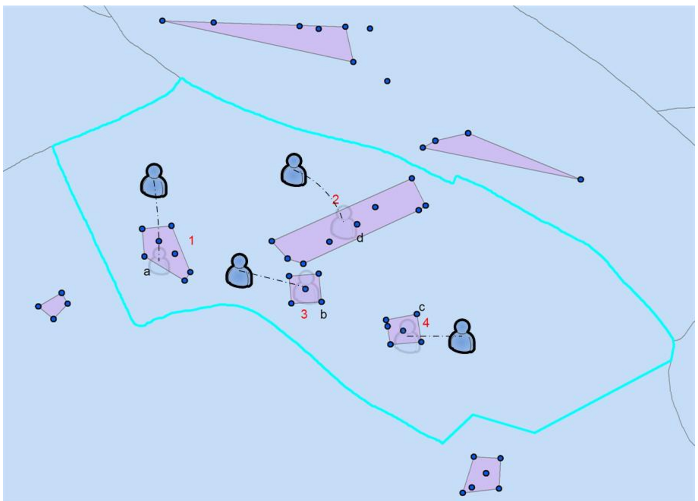

Figure 5.10: Shifting of the user's geolocation while we are using the local name of the chosen village.

5.2.3 Spatial data display as a text (SDDT)

The nature of the spatial data we are displaying to reference each water point is depend on the stored landmark features that are found near to the water points. Because some water points are close to each other they can share the same type of reference points. As part of location information we are also display the walking time to the selected water points. The time is calculated based on the distance between the user location and the selected water points. As shown in Figure 5.10 the geolocation of the user is shifted to the center of one of the user's chosen local name so this has an effect on the distance, and consequently on our suggestion of the walking time to go to the water points.

Chapter 6

Discussion, Conclusions and Recommendations

This chapter discusses the main concepts, and reflects on the basic findings of this research project. This will help us to find out the strength and limitation of our project in order to give recommendations for related future studies.

6.1 DISCUSSION

LBSs are designed for mobile device users that add value after identifying their current location (Section 2.1). As the first step of LBS, mobile phones position should be computed in some way (Section 2.6). But for LEMPs the position can be computed differently (Section 3.1) and in this research project two methods are designed (Section 4.2.1) for two different scenario.

The first method is preferred for the scenario when the application is able to guess the user location but the users are unable to enter their local name correctly. For example, the user's service request message can be in the form of "I don't know where I am but I need to go to the nearest water point". This method depends on the mobile operators because it requires data from the operators server (section 4.2.1). In addition to that, a better approximation of the user location can be computed through installing additional equipments and upgrading related software in the base station (Section 3.1).

The second method is preferred for the scenario when the application is unable to guess the users location from their service request messages but the users are able to enter their local name and street names correctly. The user's service request message can be in the form of "I live in 'Mwasagela' and I need to go to the nearest functional water point". Therefore, the application can be developed in order to allow the users to input their local name then query further based on the aim of the service.

This method can be supported via receiving a cell broadcast service messages about their local names from the nearest cell tower (Section 3.1.3). Even though it is mobile operator dependent, it can help the user to input local names properly without spelling error. Based on the explained strengths and weaknesses of these two methods (Section 5.2), it is possible to conclude that they are complementary methods to each other.

Since LEMPs do not have internet capability, the communication between the application server and the mobile phone can be built based on the text channel. USSD is the preferred text channel over SMS, as it allows communication between the mobile phones and a network based application server in real time and session based (Section 3.2.1). After mobile phone location determination, in order to display the spatial data on the LEMP screen (Section 4.2.3), we propose to describe the location using text. In addition to the text description, measuring the distance between the user and the target destination in the form of walking time is also help the user in order to understand text form of spatial data.

6.2 CONCLUSIONS

This section describes how the main research objectives were met by answering the research questions, which were formulated based on sub-objectives.

1. ***How can the location of a mobile device be determined?***

   Currently, LBS developers use radio based technology to determine the location of the mobile phone instead of asking the user to input their address manually. To compute the location of the phone there should be two ends, one is fixed, is the base station, and the second one is a moveable that is the mobile phone, which we are going to measure its position. Both ends used to emitting and receiving radio signals. So, the computation can be done on either end, based on the capability and installation of the instrument. On smart phones, the computation can be done on the mobile phone itself.

   Unlike smart phones, for LEMPs their position can be computed at the fixed end by using mobile networks and installing additional instruments in order to improve the accuracy.

2. ***How can the LEMP users location information be identified, in the absence of any built-in location sensing techniques?***

   After the communication between the third party and the LEMP is established based on the text channel, there are two possible methods to obtain the locations of the users. One is via interactive communication to obtain the locations of the users from the user themselves. The second method is working collaboratively with the mobile operators. That is configuring the carrier's USSD server in order to transfer the geolocation of the cell tower from their billing records.

3. ***Which features of a mobile phone can support access to LBSs?***

   For the provision of LBS many technologies are required (Section 2.2). So in order to support this technologies a mobile phone should have the following features location sensor equipments (Section 2.6), internet capability, and the ability to installing and working seamlessly with the third party software.

4. ***How can the LEMP users transfer their location information for third party application servers, in the absence of internet capability?***

   In the absence of Internet, location information can be dealt with through one of the mobile operators infrastructure, text channel. There are two types of text channels: SMS and USSD. Unlike SMS, USSD allows communication between a mobile phone and a network based application server in a real time and session based. These and many other basic features of the USSD make USSD an increasingly adopted type of technology over the SMS application.

5. ***What location accuracy is needed, under which circumstances, e.g., what accuracy is enough to find the nearest water points?***

Not all types of LBS require the same level of accuracy for the current location of the user. In our use-case (uneven distribution of the water points over the village), obtaining the user location based on available local names (water point gazetteers) is enough. Because the local names are used to reference water points.

6. ***How can we display spatial information on a user's LEMP screen, as replay to their service request?***

   USSD allows neither formatting and layout nor the embedding of graphics such as logos. So it is not possible to display spatial information in the form of a graph or any other layouts on LEMPs screen. Therefore instead it is possible to record all publicly known and/or natural landmark features of the area in the database, and display them in the form of text.

6.3 RECOMMENDATIONS

- Despite its own advantage of using crowdsourcing to collect the land mark features around the water points, it is still recommended to use automated means of collecting landmark features from satellite image and map.
- In this research two methods are used for user location determination. Although they can be used separately, it is recommended to use them in combination.
- No efforts were made to correct the spelling of users while they enter wrongly spelled location names, there is need for such an improvement.
- There are two types of text channels: USSD and SMS. In this research only USSD is used as a means of service delivery. To improve one of the constraints of USSD (lack of embedding of graphics) it is recommended to use SMS together with USSD.

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Appendix A

Crowdsourcing Implementation

REPORTING PAGE

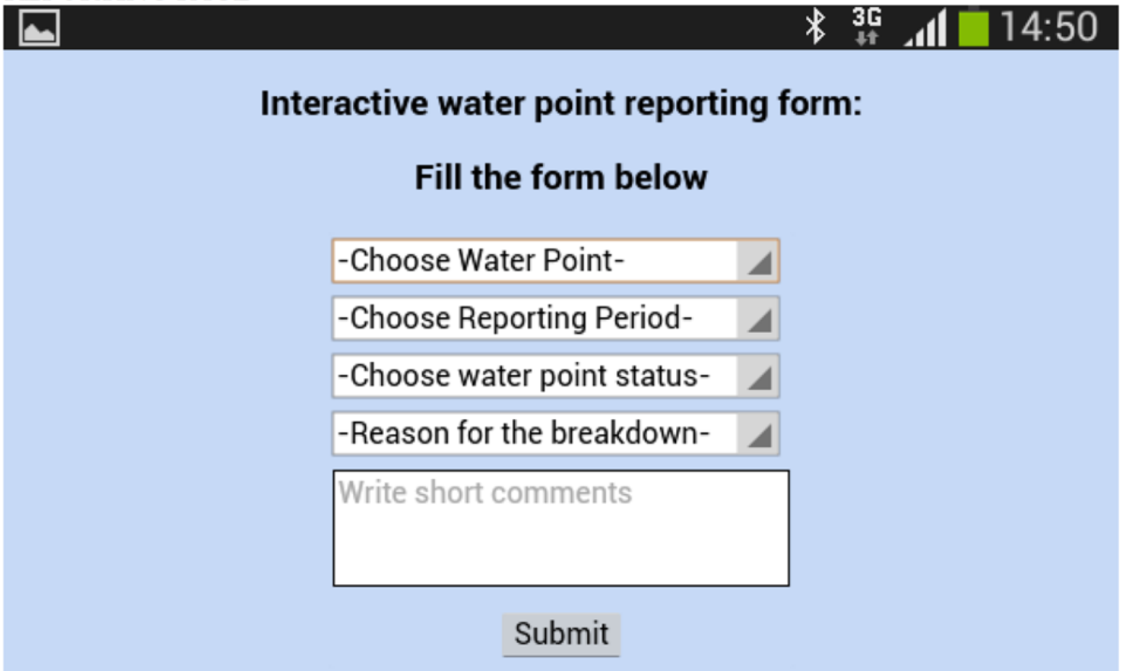

Figure A.1: This are the already available application to collect water point status.

REPORTING PAGE

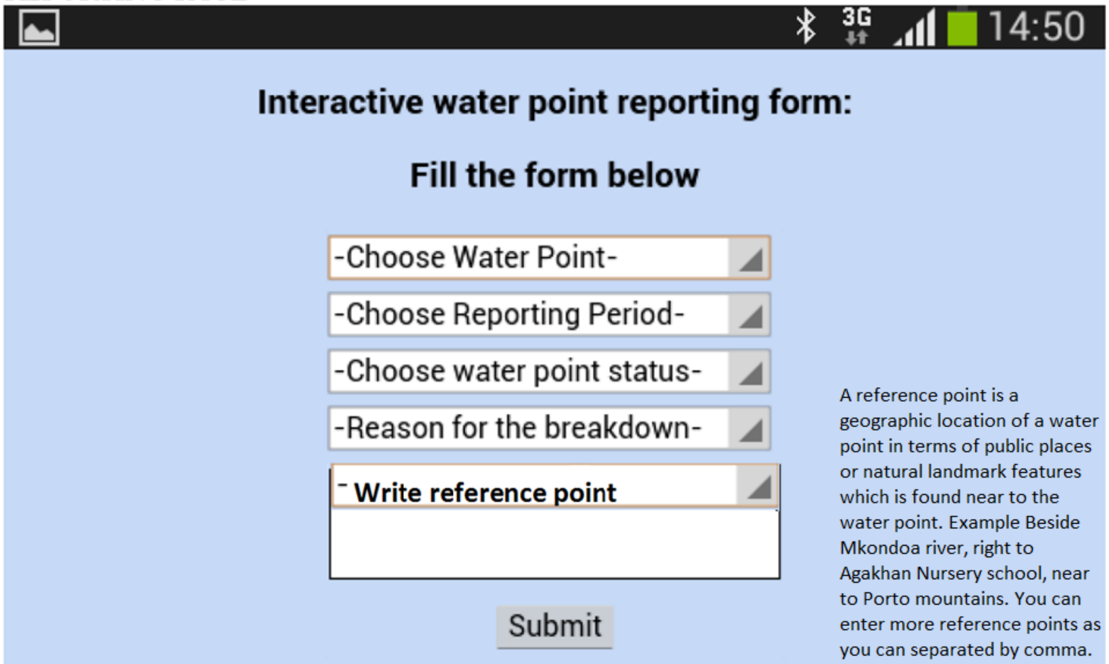

Figure A.2: Crowdsourcing approach for Land mark feature collection by modifying already available application in order to get landmark feature for each water points in the database.

Appendix B

Screen shoots Of the application

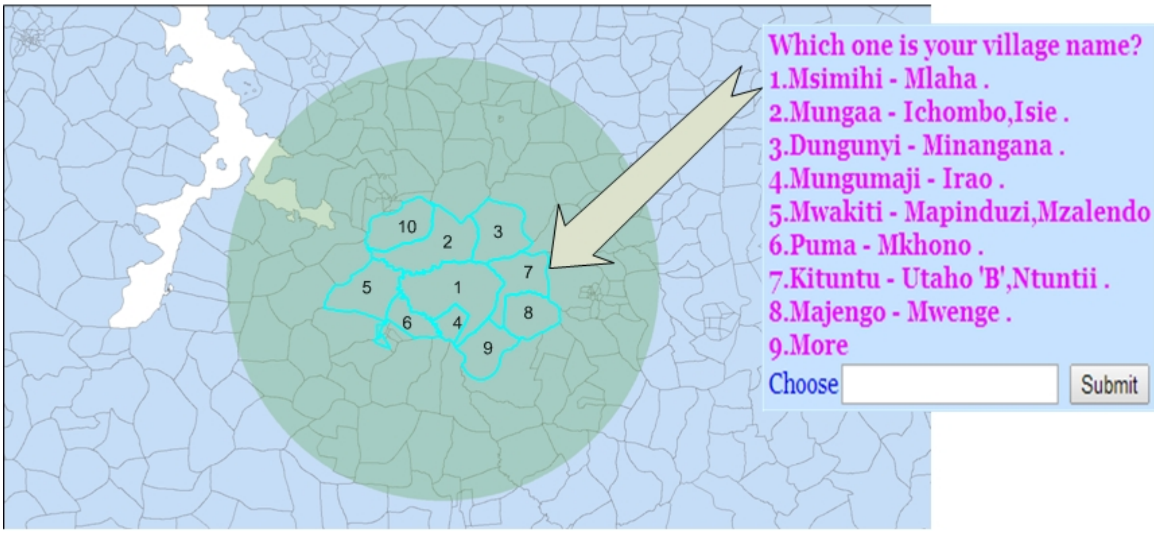

Figure B.1: Buffered areas based on the maximum coverage areas of the visited base station transceiver.

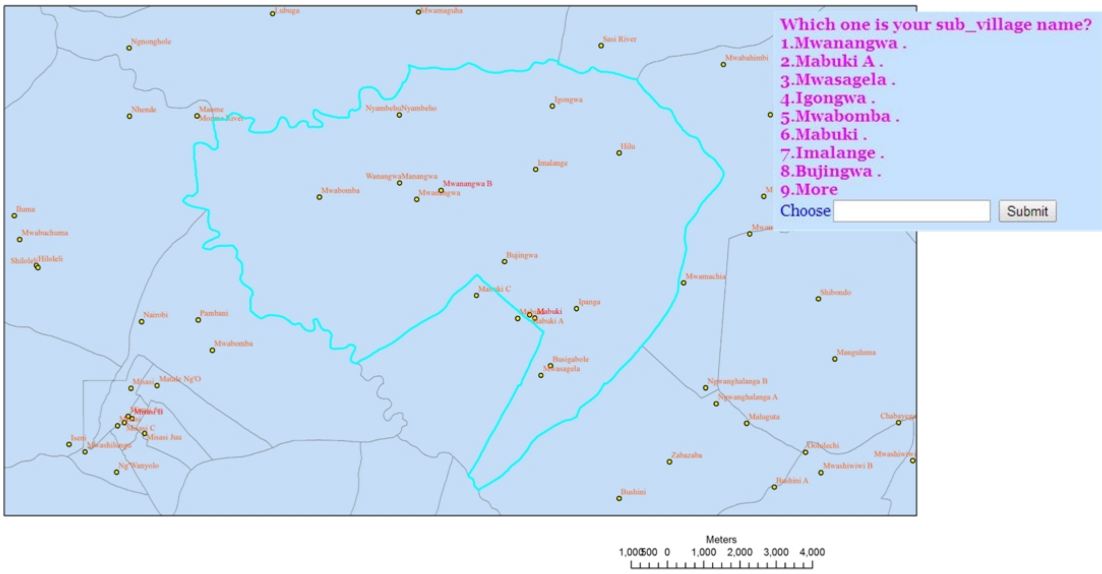

Figure B.2: USSD menu of the first group of randomly selected local names.

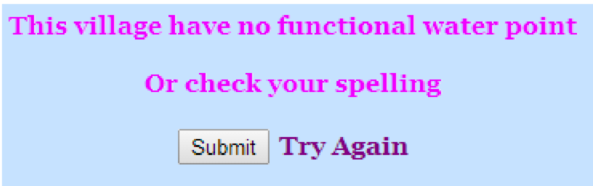

Figure B.3: Error message replays by the application because of spelling error in user input of Village name.

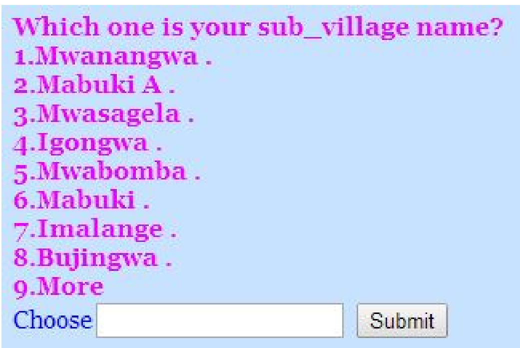

Figure B.4: USSD menu of the first group of randomly selected local names.

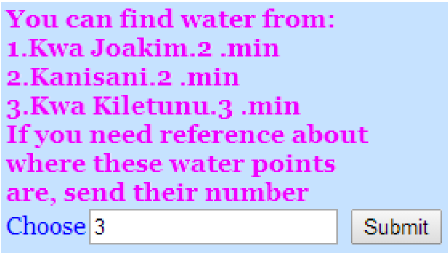

Figure B.5: USSD menu of available closest water points.

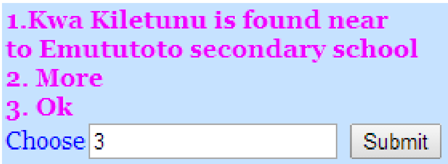

Figure B.6: USSD menu of Location information.

Appendix C

Sample PHP script to buffer the geolocation of visited BTS

```
<?php
    $host = "host=127.0.0.1";//create database connection
    $port = "port=5432";
    $dbname = "dbname=postgis_tanzania";
    $credentials = "user=#### password=####";

    $db = pg_connect( "$host $port $dbname $credentials" );
    if(!$db){
        echo "Error : Unable to open database\n";
    } else {
        //echo "Opened database successfully\n<br>";
    }

                $long = $_POST["long"]; //geolocation of the visited cell-ID
        $lat = $_POST["lat"];
        //buffer geolocation of the visited cell-ID and select the intersected village name

$sql =<<<EOF
           select v.street, v.geom, count() as frq from reproject_village as v
   INNER JOIN recell_id as c ON public.st_intersects(st_buffer(c.geom, 30000), v.geom)
   where c.long='$long' AND c.lat= '$lat' GROUP BY street, v.geom ;

EOF;

    $ret = pg_query($db, $sql);
            $numrow=pg_num_rows($ret);
           //check if the USSD menu is not exceeding from recommended number of menu
           if ($numrow<9){ ?>
           <style type="text/css">
   body {
           font-family: Georgia, "Times New Roman",
              Times, serif;
      color: purple;
      background-color: #C6E2FF }
   </style><?echo "<font color=#f000ff> <b>Which one is your village name? </b></font><br>";

           $i=1;
           while($row = pg_fetch_row($ret)){
           //produce USSD menu of village name preceded by numbers
           echo "<font color=#f000ff> <b>$i."."$row[0] .</b></font>", "\n","<br>";
           $i++;
                       }
?><div style="color:#0000FF", align="left">
```

```
<form action="pgn1.php" method="post">
Choose<input type="integer" name="vinum">
<input type="submit" >
</form> </div><?
}//Produce village name in ascending order based on their distance from the visited Cell−ID
   else{ $sq2 =<<<EOF
           select st_distance($ret.geom, c.geom) as distance
           from $ret INNER JOIN recell_id as c ON st_intersects(st_buffer(c.geom, 30000), v.geom)
           where c.long='$long' AND c.lat= '$lat' order by distance ;

EOF;
$ret = pg_query($db, $sq2);
           $numrow=pg_num_rows($ret);

$i=1;

while($row=pg_fetch_row($ret)){

echo "<font color=#f000ff> <b>$i."."$row[0] .</b></font>", "\n","<br>";
           $i++;
           }//produce pre−defined hyperlinks for extended output
           echo "<font color=#f000ff> <b>9.More</b></font>\n";
?><div style="color:#0000FF", align="left">
<form action="pgn2.php" method="post">
Choose<input type="integer" name="vnum">
<input name="send" type="submit" >
</form> </div><?

}

    if(!$ret){
        echo pg_last_error($db);
   exit; }

    pg_close($db);
           ?>
```