Assisted GPS for Location Based Services

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Abstract

The mobile operators are seeking for opportunities to create differentiation and increase profit. One powerful way is to provide personalized mobile services. A good example of personalisation is by location. Services based on position are called Location Based Services – LBS. To realise LBS, some sort of positioning method is needed. The two most common positioning methods today are Global Positioning System - GPS and network based positioning. GPS is not fully suited for LBS because you need an additional handset to receive the satellite signals. In network positioning however, you only need a mobile phone, but on the other hand, the accuracy is far less, only between 100 metres up to several kilometres.

What technology would be a good positioning technology for location based services? Could A-GPS be such technology? A-GPS is a positioning system which uses the same satellites as GPS, but besides that, it also uses a reference network. The reference network tracks the receiver and the satellites. It also makes some of the heavy calculations that the handsets are doing in the GPS system. That makes the A-GPS receivers less power consuming and more suited to be implemented into mobile phones. Furthermore, A-GPS are more sensitive, meaning that it easier can receive signals when using indoor, for example.

The question is if A-GPS technology holds its promises? Does A-GPS really work well in mobile phones? Is the accuracy and availability as good as the theory says and is it possible to implement an own, well working, location based service into an A-GPS mobile phone?

Preface

I was doing our thesis work on the company WIP – Wireless Independent Provider in Karlskrona, Sweden. It is a small software company specialised on mobile services.

I would like to thank the staff of the company WIP, who has been very supportive and understanding. They have never denied me a helping hand. Extra thanks to our supervisors Anders Larsson and Fredrik Tellandersson at WIP, who has helped and guided me throughout the whole thesis work.

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1 Background

This thesis work was done at the company Wireless Independent Provider – WIP, that had interrest in positioning systems and Location Based Services.

As the market of positioning and location based services gets bigger, the company WIP has the intension to be well prepared in this area. They would like to have different applications that use the positioning technologies to provide their costumers.

As an example, today WIP has an application called “Search finder”, which could use the general GPS technique. Search finder is a real-life game about the history of Karlskrona, using the mobile phone as a guide. The players, in reality often a group of high school youths, get a phone which provides them with instructions about what to do and where to go. When the game starts, the group gets the first directions of where to go in Karlskrona. They also get some information about the place. When they get there they can find a lead word which they should SMS to a given number. When that is done, they receive a question about the place to the phone, which they should answer. After that, they get instructions of how to take a certain picture of the group and the place, which confirms that the group really has been at the specific place. When this is done, they get new directions to another place. And so the game goes on in similar way through a dozen of different places.
One extra feature of this game is that a GPS handset can be carried by the group in order to keep track of them. The GPS handset communicates with the cell phone with wireless Bluetooth technology. The phone forwards the location information to a server, which sets up a map and shows the location of the group. This makes it possible for a teacher, or someone involved in the game, to keep track of the different groups throughout the game.

But there are some flaws in this system. For instance a GPS handset is rather expensive and maybe it would be more convenient to use a cell phone with A-GPS, instead of both a phone and a GPS handset. Another rather annoying thing is that the GPS handset needs line of sight to the GPS satellite, that means that the GPS doesn't work too well indoor. In addition if the satellite loose track of the handset it will take some time to re-establish. That could be very annoying. Maybe A-GPS can handle indoor positioning in a better way than general GPS can.

The first part of this master thesis is to compare different ways of positioning that exist today. To explain how the different systems work and what are their benefits and their disadvantages.
The second part is to implement a positioning application, using the A-GPS technique, and then evaluate how well it works compared to both general GPS and net-based positioning. we will particularly evaluate the accuracy, the

positioning time, availability and functionality. we decided to do it on a specific phone. One phone that is well suited for the Search Finder game is Motorola's A925 which is equipped with both A-GPS, digital camera and relatively large screen.

2 Location based services - LBS

The mobile operators are seeking for opportunities to create differentiation and increase profit. One powerful way is to provide personalized mobile services. A good example of personalisation is by location [1].

2.1 What are LBS?

LBS are a set of services based on location. You can divide location based services into two categories, the end user application perspective and the developer and vendor perspective. From the end user perspective we have for example traffic- and weather report, driving direction and routing, entertainment applications, wireless advertising and store locations. From the developer perspective we have mapping, GPS-navigation, proximity searches, destination guide, tracking (E-911, vehicles- and friend-finder), telematics, location based billing and advertising.

2.2 How it works

To provide LBS you first need to have some kind of positioning method. To give the information about nearest cinema, you need the location not only for the cinema but also of course for the subscriber. The location for the cinema is fixed, so that’s no problem. It's just implemented in the application map. But the subscriber’s location must be positioned by some method. Most of the LBS today are using network based positioning methods, like Cell-id, but any method could be used. When you are making a positioning an id-info is sent to an application server. The position is sent to the application in a server or back to the client, perhaps through a middleware that handles security and quality. The location information may be tied to further database of services containing information and location of restaurants, hotels etc, who may send advertisement or pricelists to the costumer.

2.3 LBS middleware

Middleware are required for all robust LBS implementations. The middleware is an application that doesn’t provide the services themselves, but rather enables LBS and handles the quality and security. One example of LBS middleware is the location manager function. The location manager function can be employed to convert positioning information into useful location information and make it available for LBS applications. This functional element acts as a gateway or hub for location.

2.4 LBS security

The security is vital in any LBS, especially when dealing with money. Wireless billing is one example. Stock exchange is another. Even aspects of integrity make the security important. As a subscriber you don't want to be tracked by someone who shouldn't have the access to do it. We won't dig deeper into the issue of security more than that we mention its importance, since it would be a subject of a thesis in its own.

2.5 Geographic information system (GIS)

One important issue of LBS is the geographical information system. The GIS provides the tools to provision and administer base map data such as man made structures. Simply put, a GIS combines layers of information about a place to give you a better understanding of that place. What layers of information you combine depends on your purpose - finding the best location for a new store, analyzing environmental damage, viewing similar crimes in a city to detect a pattern, and so on.
GIS information also includes information about radio frequency characteristics of the mobile network. This allows the system to deter the serving cell site of the user.

2.6 Applications

Many different applications are well suited for LBS. Here we've listed some examples. Probably there will be many more kind of services in a near future.

- Destination guides with maps and directions
- Location based traffic- and whether alerts
- Wireless advertising and electronic coupons
- Movie, theatre and restaurant location and booking
- Store location applications (cheapest price, brands etc)
- Emerging friend, child or car (finders)
- Personal messaging (live chats with friends)
- Mobile yellow pages
- info services (stock, sports, news)
- Personalized services (Wireless portals may have personal information about preferences of a subscriber and may serve or push relevant content to that subscriber)

3 The GSM network

As we have already mentioned, you need some sort of positioning method in order to apply location based services. There are some methods based on

satellite navigation, some based on the mobile network infrastructure or both. We will start by explaining some positioning methods, using the GSM network.
To fully understand how the positioning within the GSM network actually works, you need to know the basics of GSM. The following text explains the most important parts in the GSM network [2]. The part about the cell structure is of special importance in the positioning point of view.

The GSM networks consist of three subsystems which each of them contains different components. First of all we have the Radio Subsystem, which consists of the Mobile Station and the Base Station Subsystem. The Base Station Subsystem includes Base Transceiver Stations and Base Station Controllers. The tasks of the Base Station Subsystem is to take care of Frequency hopping, channel coding, handover and radio channel management.

The second subsystem is the Network and Switching Subsystem, which consists of a Mobile Switching Centre and three different registers, the Home Location Register, the Visitor Location Register and the Equipment Identity Register. The main tasks of the Network and Switching Subsystem are to store data about the mobile subscribers, accounting, call forwarding and signalling.

The Third and last subsystem is the Operation Subsystem, which consists of an Operation and Maintenance Centre and an Authentication Centre. Operation Subsystem makes the user specific authorization and checks the user rights.

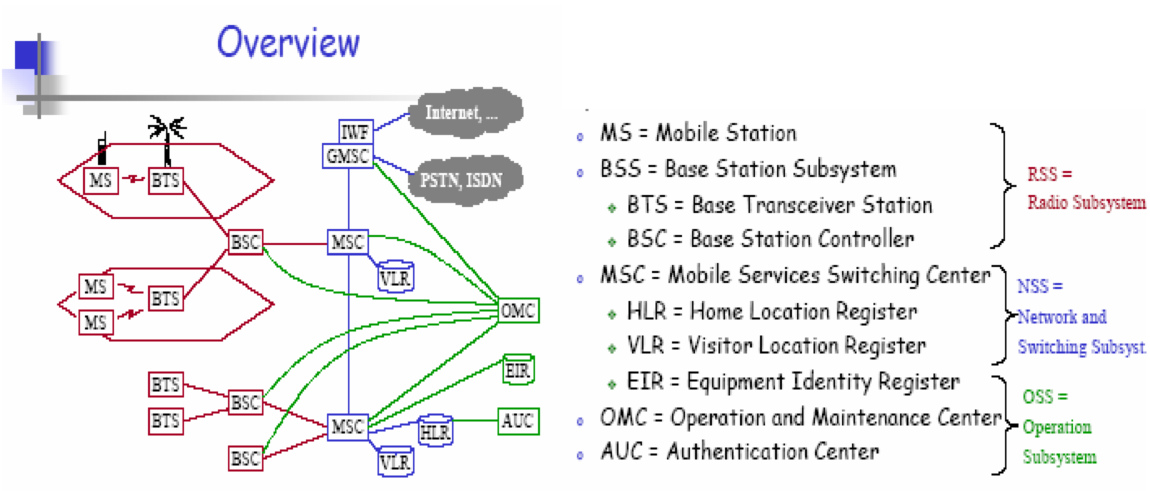

Figure 1: The GSM architecture

3.1 The cell structure

Each antenna of a base station covers a cell, which is a restricted geographic area of the country. To ensure that costumers can continuously use a phone when they are on the move, cells need to overlap slightly. When a user nears the edge of a cell and enters the overlap area with the next cell, the network can hand over from one base station to the next one. The size of the cell depends on current and future costumer call usage in this geographical area, but also on the physical terrain of the area. Radio signals are attenuated by man-made and natural obstacles such as buildings, trees, hills and valleys. This has an impact on the quality of mobile phone coverage. In urban areas the cells are much smaller than in rural areas because of the obstacle buildings and the fact that there are many more users per square metre than in rural areas.

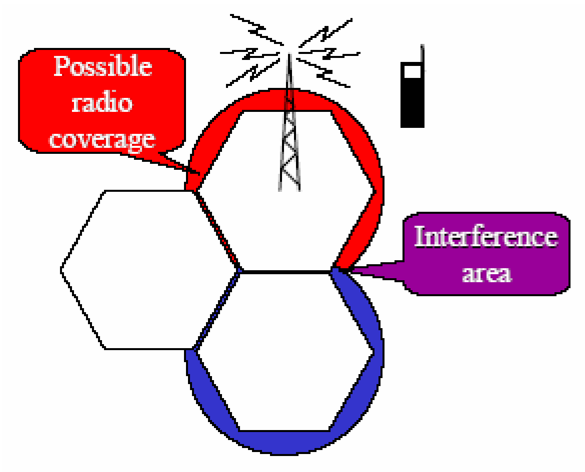

Figure 2: The GSM cell structure

3.2 How calls are made and received

The microphone of the mobile phone converts voice into electric signals. These electric signals are then sent to the base station antenna. In the other direction, the signals emitted by the base station antenna are received by the mobile phone and converted into mechanical vibrations (sound) by the speaker.
In order to have a two-way conversation without interference from other calls, each call must be allocated a radio channel at which to transmit and one at which to receive. Each base station uses a certain number of all the radio channels available to the mobile operator in its allocated frequency range.
However, the limited number of radio channels available to each operator means that only a limited number of simultaneous calls can be made. If all radio channels are in use no further calls can be made.
Once a call reaches a radio base station it is sent across the mobile operator's network to a 'switch' where it is transferred to the network of the destination customer. The call will be passed through an underground fibre optic cable or via a 'point to point' fixed radio link between base stations, which require a direct line of sight.

3.3 Positioning within the GSM network

It is today possible to locate mobile phones within the GSM network, without making any improvement of the network. There are a few different techniques which make it possible; however the accuracy is very poor, independently of which technique that is used. We will briefly explain the different techniques plus the advantages and disadvantages [1].

3.3.1 Cell ID – Sometimes called Cell Global Identity (CGI). The network operator uses cell id to identify in which cell the caller is at a given time. This is a very approximate method. It is often complemented with the timing advanced (TA) information. TA is the measured time between the start of a radio frame and a data burst. This information is already built in the network and the accuracy can be decent when the cells are small. The combined cell-id and time arrival methods are often referred as CGI-TA.

3.3.2 E-OTD - Enhanced Observed Time Difference - It is a hybrid technology that uses both the handset and the network to determine a caller's location. The technology compares arrival times of wireless phone signals to find the caller. E-OTD requires minor software upgrades to the network and E-OTD chips are required in the device and a hardware component (LMU - location mobile unit) is added to the network's base stations

3.3.3 TDOA - Time Difference on Arrival - a technology patented by True Position, affords another way of deducing location, by timing signals between users and base stations. This is accurate and doesn't require handsets to be modified. However, in a typical network, equipment has to be added to tens of thousands of base stations.

3.3.4 Agilent's acceSS7 - Uses a bunch of technologies to achieve its goals, but all of them are based on adding probes to the few hundred base-station controllers in a typical network. No modifications are necessary in handsets of base stations, which keep the cost down.

Each of the methods used to obtain location information has its own advantages and disadvantages. Operators usually choose a variation of one or more of the systems, depending upon which application best suit the legacy network already in place. As position location technology moves forward, accuracy and cost of implementation will improve, but it is likely that no single technology will prove better than all the rest for all environments.

4 GPS

A satellite navigation system is far more accurate than today's GSM network positioning methods. It can track a handset down to a few metres accuracy. There are some disadvantages though. It requires that the mobile device is equipped with some sort of receiver that can receive the signals from the satellites. Furthermore, the receiver needs to be in line of sight with the satellites, which means that indoor positioning doesn't work well. The most common satellite navigation system today is GPS. However, there are some other techniques as well that uses the GPS satellites but also uses additional components. One such technology is called A-GPS. Since A-GPS is based on the same satellites and uses similar technique as GPS we will start by explaining the basics of GPS. After that we will also explain A-GPS and why A-GPS is better suited for implementing into mobile phones.

GPS, which is short for Global Positioning System, is a satellite navigation system. GPS can, at any time give you an exact location where ever you are. GPS consist of satellites circulating in orbits around the earth. These satellites are monitored by ground control stations located all over the world. The satellites transmit signals which can be received by anybody with a GPS receiver, and will then get the exact location with great precision. GPS was installed by the U.S military in purpose of defence, but new uses for it are constantly being discovered. GPS consists of three different parts, the space segment, the user segment and the control segment. We will now discuss these parts in more detail [3].

4.1 The satellites

There are 24 satellites located 11 000 nautical mile up from the face of the earth. They are positioned so that we can receive signals from six of them nearly 100 percent of the time at any point on Earth. You need that many signals to get enough information for the positioning. The satellites are equipped with clocks with less error rate than 3 billions of a second. This is important in order to get the exact propagation time for the signals. This information is later used to calculate the location.

4.2 The ground control stations

The ground control stations consists of unmanned monitor stations which are located on different parts of the world, one main control station and four large antennas which transmits signals to the satellites. The stations monitor and track the satellites.

4.3 The receivers

The receivers can be held by hand or be installed into cars, aeroplanes or cars. These receivers receive, decode and compute the signals from the satellites. There are hundreds, perhaps thousands of different receiver models. Many models are about size of a mobile cell phone, but there are even smaller.

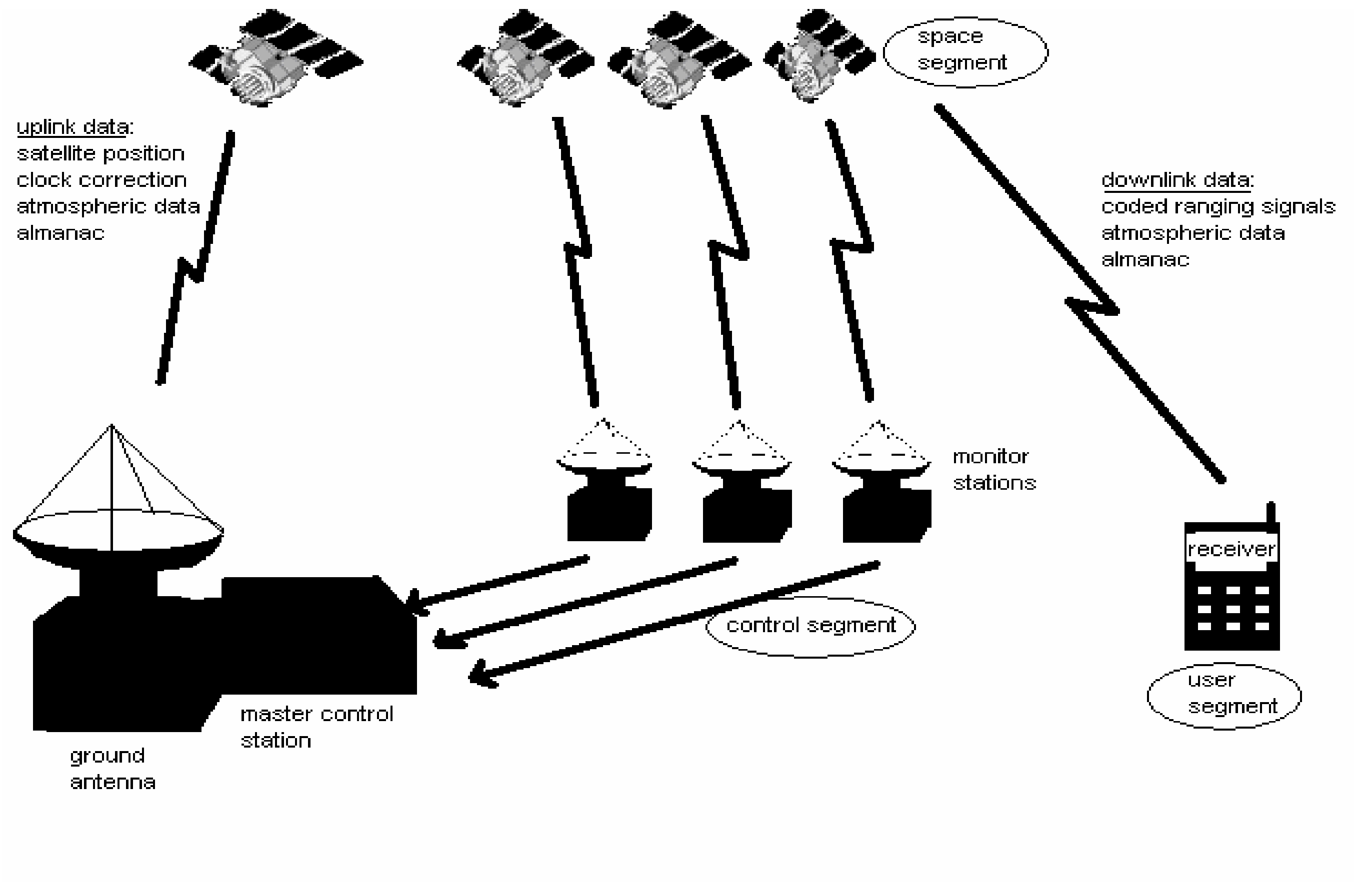

Figure 3: The GPS segments

4.4 How GPS works

The principal of GPS is that you measure the distance between the satellite and the receiver. This is possible to do if we know the transfer time and the velocity of the signal. If we know the distance from the satellite, we know that we are somewhere in the surface of an imagined sphere around the satellite, with the distance as radius. If we further know the distance from another satellite it means that we are located somewhere on a line where the two spheres would intersect each other. With a third satellite we would know that we are in one of the two points where all three imagined spheres would intersect. One of these two points can often be discarded with algebraic calculations. If not, information from a fourth satellite may be used.

When measuring the distance between the satellite and the receiver there are a couple of things to consider. The time for a signal to reach the receiver may take about 0.06 seconds. That makes us understand that we need very precise clocks in the satellites. If we assume that the clocks are sufficiently precise, the problem of measuring the propagation time for the signals remains. This is achieved in a special way, which we will explain now.
The transmitter and receiver are sending a certain code, so called pseudo random code (PRC) at the same time. This code consists of a sequence of randomly chosen pulses. Then you delay the received code so that it is exactly synchronized with the code sent by the receiver. When this is done, you know how much you needed to delay the signal and therefore you know the transmission time. Then you multiply with the velocity of the signal, which is close to the speed of light, and you get the distance.
Direction of movement is determined from changes in geographical position over time. Speed is calculated by dividing distance travelled over time and /or use the Doppler effect. The Doppler Effect is the phase shift of signals received when a constant frequency source is moved away from or towards a receiver. An example of this is a loud Motorcycle travelling at constant speed past a pedestrian. The noticeable difference between the approaching and departing frequency is a result of the Doppler Effect. The phase shift of a signal from or between moving objects can be measured. This phase shift is then used to calculate speed between objects.
Like we said before, we assumed that the clocks in the satellites were very precise. The fact is that an error of a thousand of a second may cause a positioning error of up to 200 miles. Therefore the satellites are equipped with atomic clocks, so there are no problems. The problem is to achieve precise time in the receivers. In practice you can't put atomic clocks into the receivers, because that would make them so expensive that no one would buy them. Therefore, a brilliant technique is used. we explained earlier that the receiver would need signals from three satellites to calculate its location. If you add the signal from a fourth satellite, then of course the distance from this satellite should coincide with the intersection from the other satellites. If not, the timing must be wrong. If we then adjust all the clocks until we find a perfect intersection from all four satellites. How much did we adjust? That much the clock in the receiver must have been wrong. We correct the clock in the receiver and now we have a perfect synchronization. This procedure is going on continuously.

The better you can measure the propagation time from the signals and the preciser you know the satellites position the better precision in the positioning is achieved. Today it's possible to locate the receiver with less error than parts of a centimetre.

4.5 Sources of GPS signal errors

Factors that can degrade the GPS signal and thus affect accuracy include the following [4]:

- Ionosphere and troposphere delays — the satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
- Signal multipath — this occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.
- Receiver clock errors — a receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.
- Orbital errors — also known as ephemeris errors, these are inaccuracies of the satellite's reported location.
- Number of satellites visible — the more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.
- Satellite geometry/shading — this refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.
- Intentional degradation of the satellite signal — Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

5 Assisted GPS – A-GPS

The GPS system has some restrictions which makes it, in some senses, bad suited for implementing into, for example, cell phones. To start with, the receivers are quite power consuming. A cell phone would need far better batteries than available today if the conventional GPS-receivers were added to the phones. The power consuming comes from the fact that rather heavily calculations are made and that the receiver has to cover a large frequency spectrum for the satellites signal, due to the Doppler Effect which we explained in the GPS part.
Furthermore the time-to-first-fix, the time to calculate the initial location, is about 20-60 seconds for GPS and sometimes even more. For GPS where you are making the positioning continuously that's no problem. It just makes the initial positioning slow. But for the mobile user, you probably just want to make one positioning at the time. So the 20-60 seconds time-to-first-fix would make the positioning rather annoying for the user. To solve these problems the A-GPS system was developed [5].
In the United States, the government wanted a system that could make a positioning of an emergency 911 caller. They wanted the system to be fast, precise and function at any time at any place. GPS wasn't good enough, in aspect of positioning time and indoor function. This demands from the US government contributed to the development of A-GPS, and there is now a standard for this in particular, which is called E-911. A similar system in Europe called E-112 is under development. The US governments have ordered that every mobile network in the United States must be able to make precise positioning before the end of 2005 [6].
The A-GPS is similar to GPS. It uses the same satellites and it uses the same principles for calculating the position. The big difference is that A-GPS has a reference network and a positioning server. These components make the heavy calculations which are done by the receivers in the GPS system. The A-GPS receiver is therefore less complex and consumes less battery. Adding to that, the A-GPS receiver is more sensitive which makes indoor positioning possible. we will explain why that's so later on. The assistance from the reference network also makes the first positioning much faster, approximately one to eight seconds.

5.1 Three components

The three main system components are a wireless handset with partial GPS receiver; A-GPS server with reference GPS receiver that can “see” the same satellites as the handset and wireless network infrastructure, that is, base stations and a mobile switching center (MSC).

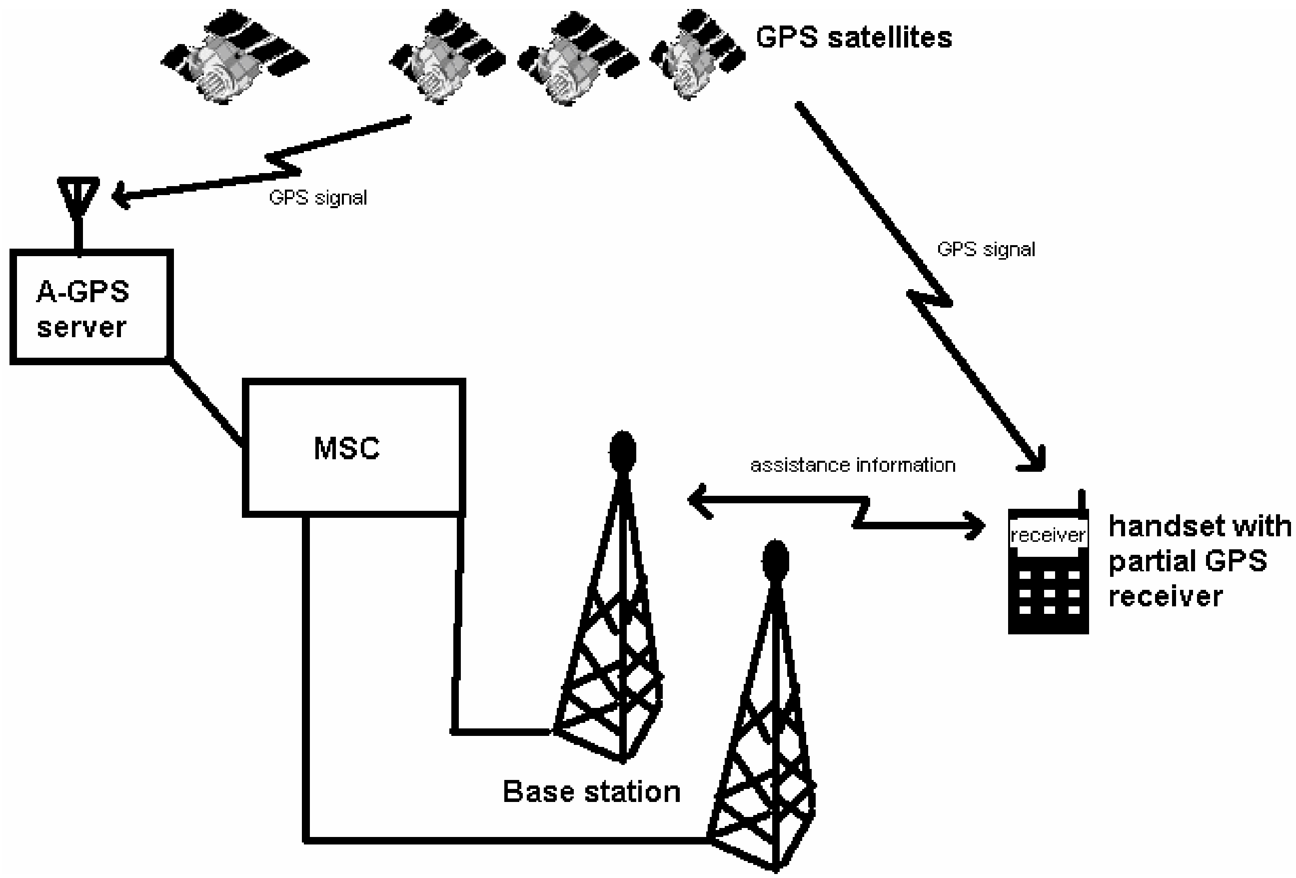

Figure 4: The assisted GPS components

Since an A-GPS server can obtain the handset's position from the MSC (up to the level of cell and sector), and at the same time monitors signals from GPS satellites seen by the mobile station, it can predict the signals received by the handset for any given time. Specifically, it can predict the Doppler shift (due to satellite motion) of GPS signals experienced by the handset receiver, as well as other signal parameters that are a function of the mobile's location. The search space for the actual Doppler shift and PRN phase is therefore greatly reduced, and the A-GPS handset receiver can accomplish the task in a small fraction of the time required by conventional GPS receivers. In addition, the A-GPS server maintains a connection with the handset receiver over the wireless link, asking it to make specific measurements, collect the results, and communicate them back. After de-spreading, an A-GPS receiver could pass the pseudo random code phase information back to the A-GPS server, which would then calculate the mobile location coordinates.

6 Present positioning services

There are some positioning services out there today. Probably there will be many more in a near future. Besides that, there are also many tools available for developers to develop their own positioning service. Below will briefly describe three positioning services, provided by mobile operators in Sweden. There are small or no differences between them. They all use the cell-id technology which is quite poor in terms of accuracy. The biggest difference is that 3 Guru has support for A-GPS. One important thing to remember is that you need to know the operator that is used by the one you want to locate. And, for integrity reasons, you also have to have admission from the mobile user before you can locate him. That makes this whole positioning service to be quite a procedure. It is not possible to just make a positioning request to any mobile subscriber and, if he allows it, get his location in a quick and smooth way.

6.1 Telia Friend Finder

Friend Finder from the Swedish operator Telia provides a positioning service for mobile devices. Friend Finder makes it possible for you to find your invited friends. Through SMS, WAP or internet you will get an estimation of where you find your friend within a couple of hundreds of meters accuracy, depending on the cell size. When positioning from the web, you will also get a map where your friend is positioned. Telia Friend finder is a GSM-network based service which means that no extra technology is needed in the mobile devices or the network stations. But the accuracy is not particularly good, especially not in rural areas where the cell sizes are large.
An extra feature to Friend finder is a car positioning feature, carGuard. The idea is to keep track of your car in anti-car-theft purpose [7].

6.2 3 Guru

Guru from 3 is another positioning service. It is similar to Friend-finder. With Guru you may get map information to all 3-supported mobile devices. The accuracy is similar to other network based positioning services, like friend finder. Though, Guru supports A-GPS. That means, if you have a mobile device with A-GPS support you may get accuracy down to street name and address [8].

6.3 Vodafone positioning

Vodafone positioning is the positioning service from Vodafone. Like the other it's also a network based service. To use it you need a phase 2+ gsm mobile phone, which in wide terms are almost all mobile phones from year 2000 and later [9].

7 A positioning application

In order to see how well the A-GPS technology works for mobile devices we designed and implemented a positioning application for an A-GPS cell phone, Motorola A925. Motorola A925 has support for Java 2 Micro Edition, so that's the language we chose to use. Our main goal with this application was to see how well A-GPS works in reality in terms of accuracy, availability and time to get a fixed position. There are a couple of things to consider when programming applications for mobile phones. We will try to explain how the development software works and what to considerations to think about [10].

Figure 5: Our assisted GPS application on Motorola A925

7.1 Java 2 Micro Edition

Sun Microsystems has defined three Java platforms:

- Java 2 Standard Edition (J2SE)
- Java 2 Enterprise Edition (J2EE)
- Java 2 Micro Edition

Java 2 Micro Edition is a platform specially designed for consumer electronics such as satellite decoders, and embedded devises such as mobile phones and personal digital assistants (PDAs). These devises are sometimes referred as

pervasive devises. All these devices are of course limited in terms of memory and function. Furthermore the variances between different devices are large. Therefore, the different devices are divided into different families, which have similar requirements for memory and processing power. Configurations and profiles are the main elements that comprise J2ME's modular design. These two elements enable support for all devices out there which J2ME supports.
A J2ME configuration is a specification that identifies the system-level facilities available, such as a set of Java language features, the characteristics and features of the virtual machine present, and the minimum Java libraries that are supported. Software developers can expect a certain level of system support to be available for a family of devices that uses a particular configuration. A configuration also specifies a minimum set of features for a category of devices. Device manufacturers implement profiles to provide a real platform for a family of devices that have the capabilities that a given configuration specifies.
The other J2ME building block, the profile, specifies the application-level interface for a particular class of devices. A profile implementation consists of a set of Java class libraries that provide this application-level interface. The creators of J2ME intend that a profile should address the needs of a specific device category or vertical market pertaining to that device category to guarantee interoperability between all devices of the same category. In other words, to define a standard platform for Java application development. For example, a profile might support a network communication facility for SMS standard. Because the SMS standard is ubiquitous feature of mobile telephony, it makes sense to define this service in a profile that targets mobile phones, rather than to build it into a configuration.
A profile is implemented on top of a configuration, one step closer to the real-world applications. Typically, a profile includes libraries that are more specific to the characteristics of the category of devices they represent than are the libraries that comprise configurations. Applications are then built on top of the configuration and the profile; they can use only the class libraries provided by these two lower-level specifications.

7.1.1 Configurations - CDC/CLDC

The two configurations that exist currently represent two categories of pervasive devices:

- Connected Device Configuration(CDC) which supports Constantly connected network devices
- Connected, Limited Device Configuration (CLDC) which supports personal intermittently connected mobile devices.

The CDC specifies a minimal set of class libraries, which do not include the full set of Java 2 SE packages and classes. These are subsets of the Java2 SE packages and classes.

The second of the two configurations, CLDC, supports personal mobile devices, which constitute a significantly less powerful class of devices than the one that CDC supports. Because of the wide variety of system software on various personal devices, the CLDC makes a minimum assumption about the environment in which it exists. CLDC is different from, yet also a subset of the CDC, see figure. Like the CDC, the CLDC specifies the level of support of the Java programming language required and the set of class libraries required. Example of Java packages supported by CLDC is java.io, java.lang, java.util and javax.microedition.io.

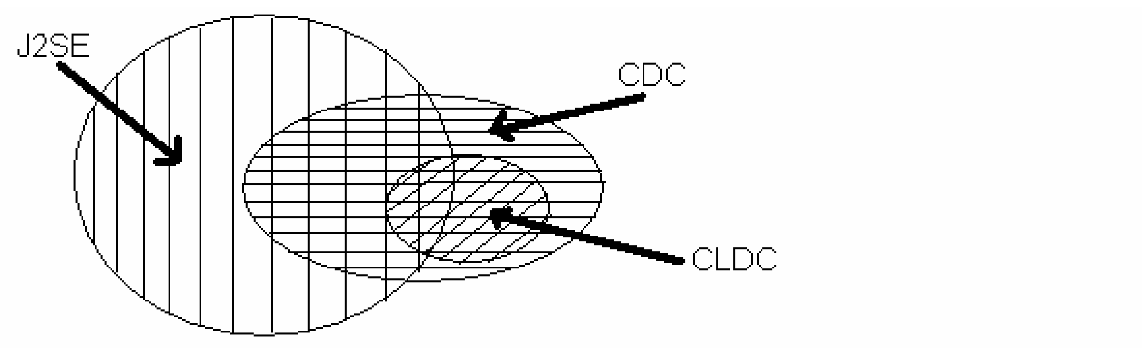

Figure 6: The CLDC is a proper subset of CDC

In other words, when developing an application for a mobile phone in a J2ME environment, you need to know what classes and packages, which you may be used to from J2SE, that are supported by CLDC.
To take this a little bit further, there are today two versions of CLDC, CLDC 1.0 and CLDC 1.1. CLDC supports some additional J2ME classes, which CLDC 1.0 doesn't.
Therefore, you need to know, before you start developing, which CLDC to comply with. On one hand, CLDC 1.0 has fewer J2ME classes supported, but on the other hand, there are several more phones that support CLDC 1.0 than CLDC 1.1. That's a trade off you have to make between compatibility and functionality. For instance, there is no support for the Double or the Float class, in CLDC 1.0., which there is in CLDC 1.1. That fact created lots of problems to us during our development of the positioning application, see *difficulties and possible solutions*.

7.1.2 Profiles – MIDP

Because the category served by the CLDC encompasses so many different types of personal devices, potentially many different profiles are necessary to support them all. The most well known of these profiles is the Mobile Information Device Profile (MIDP). The MIDP layers atop the CLDC and defines a set of user

interface APIs designed for contemporary wireless devices. Roughly, you can say that MIDP addresses the least common denominator of device.
Though, as the technology develops, the least common denominator for mobile devices enlarges. That fact means that the MIDP also have to be updated. Today there are, similar to CLDC, two versions of MIDP, MIDP 1.0 and MIDP 2.0. Also, MIDP 2.0 supports more classes than MIDP 1.0. The same trade off discussion could be made regarding MIDP as regarding CLDC. A MIDP implementation must consist of the packages and classes specified in the MIDP specification. Additionally, it can have implementation-dependent classes for accessing native system software and hardware. Examples of MIDP packages are java.microedition.lcdui, javax.microedition.midlet, javax.microedition.rms plus the packages mentioned before in the CLDC text. More information about CLCD and MIDP specifications can be found at www.java.sun.com.

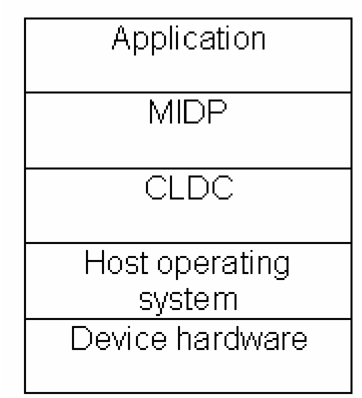

Figure 7: The CLDC platform stack

7.1.3 SDK - Software Development Kit

When you are about to develop an application with J2ME you'll need a special develop environment. Apart from a J2ME compiler you'll also need some sort of simulator, which simulates the performance of a mobile phone. It would be rather annoying to have to transmit the application to a real phone during the development process, after each compilation. Therefore, Sun Microsystems provides a Wireless Toolkit, a toolbox for developing wireless applications that are based on J2ME's CLDC and MIDP, free to download from sun.java.com. This toolkit contains all software needed to compile your program code and simulate your application. This software simulates a general mobile phone, in terms of screen size, user interface and other mobile specific features. Though, as we mentioned, this simulator is *very* general. It doesn't simulate features, which are specific for one or a few phones. For example, the screen size is different on different phones, but the simulator does only support a few standard screen sizes. This means that when you simulate your program, it may look quite different from how it would look in a specific phone.

The solution on this problem is in many cases solved by the phone manufacturers. Most of the big manufacturers have released a software development kit (SDK) that contains a simulator for specific phones. For example Motorola, Nokia and SonyEricsson have lots of SDKs which represents their most popular phones. Most of the time, you could just use these SDKs together with the wireless toolkit, to have a simulator which represents your phone quite well. But still, the simulators are seldom perfect. Just because the application looks good and works perfectly in the simulator doesn't necessary mean that it does in the real phone. For example, in our case, the simulator couldn't understandably simulate the positioning, since the simulator clearly doesn't include any GPS device. Therefore, you'll never know for sure, how well your program works, before you have the application installed and tested 'for real'. A good idea is, to test the application on your phone, every now and then during the development process.

Figure 8: Our assisted GPS application in Wireless toolkit

7.2 Location API

To know how to implement a positioning application for Motorola A925, Motorola has written an API for developers. This API describes what methods and classes supported for positioning. Without the API you are really left without a clue. The location API for Motorola A925 clearly describes what all the different methods supported can do and what arguments they need and types of values that they return. There are even code examples shown. A location API is crucial, if you are developing a positioning application for any device. Turn to the phone manufacturers if you need a location API for your specific device.

7.3 Maps

To make a good positioning application and provide a good location service you most likely will need some kind of map. It's not particularly interesting for a user just to know the latitude and longitude for a location. To take benefit of the location information they will need to have a map, pointing out the location. There are many companies out there providing maps of different kinds, but the companies seldom provide maps for free. The maps are often copyrighted and even if you buy a map you probably have no right to distribute the map to the users of your application. Therefore, the best way may be to let the users of a positioning application download their own maps from Internet instead of have the maps included in the application.

7.4 Difficulties and possible solutions

7.4.1 Coordinate representation standards

There are many different standards when representing map coordinates. The most common standard in Sweden is RT90. Most maps in Sweden use this representation and so does most Swedish companies that provide maps for the World Wide Web. Unfortunately most GPS handsets and A-GPS phones doesn't. Most devices represents map coordinates in a standard called WGS84 – World Geodetic System 1984. Furthermore, there are also various ways to represent coordinates within a specific standard. In RT90 you can represent the coordinates in decimal degrees or decimal minutes. It can also be represented in radians.

To transform coordinate representation from WGS84 to RT90 you need to do a relatively heavy 7-parameter transformation (see appendix). On the World Wide Web there are lots of tools for doing transformations between many different coordinate standards but they might not be able for your phone. But in the end, the interest for the user is probably not to get coordinates of his position, but a map pointing out the location.

In our case, we got the coordinates from our A-GPS phone in RT90, which made things easy for me. Well, not too easy. It was indeed represented in RT90. But it wasn't represented in the usual formats decimal degrees or degrees, minutes and seconds. The format was arc minutes multiplied with 10^5. One arc minute is 1/60 of 1 degree. In the end, we just needed to divide our positioning figures by $60 * 10^5$ to get the right representation and format. The difficulty wasn't to make this calculation, but to investigate which form and representation we got from the device. In the beginning we thought that it was WGS84 coordinates that we received, since we didn't recognised the format. If that would've been the case there would've emerged some other problems which we will discuss later on.

We thought that the most important thing, though, wasn't to display the proper latitude and longitude in right format, but to display the right location on a map. To do that we needed to know the corner coordinates of the map we intended to use and the height and width of the map in pixels. Then we could calculate the latitude and longitude per pixel and out of that data point out the present position on the displayed map.

As we mentioned before, the coordinates received are often represented in WGS84. The problem then would've been to transform the coordinates continuously to RT90. We will in the next piece of text explain why this would've been such difficulty and how to evade it.

7.4.2 Lack of float and double data types in CLDC1.0

Earlier we discussed that you need to know what protocol and configuration supported by your mobile phone. In our case, the Motorola A925 supported MIDP 2.0 and CLDC 1.0. The problem here was that it didn't support CLDC 1.1, which includes support for the float and the double classes. This was a big disadvantage. The most common Swedish latitude and longitude format are represented as double values, in other words decimal values. But our phone has no support for such types of data. One solution to this problem could be to multiply the coordinates with such great number (i.e.100 000), that the value turns into an integer. But in order to represent the coordinates into a map, shown on the screen, you need to do some calculations on these coordinates. Two examples of calculations needed are pixels per latitude and pixels per longitude, which means how many pixels on the screen represents one latitude or one longitude unit. Other calculation examples could be if you need to do transformations between different map coordinate systems. These calculations give solutions that are decimal values.
The best way to circumvent this problem may be to implement an own float class, using arrays, or reuse a free float class implemented by another programmer before you, which includes mathematic methods similar to the CLDC 1.1 float class. Two such free float class are found in the packages net.dclausen.microfloat and henson.midp.float (see appendix). In our case we used Henson.midp.float. That package included all operations that we needed for this purpose. Now, making mathematical operations with a float object is not that simple as it would have been to make operations on a float data type in CLDC1.1. You can't just multiply an object with another, as you can with float data types. Instead you have to create an object of the float class and then use a multiplication method that follows with the float class. That makes the whole mathematical procedure quite tricky, but still it might be the best solution anyway.

Back to the problem with continuous transformation of coordinates, which we started to discuss in earlier text. You may now see that the 7-parameter transformation could be quite tricky to make on a CLDC1.0 mobile phone. Just as a curiosity, we tried to do that anyway, using the methods included in Henson.midp.float package, during the development of our application. In our case, one coordinate transformation took over 20 seconds for the mobile phone to calculate. Though, this was just a curiosity and no scientific study. Maybe it is possible to make such calculations greatly faster, though we couldn't.

7.5 Test

When we tested the application, our main tasks were to know how well the application worked indoor, how long the TTFF was and how accurate it was. Our tests included four parts, TTFF outdoor, TTFF indoor, accuracy outdoor and accuracy indoor. The indoor accuracy was made by first getting the first fix outdoor and then go indoor, to test if the application continuous to work and at which accuracy. Furthermore we wanted to do the testing procedure in different weather conditions, because the weather conditions might affect the signals from the GPS satellites. All the tests were made in the city of Karlskrona, a small city with rather small buildings that wouldn't interfere with the satellite signals very much.
Our first test case was made on a very bright and sunny day, without clouds that could affect the satellite signal. The second test was made on a very cloudy day. The third and last test was made on a day with partial cloudy weather.

To start with the TTFF outdoor varied quite much. The sunny day it was decent, between 10 – 20 seconds. The partial sunny day it was between 20 seconds and 5 minutes. The cloudy day it was between 5 minutes up to one hour.
In all the tests, we were unable to get a first fix when indoor, independently of the weather.
The accuracy on the other hand was quite good, independently of the weather. When we were standing still, the accuracy was between 2 to 15 metres. When in motion, the accuracy was between 50 to 150 metres, but when we stopped, the accuracy increased to 2 to 15 metres within a couple of seconds.
The indoor accuracy was in all test cases unavailable when the roof of the building was thick, as it is in normal conventional buildings. In other words, the application couldn't display any position at all when going indoors. Though, when going inside the galleria with glass roof, the application worked as well as outdoors when the weather conditions were perfect. But still it didn't work in the galleria the cloudy or the partial cloudy day.

7.6 Evaluation

The purpose of using A-GPS as positioning method was to get positioning without using an extra GPS handset but still with good accuracy, without taking too long before first fix and with indoor availability. The theory stated that it should be possible, but when we tested our application, using an A-GPS mobile phone, two of the main purposes failed. The time to first fix was unacceptably long in bad weather conditions and the indoor availability was very poor. The application must of course work in bad weather conditions as well as in good.
That got us thinking that something might be wrong. When using our network operators positioning service, there was no such delay. And the delay shouldn't be derived to our application. We thought there must be some kind of limitation in the network or something similar. So, we got in contact with both Motorola and our network operator 3. Unfortunately, we had no answer at the time of writing this report to that question.
Another thing that concerned us was that it was hard to get any indoor position fix. That was another theoretical benefit with A-GPS compared with GPS.
When coming to accuracy, our test results showed that the positioning error was from 2 meters up to 150 meters when in motion. That was decent and somewhere around what we expected.

8 Future Work

Our application was only tested on Motorola A925, since that phone was the only available A-GPS phone when our thesis work started. Since then a couple of new phones with A-GPS support has reached the market, for instance Motorola A1000 and HP 6515, and there will probably be many more in a near future, due to the E-911 demands in the United States. It would be very interesting to know if the poor indoor functionality and long TTFF would be better on future phones.

Furthermore, a platform for positioning applications that works independently of what positioning method and data bearer that is used would be very interesting. In other words, if your phone only has access to network based positioning, the application would adjust to that, and if the phone has A-GPS support, that would be the method used for positioning.

9 Conclusion

The big question was, is it really a good idea to use a mobile phone with A-GPS instead of a GPS handset combined with almost any phone that has Bluetooth technology. we think not. Not today with Motorola A925 anyway. Maybe there are phones with A-GPS that have more sensible antennas which makes both the positioning time to decrease and also works better indoor, or maybe there will be in the near future. Maybe there are some limitations in the mobile network that held back the A-GPS functionality. In any way, our tests showed that the A-GPS functionality was not good enough to replace a conventional GPS together with a Bluetooth mobile phone.

Our application is developed with CLDC 1.0 and MIPD 2.0 and the future phones will probably be compatible to this protocol and configuration. That means that it most certainly is possible to test our application on future phones. The question is however, if the location API for the future phone is similar to the location API for Motorola A925. For Motorola phones it probably will. Hopefully I'll get the chance to come back to this project in a near future to make some new tests with new phones in order to see if it gets any better.

10 References

[1] Location-Based Services
http://www.mobileinfo.com/LocationBasedServices/index.htm#definition
2004-04-15

[2] Computer- and telecommunication
http://www.its.bth.se/courses/eta031
2004-04-15

[3] All about GPS
http://www.trimble.com/gps
2004-04-15

[4] What is GPS?
http://www.garmin.com/aboutGPS/
2004-04-15

[5] Assisted GPS: A Low-Infrastructure Approach
http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=12287
2004-04-15

[6] E-911 roundtable
http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=12235&pageID=1
2004-04-15

[7] Swedish mobile operator Telia
http://www.telia.se
2004-04-15

[8] Swedish mobile operator Tre
http://www.tre.se
2004-04-15

[9] Swedish mobile operator Vodafone
http://www.vodafone.se
2004-04-15

[10] Piroumian, Vartan (2002) Wireless J2ME platform programming: Prentice Hall, ISBN 0-13-044914-8

11 Appendix

11.1 Relating websites

A website that explains what Geographic Information System is:
http://www.gis.com/whatisgis/index.html

A website about location based services:
http://www.mobileinfo.com/LocationBasedServices/index.htm#definition

A website of the GSM association:
http://www.gsmworld.com

A website about GPS:
http://www.trimble.com/gps

Another GPS website:
http://www.ultralighthomepage.com/gps_system.html

A bachelor thesis about real time positioning, containing coordinate transformation formulas:
http://www.ep.liu.se/exjobb/isy/2002/3246/exjobb.pdf

Free float classes for CLDC 1.0:
http://henson.newmail.ru/j2me/Float.htm
http://henson.newmail.ru/j2me/Float11.htm

Free double and float classes for CLDC 1.0:
http://www.dclausen.net/projects/microfloat/javadoc/net/dclausen/microfloat/MicroDouble.html

Sun Microsystems website. Here you can find Java 2 Micro Edition and Wireless Toolkit for J2ME:
http://java.sun.com/

A New Spin on Location Services:
http://www.telecommagazine.com/default.asp?journalid=3&func=articles&page=0409t10&year=2004&month=9