LOCATION BASED SERVICES: DEVELOPING MOBILE GIS APPLICATIONS

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: …………………………………….

Date: …………………………………….

ABSTRACT

The substantial growth of the Internet during the past few years has sparked the adaptation of several fields of current technologies to its demanding and cutting-edge standards. Mobile wireless cellular engineering and Geographic Information Systems (GIS) are two such technologies. Integrating these two technologies has resulted in the possibility of providing a type of useful functionality in the form of a technological service to the public in terms of their geographical location, named Location Based Services (LBS). An LBS can be defined as any service or application that extends spatial information processing or GIS capabilities to end users via the Internet and/or wireless networks. Thanks to wireless cellular engineering, GIS, computer programming and a little intellectual ingenuity, LBS now has the ability to provide a solution to the persisting problem of the intractable incapability of prevalent technology to extend utile spatial information to a user in terms of his/her geographical location.

The purpose of this study is to investigate how geographical information, derived from GIS processing, can be supplied and presented in a useful manner to users' mobile electronic devices, using today's available technology. A sample LBS application will demonstrate how this is achieved in the South African context. It includes features such as position location, street finding, shortest street route calculation, and map display, all on a mobile cellular device. Relevant issues such as impending wireless cellular technology, development cycles, implementation, costs, revenues and shortcomings are also discussed.

OPSOMMING

Die Internet se onlangse groei het veroorsaak dat vele aspekte van hedendaagse tegnologieë aangepas is om tred te hou met die nuutste en mees veeleisende standaarde. Mobiele sellulêre tegnologie en Geografiese Inligtingstelsels (GIS) is twee sulke tipiese tegnologieë. Deur hierdie tegnologieë te integreer het die moontlikheid ontstaan om nuttige gebruikersfunksionaliteit in die vorm van 'n tegnologiese diens aan die publiek te verskaf met betrekking tot hul geografiese ligging. Hierdie tipe van diensbedrywe staan bekend as Ligging Gebaseerde Dienste (LBD). 'n LBD kan gedefinieer word as enige diens of toepassing wat ruimtelike inligtingprosessering of GIS vermoeëns aan eindgebruikers via die Internet of koordlose kommunikasie-netwerke verleen. Danksy sellulêre ingenieurstegniek, GIS, rekenaarprogrammering en 'n bietjie intellek, het LBD nou die vermoë om 'n oplossing te bied vir die probleem van heersende tegnologie se onvermoë om nuttige ruimtelike inligting aan eindgebruikers met 'n bekende geografiese ligging, te lewer.

Die doel van hierdie studie is om die hedendaagse tegnologieë wat gebruik kan word om geografiese inligting aan 'n gebruiker se mobiele elektroniese eenheid te lewer, na te vors. 'n Koordlose applikasie sal demonstreer hoe hierdie doelwit bereik word in die Suid-Afrikaanse konteks. Hooftrekke soos liggingsvasstelling, straat-opsporing, kortste-roete berekening, en kaartvertoning word op 'n mobiele sellulêre platform ge-implementeer. Toepaslike onderwerpe soos toekomstige koordlose sellulêre tegnologie, ontwikkeling-siklusse, implementering, kostes, inkomste en tekortkominge word ook bespreek.

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CHAPTER 1: EXTENDING GIS CAPABILITIES ONTO MOBILE DEVICES

"Anywhere, anytime, any device – this is the short definition of the rapidly growing field of location services. It's where wireless and GIS technologies meet on the Web and it is changing the way businesses and individuals operate" (ESRI 2001a).

In the last few years the Internet has become almost a household name (Green 1997). Many advertisements in newspapers and magazines, on television, and even on roadside billboards now show the familiar "www" or ".com" addresses. Most computer magazines have columns and articles on the Internet, as do newspapers in the Information Technology (IT) sections. Small businesses and individuals also have their so-called Home Pages. The World Wide Web (WWW) is vast and presents exciting opportunities for anyone who has geographic data, analyses geographic data or otherwise adds value (Limp 1997).

The substantial growth of the Internet during the past few years has sparked the adaptation of several fields of current technologies to its demanding and cutting-edge standards. Such technologies have been changed and enhanced to facilitate the incorporation of the Internet or related Internet protocols (Zhuang 1997). One such technology is that of mobile cellular phones. Cellphones have enjoyed increased use and acceptance in South Africa since 1995. The South African cellphone subscriber base for March 2004 was estimated at 14.5 million users (Finance24 2004a), and total world subscriber base for 2006 is estimated at 2 billion users (Finance24 2004b).

Wireless Application Protocol (WAP) was the first technology developed (and globally released shortly before the turn of the millennium in December 1999) to support the transfer of data between cellphones and web servers using technologies similar to that of the Internet, and displaying it to the subscriber in a similar fashion as a web browser on a Personal Computer (NETmaster Africa 1999; Computing SA 2000). Similar technologies, which address each other's limitations, have also been developed or are being developed, or have been suggested (NETmaster Africa 2000).

If there was something not forecast 15 years ago it was the contribution now delivered by the Internet to the distribution of geographic information (Van Eck & De Kuijper 2000). With the subsequent rapid expansion and development of the Internet and the WWW, Geographical Information Systems (GIS) extended onto websites are becoming ever more popular and as a result numerous sites have added GIS capability on their websites (Zhuang 1997). Furthermore, Mobile Geographic Information Systems (M-GIS) are emerging as a result of integrating GIS, Global Positioning Systems (GPS), wireless communications and mobile computing technologies (Karimi

2000). Providing this kind of functionality to the general public has sparked off the initiation and development of so-called "Location Based Services" (Francica 2000).

A ***Location Based Service (LBS)*** can be defined as any service or application that extends spatial information processing or GIS capabilities to end users (based on their geographic location) via the Internet and/or wireless networks (ESRI 2000 & 2001d). Such services combine scalable GIS technology, easy-to-use browsers, mobile and wireless devices, and wireless and Internet infrastructure with web servers to provide information and services whenever and wherever they are needed (ArcNews 2001).

A ***Mobile Geographic Information System (M-GIS)*** can be defined as a subset of an LBS (Informa Telecoms Group 2002a). Whereas an LBS extends spatial information processing or GIS capabilities to end users via the Internet and/or wireless network, an M-GIS limits that extension to only mobile devices, as to create an abstract "portable GIS". This study looks at LBSs in general but focuses on M-GISs, with specific reference to a sample M-GIS application developed. Also, for the purpose of this study, an application that delivers geographical information (based on location) to a non-mobile (fixed) device, will be classified as an LBS. An application that delivers geographical information (based on location) to a mobile device, will be classified as an M-GIS.

1.1 OBJECTIVES, APPROACHES AND METHODOLOGY

The aim of this study is to investigate how geographical information, derived from GIS processing, can be supplied and presented in a useful manner to mobile devices. A sample M-GIS application will demonstrate how this is achieved. Thus, this research project aims to fulfil these three goals:

1. **to research the latest emerging LBS and M-GIS technologies that can be put to use for such applications;**
2. **to investigate the development of a sample M-GIS application which uses the best suited technologies available; and**
3. **to demonstrate the usefulness and benefits of such an M-GIS application in the South African context.**

Research material for this study originates from a wide variety of sources. Literature from journals, magazines, newspaper articles and conference proceedings provide a theoretical background. This is complemented by a wealth of information on LBS and M-GIS applications (including its components) found on the Internet. The author also obtained valuable experience and information from working in the mobile telecommunications and GIS fields for a number of years. All of these sources proved to be extremely useful and supplied a very thorough insight and background for research on LBS and M-GIS applications and components. A number of current commercial LBS and M-GIS applications are also investigated and supplied as examples in the next chapter. This delivered an important understanding of the practical application of M-GIS theory.

The theory and insight obtained from the research were practically applied by means of the development of a complete M-GIS project. The M-GIS application formed part of this project and was successfully presented and commercially deployed on compatible mobile phones in South Africa’s consumer market.

1.2 STUDY AREA

South Africa is traditionally known to be "lagging" behind other first world countries like Europe, Asia and North America as far as technological advances are concerned (Vodacom 2003). Luckily, this "lagging" seems to have diminished significantly over the last couple of years. Although new technologies relevant to LBS and M-GIS are still being implemented first in those other countries, South Africa is nowadays not technologically as far behind (Vodacom 2003).

South Africa was chosen as the study area because the status of LBS and M-GIS in the country can be properly investigated. Great technological growth opportunities are apparent (Vodacom 2003), and this suits the development and implementation of LBS and M-GIS projects perfectly. The sample M-GIS application developed for this study also uses a South African geodatabase.

1.3 RESEARCH FRAMEWORK

The chapters of this thesis closely follow the order in which research was conducted. This introductory chapter focussed on the general background of LBS, M-GIS and its components. The objectives of the study were stated and the study area explained. In the next chapter some of the current trends of LBS and M-GIS locally and internationally are researched. The current status of LBS and M-GIS projects in South Africa is illustrated by means of a few example LBS and M-GIS applications already commercially available. Chapter 3 describes the various technological components that can be used for the development and implementation of a typical M-GIS project, while chapter 4 outlines the development and implementation of a practical M-GIS application. Chapter 5 evaluates the sample M-GIS application, taking into account its shortcomings, costs and revenues. Chapter 6 concludes the study by revisiting the research objectives and application improvements, and future research opportunities are suggested.

CHAPTER 2: CURRENT STATUS AND TRENDS OF LBS AND M-GIS

A vast amount of Location Based Services (LBS) and Mobile Geographic Information Systems (M-GIS) have been commercially deployed worldwide since 2002 (Vodacom 2003). The author also found a number of M-GIS services that were started in 2001, which had promising prospects, but died a slow death a year or two afterwards. Outdated websites, some of which have not been updated for a long time, are reminiscent of these once promising M-GIS applications but which are now non-existent.

Why did these initial M-GIS offerings fail? A number of possible reasons are suggested, but there is not one single answer (Wireless Developer Network 2003). However, the assumed reasons all bear down to the following main encapsulating problem: the mobile (cellphone) market was not ready for it. The infrastructure and GIS technology were there, the users were there, but the cellphones were not capable of receiving large volumes of geographical information (usually raster maps). The map downloads were too slow and the users too impatient. Also, the display limitations (Liquid Crystal Display (LCD) screen resolution, number of colours) of the cellphones of the time were the main factors hampering the proper presentation of geographical information, for example street maps.

Fortunately, cellphone capabilities have improved tremendously since 2002. They now have the ability to receive and transmit data at speeds supported by most cellular networks. Their display capabilities have also improved, and large full-colour high-resolution LCD screens are now almost the norm on most available cellphones. Speed and display limitations are something of the past; cellphones are now ready for content-rich applications.

Can LBS and M-GIS provide a solution to the persisting problem of the intractable incapability of prevalent technology to extend utile spatial information to a user in terms of his/her geographical location? The objectives of this study (as listed in Section 1.1) attempt to provide the answer to this.

Six current LBS and M-GIS applications are discussed below. One of them is available internationally and locally, whilst the others are available only locally. This does not mean to say that similar services do not exist overseas; it only means that the LBS or M-GIS service, as it is known by its unique name, exists in South Africa and is illustrated below as such.

1. Map & Guide Navigator

Map & Guide GmbH is a GIS product specialist company in Karlsruhe, Germany. Amongst other GIS products, they have recently released a software program that runs on a Pocket PC displaying a map and providing turn-by-turn street route instructions. This program is intended to be used for in-car navigation along with a Global Positioning System (GPS) receiver, and is very useful. Through a partnership with MapIT (Pty) Ltd this product has now also been released in South Africa, using the MapStudio South African map set, and was named "Map & Travel Navigator South Africa 2004".

The Navigator is an M-GIS application that runs totally stand-alone and performs no communication with any web or map server. The complete digital map database is loaded and stored on the Pocket PC itself. The internal Central Processing Unit (CPU) of the Pocket PC also performs all the route calculations and other processing. The Navigator has the following main features:

- user can enter any number of destination points (from street address, map, Points of Interest (POI), Microsoft Outlook Contacts address or favourite locations), and the program calculates an optimum route between all the points
- Microsoft Outlook Contacts addresses on the user’s Personal Computer (PC) can be placed on the Pocket PC and street addresses within can be used as destination points
- fully detailed driving instructions given visually (on a full-colour map display) as well as aurally (clear and concise voice driving instructions)
- uses South African street map dataset with full street detail for major towns, all freeways and main roads for the rest of the country
- uses South African POI dataset (police stations, petrol stations, schools, hospitals, etc.); user can also search for nearest POI from current location
- in case the user does not follow the calculated route, a new route is instantly calculated automatically and shown on the map
- special “Position Tracking Mode” available (no routing – only tracks the moving position of the driver on a map)

The Navigator has been met with success in South Africa. Over 1500 copies have already been sold. Some screenshots of its Graphical User Interface (GUI) are presented in Figure 2.1 below.

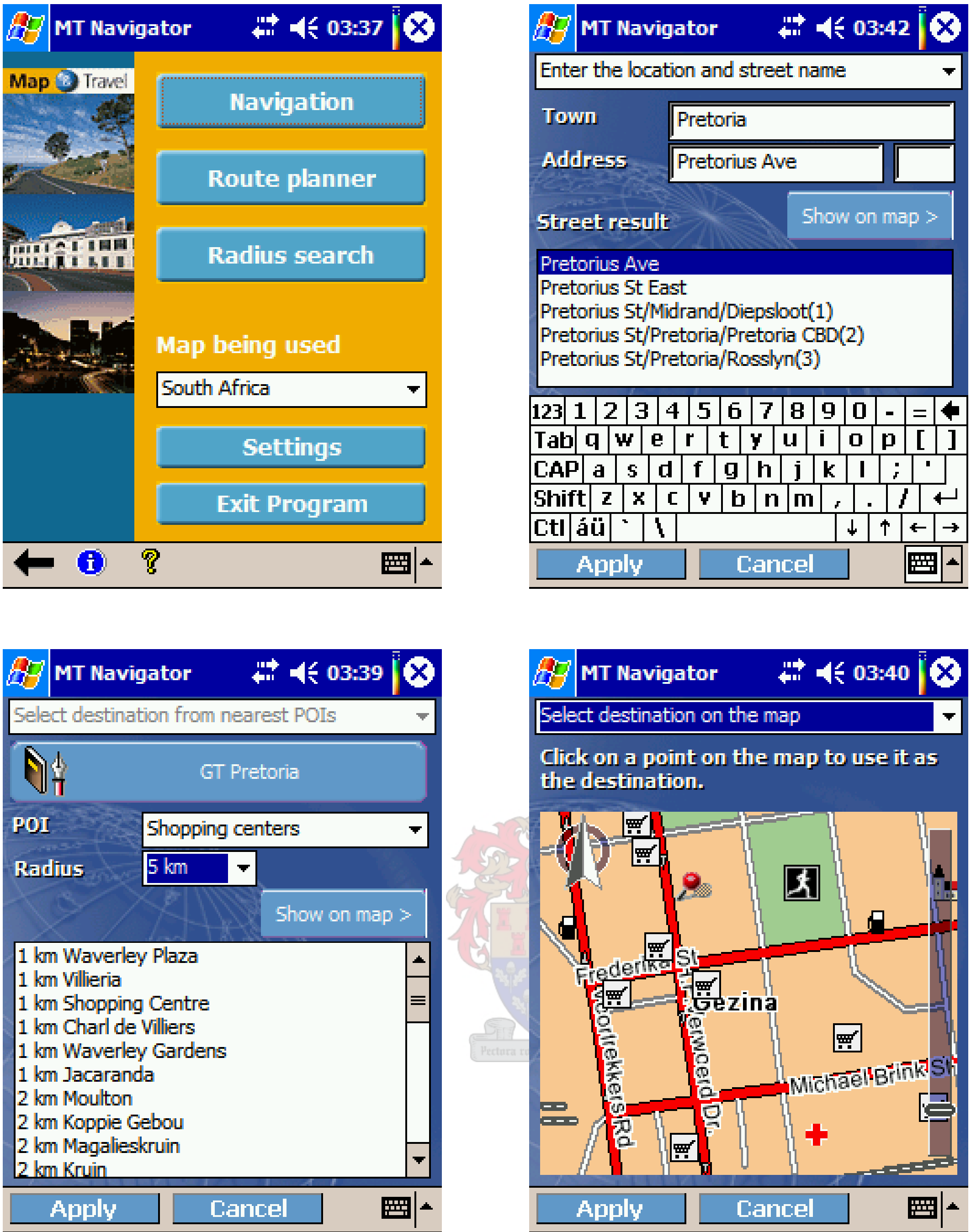


Figure 2.1 Map & Travel Navigator screenshots

2. Vodacom SA

Vodacom SA hosts a number of useful LBSs developed by Cellfind (Pty) Ltd (CellFind 2004; Vodacom 2004). They are discussed below.

2.1 Look4it

Look4it provides a variety of information of facilities and services available in the user's vicinity (Look4it 2004) and was developed in association with AfriGIS (Pty) Ltd. The location information of the cellphone (and its user) is used to determine which required information for the vicinity of the user should be displayed. This type of LBS service is classified as an *Active LBS* – the user personally requests location information based on his/her own position. It uses the Nearest Cell Mast location technique (see section 3.3.2 for more details). A database of commercial services is maintained and when the user wants information on a specific public service, a database table lookup is performed on the central processing server and all the specified services that fall within the area of the user's nearest cell mast, is returned. The Man-Machine Interface (MMI) service menu is invoked by dialling *120*555# from the cellphone.

2.2 Look4me

Look4me allows a user with access to a web browser to view a map around the location of a queried cellphone (Look4me 2004). This type of LBS service is classified as a *Passive LBS* – a third party requests location information from the user. It is particularly useful for parents wanting to know the location of their children. “Look4me For Business” can be used to locate mobile workforces any time of the working day without interrupting their activities. This LBS uses the “Time Differential of Arrival” location technique (see section 3.3.3), as well as MapStudio's digital SA map dataset.

2.3 Look4help

A user's cellphone becomes a mobile panic button when he/she saves the number *120*888*888# as a speed dial (CellFind 2004). The pre-defined recipients of the distress message and location information can then contact the user in distress, physically come to his/her rescue or contact an emergency service. This LBS also uses the “Time Differential of Arrival” location technique.

3. MTN FindMe

In 2002 MTN SA launched their FindMe service as part of their range of Value-Added mobile services known as MTN-ICE. This M-GIS service allows an operator to give verbal driving instructions to a lost user calling in for assistance.

The user phones a specific number and the Nearest Cell Mast location technique is used to locate him/her in a general area. This location is passed to the operator who can then ascertain the exact location of the user and give him/her street directions to where he/she wants to go. This service is still operational today, although details of it on MTN-ICE's website no longer exist.

4. SmartRoute

SmartRoute is the latest innovation released by SmartSurv Wireless (Pty) Ltd that allows any person with the appropriate cellular phone to enjoy all the benefits of street navigation normally only available on high-end motor vehicles (SmartSurv Wireless 2004). The application runs on cellphones using the Symbian 7.0 operating system, such as the Nokia 6600 and Siemens SX1. A Java Mobile Information Device Profile (MIDP) application is loaded onto the phone which communicates (using General Packet Radio Service (GPRS)) with a web server. The user's location (obtained from a GPS receiver) and destination are sent to the server and a route corridor is calculated and sent back to the cellphone by means of a Multimedia Messaging Service (MMS) message containing a colour map showing the next driving direction indicated on a street crossing. All that remains is for the driver to follow the visual guidance and voice-prompted turn-by-turn instructions to the desired destination.

5. AfriGIS Swoop

AfriGIS Swoop, developed and deployed in 2000 by AfriGIS, is a web service that allows a user to enter a source and target location, after which a route between the two locations is calculated and presented on a map, with turn-by-turn directions, in the user's web browser (AfriGIS 2004). The user has the option of having the system send him/her the directions via Short Messaging Service (SMS) to his/her cellphone. Although this service initially appeared promising, it is not in service anymore (error messages are shown when attempting to route), and is currently being upgraded.

These examples of LBS and M-GIS applications are by no means complete. They are bound to develop even further and spark off further ideas which will develop into secondary LBS and M-GIS applications. There are also many more similar LBS and M-GIS projects like the above that are currently in operation worldwide. By means of the above examples, the author has given a small glimpse of what is possible with LBS and M-GIS applications. The sample M-GIS application developed for this study has some elements of the above examples in its functioning or capabilities. But before the sample application is discussed, an understanding of the necessary components for an M-GIS needs to be gained first. This is the focus of the next chapter.

CHAPTER 3: M-GIS COMPONENTS

A Mobile Geographic Information System (M-GIS) project consists of several components which represent individual technological fields conceptual to the architectural design of the project (Sarjakoski & Lehto 2003). Client components consist of all the physical mobile devices that are compatible with the front-end requirements of an M-GIS application; in other words, they are the mobile devices that the application can run on. The communication technologies and infrastructure components ("middleware") allow for the transmission of requests and responses between the client and server components. The server components are all the hardware and software involved in serving the client-side of the M-GIS project on the web server and the map server.

Position determination (location) technology is considered part of the middleware components for the purpose of this research theme. It deals with the ways in which the position of the user wanting geographical information can be located.

The last important component is the geodatabase. It is the spatial data source of all the geographical information that can be effectively presented on the user's mobile device.

Each of the four abovementioned components are discussed in turn below. Research results are presented comprehensively, but by no means represents all of the possible subcomponents that could theoretically exist and be usable for any arbitrary M-GIS application. For the sample M-GIS application of this research, only a selected set of subcomponents was available and/or was used. Chapter 4 discusses and explains this in more detail.

3.1 CLIENT COMPONENTS

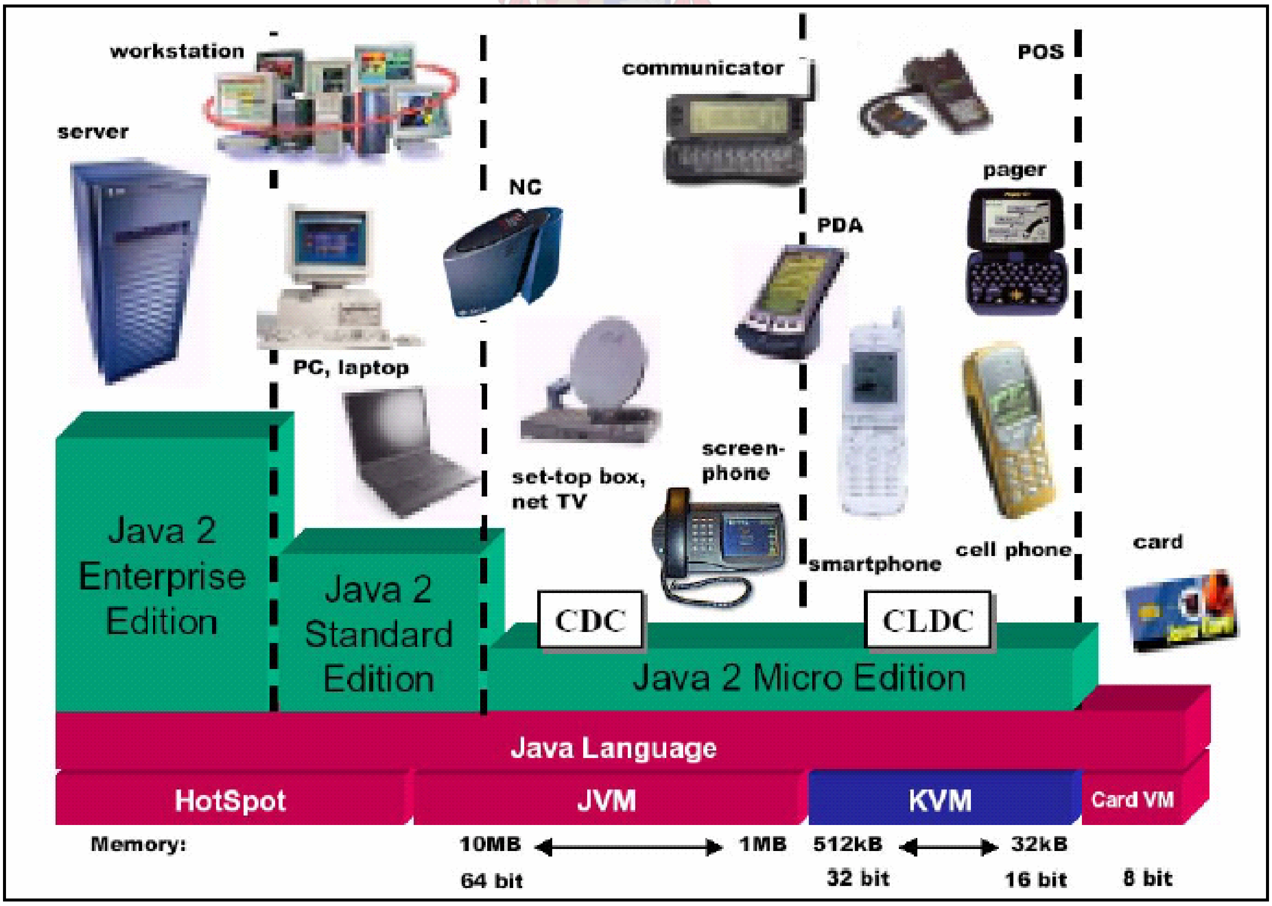
Technological advances in the field of mobile computerised devices have resulted in a large variety of such products entering the markets during the past decade (Graham *et al.* 2003). The extent of this variety will by no doubt increase even further in the forthcoming years. This is very advantageous to M-GIS applications since it brings about a high degree of diversity to the range of devices that would allow for M-GIS applications to be run on. These devices are also allowing for an increasing degree of interoperability between the devices and communication infrastructures. This section briefly covers all of the mobile devices that would be suitable for M-GIS applications.

3.1.1 Mobile cellular phones

Mobile cellular phones ("cellphones") must surely be the most popular mobile device in the market today, however not all cellphones are compatible with all promised features of M-GIS applications (Informa Telecoms Group 2002a). There are indeed limitations involved, mostly in terms of the physical capabilities of the cellphone, as well as the communication protocols it is compatible with. The grouping of these limitations is generally according to the cellphone's classification. The five main classifications are discussed below.

3.1.1.1 Mobile Information Device Profile

In 1999 Sun Microsystems announced a redefined architecture for the Java platform, aimed to make it simpler for software developers, service providers and device manufacturers to decide what aspects of technology they need (Alexander 2001). The revised structure consists of three editions of the Java platform: Java 2 Platform Standard Edition (J2SE), Java 2 Platform Enterprise Edition (J2EE) and Java 2 Platform Micro Edition (J2ME). J2EE provides functionality required for heavy-duty server systems, and J2SE for the desktop or workstation devices. J2ME is designed to fit devices with small amounts of memory and other resources (see Figure 3.1).



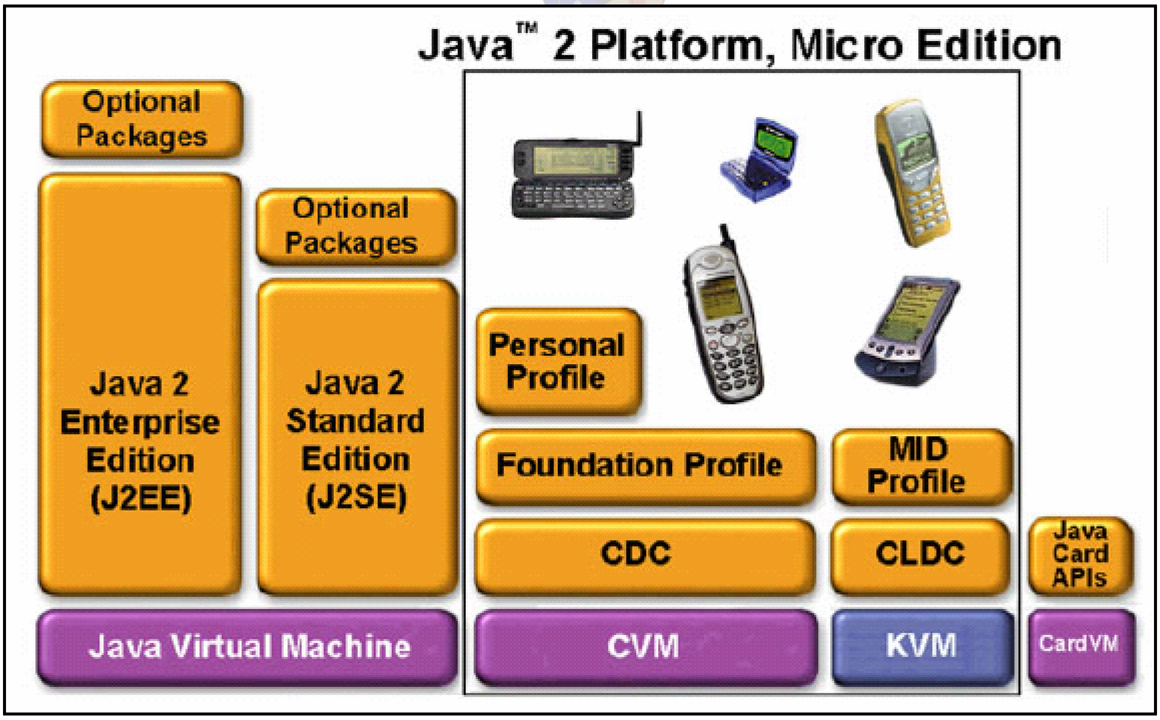
Source: Alexander 2001

Figure 3.1 The Java language

Software applications on all three Java editions can be developed using the same application programming technique. Applications designed for J2ME will also work in J2SE and in J2EE. Within J2ME, major types of consumer devices are grouped into a limited number of categories, such as wireless devices (pagers and cellphones), screenphones, car and Personal Digital Assistants (PDA). Each category will include the minimum set of Application Programming Interfaces (API) useful for that kind of product and a Java Virtual Machine (KVM) required to support those APIs (Sun Microsystems 1999).

To date, software application developers have already downloaded tens of thousands copies of J2ME from Sun Microsystems's website. Innovative solutions for wireless devices such as entertainment and business applications are being widely developed and deployed today. A recent market research study by Evans Data Corporation showed that over 33% of wireless application developers intend to develop for J2ME - the highest response garnered for any wireless platform (Sun Microsystems 2001). Since its introduction in June 1999, J2ME has been supported by wireless carriers and mobile cellular device manufacturers.

J2ME consists of KVM core libraries and APIs. There are two configurations of J2ME: Connected Device Configuration (CDC) and Connected Limited Device Configuration (CLDC) - see Figure 3.2.



Source: Alexander 2001

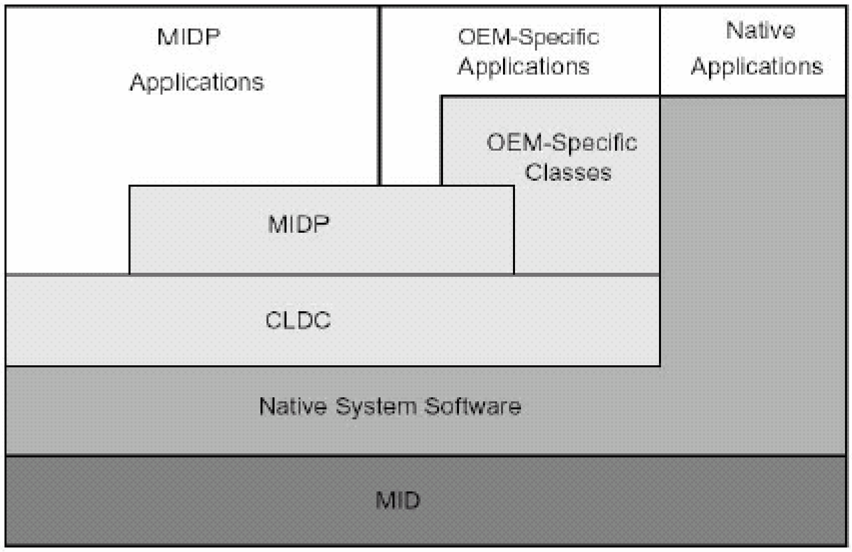
Figure 3.2 J2ME structure

Alexander (2001) defines KVM as a small-sized computer software program specifically designed for small devices with lack of resources. It is made as small as possible, but it maintains support for all main features of Java. The letter "K" in KVM stands for "kilo" – the amount of memory used by the virtual machine is measured in kilobytes. KVM can be run on 16-bit or 32-bit microprocessors with a total system memory of less than 128 kilobytes (for the most compact version). This version is used in cellphones, pagers and organizers (e.g. PDAs). These 128 kilobytes contain the KVM itself, some Java class libraries and some space for running Java applications.

CLDC defines a Java platform for a group of devices with similar memory total size and similar resources. CLDC is needed to define a standard Java platform for small connected devices to allow them to download Java applications and content, and to allow other software developers to create applications for the particular devices.

MIDP is designed to operate on top of the CLDC. It was produced by the Mobile Information Device Profile Expert Group (MIDPEG) and its main objective is to establish an open application development environment for Mobile Information Devices (MID). To achieve this goal the MIDPEG has defined a MID to be a device that should have the following minimum characteristics:

- Display:
    - Device screen resolution: 96 by 54 pixels; pixel shape ratio: approximately 1:1
    - Display depth: 1-bit (i.e. monochrome)
- Input:
    - one or more of the following user input mechanisms: "one-handed keyboard" (simple cellular phone keypad), "two-handed keyboard" (usual computer keyboard) or touch screen (with the aid of a stylus)
- Memory:
    - 128 kilobytes of ROM for the MIDP components (content of this memory remains the same after user switches the device "off" and then "on")
    - 8 kilobytes of ROM for application-created persistent data
    - 32 kilobytes of RAM for the Java runtime
- Networking:
    - Two-way, wireless, with limited bandwidth



Source: Alexander 2001

Figure 3.3 MIDP position in a device

Figure 3.3 illustrates how MIDP fits into a mobile device. The lowest-level block (MID) represents the MID hardware. On top of this hardware is the native system software. This layer includes the operating system and libraries used by the device. The next level of software is the CLDC. This block represents the KVM and associated libraries defined by the CLDC specification.

A MIDP application, or MIDlet, is one that utilises only the APIs defined by the MIDP and CLDC specifications. Applications that run on devices supporting MIDP are called MIDlets. Like Java Applets, MIDlets are controlled by the software that runs them – in this case the cellphone that supports MIDP and the J2ME CLDC. An M-GIS application that would be developed using this software development technology, would be known as an M-GIS MIDlet.

J2ME has the following distinct advantages:

- Applications are loaded on demand. The user can choose to download applications he/she needs rather than buying a device with applications pre-installed by the device manufacturer, making this cost-effective and efficient.
- Java technologies come with libraries that allow an application developer to build a richer, more intuitive Graphical User Interface (GUI). This allows service providers to offer easy-to-use personalised applications and services which makes their offering more diverse.
- Java technologies allow more intelligent use of network bandwidth because applications are downloaded onto the device and run locally, so the network is used only when data is needed from the server.

- Java technology provides cross-platform and multiple device support. J2ME and MIDP technologies can run the same application on any supported system type.

Motorola is ahead of other manufactures in developing and producing Java-enabled phones (Alexander 2001). Here are some examples of MIDP-compatible cellular phones:

Motorola Accompli-008

Nokia 9210i

Nokia 7650

Siemens SL45i

Source: Sun Microsystems 2003

Figure 3.4 MIDP-compatible cellular phones

3.1.1.2 Wireless Application Protocol

In December 1999, just before the end of the previous millennium, the first cellphones that supported wireless Internet browsing were released. The key to this breakthrough was the acceptance of the Wireless Application Protocol (WAP) as the *de facto* standard for mobile Internet use. The WAP specification for delivering Internet content to mobile devices was formulated by the International WAP Forum formed in 1997 (Planting & Bidoli 1999).

The WAP Forum (2001) defines WAP as “an open, global specification that empowers mobile users with wireless devices to easily access and interact with information and services instantly”. The purpose of WAP is to enable easy and fast delivery of relevant information and services to mobile users. Handheld digital wireless devices such as cellphones, pagers, two-way radios, smartphones, screenphones and communicators would be made able to support and use WAP. The first cellphone released with WAP support was the Nokia 7110 (Bornman 1999), benchmarking the emerging so-called “2G” (Second Generation) set of mobile wireless devices”.

Besides being a communications protocol, WAP is also an application environment. It can be build on any operating system, including Microsoft Windows CE (intended for mobile devices). A WAP-enabled device can thus be seen as a micro-browser: client software designed to overcome challenges of mobile handheld devices that enable wireless access to services such as Internet information in combination with a suitable network server (known as a WAP Gateway Provider).

The initial release of WAP version 1.0 was not without its limitations (Brown & Chidi 2000). Older wireless devices, constrained by small Liquid Crystal Display (LCD) screens, limited processing power and bandwidth, could not handle Hypertext Markup Language (HTML) documents (ESRI 2001d). However, WAP has evolved to deal with these problems. From the creation of Extensible Markup Language (XML) came Wireless Markup Language (WML). Wireless data content is not directly encoded in XML, but in a specific markup language defined, using XML. WML is an example of a specific language for wireless applications that is fully compliant with XML's rules. WML is thus an XML application, and the core specification of WAP.

Currently there are a number of local companies that complement cellular services by supplying WAP packages with mobile phone packages, one of them being WorldOnline SA. This WAP service has been functioning very well with simple text messages and small images, but larger images, greater amounts of text and raster maps have given problems in the sense that it takes too long to download, because of limited bandwidth. Another problem is the limited display capabilities and functionality of entry-level WAP-enabled cellphones, especially that of the Nokia 7110 and the newer Nokia 3330. For WAP to have been successful in larger applications and wireless data transfers, data download rates (thus in effect available bandwidths) would have to be increased through advances in Global System for Mobile Communication (GSM) cellular technology, thus making it possible for more graphical applications to be delivered to the phone (Ferranti & Niccolai 2000).

WAP effectively works in a series of transmission steps (ESRI 2001d). The user of a mobile device, such as a WAP-enabled cellphone, keys in a desired web address into a micro-browser, which sends the request using radio waves to the WAP Gateway Provider. This server, connected to the Internet, locates the requested web page. The page is converted from HTML to WML and the WAP Gateway Provider prepares the WML page for wireless transmission. The user's mobile device receives the WML script and its built-in micro-browser interprets and displays it on the device's LCD screen. From the screen the user can then select menu options, links, pages, etc. which is in effect very similar to the original web page. The page contents can even be transmitted through the device's infrared, Bluetooth or Wi-Fi port (if supported) to any other compatible device (Laing 1999).

3.1.1.3 Symbian operating system

Symbian OS is the advanced, open, standard operating system licensed by the world's leading mobile phone manufacturers (Wireless Developer Network 2003). Symbian OS is designed for the specific requirements of data-enabled Second Generation (2G), Second-and-a-half Generation (2.5G) and Third Generation (3G) cellphones (see Section 3.2.2). Compact enough to fit in the memory of a mobile phone, Symbian OS was initially planned to be a full operating system in terms of functionality. Symbian OS is already available in a large range of World Smartphones, cellphones, and PDAs. With the introduction of Symbian OS version 7.0, the range of mobile phones with Symbian OS will expand even further (Informa Telecoms Group 2002b).

Symbian OS is the basis of the next generation of mobile phones. It is the common core of APIs and technologies that are shared by all Symbian OS phones.

3.1.1.4 Short Message Service, Enhanced Message Service, Picture-SMS

Short Message Service (SMS) is an application which became a runaway success in the mobile cellular world (News24 2001b). SMS is the second biggest growing service world wide (News24 2001a). Current surveys predicted that 40 percent of future 3G wireless network use would be dedicated to checking e-mails and sending and receiving messages, proving that no matter how phones are marketed, at the end of the day, text sells.

Mobile messaging is evolving beyond text by taking a development path from SMS to Enhanced Messaging Service (EMS) to Multimedia Messaging Service (MMS) (Mobile Lifestreams.com 2000a & 2000b). EMS is the ability to send a combination of simple melodies, pictures, sounds, animations, modified text and standard text as an integrated message for display on an EMS compliant mobile phone. Mobile Lifestreams.com (2001b) believes that EMS and MMS (see Section 3.1.1.5) will be essential next generation messaging technologies.

Recently, Vodacom SA has started to implement various Value-Added Services (VAS) using SMS. Subscribers can send various “codes” via SMS to the Message Receiving Centre which would return the requested information to the subscriber, e.g. the latest news, weather, a joke, etc.

3.1.1.5 Multimedia Messaging Service

The Multimedia Messaging Service (MMS) is the ability to send and receive messages comprising a combination of rich media including text, sounds, images and video to MMS capable handsets (Vodacom 2001). Today's popular text-based SMS services can be enhanced with richer MMS content. MMS also offers a radically better end-user experience compared to text only-based SMS services. For example, a weather service can be extended from text-based information to include animated weather maps and forecast graphs with MMS capable terminals. Personalisation will be more effective with e.g. new audio formats and colour screens.

MMS is the key business case driver for General Packet Radio Service (GPRS) and is also the central driver for the 3G business case. MMS will contribute significantly to returns on 3G investments (MapFlow 2002).

3.1.2 Palm handhelds

Palm handhelds are small-sized portable computers that were released in the 1990s. Although they are still around today with new models, their data storage capacity and especially processing power do not allow for any reasonable form of geographic information processing. This might change in the future, however.

3.1.3 Pocket PCs

CE-Windows.Net (2004) defines Pocket PCs or PDAs as small computers that fit in the handpalm which run the Microsoft Windows CE operating system version 3.0. It includes Microsoft programs like Pocket Word, Pocket Excel, Calendar, Contacts and Tasks as well as many other applications. It provides a Microsoft Windows look-and-feel GUI to the user by means of a relatively large colour LCD touch-pad screen. Processing power are mostly provided by the StrongArm processor, for which speeds vary between 150 Megahertz (MHz) and 500MHz. Pocket PCs have their own internal storage space for add-on applications and data, which is usually sized around 64MB to 128MB. Users can add additional storage capacity by means of removable storage cards that can be slotted into the device. These storage cards are either of the type Secure Digital (SD) or Compact Flash (CF) and sizes vary from 32MB up to 2 GigaByte (GB).

Because of Pocket PCs' favourable characteristics, they are ideal for M-GIS applications (Map & Guide 2004). Their communications abilities include Bluetooth and infrared which is used for short-range communication between other compatible devices, and Wi-Fi (also known as Wireless Local Area Networks (WLAN)) for short or medium-range communication). They function as miniature computers which can store digital geographical data and run software applications that can make use of the geographical data. For instance, a street navigation software program can use a Global Positioning System (GPS) receiver (connected to the Pocket PC) to obtain a geographical location and supply turn-by-turn voice instructions to the user, as well as display a street map of the user's location (obtained from the stored geodatabase).

Recently Pocket PCs with cellular GSM capability have also been released. This is basically a combination between a normal Pocket PC and a cellphone. Although still relatively expensive, the benefits of both are captured in one single handheld device.

3.1.4 GPS receivers

Garmin is the international market leader of mobile GPS receivers. These receivers show their locations in coordinates on LCD screens (monochrome or colour) with or without a map backdrop. For some of these devices the user can purchase a map set of the country where he/she wishes to use it, and load the map data onto the device. Some of the devices, like the GPSMAP 76 and the StreetPilot 2610, also provide optimum street routing functionality. Although these devices can be perceived as excellent platforms for M-GIS applications, writing 3rd party M-GIS software for them are difficult, as they do not conform to as many open programming standards as Pocket PCs running Microsoft Windows do. On average they are also more expensive than Pocket PCs.

3.1.5 Laptop computers

Laptop computers are like conventional PCs but significantly smaller so that they are portable. They use smaller components than PCs and a flat LCD screen instead of a display monitor, and operate on rechargeable batteries. A geographical mapping program installed on a laptop can turn it into an M-GIS system, provided the map dataset used by the system is installed on the laptop, and it can obtain its location using a connected GPS receiver as well.

3.1.6 Summary

Although there is a vast range of mobile devices in the market today, the above listing shows which of these generic classes of devices do have the capability to support an M-GIS application. Such applications can be tailored to function on a specific class or subclass of today's mobile devices, and this section concludes with a checklist by Graham *et al.* (2003) which are most important when considering the physical capability of a particular mobile device to run a typical M-GIS application:

- The programming language used for the particular M-GIS application must be properly supported by the operating system running on the particular mobile device.
- If the geographical database is not stored and locally queried on the device, the geographical information must be sent to the device via “Over The Air” (OTA) transmissions.
- If the geoprocessing on the database (e.g. shortest street route) is not performed locally on the device, the (geo-)server has to perform it and send the results to the device.
- The device must be able to satisfactory display the resulting geographical information (e.g. a map, street route, etc.).

3.2 COMMUNICATION TECHNOLOGIES AND INFRASTRUCTURE

By definition, M-GIS means useful geographical information presented on a user's mobile device (Graham *et al.* 2003). When any part of this information (or the processing of data in order to deliver information) cannot be presented on the mobile device, it has to be transmitted to the device. This is where communication technologies and infrastructure (“middleware”) components come into play. There are several relevant communication technologies deployed in the past two years that can be used for a typical M-GIS application. Which of those technologies are used and how it is used depend significantly on the architectural design of the particular M-GIS application and the capabilities of the mobile device destined to receive the useful geographical information. This section outlines the communication technologies that can be utilised for an M-GIS application, and also briefly explains the techniques involved in such a process.

Transmission of information occurs either using electric ground cables and wire systems ("hard-line" infrastructures), or wireless transmissions (OTA).

3.2.1 Hard-line infrastructures

Surely the most well-known communication medium for computerised systems today is the Internet. Although communication using pure Internet usually consists of mostly hard-line infrastructures, it is highly suitable for communications between systems that are part of an M-GIS project but not between the mobile device and the first-in-line server it communicates with.

3.2.2 "Over The Air"

Radio waves are used for the finite transmission of analogue and digital information. The latter is applicable in this case and the current three types used for cellular communications to mobile devices are briefly discussed.

3.2.2.1 Global System for Mobile Communication

Cellular telecommunication is one of the fastest growing and most challenging telecommunication applications ever (Vodacom 2003). Today it represents a large and continuously increasing percentage of all new telephone subscribers around the world. In the long term, cellular digital technology may become the universal method of communication.

A GSM system is designed as a combination of three major subsystems: the network subsystem, the radio subsystem, and the operation support subsystem (Redl *et al.* 1995). In order to ensure that network operators will have several sources of cellular infrastructure equipment, GSM decided to specify not only the air interface, but also the main interfaces that identify different parts. There are three dominant interfaces, namely, an interface between the Mobile Switching Centre (MSC) and the Base Switching Centre (BSC), an interface between BSC and the Base Transceiver Station (BTS), and an interface between the BTS and Operational and Maintenance Centre (OMC).

The GSM system is realised as a network of radio cells, which together provide complete coverage of the service area. Each cell has a BTS with several transceivers. A group of BTSs are controlled by one BSC. A BSC controls such functions as hand over and power control. The OMC subsystem includes the operation and maintenance of GSM equipment and supports the operator network interface. It is connected to all equipment in the switching system and to the BSC. The OMC performs GSM's administrative functions (e.g. billing) within a country.

GSM Circuit Switched Data (CSD) supports one user per channel per time slot (3G Generation 2004). High Speed Circuit Switched Data (HSCSD) gives a single user simultaneous access to multiple channels (up to four) at the same time. As such, there is a direct trade-off between greater speed and the associated cost from using more radio resources - it is expensive for end users to pay for multiple simultaneous calls.

Assuming a standard Circuit Switched Data transmission rate of 14.4 kilobits per second (kbps), using four timeslots with High Speed Circuit Switched Data (HSCSD) allows theoretical speeds of up to 57.6 kbps. HSCSD is easier to implement in mobile networks than GPRS because some GSM vendor solutions require only a software upgrade of base stations and no new hardware.

3G Generation (2004) explains a couple of reasons why HSCSD may be the preferred bearer for certain applications when compared to GPRS. The fact that associated packets can be sent in different directions to arrive at the same destination should in theory make the transmission more robust since there are many different ways of achieving the end result. However, this nature of packet transmission means that packets are subject to variable delay and some could be lost. Whilst packet retransmission is incorporated into the GPRS standards, naturally this process does take time and in the case of applications such as video transmission can cause poor quality images. HSCSD is mainly supported by Nokia with little success (3G Generation 2004).

3.2.2.2 General Packet Radio Services

Today’s carrier service is the worldwide accepted GSM and General Packet Radio Services (GPRS) standard. GPRS, part of 2.5G, enables mobile phones to send data packets simultaneously, allowing data to be transmitted at 115 Kb/second, with rates predicted to increase to 384 Kb/second in the following years (Els 1999). Because the data is sent in packets, users will continuously be connected to the cellular service and charges will apply only when data is transmitted or received.

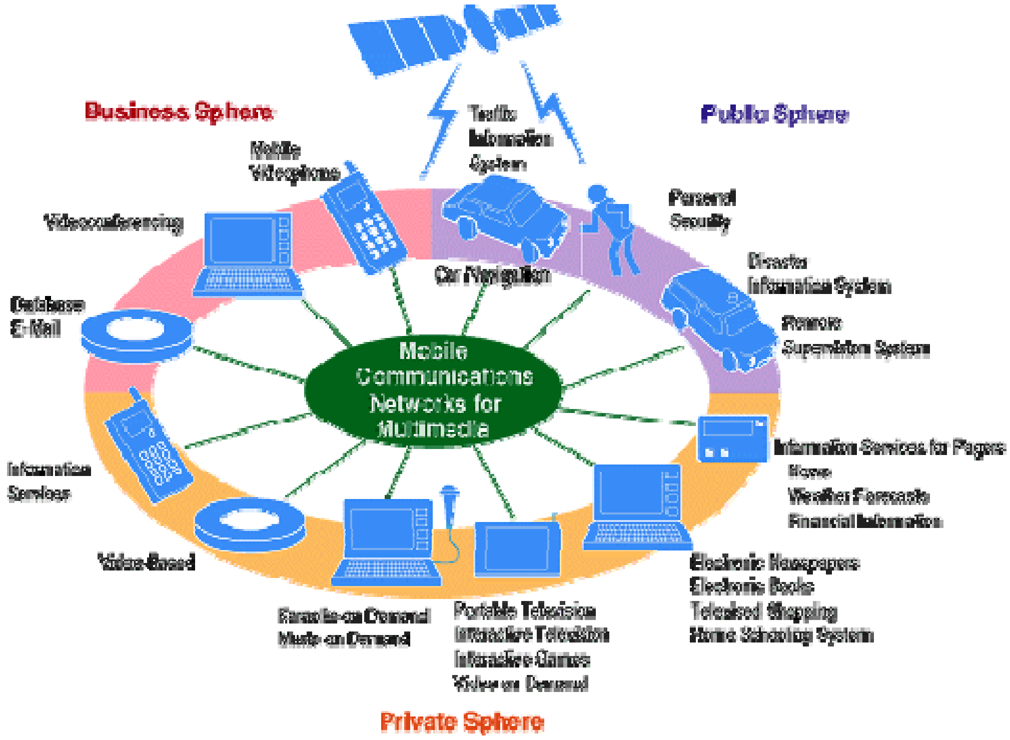
An enhanced version of GPRS still in its research phase is Universal Mobile Telecoms System (UMTS) which will allow data transfers of 2 Mb/second – almost 40 times faster than today’s dial-up modems – therefore facilitating the possibility of on-the-fly mobile video conferencing.

GPRS has several unique features which GSM World (2000) summarises as:

- Speed - theoretical maximum speeds of up to 171.2 kilobits per second (Kb/s) are achievable with GPRS. This is about three times as fast as the data transmission speeds possible over today's fixed telecommunications networks and ten times as fast as current CSD services on GSM networks. By allowing information to be transmitted more quickly, immediately and efficiently across the mobile network, GPRS results in a relatively less costly mobile data service compared to SMS and CSD.
- Immediacy - GPRS facilitates instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage. No dial-up modem connection is necessary. This is why GPRS users are sometimes referred to be as being "always connected". Immediacy is one of the advantages of GPRS (and SMS) when compared to CSD.
- New and better applications - GPRS facilitates several new applications that have not previously been available over GSM networks due to the limitations in speed of CSD (9,6 kb/s) and message length of SMS (160 characters). GPRS enables the Internet applications on desktops from web browsing to chat over the mobile network.

3.2.2.3 Universal Mobile Telecommunications System

Universal Mobile Telecommunications System (UMTS) is a Third Generation (3G), broadband, packet-based transmission of text, digitized voice, video, and multimedia at data rates up to and possibly higher than 2 megabits per second (Mbps), offering a consistent set of services to mobile computer and phone users no matter where they are located in the world (3G Generation 2004). Based on the GSM communication standard, UMTS, endorsed by major standards bodies and manufacturers, is the planned standard for mobile users around the world by 2005. Once UMTS is fully implemented, computer and phone users can be constantly attached to the Internet as they travel, and as they roam have the same set of capabilities no matter where they travel to. Users will have access through a combination of terrestrial wireless and satellite transmissions. Until UMTS is fully implemented, users can have multi-mode devices that switch to the currently available technology (such as GPRS) where UMTS is not yet available (Andersson 2001). The higher bandwidth of UMTS also promises new services, such as video conferencing. UMTS promises to realise the Virtual Home Environment in which a roaming user can have the same services to which the user is accustomed when at home or in the office, through a combination of transparent terrestrial and satellite connections. Figure 3.5 illustrates how mobile communication networks for multimedia may look like once UMTS is fully implemented.



Source: 3G Generation 2004

Figure 3.5 Mobile communication networks for multimedia when UMTS is implemented

3.3 POSITION LOCATION

Position location is the process of determining the geographical location (expressed in a particular coordinate projection system, e.g. the World Geodetic System 1984 (WGS84) ellipsoid) of a person or object on the globe, using what is known as locationing technology (Wireless Developer Network 2003). The currently available locationing technologies are discussed below.

3.3.1 Manually

By means of a human's awareness of his/her surroundings, he/she can use the GUI of an M-GIS application (either mobile or fixed) to interface with the Man-Machine Interface (MMI) of the application, in order to manually enter his/her location in a geographical format as required. This can be one or more of the following ways:

- geographical coordinate
- street name (and street address number, if available)
- street crossing names
- Point of Interest (POI) name

This location information can then be accepted by the M-GIS application for further processing.

The location accuracy of this method is dependent on the accuracy of the human location input.

3.3.2 Nearest Cell Mast / Single Cell-ID

The general location of a user with a mobile phone is always known to his/her Mobile Cellular Operator (MCO) on which roaming is taking place. This is because the MCO records the Cell-ID of one of the nearest cell masts to which the cellphone is connected to for communications.

Although the accuracy of this method can vary between 100m and 30km, it is a relative simple and cost-effective means of determining location, since no special upgrade to cellphones or cell masts are needed, i.e. the technology is already in place to facilitate this. MTN's FindMe and Vodacom's Look4it services are examples of M-GIS applications that uses this method (see Chapter 2).

3.3.3 Multiple Cell Triangulation

This is a sophisticated technique of cellular location. Two or more cell masts are needed to accurately pinpoint a cellphone's location. The particular MCO's GSM network also needs to have the necessary hardware and infrastructure in place in order to support accurate position locationing. There are four ways in which this is done:

Angle of Arrival

The cellular signal strength is measured and compared between two nearest cell masts. An estimation of the cellphone's location is determined within an accuracy of 150m to 300m.

Time of Arrival

The time of cellular signal arrival is measured and compared between two or more nearest cell masts. An estimation of the cellphone's location is determined within an accuracy of 100m.

Time Differential of Arrival

This is a more advanced technique based on Time of Arrival and uses three or more nearest cell masts. Location accuracy is improved to between 50m and 75m.

Radio Camera Technology

This is a very advanced location determination technique where the shape of the GSM waveform is analysed. Accuracy of 50m or less can be obtained.

Since accurate positioning is important for typical M-GIS services like street routing, it is clear that the better locationing technology used, the more accurate the source location of the user can be assumed, and less chance that inaccurate source location fed into an M-GIS application can occur.

3.3.4 Global Positioning System

Using Global Positioning System (GPS) currently provides the best possible location positioning accuracy (Garmin 2000).

GPS is a worldwide radio-navigation system consisting of a constellation of 24 satellites (in orbit around the earth) and their controlling ground stations. This system was built by the United States Department of Defence at a cost of approximately US$12 billion. Originally an accuracy scrambling system was implemented to all GPS users except United States military personnel. However, this restriction had to be removed during the 1991 Gulf War since United States military ground units did not have enough accuracy descrambling GPS receivers, so that conventional and commercial receivers had to be used. Ever since, GPS now provides full accuracy (1m) to all GPS receivers. With some advanced forms of GPS, position measurements can be made accurate to 1cm.

GPS receivers use the satellites as reference points to calculate positions. These receivers have been miniaturized to just a few integrated circuits and so are becoming very economical, which makes the technology accessible to virtually everyone. Today, GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, and even Pocket PCs.

GPS effectively works in five sequential steps (Garmin 2000):

1. The basis of GPS is "triangulation" from satellites.
2. To "triangulate," a GPS receiver measures distance using the travel time of radio signals.
3. To measure travel time, GPS uses very accurate timing techniques.
4. Converting travel time into distance, the satellites’ locations in orbit are determined. High orbits and precise monitoring are used to obtain this.
5. Any delays the signal experiences while travelling through the atmosphere are compensated for.

This section aimed at providing the reader with a solid background on the communication technologies and infrastructure relevant to a typical M-GIS application. Hard-line and OTA transmissions were discussed and its relevance and usability to M-GIS was described. Basic and advanced positioning technologies, which are readily available today in South Africa, were shown to be of great use to M-GIS applications where the user's location is important in providing useful geographical information to him/her.

However, the heart of most M-GIS applications lies at the servers, which is discussed next.

3.4 SERVER COMPONENTS

Most of the physical processing done by a thin-client M-GIS application occurs on the computer servers. Two types of servers are needed: a web server to handle requests from and responses to the client (via the MCO Gateway), and a map server to analyse the requests from the web server and to prepare the relevant geographical information and return it to the web server. These two conceptual servers can in fact be one machine, but this is usually not recommended because of the potentially severe load generated by multiple M-GIS requests and the subsequent preparation of geographical information for those requests. Thus, two machines are typically used. They may or may not reside in the same Local Area Network (LAN).

The hardware specifications for the web and map server are not discussed here; the servers used for the sample M-GIS application are representative of typical hardware specifications for such servers; refer to Chapter 4 for more details.

The software that can be used for an M-GIS application are divided into two categories: those that run on the web server and those that run on the map server (Graham *et al.* 2003). There are also some generic software programs that should run on both machines, for example an operating system, HTTP/XML parsers, Servlet engines, etc.

3.4.1 Web server software

The software needed for the web server is typical for most web servers. Since most programming languages are designed to function under a wide range of different operating systems, it is up to the developer to decide on one or more programming languages that are convenient to him/her. Based on prior research the author has concluded that the following popular software can be used on the web server (divided into broad categories):

3.4.1.1 Operating system

- Microsoft Windows 2000 (or 2003) Server
- Linux (any major distribution) with Apache as web server software

3.4.1.2 Servlet engines

The task of Servlet engines ("Servlets") is to handle incoming requests from the client, communicate with the map server, and return the geographical content received from the map server back to the client. The following Servlet engines are suitable and widely used:

- New Atlanta Servlet ServletExec (for Windows OS)
- JBoss/Jakarta Tomcat Catalina (for Linux OS)

3.4.1.3 Programming languages

The programming language should be able to send and receive TCP/IP HTTP communications from the MCO Gateway as well as the map server. Examples of programming languages that would be suitable for this are:

- Java 2 Enterprise Edition (J2EE)
- C++
- C# (on Microsoft .Net framework)
- Delphi
- Visual Basic

3.4.1.4 XML parsers

If the syntax type of the communication with the map server or billing server is XML, for instance, an XML parser is needed to encode and decode ("parse") the XML code sent between the two machines via the HTTP TCP/IP protocol (Box *et al*. 2000). Java has a good XML parser object built into its API, while Visual Basic applications can make use of the Microsoft HTTPXML parser object (Pitts 1999).

3.4.1.5 Other software

It is always recommended that any web server open to the Internet be protected by good anti-virus software to protect itself from malicious viruses, hacking, etc. A good and secure firewall server, situated between the web server and the external Internet, is also a good idea as an extra measure of protection.

3.4.2 Map server software

This is the server that will perform most of the geographical operations in order to deliver useful geographical content on request. Besides the generic software that are needed for the web server (e.g. operating system, HTTP/XML parsers, Servlet engines, etc.), a substantial amount of GIS software and software capable of performing geographical operations are needed on the map server. These software can be divided into two categories: software for the generation of basic map backdrops, and software for preparing special geographical information (e.g. optimum street routes). Typical examples of both GIS software categories are discussed below.

3.4.2.1 Map generation software

Most M-GIS applications will require a basic street map as backdrop to more special geographical content. The market leader for generating digital maps from a geodatabase is ESRI's ArcIMS (Internet Map Server). Alternatively, Scalable Vector Graphics (SVG), Linux’s Geographic Resources Analysis Support System (GRASS) and OpenSource MapServer are three other commonly-known mainstream platforms for generating digital maps. These platforms could also have been used for serving maps to this study’s sample M-GIS application (MobiMap), but because of the complexity of the MapStudio geodatabase, SVG was found not to sufficiently support of the spatial formats used by the MapStudio geodatabase. GRASS runs on the Linux operating system, but the only available web server at MobiMap’s disposal was a Windows-operated server (which was already running several other Windows server applications). OpenSource MapServer is very similar to ArcIMS in terms of capabilities and would have been a possible choice, but familiarity with the ESRI range of products and map formats, as well as the fact that ArcIMS supports more raster map image formats, it was decided to use ArcIMS for the digital map generation. Thus, ArcIMS is used in the case study to illustrate the serving of digital maps to MobiMap client devices.

ArcIMS is sophisticated server-side software which follows an integrated approach to creating and maintaining geography-based websites (ESRI 2002). ArcIMS offers powerful GIS capabilities in an easy-to-use framework. It is the latest solution ESRI has created for serving maps on the Internet, and has evolved from other ESRI solutions (explained below), taking some of the best elements of each. However, each IMS solution offers unique features and functionality so that one product does not replace another.

ArcView Internet Map Server is an extension to ArcView GIS 3.1/3.2 that enables live mapping and GIS applications on the Internet. No programming needs to be done because the extension provides a ready-made Java Applet called MapCafé, allowing people to view, browse, explore, and query ArcView GIS documents on the Internet.

MapObjects Internet Map Server is an extension product for MapObjects that is designed for Windows developers who want to build custom web applications (ESRI 2001f). MapObjects IMS combines the ease of use of ArcExplorer with the power and flexibility of MapObjects, customizable with Visual Basic, Delphi, Visual C++, and other programming languages.

ArcIMS clients send requests for maps to the ArcIMS server using HTTP. After the request is sent the connection to the server is closed while the ArcIMS server generates a response. Each combination of request sent to the server and the corresponding response is called an atomic transaction.

ArcIMS software is a popular foundation for distributing GIS data and applications on the Internet (ESRI 2002). It includes software for creating and administering mapping websites, server components for serving, and client software for viewing those sites.

ArcIMS server-side components work with a web server to distribute mapping data through the World Wide Web (WWW). Like web server software, ArcIMS is always running in the background on the server machine, waiting (“idling”) until it is needed.

In terms of client-side components, ArcIMS supports HTML and Java Client Viewers that significantly optimise the performance of many operations. HTML Viewers are lightweight clients that receive image maps from the ArcIMS Spatial Server. Java Viewers serve information to a client browser in a specially optimised compressed format, resulting in new processing capabilities.

3.4.2.2 Network routing software

This research focuses on one particular useful GIS capability namely network routing. In the context of an M-GIS application, this capability could be put to use to provide the user with optimum street route directions. The concept of network routing is briefly explained, after which two examples of institutions offering street network routing services are discussed.

Network routing relies on an implementation of a shortest-path algorithm on an interconnected line network (ESRI 1991). An algorithm is a step-by-step procedure that results in a conclusion, like the least-cost path. There are several algorithms that find least-cost paths through such a network. Perhaps the most well known algorithm is generally credited to Dijkstra. It is one of the simplest path finding algorithms and many software routing engines make use of it.

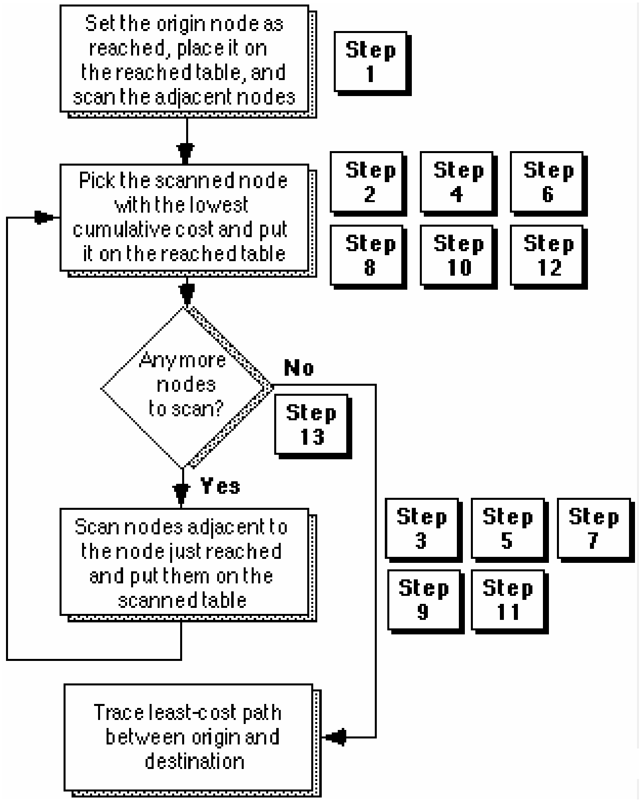
Least-cost paths will be found from the origin node. Given any node, the adjacent nodes are the nodes at the other end of the line segments connected to that node. A reached node is any node that has been reached by the least-cost path. A node becomes reached when it has the lowest cumulative travel time from the set of scanned nodes. This will become apparent when the algorithm is executed, and is the salient feature of the algorithm.

A "reached table" is created and contains information about nodes that have been reached by the least-cost path. The reached table has one record for every node in the coverage. It contains the following items:

- nodes: each containing the cumulative cost (which is the cost (such as time) it takes to reach the node by the least-cost path, as calculated by the algorithm);
- previous node (which is the adjacent node from which travel was made); and
- a scanned node which is any non-reached node adjacent to a reached node.

A "scanned table" is created and contains temporary information for the algorithm. At each step of the algorithm, entries are added or subtracted from the scanned table, so the number of entries in the scanned table varies. Cumulative cost and previous node have the same definition as in the reached table. An unscanned node is any node that has not been scanned or reached.

The flowchart in Figure 3.6 illustrates the correspondence between the flowchart components and the general steps of the algorithm.



Source: ESRI 1991

Figure 3.6 Network routing analysis flowchart

The author's research revealed three very popular street network routing software programs currently available in the market. They are the ChronoX Routing Engine by Magellan Engénierie, the Routing Engine by Map & Guide GmbH, and the RouteMAP IMS Engine by ESRI.

Magellan ChronoX Routing Engine

ChronoX, developed by Magellan Engénierie, is a powerful engine to add advanced functionalities in relation with the road network to Windows based applications. If a vector ESRI Shapefile or MapInfo Tabfile contains individual segments of roads, ChronoX can operate on it. It uses these segments to calculate a route through a road network (optimised by time or distance), and returns the IDs of those road segments, representing the resulting route. ChronoX comes in the form of a 32-bit Microsoft Windows ActiveX Control (OCX) (to be installed on the processing server) and has the following characteristics:

- Distance, time or cost computation - by using any geographical attributes of each road segment, total distance, time and costs can be calculated.
- Handling of road hierarchy - time-optimised routes can be delivered by making use of road segment attributes indicating weights, thus presenting the roads as a hierarchical network.

- Fully customizable “roadbooks” - the ChronoX roadbook is the data structure which stores the optimum calculated route, and can be customised for specialised presentation purposes.
- Advanced settings and vehicle library - different vehicle profiles can be created and subsequently stored in a vehicle library. When a route is requested, the particular vehicle profile to be used can be specified.
- Features to tie up (x,y) locations or POIs to a network - a route can be forced to include specified road segments. For example, if a POI is known to exist close to road segment ID number 110, a simple specification to the routing request will ensure that the calculated route uses road segment ID 110.

Because of its ease of use, impressive performance and rich diversity of functions, the ChronoX version 3.0 Routing Engine was used in the M-GIS sample application of this research study. See Chapter 4 for more details on how it was implemented.

Map & Guide Routing Engine

The Map & Guide Routing Engine, developed by Map & Guide GmbH in Germany, is part of its proprietary Internet map server software called iNETServer. Similar to Magellan ChronoX Routing Engine, the Map & Guide Routing Engine is a 32-bit ActiveX (OCX) control that can be utilised on a server to deliver a vast array of GIS functions. This routing engine is used by the SmartRoute M-GIS product (see “SmartRoute” in Chapter 2).

ESRI RouteMAP IMS Engine

RouteMAP IMS by ESRI allows for the creation of a web page with maps and detailed driving directions (ESRI 2001c & 2001e). Its stand-alone software resides on the web server and the administrator can change, edit, and serve an unlimited number of maps and routes, while having total control of the GUI and content.

RouteMAP IMS can also be used by Application Service Providers (ASPs) who want to offer customers the ability to map their locations. Using a standard web browser, individuals can access these maps to find and route to the nearest company locations. In this case, map data resides on the ASP’s computers and are served to customer websites that have map authoring software for map creation and publishing.

Normally, RouteMAP IMS only functioned with United States or European formatted geographical data (in terms of the codes they use as naming convention for their address locations). However, according to Martin (2005 Pers com), ESRI's development branch in South Africa (GIMS SA) is now in the process of modifying RouteMAP IMS to work with South African address formats as well. This opens the door of opportunities for local application developers interested in using RouteMAP IMS as routing engine for web-based street routing applications.

3.5 GEODATABASE

No M-GIS application can be complete without a sufficient geodatabase to derive useful geographical content from. This section briefly describes the properties of the South African geodatabase that was used for the sample application.

MapStudio is a leading supplier of paper maps and digital map data in South Africa. Because of this and the fact that its very complete digital geodatabase is in the popular and convenient ESRI Shapefile GIS format, it was decided to use this geodatabase for the delivery of geographical information to the study's sample M-GIS application.

The MapStudio geodataset is jointly owned in a 50:50 rights division agreement by MapStudio SA (Pty) Ltd and MapIT (Pty) Ltd, and consists of the following subsets:

- ESRI Shapefiles for South African geographical features (streets, towns, built-up areas, etc.)
- ESRI Shapefile containing more than 500000 segments of SA roads (for routing purposes)
- POI table - contains approximately 29000 POIs, categorised into 51 categories.
- National Address Range (NAR) table - contains nearly 600000 national street addresses.
- Road Crossings (RC) table - contains nearly 200000 street crossings. These street crossings can be used in a search for the closest street crossing to the user's location, for instance. As destination, he/she might also want to specify a street crossing. These are two points that can be used as the start and stop points to calculate an optimum route.
- Commercial content tables - contain the locations and information of commercial institutions offering services which can be displayed on raster maps.

The next chapter demonstrates the development and implementation of a real-time live M-GIS application, aptly named ***MobiMap***. With a sufficient background on all the components relevant to a typical M-GIS, the reader can turn over and see all the theory put to the test.

CHAPTER 4: SAMPLE M-GIS APPLICATION DEVELOPMENT

In order to demonstrate all the facets pertinent to a Mobile Geographic Information System (M-GIS) application, the author designed, developed, tested and implemented a sophisticated M-GIS project over a period of approximately two years (2002-2003). This project would serve as a case study to demonstrate an M-GIS application in South Africa.

The technology available during the two-year period was utilised for the development and implementation of this project. During the course of the two years, the number of relevant technologies available in South Africa increased dramatically, along with the service quality of existing technologies. The development of the M-GIS project was kept dynamic in order to facilitate improvements and/or incorporations of emerging technologies, thus ensuring the project remained up-to-date and as far as possible representative of relevant M-GIS technologies. By staying in touch with the mobile device and GIS industry, the author succeeded in the consequent implementation of the M-GIS project, which has become known as ***MobiMap***.

Project MobiMap is discussed in detail below. First, the initial objectives of MobiMap are stated. Following that, the application design is laid out (as formed around the objectives). All the expected required hardware and software technologies are listed thereafter, as well as which were chosen (or available) for use. The application development is then explained in detail. Project implementation follows the final testing stage.

4.1 OBJECTIVES

MobiMap had to achieve a number of objectives, which were divided into two distinctive classes: holistic objectives (to demonstrate the general capabilities of a typical M-GIS) and physical objectives (hardware compatibilities, speed requirements, etc.).

The following most important holistic objectives were set for MobiMap:

1. to demonstrate how the merging of several technologies could successfully deliver a usable and scaleable M-GIS application;
2. to highlight the aspects of an M-GIS application that are significantly dependant on the technology of the time, in terms of reliability, shortcomings and improvements; and
3. to act as a suitable, representative and practical project which fulfils and complements this research thesis.

The following most important physical objectives were set for MobiMap:

1. A sophisticated yet simple and efficient design, development and implementation process.
2. A high degree of cost-effectiveness applied to as large extent as possible during the whole Software Development Life Cycle (SDLC).
3. Technological constraints have to be adhered to (e.g. availability of hardware and infrastructure).
4. Application design has to be dynamic in order to facilitate scalability as user base and functionalities grow.
5. Man-Machine Interface (MMI) has to be simplistic and user-friendly.
6. Application design and utilisation of infrastructure has to ensure an acceptable level of reliability.

Throughout the course of the design and development of MobiMap the above holistic and physical objectives were pursued as far as possible. As can be expected from any typical computer application, a number of problems were encountered, some of which were foreseen, and some not. However, it is believed that the above objectives were fulfilled to satisfactory levels, and all expectations in terms of performance and results were met.

Although MobiMap was primarily designed and developed by the author, there are some minor software components which must be accredited to other fellow developers and Third Parties. Without these software components, MobiMap's components would not have been able to interact with each other today as it does. Full recognition to these persons and parties are given in the "Acknowledgements" section at the start of this study.

Henceforth, the physical work on MobiMap commencing with its design is discussed below in detail.

4.2 DESIGN

Good designs are imperative to the development and success of any technological project (Graham *et al.* 2003; Reichenbacher 2003). The following guidelines from Reichenbacher (2003) are crucial to follow when designing any project of similar stature to an M-GIS project:

Scalability and expandability

Technological advances in the computer, electronics and telecommunication fields are happening today at such a fast pace that any system that bases its functionality on such technologies are bound to become what's known as a "legacy" system as soon as the technology it utilises becomes obsolete (or worse, unsupported). Therefore it is very important that the system be designed to allow for expansion of functionality and/or upgrades of the mission-critical components that form an integral part of the system.

Simplicity and efficiency

Excessively complex system designs are usually doomed to become a behemoth of programming components and eventually stagnate to become a system that is too complex to complete, debug, implement and maintain (physically and financially). One way which is usually very successful in avoiding this trap is to follow the Extreme Programming (XP) approach when developing the programming code that will form the heart of the operation(s) of the system. However, implementation of this unique approach should ideally already start with the system design.

Multiple and qualified inputs

An M-GIS system will typically consist of a variety of technological components (referred to here in the abstract sense) that span across several scientific fields. The two main relevant fields here are computer programming and GIS. Another important field is billing. These three fields alone warrant expert input and opinions from at least three professional persons or entities: computer programmers, GIS specialists, and system billing consultants. The harmonic and smooth co-operation of all the relevant components of an M-GIS system deserves that its design be professionally undertaken by experts in the fields of all the technological facets it entails.

The author endeavoured to follow and implement the above guidelines in the four fundamental designs of MobiMap, namely:

1. Architectural design;
2. Functional / MMI design;
3. Business model design; and
4. Graphical User Interface (GUI) design.

Each of the above designs are illustrated diagrammatically and explained next.

4.2.1 Architectural design

This is MobiMap's first and most encapsulating design, illustrating most of the major hardware components involved (see Figure 4.1). By means of a quick glance, the important hardware systems can be distinguished as well as how they interact with each other.

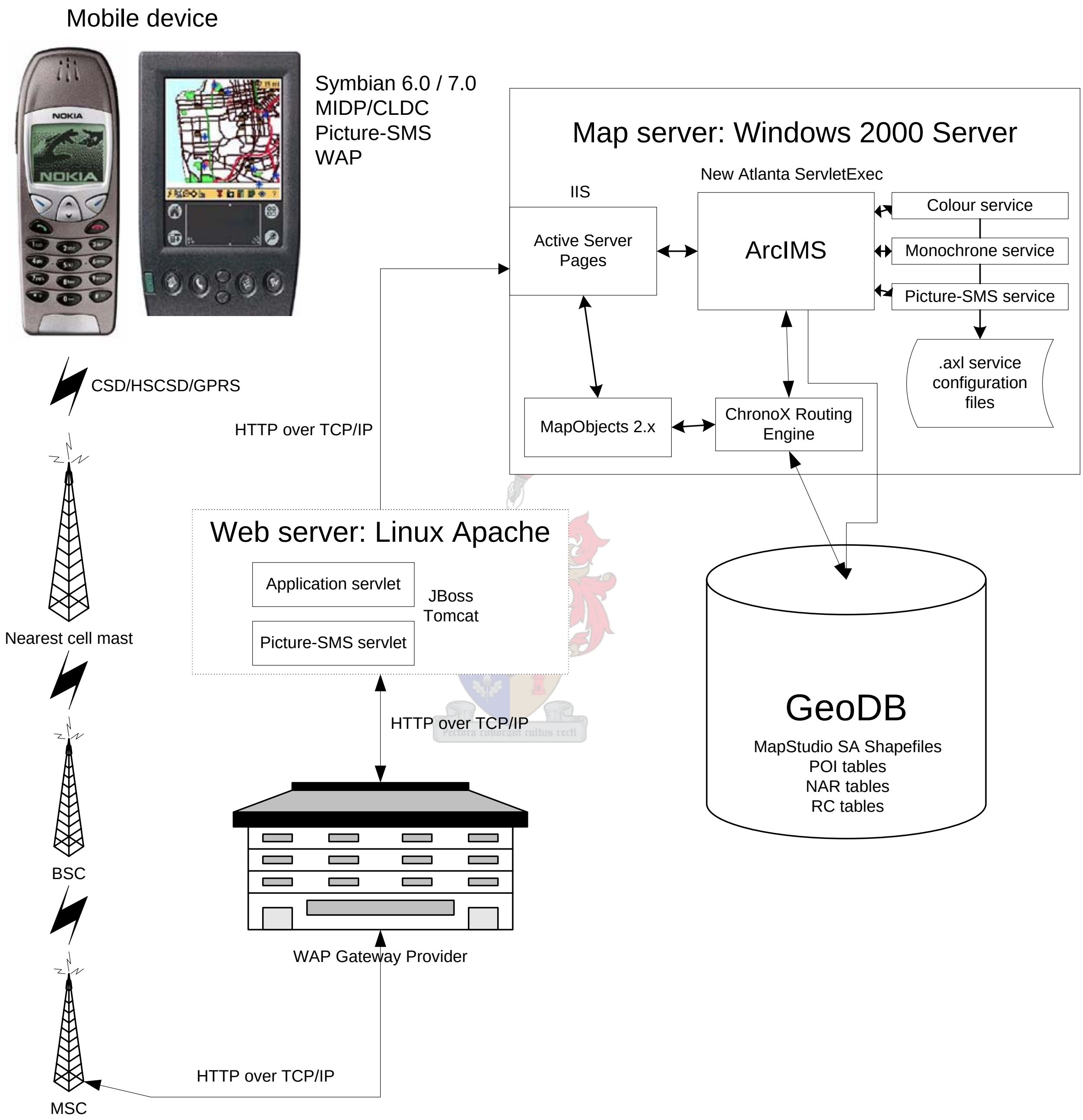


Figure 4.1 Architectural design

The client device (in this case a cellphone) makes a request for geographical information. This request is carried "Over The Air" (OTA) to the nearest cell mast, Base Switching Centre (BSC), Mobile Switching Centre (MSC) and finally to the Mobile Cellular Operator (MCO) Gateway Provider, which redirects the request to the web server via Hypertext Transfer Protocol (HTTP) over Transmission Control Protocol / Internet Protocol (TCP/IP) on a hard-line transmission. The web server, running a Linux Operating System (OS) distribution with Apache as the web server software, marshals the request to the appropriate Servlet, managed by JBoss Tomcat. The request is re-formatted to Extensible Markup Language (XML) syntax and sent to the map server. An Active Server Page (ASP) acceptor page, managed by Microsoft's Internet Information Server (IIS) on the map server, accepts the request and uses the relevant ArcIMS service to prepare the geographical information. The spatial data for this information is retrieved from the appropriate geodatabase table(s). If a street route was requested, the ChronoX Routing Engine is invoked as well. The response travels all the way back to the web server and eventually the client application on the cellphone presents the geographical information to the user.

4.2.2 Functional / MMI design

A flow chart is used here to illustrate how MobiMap functions (Figure 4.2). Each of the steps, from the time when the user initiates the system, up to when he/she receives the required geographical information (ultimately a digital map indicating a shortest street route (or not), and/or shortest route turn-by turn directions), are presented in logical order. The MMI allows for the functional workings of the application to take place, therefore forming part of MobiMap's functionality.

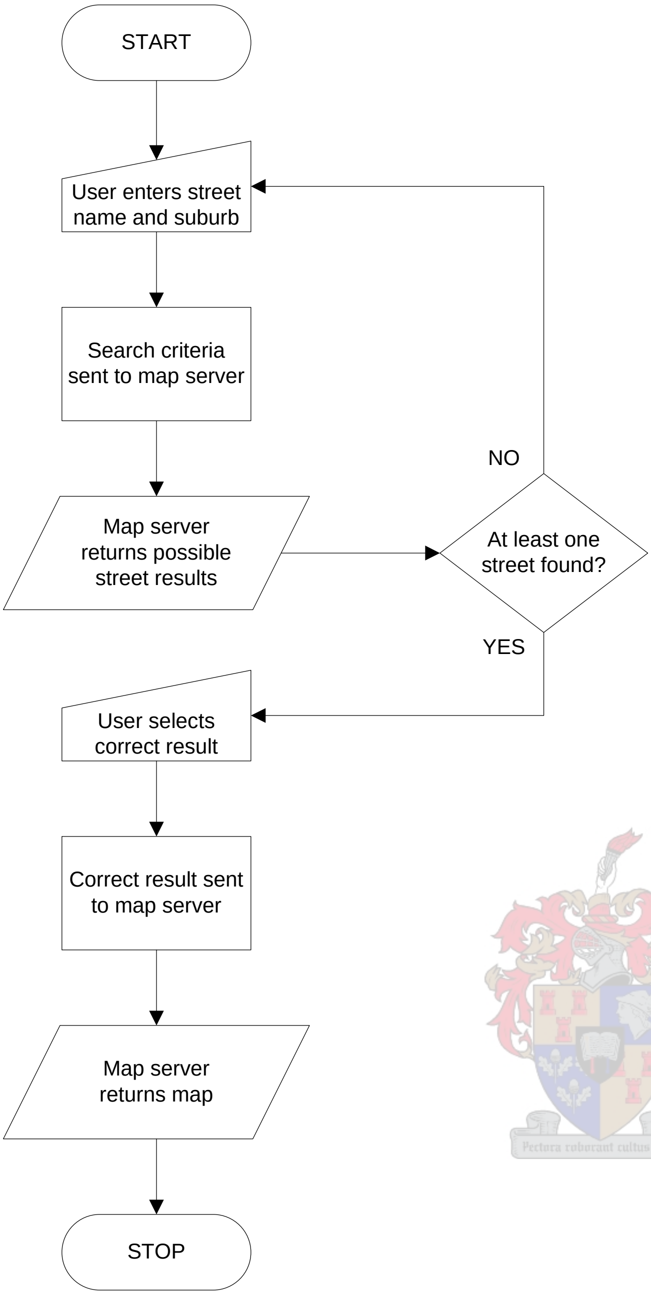


Figure 4.2 Functional / MMI design

The user enters a street name (mandatory) and suburb name (optional) and the search criteria are submitted to the map server. The map server searches the street database for matching records. A list of possible matching records is returned to the user. If no records were found, the user can try entering a street name again. When the user chooses the correct street, its name is returned to the map server, which generates a raster map with the geocentroid of the street as centre point. This map is then returned to the user.

4.2.3 Business model design

The main purpose of the business model design (Figure 4.3) is to illustrate how the user gets billed for the use of MobiMap. Billing is a very important facet of any commercial system, so it is important that this design also adhere to the aforementioned design guidelines.

MobiMap's billing was developed and implemented in co-operation with ExactMobile (Pty) Ltd.

Users subscribe to the MobiMap ExactMobile service (receiving a username and password) prior to using the application, and credits are purchased. A fixed, pre-determined amount of credits are subtracted from the user's account each time he/she successfully receives a map on his/her cellphone.

The user logs in to the ExactMobile system. He/she performs a street search and gets search results back. The moment a map is requested, a credit check is performed on his/her account. If sufficient credits are available, the process continues. If not, the user is reminded to purchase more credits.

The user is only billed (i.e. a fixed amount of credits subtracted from his/her account) when the client device (cellphone) sends an acknowledgement transmission to the web server stating that the map has been fully received and displayed successfully.

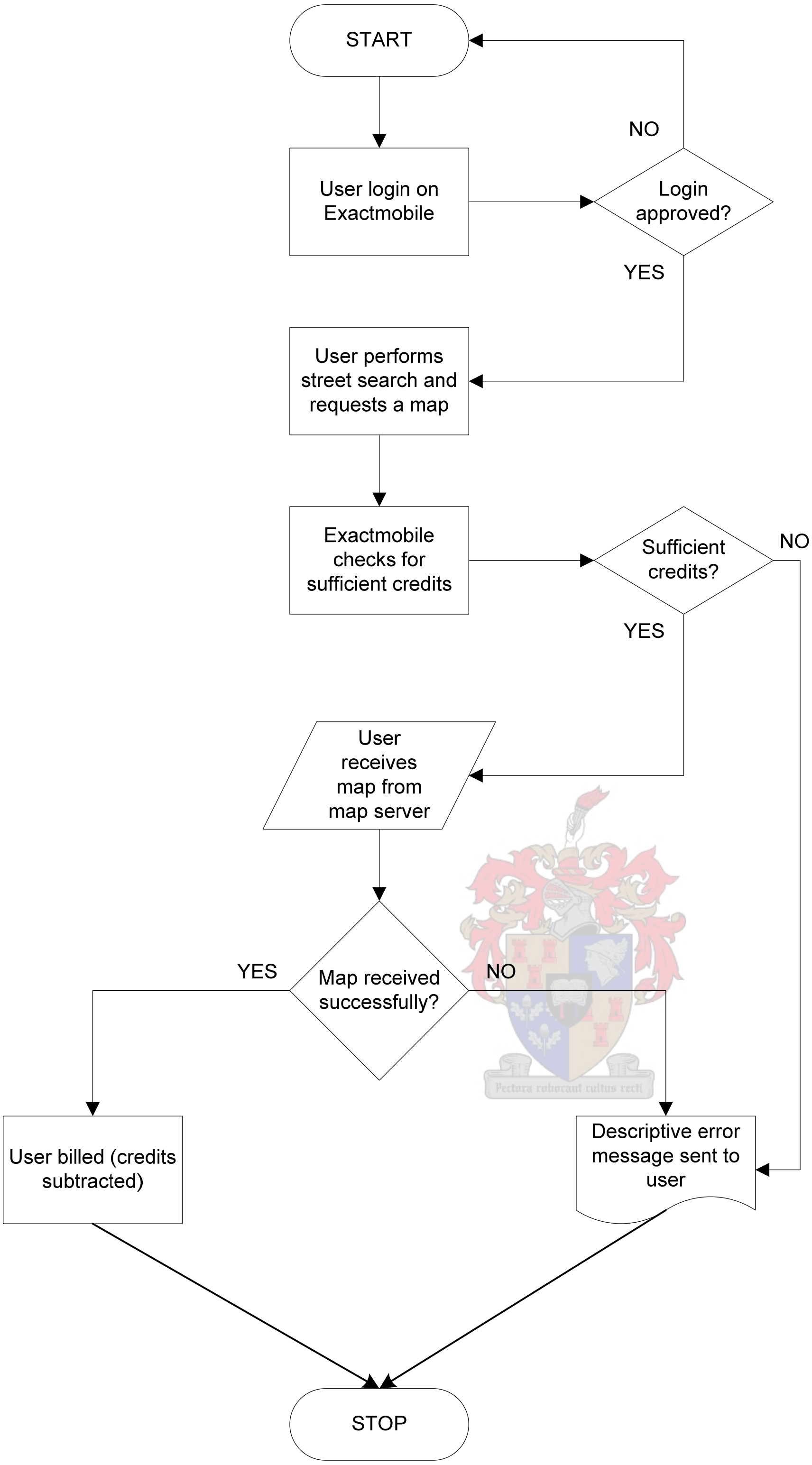


Figure 4.3 Business model design

4.2.4 GUI design

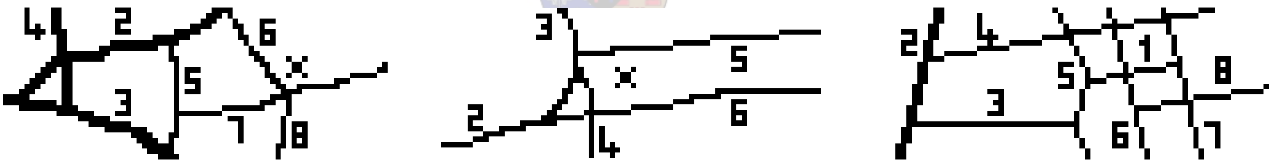
MobiMap's GUI is the visible interface between the user and the MMI. The GUI consists of several screens on the mobile device that pop up depending on the current step the user is busy with in the MMI. These screens were mostly designed on-the-fly and modified continuously as needed. A few screenshots below illustrate what the final GUI looks like on all the relevant mobile devices

(Figures 4.4-4.7). The GUI screens differ from device to device, but the graphical components that are present on each screen representing a particular step in the MMI, are conceptually similar.

Figure 4.4 Map screen GUI on Motorola Accompli 008 (MIDP)

Figure 4.5 Map screen GUI on Nokia 9210i Communicator (Symbian OS 6.0)

Figure 4.6 Map screen on Nokia 3510 (Picture-SMS)



<Large area>	<Medium area>	<Small area>
Sub=Stellenbosch	Sub=Stellenbosch	Sub=Stellenbosch
x=Crozier +-	x=Crozier +-	1=Crozier
2=N1	2=R310	2=Adam Tas
3=N2	3=R304	3=Alexander
4=N7	4=R44	4=Merriman
5=R300	5=Merriman	5=Bird
6=R304	6=Dorp	6=Andringa
7=R310		7=Ryneveld
8=R44		8=Victoria

Figure 4.7 Three different-scaled map screens on Nokia 3510 (Picture-SMS)

4.3 HARDWARE AND SOFTWARE REQUIREMENTS AND USAGE

Technology, as it is known in the abstract sense of the word, is applied practically by means of man-made products. The relevant products in this case are computer (or electronic) hardware, computer software, geographical data and telecommunications infrastructure. Successful development and implementation of MobiMap required an extensive array of the abovementioned three technological products. The following section briefly explains the details pertaining to the specific make and type of these products available (at the time of development and implementation), required (to obtain acceptable levels of operation, reliability and speed of geographical content delivery to the user), and ultimately acquired and utilised.

4.3.1 Computer/electronic hardware

4.3.1.1 Microcomputer servers

An Intel Pentium-class Personal Computer (PC) was made available for the development and implementation of the server-side components of MobiMap. This server thus provided a complete service delivery of the geographical content pertinent to MobiMap, from the map server to the client device. The particular hardware specification of the server (e.g. Central Processing Unit (CPU) speed, hard drive storage and Redundant Array of Independent Disks (RAID) service, Random Access Memory (RAM) storage, etc.) was considered typical for the time and delivered acceptable performance. The hardware was upgraded from time to time to keep pace with the increased server load.

Another Intel Pentium-class PC was made available for serving digital maps to the web server. Since this map server also services Internet mapping websites with digital maps, its hardware specifications were slightly higher than that of the web server. Today, this map server serves on average approximately 30000 ArcIMS-generated raster maps per day to Internet mapping sites, MobiMap, vehicle tracking systems (e.g. NetStar and Tracker), and others. The CPU load over a 1 hour monitoring period is on average 80% which is considered acceptable.

The billing servers are a collection of two or more Pentium-class PCs which handle all billing-related transactions relevant to MobiMap. These servers are managed and maintained by ExactMobile.

4.3.1.2 Microcomputer development machines

These are ordinary office-specification desktop Pentium-class PCs that the author used to develop, debug and test the programming code for MobiMap. The specifications of those PCs used corresponded with the highest set of system requirements of the collection of programming languages and source code compilers needed. A permanent connection to the Internet was also needed to monitor results during the development and testing of MobiMap, since both the web server and map server were located at remote premises.

4.3.1.3 Mobile/handsfree devices

The following Java 2 Micro Edition (J2ME) / Mobile Information Device Profile (MIDP) compatible cellphones were available to develop the J2ME leg of MobiMap on: a Motorola Accompli A-008, T720 and a Nokia 7650.

The following Wireless Application Protocol (WAP) compatible cellphones were available to develop the WAP leg of MobiMap on: a Motorola T720, a Nokia 3330, 6310i and 7650.

The following Symbian 60 OS compatible cellphones were available to develop the Java 2 Standard Edition (J2SE) leg of MobiMap on: a Nokia 7650 and 9210i.

The following Picture-SMS compatible cellphones were available to develop the Short Messaging Service (SMS) leg of MobiMap on: a Motorola T720, a Nokia 3330, 3510, 6210, 7650 and 9210i.

Some of the above cellphones were both Global System for Mobile Communication (GSM) and General Packet Radio Service (GPRS) enabled in order to facilitate successful and efficient communications between the phone and the web server.

4.3.2 Computer software

4.3.2.1 Programming

The programming of MobiMap's source code was implemented in three conceptual cores: programming on the web server, the map server, and on the mobile devices (known as client programming).

The main server components for handling incoming requests and serving the appropriate results were programmed in Java 2 Enterprise Edition (J2EE). JBoss Tomcat was used for the deployment and maintenance of each of the Java Servlets. JSwat was used for code debugging, and Ant was used to conveniently compile all Java classes and dependencies with single-line commands and parameters. JUnit was used for the XP testing of each source code compilation, while JUnitPerf was used to measure and fine-tune the performance of the web server running the Servlets. Two scripting languages, Perl and Python, was marginally used for executing some Linux scripts pertaining to the SMS leg of MobiMap.

WAP programming was also done on the web server which, when requested from a mobile device, runs on the server and serves Wireless Markup Language (WML) formatted content back to the device.

Requests for geographical data from the web server was handled by ASP POST acceptor pages (running under IIS version 6.0) deployed on the map server. A combination of JavaScript and VBScript pages handled all incoming requests, communication with ArcIMS (via the ArcXML markup language), and delivery of results back to the web server. MapObjects 2.x was used to instantiate point and line objects (amongst others) in the ASP code in order to facilitate the creation of geographical objects in the correct format as required by the methods of the ChronoX Library (which was also instantiated as an object in the executed ASP code). Java Runtime Edition (JRE) was also needed on the map server as one of ArcIMS's pre-requisites. Version 1.3.0 was initially installed, which was later upgraded to version 1.3.1 to overcome instability issues.

Client programming in MobiMap translates to programming on the devices which act as clients in the transactional architecture, in this case cellphones. J2ME was used to program source code which was compiled to byte code (Java Classes) which adhered to the MIDP specification on the MIDP-compatible phones. J2SE was used to develop classes that would run on Symbian 60 (version 6.0) operating systems on a select few of the cellphones available, as well as for the Picture-SMS compatible cellphones.

The Motorola cellphones (Accompli A-008 and T720) also had custom classes that contained dedicated GUI widget objects. These were also compiled and loaded on the Motorola phones and were used by the J2ME GUI classes on them to display and use Motorola-specific GUI widgets.

4.3.2.2 GIS programs

ArcIMS 3.1 (which was later upgraded to ArcIMS 4.0) was used to generate raster maps based on the geodataset. The other alternative GIS programs or platforms that could have been used to generate maps include Scalable Vector Graphics (SVG), Geographic Resources Analysis Support System (GRASS) and OpenSource MapServer. See Section 3.4.2.1 for an explanation why ArcIMS was chosen for the digital map delivery to MobiMap.

Requests for geographical data were made to the three ArcIMS background services (Application Server, Monitor, Tasker) running on the map server. The syntax of these requests (and responses from ArcIMS) was the ArcXML format. Separate front-end ArcIMS services were created using the ArcIMS Administrator program; each of those serviced a particular family of requests from the web server (either request for a colour map, monochrome map, or Picture-SMS map). These services are configured separately by ArcXML-formatted configuration files, detailing which map layers are shown on the map, how each of their geographical features are styled, etc. These ArcXML configuration files are also known as ".axl" files.

The ChronoX Street Routing Engine 3.0 from Magellan Ingénierie was used to provide the optimal street routing functionality of MobiMap. As explained in 4.3.2.1, MapObjects server-side objects were instantiated in the executed ASP code on the map server to facilitate the creation of geographical information which is needed by the ChronoX libraries.

4.3.2.3 Operating system and administrative services

The development of the programming code was done on a Pentium-class PC running Microsoft Windows XP Professional. The web server runs on Linux Apache and the map server on Microsoft Windows 2000 Server. Microsoft IIS version 6.0 is responsible for the handling of all the Internet requests and responses through ASP pages running as web services. New Atlanta ServletExec allows for the deployment of Java Servlets (as implemented by ArcIMS) and Java Server Pages (JSP) on IIS in a standard, robust, high-performance environment. Thus, in order for ArcIMS to operate successfully, a Servlet engine like New Atlanta ServletExec is necessary. Version 4.1.1 was used. JBoss Tomcat was used as the Java Servlet deployer on the web server.

4.3.3 Geographical data

MapStudio's digital geodatabase was used to supply the delivery of geographical information to MobiMap. Although the usage of a spatial database engine would have improved the efficiency and performance of spatial data retrieval, it was decided not to use such an engine as acceptable performance was obtained using bare ESRI Shapefiles stored on the map server's hard drive. ArcIMS was quite efficient and quick in generating raster maps from those Shapefiles. However, if MobiMap grew to such an extent that vector maps would have had to be generated, a spatial database engine like ESRI's ArcSDE would be needed. This would significantly redude the time needed to generate vector maps. Vector map generation as a solution to map delivery to MobiMap client devices is discussed in more depth in Section 5.1. Also refer to Chapter 6.

The following subsets of the geodatabase were used:

- ESRI Shapefiles for South African geographical features (streets, towns, built-up areas, etc.)
- ESRI Shapefile containing segments of SA roads (for the purpose of street routing)
- Points of Interest (POI) databases
  All POIs are configured to be displayed (with appropriate icons and labels) by default on all maps served to MobiMap by means of the .axl configuration file for the ArcIMS front-end services used by MobiMap.
- National Address Range (NAR) database
  All address points are configured to be displayed (with appropriate icons and labels) by default on all maps served to MobiMap by means of the .axl configuration file for the ArcIMS front-end services used by MobiMap.

4.3.4 Telecommunication infrastructures

The following section describes the various telecommunication infrastructures that are used by MobiMap. The OTA telecommunications consisted of GSM and/or GPRS. Ground connectivity was achieved by means of Telkom SAIX (South African Internet eXchange) landlines transmitting TCP/IP requests and responses formatted according to the popular HTTP protocol.

4.3.4.1 GSM and GPRS

All of the utilised cellphones (see 4.3.1.3), with the exception of the Nokia 3330 and Nokia 6210, have the ability to perform both GSM and GPRS OTA transmissions. GPRS is a faster and more efficient, cost-effective means of cellular data transmission, and thus it was used for MobiMap running on cellphones. Normal GSM protocol was used for SMS/Picture-SMS transmissions.

At the time of MobiMap's development, GPRS were just beginning to be implemented by South Africa's two mobile cellular operators. As a result, there were plenty of GPRS service downtimes, which negatively affected development and testing of MobiMap's communication functions. As time passed, the quality and speed of the GPRS services improved considerably, and by the start of 2003 MobiMap could reliably communicate with the web server with very few (if any) intermittent GPRS service.

4.3.4.2 Internet (TCP/IP)

A permanent 96kb/s Internet connection enabled the author to successfully transfer compiled Java Classes to the web server and ASP code to the map server. Monitoring of the transaction log files made debugging possible. A permanent Internet connection between the web server and the map server also allowed for requests to be passed from the web server to the map server, and responses to be returned.

4.4 DEVELOPMENT

Development of most of the components was done in parallel. A simple "Hello World" client application was developed to run on the cellphones. The telecommunication infrastructures was organised and set up so that proper OTA communications could be performed. Basic Java Servlet Classes were developed to handle requests from the cellphones and deliver "Hello World" responses in return.

Once basic functionality between the cellphones and the web server was established, simple JavaScript code was developed on the map server to deliver some geographical content back to the web server (e.g. simple street search results). More extensive geographical data was served as functionality on the client and web server was systematically increased. After 10 months the map server was capable of delivering colour and monochrome maps to the compatible cellphones. In addition to the raster maps, POIs were also included to be shown on the maps.

In late 2002 the SMS leg of MobiMap was developed. Servlet classes were developed (primarily by the author but also partly by fellow developers) on the map server to handle incoming SMS requests from the cellphones. Street search results were returned by means of SMSs returned to the cellphone. A Picture-SMS ArcIMS service was created on the map server, and this allowed for the delivery of Picture-SMSs to the cellphone.

MobiMap was complete with the exception of an optimum street routing service. JavaScipt code was developed to utilise the ChronoX routing library (with the aid of MapObjects geodata structures). Simple turn-by-turn instructions could be delivered upon request, as well as Shapefiles including a route on the generated raster map. These turn-by-turn instructions and raster maps with routes were successfully delivered to the cellphones.

The functionality of MobiMap was complete and tested by mid-2003. It was commercially deployed and implemented soon afterwards, and today runs as a successful Location Based Service (LBS) in South Africa under management and control of LBS Mobile (Pty) Ltd in association with ExactMobile (Pty) Ltd and MapIT (Pty) Ltd.

The development of MobiMap was by no means without problems. The following list explains the most significant problems encountered.

Quality of GPRS service

As stated previously, GPRS services in South Africa were being deployed during the time of MobiMap's initial development stages. Frequent service downtimes were experienced. This made the upload of the client applications to the cellphones very difficult, time-consuming and frustrating. On average about 5 uploads of client code per day were needed to test new functionality on the cellphone. Each of these uploads took at least 10 minutes, and when GPRS went down, the uploaded code became corrupted and thus upload had to be retried later the day when the GPRS service was up again. Physical testing of the functionality was also influenced by GPRS downtimes, since communications between the cellphone and the web server could not occur in such cases. In some instances GSM was used instead of GPRS in the case of a continued GPRS service downtime, but since using GSM is much more expensive than GPRS, this solution was eventually discontinued.

Quality of Internet service

Interruption of Internet services was also quite frequent. More often than not the service was very slow. Since MobiMap's development was done in Stellenbosch, and both the web server and the map server were hosted in Johannesburg, slow Internet services negatively affected MobiMap's testing. Raster map delivery to the phones was usually slow, and since map download was quite a frequent task in the development, this negatively affected development speed.

Unfamiliarity with new development software

Previously the author was not familiar with Java, JBoss Tomcat, ArcIMS, MapObjects, to name but a few. Significant time was needed to become acquainted with these new development software programs, perform debugging, optimisation, etc.

Unstable map server

Stability was very hard to maintain on the map server. The author had to use slow Remote Desktop Connection programs to sort out crashes and other instability problems, or even telephone calls to the map server administrators in Johannesburg, asking them to diagnose and/or fix server problems. When ArcIMS 3.1 was upgraded to version 4.0, and JRE 1.3.0 to version 1.3.1, stability improved significantly. The map server was also hacked a couple of times, after which total downtime resulted. Updated Microsoft Service Packs were continually installed, which usually minimized Microsoft security flaws and other backdoors, resulting in improved stability and less chance of server hacking. The security of the firewall computer behind which the map server resided was also improved and upgraded. Frequent power failures at the Johannesburg hosting site of the two servers also resulted in service downtimes. Uninterruptible Power Supplies (UPS) were present at the hosting site but for some reason were never properly installed.

Client requirements vs. research requirements

The immediate clients of MobiMap were a collection of the stakeholders and venture capital providers of the project (while the end-user clients would be the subscriber user base). There were cases where the author had different goals in mind for MobiMap than what client requirements (which were mostly applied later in the development phase) were. However, the author managed to persuade the relevant clients into accepting compromises in terms of application requirements and research requirements. In the end, an acceptable balance was achieved between the two sides of requirements.

MobiMap, serving as an example of a typical M-GIS application, is evaluated in the following chapter. The initial objectives are also revisited by means of a conclusive summary of all of the facets of MobiMap.

CHAPTER 5: EVALUATION OF SAMPLE M-GIS APPLICATION

This chapter evaluates MobiMap as a sample Mobile Geographic Information System (M-GIS) application. The application shortcomings, future additions, and possible improvements are discussed and evaluated against the application's costs and benefits from a financial perspective (expenditures and revenues).

5.1 SHORTCOMINGS AND FUTURE IMPROVEMENTS

MobiMap has the following shortcomings which, due to either lack of development time, resources or suitable technology, were inevitable. MobiMap can be improved by addressing these shortcomings and adding new functionalities, as explained below.

No Multimedia Messaging Service (MMS)

Although MobiMap can be extended to function using MMS, this was planned but never developed. A Java Servlet would have to be written to handle MMS requests from the Mobile Cellular Operator (MCO) Gateway Provider, and return the MMS-formatted raster map in the correct format specific to MMS technical specifications. In particular, there are several code headers that need to be implemented. MobiMap MMS will offer a significant improvement over MobiMap Picture-SMS, since the quality of the delivered raster map will be much improved (colour, larger size, etc.).

Size of raster maps

The size of the ArcIMS-generated raster maps are sometimes still too large to be delivered in an acceptable time to the cellphone. The two ways of improving this is to speed up the infrastructure used for the "Over The Air" (OTA) and ground delivery, or to decrease the map size (kilobytes, not physical map dimensions).

The first solution is, in a manner of speaking, already happening since General Packet Radio Service (GPRS) speeds are constantly being improved by South Africa's MCOs. Internet speeds are also being improved by means of many hosting companies implementing an Asymmetric Digital Subscriber Line (ADSL). Thus, the sum of all communications between the map server and the cellphone is being improved.

The second solution is not really possible to implement. ArcIMS is configured to generate Portable Network Graphics (PNG) images, which results in slightly bigger raster images than Joint Photographic Experts Group (JPEG) images or Graphic Interchange Format (GIF) images, but significantly smaller than Bitmap images (BMP). If JPEG is chosen as the raster image type, image file size is reduced but a "lossy" quality map image is generated. This affects the readability of the street labels on the map. Although GIF images can now be generated directly by ArcIMS (the GIF format is a former-proprietary image format licensed exclusively to Compuserve Graphics Inc., and is open in all countries since 7 July 2004), they are still larger in file size than the PNG format. GIF also supports only 256 colours, but this is not really a problem on the ArcIMS map images since nine colours are used at most.

An exception to the above would be the case where vector maps (generated by the map server) are sent to the client devices instead of raster maps. Vector maps are significantly smaller in byte size than raster maps and would significantly reduce the download times needed for map download. ArcIMS can be configured to generate vector maps, but performance will be affected. A spatial database engine like ESRI’s ArcSDE would efficiently handle the generation of vector maps (amongst other things) in order to keep the map generation performance at acceptable levels (see Section 4.3.3). However, additional development is also needed on the client devices; the programming code will need to be able to handle vector maps and as well as display them. This is a point for future research and is discussed in more depth in Chapter 6.

Service reliability

Telecommunication services downtimes and map server instability are problems that occurred frequently during MobiMap's development (see Section 4.4.1). Although the occurrence of these problems decreased significantly over the last two years, there are still sporadic cases when downtime occurs. It is hoped that the parties responsible for these services will minimise downtimes in the future.

National map coverage

Users want accurate and up-to-date maps displayed on their cellphones. MapStudio's digital map coverage of South Africa is indeed accurate and extensive but by no means complete. There are many rural towns that exist in the geodatabase as point locations, but for which no street data is present. MapIT is constantly improving coverage by digitising absent and new streets (and other geographical man-made features) as sources for those become available (1:50000 map sheets, aerial photography, satellite imagery, cadastral data from municipalities, town planning maps, etc.).

5.2 COSTS AND REVENUES

This section briefly summarises the expenditure (costs) and income (revenues) accounted to this study’s sample M-GIS application, MobiMap. Because MobiMap is based on the various types of technologies (including hardware, software and telecommunication infrastructures) that would typically be used for M-GIS applications, its costs and revenues can be perceived as a reasonable indication of what such a typical M-GIS project would cost and deliver. Although MobiMap was developed and implemented at least one year prior to writing this thesis, current and future costs and revenues would not be too difficult to predict, provided that current inflation trends and price increases across the entire spectrum of technologies utilised, are taken into account.

The author found that the determination of costs and revenues for MobiMap was generally not too difficult to establish, and this should be even easier in future since, for example, MCOs have recently tailored their business proposals specifically for cutting-edge products making use of cellular technology, thus streamlining the costing and revenue determination processes even further: a quick look at Vodacom's (one of South Africa's MCO's) website shows a link on the first page to full information on becoming a Vodacom Wireless Application Service Provider (WASP). A company intending to develop M-GIS applications could register as an MCO WASP and get started with the business side of M-GIS development and implementation quite soon, and get reasonably accurate cost and revenue predictions without too much difficulty beforehand.

Costs, in the context of MobiMap (and most Information Technology (IT) products), include both financial (monetary) and time expenditures. Both are summarised in the next section. A brief overview of the revenue models MobiMap was based on follows, as well as some notes on the actual approximate revenues generated by MobiMap.

5.2.1 Costs

5.2.1.1 Financial costs

The financial expenses of the MobiMap project's four main stages (design, development, testing and implementation) were funded partly by LBS Mobile (Pty) Ltd and its business partners, and partly by the author. The most prominent expenses encountered in this regard were human resource costs. This is a very broad and indirect expense attributed to MobiMap, and is better measured in terms of time costs instead of financial costs. See Section 5.1.2 for an overview of the time costs associated with the MobiMap project's stages.

All of the monetary figures given below are Value Added Tax (VAT)-inclusive approximate costs (in South African Rand currency unless specified otherwise) as applicable at the time. However, ranges are used on some items to indicate what the amount of cost variation would have typically been, depending on the specification levels of the hardware or software used. The actual cost of the particular hardware or software unit can thus be assumed to be the average between the minimum and maximum values of the cost range.

Hardware

- Web server: R15000 – R25000
- Map server: R20000 – R30000
- Billing server: R15000 – R25000
- Development Personal Computers (PC): R10000 each
- Cellphones (A-008, T720, 7650, 3330, 6310i, 9210i, etc.): R500 – R10000 each

Software

- Web server (Linux Apache, Java 2 Enterprise Edition (J2EE), JBoss, JSwat, Ant, JUnit, JUnitPerf, Perl, Python, etc.): no costs
- Map server:
    - Microsoft Windows 2000 Server: R5000
    - ESRI ArcIMS 3.1: R70000 with 20% annual maintenance fee
    - ESRI MapObjects 2.x: no cost if used in conjunction with ArcIMS
    - Sun Java Runtime Edition (JRE): no cost
    - New Atlanta Servlet ServletExec: $800
    - ChronoX 3.0: 10000€ - 20000€ depending on usage circumstances (e.g. single/multi-user)
- Billing server (Microsoft Windows 2000 Server): R5000
- Development PCs (Microsoft XP Professional): R900 each
- Cellphones (Java 2 Micro Edition (J2ME) for Mobile Information Device Profile (MIDP), Symbian OS, etc.): no costs

Geodatabase

The MapStudio/MapIT digital geodatabase for South Africa was created from various sources of spatial data over a period of four years and is updated twice a year. The costs involved with the creation and maintenance of this digital spatial data source would not be directly attributed to MobiMap since there are a number of other clients (and products) that make use of the geodatabase as well. It would thus be difficult to make an estimate of the direct costs of this geodatabase relevant to MobiMap. Nevertheless, the geodatabase is made available to users at a monthly fee, determined on the individual client's circumstances and usage profile(s). In MobiMap's case these cost figures varied significantly over time.

5.2.1.2 Time costs

The time costs applicable to MobiMap are specified with regard to the project's four main stages, namely its design, development, testing and implementation.

Design

MobiMap's initial design work consisted of daily meetings with relevant parties, including LBS Mobile (Pty) Ltd and its associates, developers and the author, for a period of approximately 3 weeks. The architectural, functional, business model and Graphical User Interface (GUI) designs (see Section 4.2) were fundamentally drawn up during this period. Thereafter, weekly design sessions were held to plan and discuss modifications and/or improvements to the initial design(s).

Development

Development of MobiMap's components (client-side and server-side) was performed mostly in parallel, starting in early 2002, and completed in early 2003 (see Section 4.4). Thus, approximately one year of work (taking normal office hours into account) was needed, and was provided by one developer (the author).

Testing

Three weeks were needed to test MobiMap functioning as a whole. In that time, various bugs and other problems were also corrected that were not detected during the development phase.

Implementation

Putting all the external systems in place for MobiMap's implementation as a commercial consumer product took approximately one month. This task consisted mostly of configuring the billing systems. Billing servers were installed and contracts and agreements were put into place to facilitate the administrative aspects of the business model offered by ExactMobile (Pty) Ltd. Most of the implementation was performed by ExactMobile and other senior relevant parties, with the author providing assistance from a developmental perspective when required.

5.2.2 Revenues

MobiMap's revenue results from ExactMobile credits debited against users' accounts after they successfully receive maps on their cellphones (refer to Section 4.2.3). This functions according to ExactMobile's *business model*. The reasons for the choice of this particular business model are briefly explained next, and other possible models for M-GIS application revenue generation are given. Some actual revenue figures for MobiMap conclude this section.

5.2.2.1 Models

Although there are a number of different business models that can be used to generate income for any typical M-GIS application, the choice of model for MobiMap was done for two reasons.

Firstly, LBS Mobile (Pty) Ltd approached a number of companies that were willing to perform transactional costing procedures on MobiMap communications, i.e. between the client and the server. All offerings (and revenue sharing requirements) were taken into account and ExactMobile (Pty) Ltd was chosen as business partner responsible for MobiMap's billing.

Secondly, ExactMobile's business model has a number of distinctive advantages, namely:

- The user has already paid for the maps he/she intends to download. Thus, the collection of revenue from the billing process is quicker.
- Users don't have to be sent bills for their map downloads. This makes for less administration on both LBS Mobile's side, ExactMobile's side and the user's side.
- The model is robust because of its simplicity, and the user is not billed unless a complete map is successfully received on his/her mobile device.

ExactMobile's business model also has a few disadvantages:

- Additional communication steps are introduced. The billing server at ExactMobile has to be contacted (from the web server) before and after map delivery to the user's mobile device.
- The billing server has to perform more processing in order to firstly notify the web server if the particular user has sufficient ExactMobile credits to download a map, and secondly to debit a number of credits against the user's account.
- Users have to purchase sufficient ExactMobile credits before being able to download maps. In the case of an emergency and a user urgently requesting a map, he/she will not be able to download a map before going through the process of purchasing additional credits first.

Other business models which can also suit a typical M-GIS application are mostly divided between "pre-paid" revenue or "on-the-fly" revenue, or combinations thereof (Informa Telecoms Group

2002a). One example is a system where successful map downloads are merely logged on the user's account and he/she receives a monthly bill. An initial registration fee, as well as an additional monthly connection fee, can be charged against the user's account. Another example is to have the user pay a registration fee and a (higher) monthly connection fee, but he/she is then free to download as many maps as desired. Another option is to bill the user per map size downloaded. This would suit a server and communication system where there are significant cost factors involved with the amount of Internet or OTA traffic generated, or where the web and map server have to handle large amounts of map requests, and performance are severely affected by larger map size requests (Wireless Developer Network 2003).

The advantages and disadvantages of each business model considered should be weighed up against each other, taking the particular M-GIS project setup into account. Revenue should be generated and attributed to components of the system where costing is high or expected to be high. In turn, components that involve very few (or no) costs should not directly receive too much of the generated revenue. This will ensure a well-balanced M-GIS system from a financial point of view, especially if future trends in component costing are foreseen and taken into account when deciding on a particular business model and its future revenue generating capabilities.

5.2.2.2 Results

One MobiMap colour map download (excluding Picture Short Message Service (Picture-SMS) maps) costs 40 ExactMobile credits. One such credit costs R0.10, thus one map download costs R4.00. On average, 666 maps were downloaded per month in 2004, with a total of 8000 maps for the whole year. This amounts to R32000 gross revenue (attributed directly to map downloads).

Picture-SMS map downloads are billed through ExactMobile as well, but rather per SMS sent from the user, instead of a map received. The user needs to send at least two SMS's to get a Picture-SMS map, and each SMS is charged from the user's cellular account at premium SMS rates. Approximately 9000 Picture-SMS maps were generated during 2004, so taking a premium SMS rate (for 2004) of R3.50 times two (for two SMS's sent per Picture-SMS map received), this amounts to a total gross revenue of R63000.

Not including the gross revenue generated in 2003 (since MobiMap was deployed live only in the second half of 2003), it can be concluded that R95000 gross revenue was generated by MobiMap during 2004. Revenue sharing as per contract agreement(s) determines the amount of income divided between the respective business partners and stakeholders associated with MobiMap.

As can be seen from the above figures, MobiMap delivered significant revenue during a measurement period of one year. However, the initial and continuous expenses as listed in 5.2.1.1 are significant as well. It is thus clear that a fairly large sum of capital is required to get an M-GIS project such as MobiMap up and running. The time costs as listed in 5.2.1.2 will result in additional interest costs based upon the amount of initial capital invested, as well as possible loss of revenue due to delays with early market penetration strategies, and/or competitors filling up the available market shares instead (Pekkinen & Rainio 2003).

This section concludes with a list of five points the author deems most important for M-GIS projects such as MobiMap to be feasible from a costing and revenue point of view:

- The initial stages of the project must be started and completed in a short as possible time, to minimise (a) costs due to interest based on initial capital investment(s), (b) delays with early market penetration strategies, and/or (c) competitors filling up the available market shares.
- The most suitable business model must be chosen based on the project's holistic setup and components (see Section 5.2.2.1).
- Application design must be of such a nature that maintenance costs (after project implementation and commercial deployment) should be minimal (see Section 4.2)
- Exact prices for billing must be carefully decided upon. Setting prices too low may deprive the project of valuable income, and prices are often difficult to change or raise at later stages. Setting prices too high may cut out a significant portion of the target consumer market, and pave the way for competitors wanting to penetrate the market with their own M-GIS applications instead (Pekkinen & Rainio 2003).
- Hardware and telecommunication infrastructure setup(s) must be performed and managed in such a way to ensure that service downtimes are kept to an absolute minimum (refer to Section 4.4). If necessary, contractual penalty clauses must be included in Service Level Agreements (SLA) with the relevant 3rd party service providers, to (a) lawfully motivate them to provide acceptable levels of service, and (b) be compensated for lost revenue in unfortunate cases of unacceptable service.

5.3 CONCLUSION

Although MobiMap took a relative long time from its initial design and planning stage, up to the point when it was completed and commercially implemented, it must be kept in mind that this was the first of its kind attempted in South Africa. No other M-GIS project was successfully designed, developed, deployed and implemented to the extent that MobiMap was. It can thus be seen as a "pioneer" project, demonstrating how new and cutting-edge technology could be used to create a useful application that never existed before in a country. MobiMap's original objectives are revisited below to determine to which extent these were fulfilled.

5.3.1 Holistic objectives

1.) To demonstrate how the merging of several technologies could successfully deliver a usable and scaleable M-GIS application.

Bar the service and stability problems encountered, MobiMap now offers very acceptable uptimes. A wide variety of technological fields are utilised in order to deliver a map in the user's hand. The map has proved usable and the chances of a user getting lost are very small. MobiMap is scalable in terms of the compatible mobile phones it will run on (from the top-end Nokia 9210i Communicator to any entry-level Picture-SMS capable cellphone) and able to address a wide target market. Its design is also scalable in terms of future improvements and additions (e.g. MobiMap MMS – see Section 5.1 and 6.2).

2.) To highlight the aspects of an M-GIS application that are significantly dependant on the technology of the time, in terms of reliability, shortcomings and improvements.

Users of MobiMap are well aware of its abilities and limitations. These were made clear in its marketing and user manuals. The user will also have a better understanding of the technology and how this helps his/her installation of MobiMap operate.

3.) To act as a suitable, representative and practical project to comply with the requirements for a scientific research thesis of this nature.

MobiMap took a long time to develop but it is scaled to suit the extent of this research theme quite well. All relevant components of a modern M-GIS system are implemented and used. The available technologies are well represented by means of MobiMap's functionality - all must function harmoniously together, or the user will not get a map on his cellphone. Theoretical knowledge and insight obtained from scientific research were applied in the development of all the software components that reside and run on each of the hardware components, so that it is practically put to the test.

5.3.2 Physical objectives

1.) Sophisticated yet simple and efficient design, development and implementation.

MobiMap offers maps to users' cellphones, which travel a long way. Professional software services are optimally used to deliver quality geographical information to the client device. However, software and hardware components are kept separate and communicate with each other by means of simple and discrete atomic transactions. MobiMap also has a relative simple business model which allows for smooth and problem-free billing.

2.) A high degree of cost-effectiveness applied to as large extent as possible in the whole SDLC (Software Development Life Cycle).

Several parties had opportunity to gain from MobiMap. These gains were financial and scientific of nature. Because of the financial factors, there were a number of constraints to adhere by. Although most of the required hardware can be considered quite expensive initially, it must be remembered that these are mostly only initial costs. Hardware maintenance is a substantial smaller financial expense in comparison with the initial cost, especially in MobiMap's case. In terms of software costs, many of the development platforms used for MobiMap were free of charge (e.g. the Java programming language). The only actual software costs are those of the Microsoft operating systems running on the development PCs and the servers, and ESRI software’s initial and maintenance costs. See Section 5.2.1 for more details.

The author endeavoured to make minimum use of the GPRS and especially GSM services when downloading new client code and testing the application's functionality. For example, a large number of bug fixes and/or new code was implemented and tested on simulation software (e.g. a Nokia 9210 Emulator program running on a development PC), before uploading it to the cellphone and then testing it.

3.) Technological constraints have to be adhered to (e.g. availability of hardware, infrastructure, etc.).

New developments in MobiMap were done as soon as the hardware and software required for it became available and/or reliable. For example, the routing functionality could only be developed once the ChronoX Routing Engine was made available. Stability issues could also only be addressed once software bug-fix updates became available (e.g. JRE, ArcIMS – see Section 4.4).

4.) Application design has to be dynamic in order to facilitate scalability as user base and functionalities grow.

MobiMap's architectural design is simple and thus hardware can easily be upgraded or increased in order to facilitate new functionalities or an increased user base. For example, a server farm can, with little changes to the programming code (mostly Internet Protocol (IP) address changes), be installed when the load becomes too much for one server to handle. This is applicable to both the web and map server.

5.) MMI (Man-Machine Interface) has to be simplistic and user friendly.

MobiMap was tested by five users (randomly chosen) who are completely computer illiterate. With the aid of online help (in the client application running on the cellphone, where applicable), users managed to download the maps they requested very quickly. The process from searching for a street to getting a map is straightforward and presented in a step-by-step fashion by MobiMap’s GUI. The MobiMap SMS service is also very quick and easy to use. Users are sent an SMS explaining the syntax of the SMS service when they used the wrong syntax.

6.) Application design and utilisation of infrastructure has to ensure an acceptable level of reliability.

Over and above the general transmission retry procedures normally found in GPRS (Andersson, 2001), TCP/IP and HTTP protocols, MobiMap also has a system of error messages presented to the user, which makes the application practically foolproof. If the web or map server is down, a message is returned to the user's cellphone informing him/her of the service downtime and advising to try again later. The web server can also detect if GPRS service is down, and the user is informed of this as well by means of a message on his/her cellphone. He/she then has the choice to use GSM, or to try again later.

If the street or location the user searched for cannot be found in the geodatabase, a message is returned to the user informing him/her of this. Either the street is too new and does not yet exist in the database, or the user spelt the street name incorrectly.

Users are only billed after they have successfully received a map on their cellphone. If the map delivery to the cellphone is interrupted or corrupted by any means, the system does not receive automatic acknowledgement of the map delivery, and the user is not billed.

MobiMap has been noted and praised in a number of local newspapers over the course of the last year. Copies of these newspaper articles can be found in Appendix A.

CHAPTER 6: SYNTHESIS AND CONCLUSIONS

Mobile Geographic Information System (M-GIS) applications are all about bringing new and exciting technologies together and offering useful geographical information and content-rich features to the consumer. This chapter concludes the study by revisiting its objectives and discussing future research opportunities, extending from both the problems encountered with the study's sample M-GIS application, MobiMap, and new features not offered by MobiMap.

6.1 REVISITING THE STUDY'S OBJECTIVES

The objective of this study was to investigate how geographical information, derived from GIS processing, can be delivered and presented in a useful manner to users' mobile devices. A sample M-GIS application was developed to complement the research done for this study.

Location Based Service (LBS) and M-GIS technologies, as used by a number of typical M-GIS applications that are already in use in the commercial market, were researched (see Chapter 2). All of the components used by these technologies were listed and explained in Chapter 3. Using current circumstances and best suited technologies available at the time, a sample M-GIS application, MobiMap, was designed, developed, tested and implemented as a fully-fledged commercial M-GIS project. It challenged and met a set of holistic and physical pre-determined objectives (see Chapter 4). MobiMap proved to be unique in its kind as the first pioneer M-GIS application launched in South Africa, using digital map data of South Africa. It has been noted and praised for its benefits and usefulness in a number of local newspapers over the course of 2004, as is clear from several newspaper articles and advertisements (see Appendix A).

However, cutting-edge technological applications such as MobiMap, or any M-GIS application for that matter, are seldom without problems. Section 4.4 discussed some of the problems related to MobiMap. Typical M-GIS applications could experience similar problems. By means of research into these problems and the desire to find solutions and create better follow-up versions of products, shortcomings can be addressed, as described in section 5.1. The following section concludes this chapter and study, and presents the reader with a number of intuitive ideas relating to M-GIS problems, shortcomings, and future possibilities.

6.2 FUTURE RESEARCH OPPORTUNITIES

MMS is the protocol for mobile messaging in the future. M-GIS applications should take full advantage of this technological offering and exploit this potential as soon as possible. No Multimedia Messaging Service (MMS) service for MobiMap was developed, and this provides great opportunities.

Client software programs running on mobile devices, as part of the M-GIS architecture, should be improved to receive true geographical information, for instance vector maps. Vector maps are much smaller to transmit "Over The Air" (OTA), thus resulting in quicker map download times. It also allows for a variety of additional geographic mapping functions, like zooming, panning, and more. Currently, MobiMap must download a new map every time the user requests a map at a different zoom level (scale).

Various techniques for improving the routing service could be introduced. For example, when calculating a fastest route, preference could be given to a route that has more left-turns than right-turns, since in countries that drive in the left lane it is usually quicker to turn left than to turn right (the opposite would be true for right lane drive countries). Another example would be to take the time of the day into account, since highways will travel slower during peak hours (these hours could typically be pre-specified by the user), thus ordinary roads should rather be used during such times.

M-GIS applications should be user-driven, not technology-driven. This basically means that the range of features offered by the M-GIS application should be determined by what the user (in the target market) wants, not what the technology can offer. MobiMap almost succumbed to this temptation a number of times, but functionality was quickly revised in such cases, to ensure that resources are not wasted continuing development on features that the end-users would not be interested in.

This study concludes with a quote from JD Wilson's article, "Mobile technology takes GIS to the field" in GEO World from June 2000, which matches the author's foresight about the exciting future of M-GIS:

"The future of most enterprise systems, especially GIS, will be defined by their mobility. Welcome to the age of m-business, m-commerce and m-GIS" (Wilson 2000).

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PERSONAL COMMUNICATIONS

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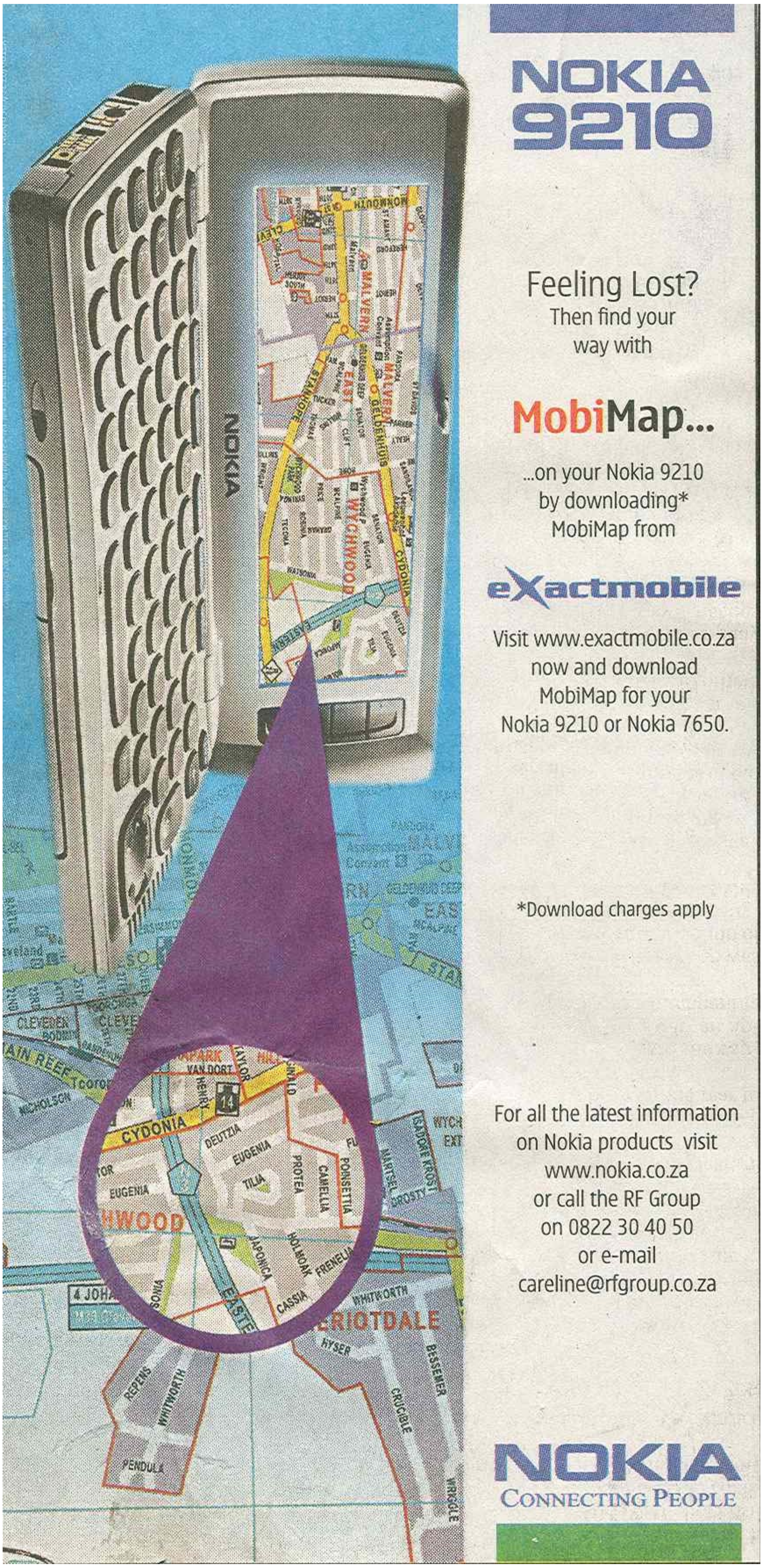
APPENDIX A



Source: Rapport 23 March 2003

Figure A1 MobiMap advertisement

HOME

NETWORK times

3 APRIL 2003

THE MAGAZINE FOR IT DECISION MAKERS

Mobile digital mapping

APRIL 2003

A new mobile map service - MobiMap - has been launched, giving cellphone users easy access to street and road maps of South African towns and cities.

MobiMap was developed in South Africa by Location Based Systems in conjunction with MapIT, a sister company of MapStudio.

The initial service offered is a simple street finder application. "To date, users of lower-end phones worldwide have not been able to receive maps on their handsets via SMS," says Braam Brink, a founder and COO of LBS.

The SMS version of MobiMap currently allows all users of Nokia picture SMS-enabled phones to receive an annotated map of the requested street and area. Although the resolution of this map is limited by the screen characteristics of the phone, it is a useful tool when map books are not available. Maps of various scales can be requested depending on the level of detail needed.

The MobiMap service is also available on all WAP-enabled phones. The WAP service provides higher resolution maps to be sent to suitable phones. These maps can be in colour on phones with colour screens.

A routing service, providing directional information from one location to another, in text and on maps, will be introduced later this year. Where the cellular networks allow this, the current location of the user will be utilised to provide maps showing the quickest, shortest or most scenic route between the user's current location and any other location.

Cellphone users can visit www.lbsmobile.com for exact instructions to use the MobiMap service.

For more information contact LBS, 021 424 6960.

Source: TechNews 3 April 2003

Figure A2 MobiMap article

Lost! Reach for your Cellphone

Cell phones are truly becoming indispensable tools for running your everyday life and now will even help you 'find' yourself, in the practical sense, that is.

An innovative digital mapping service, Mobimap, now affords cell phone users press-of-a-button access to maps of any South African city or town. Wherever you are, you can now find your location via a map being delivered directly to your handset through SMS, WAP or Java-enabled phones.

"This is another first to the marketplace for a product using the electronic map data of MapIT, says Ray Wilkinson, MD of leading developers of spatial technology products. 'MapIT developed these mapsets for ExactMobile and LBS Mobile, in a three-way alliance, using the very same maps we've come to rely on and have trusted for the last 50 years to help us find our way, the Map Studio map book. These map bases are the most accurate available and with the relationship between MapIT and Map Studio, provide specialised digital mapping information that takes the guesswork out of positioning and orientation. Mobimap is a breakthrough for location based services, a big area of growth in mapping products." Say Wilkinson.

MapIT developed the tools to vectorise maps, providing digital mapping information that makes customized mapping a reality.

"Location based systems are a huge growth industry and we are proud that this cutting edge digital mapping application was developed in South Africa," says says Braam Brink, chief operating officer of LBS, co-developers of Mobimap.
"This may well be a world first in that the full spectrum of mobile phone users, including lower-end users, will have access to information contained in the well-known MapStudio map books. There is a very limited number, perhaps two or three services worldwide, of commercial mobile services, where maps can be delivered to mobile phones," states Brink.

The third partner in bringing Mobimap to market is Exactmobile, the guys who we've all been downloading our funky ringtones from. Exactmobile have brought the marketing and billing expertise to the table. MD, Gavin Penkin is upbeat about this product and the future of mobile directional services, "Your handset is becoming closer to a PC with the integration of this technology and software being written which is downloaded directly to your phone. Current applications, like Mobimap, are built to seamlessly integrate traditional mapping services with your cell, downloading the map with easy to follow prompts."

The initial service offered by Mobimap in alliance with MapIT is a simple MapFinder application that presents text as well as a picture map of the area of interest. Mobimap currently allows all users of Nokia picture SMS enabled phones to receive a map of the requested street and area. Although the resolution of this map is limited by the screen characteristics of the phone, it is a useful tool when map books are not available. menu options at restaurants.

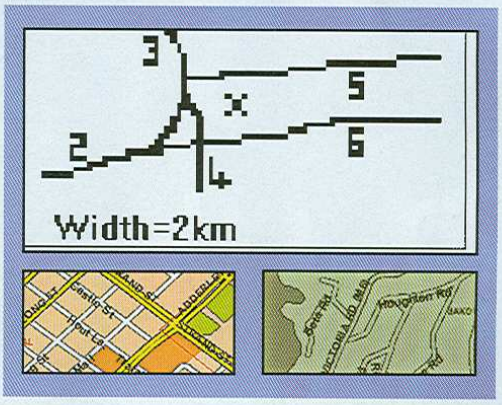
Source: The Star 8 April 2003

Figure A3 MobiMap article

maps go digital

How many times have you got lost and kicked yourself for not getting directions before you started driving?

Now, thanks to a new service called MobiMap, you'll never be lost again.



With MobiMap, you can have digital street maps of various South African locations sent directly to your picture-enabled Nokia cellphone via SMS. The service allows you to search for a map by street name, and have an annotated map of the street and area you requested sent to you via SMS.

You can even specify how detailed you want the map to be and, although the resolution of this map is limited by the screen characteristics of your handset, it's very useful when your map book's lying at home!

In future, MobiMap will also point out locations of interest, such as restaurants, cinemas, ATMs and stores, on the map.

MobiMap is also available for all WAP-enabled cellphones, offering higher resolution and colour maps if your handset has a colour screen. In future, MobiMap will also point out locations of interest, such as restaurants, cinemas, ATMs and stores, on the map. You will even be able to select the point of interest and obtain up-to-date information about it.

These points will also be customisable and interactive, so you will be able to, among other things, contact a point of interest by selecting its phone details or web address!

MobiMap was developed in South Africa by Location Based Systems and MapIT, the country's leading supplier of digital maps. Visit www.lbsmobile.com for more information and exact instructions on how to use the MobiMap service. ▣

Source: VodaWorld winter 2003

Figure A4 MobiMap article

Path mapped out for cellphone users

Lesley Stones

CELLPHONE users need never get lost again — as long as their eyesight is good enough to squint at the tiny details of a mobile map displayed on their handsets.

Street maps of towns and cities can be requested on most models of cellphones in a new MobiMap service developed by Location Based Systems (LBS) and MapIT.

"Location-based systems is a huge growth industry and we are proud that this digital mapping application was developed in SA," said Braam Brink, chief operating officer of LBS. Until now, users with lower-end phones had not been able to receive digital maps on their handsets via the short message service (SMS), he said.

The initial service is a simple street finder application. The SMS version lets users with Nokia picture-enabled phones receive a map of the requested street and area. Although the resolution is limited, maps of various scales can be requested depending on the level of detail needed.

The service for phones enabled with wireless application protocol (Wap) provides higher resolution maps that can be in colour on those with colour screens. Top-of-the-range cellphones can display high-resolution colour maps.

As the service develops, Brink said points of interest such as restaurants, cinemas and ATMs would also be displayed on the map. The user would be able to select the point of interest and obtain information about it.

A routing service to give directional information from one location to another, in text and on the maps, will be introduced later this year.

Exactmobile, a supplier of logos, ring tones and picture messages, is joining the team to add its marketing and billing experience. Details are available at www.lbsmobile.com.

Source: Business Day 27 August 2003

Figure A5 MobiMap article