Final Thesis

Field test of A-GPS on the SUPL platform and evaluation of hosted mapping services at TeliaSonera

by

Oskar Grönqvist

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Supervisors: Lars Magnusson, TeliaSonera Sweden AB
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Abstract

There have been a number of methods proposed for increasing the precision of mobile positioning systems. One of the latest methods is Assisted GPS, A-GPS, on the Secure User Plane for Location, SUPL, platform, which seems to be a very interesting alternative from TeliaSonera's perspective, thanks to minimal infrastructural investment costs.

According to theory and lab testing A-GPS has the potential of providing a very good customer value in relation to the investment needed.

There is, however, a great need to see the performance when used in real user environments and with real user equipment. This is the basis for the choice of field testing as the method used in this thesis.

The result from the field tests conducted in this thesis shows that the performance of A-GPS is very good in outdoor environments, but when used in indoor environments, poor signal strength in combination with multipath and fading becomes a problem with low accuracy and long response times as a result.

Using a hosted mapping service, in combination with A-GPS, provides the possibilities of launching location based services even outside the home network. TeliaSonera had already found such a hosted mapping service that matched their compatibility, and reliability, requirements. This thesis investigates this hosted mapping service further and finds that the quality of the cartographic presentation of the map information is very poor.

The conclusion is that A-GPS performance, today, is limited by the hardware and algorithms used. If these are further adapted to indoor conditions, A-GPS has the potential of providing the customer value promised by the theoretical performance. For a successful launch of A-GPS services there is a great need of better cartographic presentation of map information, than what is currently is provided by the investigated hosted mapping service.
Acknowledgements

This thesis would not have been possible without the support I have received from Lars Magnusson, who has been my supervisor at TeliaSonera. There are also a number of other people at TeliaSonera that have contributed with their knowledge and experience during the process of writing this thesis.

Both A-GPS suppliers have been very helpful and have provided hosted implementations for these tests and support whenever problems arose.

At the university my examiner Åke Sivertun and supervisor Michael Le Duc contributed with essential assistance, especially at the start up and finishing of this thesis.
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<td>A-GPS</td>
<td>Assisted-GPS. GPS receiver using assistance data to decrease start up time and signal strength requirements.</td>
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<td>BPSK</td>
<td>Binary Phase Shift Keying. Method used to modulate bit information on a carrier frequency.</td>
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<td>BTS</td>
<td>Base Transceiver Station. The mobile network element where the antenna is located. Often referred to as Base Station.</td>
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<td>C/A</td>
<td>Coarse/Acquisition. The code used to identify a GPS satellite and to measure its distance from the receiver.</td>
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<td>CDMA</td>
<td>Code Division Multiple Access. 2nd generation mobile phone technology widely spread in the US.</td>
</tr>
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<td>dBm</td>
<td>Decibel in relation to 1 milliwatt. $dBm = 10 \log (power / 0.001 W)$.</td>
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<td>DOP</td>
<td>Dilution Of Position. An estimate of how the GPS positioning response accuracy is influenced by satellite constellation geometry.</td>
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<tr>
<td>FCC</td>
<td>Federal Communications Commission. US government agency regulating the communications market.</td>
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<tr>
<td>GIS</td>
<td>Geographical Information System. Presenting objects and information according to spatial location. Often used as a synonym to computerized mapping.</td>
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<td>GNSS</td>
<td>Global Navigation Satellite System. Group of navigation systems using satellites for positioning and with global coverage. GPS, GLONASS and Galileo are GNSS examples.</td>
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<td>GPS</td>
<td>Global Positioning System. Satellite based positioning system owned by the US government.</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile communication. A 2nd generation mobile phone system implementation.</td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Document. Document specifying information exchange between two communicating entities.</td>
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<tr>
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<td>Java Server Pages. Used to create dynamic web content.</td>
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<td>Location Based Service. Often referred to as a mobile service that uses the location of a user as input variable.</td>
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| OMA | Open Mobile Alliance  
*An alliance of telecommunication companies formed to specify market driven mobile services.* |
| PDA | Personal Digital Assistant  
*Used as a synonym to hand held computer.* |
| PRN | Pseudo Random Noise  
*A predetermined sequence of numbers that seem to be random. Often used in computer applications where replication possibilities are desired.* |
| RRLP | Radio Resource Location services Protocol  
*Defined by 3GPP for transferring location services related information in the control plane.* |
| SLP | SUPL location platform  
*Refers to the main server in a SUPL implementation.* |
| SMS | Short Message Service  
*Used to transmit short text messages and WAP-push messages in GSM networks.* |
| SUPL | Secure User Plane for Location  
*OMA specification for mobile positioning services.* |
| TA | Timing Advance  
*Variable used in GSM networks to align user transmissions to the allocated time slot.* |
| TDOA | Time Difference Of Arrival  
*Mobile positioning method based on measuring the time difference of the arrival of a signal from the mobile phone at multiple BTSs.* |
| WAP | Wireless Application Protocol  
*Protocol specification for information access and interaction from wireless devices such as mobile phones.* |
| WCDMA | Wideband CDMA  
*Currently the most commonly used 3rd generation mobile phone system implementation.* |
Chapter 1 Introduction

1.1 Background
Traditionally, the knowledge of one’s geographic position has been a component used mainly for navigation. Today, however, TeliaSonera, which is Sweden’s largest mobile operator, see an increased demand for location based services, such as fleet management, asset tracking, and emergency services, which have new requirements on the positioning method used. The GPS receiver has been very suitable for navigational needs, but it is less suitable for the new type of services described above, due to long startup times, signal strength requirements and lack of communication channels. Positioning in the mobile phone network, on the other hand, is very fast, has better signal strength availability and a two way communication channel, but lack the precision provided by the GPS system.

When the American Federal Communications Commission, FCC, adopted the rules for the Enhanced 911 emergency service in 1996, they put pressure on American mobile network operators to increase accuracy of mobile positioning systems to be able to locate emergency callers within 125 meters\(^1\) (FCC, 1996). Many ways to achieve this accuracy has been proposed (Gunnarsson & Gustafsson, 2005), but have often turned out to require large investments in network infrastructure (Zhao, 2002). A-GPS on the SUPL platform needs new handsets with built in GPS receivers, but on the other hand it uses already available network infrastructure and requires no new hardware investments for the network operator, which makes it an attractive alternative (Burroughs & Gum, 2006). The fact that it can be used internationally is also an appealing characteristic (Magnusson, 2006). In Europe there are no requirements on positioning accuracy for emergency services, which have lead to the need of good return on investment possibilities for European operators to adopt a more precise positioning system (Burroughs & Gum, 2006). Good return on investments follows from keeping investment costs at a minimum while still delivering a good customer value. The driving forces for this will probably be the type of services mentioned above.

1.2 Purpose
The purpose of this thesis, which was formulated by TeliaSonera, is to evaluate the customer value added by A-GPS. This should be done through an investigation of the accuracy and response times. This thesis should also investigate the possibility to launch international A-GPS services by using a hosted mapping service and give a review of alternative positioning methods.

\(^1\) These requirements have changed. See FCC (2001) for more information.
1.3 Approach
From the purpose formulation, three components that have to be investigated to find the customer value are identified. The approach is formed to respond to these three components.

1.3.1 A-GPS
The approach used to find A-GPS customer value is field testing, implying that publicly available A-GPS receivers are tested in the real mobile network in some predefined typical user conditions. The choice of this approach is based on the fact that, at the start of this project, there are only theoretical evaluations and results from lab testing available.

For TeliaSonera, results from field testing in their own mobile network is very important, since this is the only way to observe the real performance of A-GPS and evaluating the customer value.

Before beginning the field testing, a theoretical study is performed to be able to relate the field testing results to theory and conclude if the results correspond to those to be expected from a theoretical point of view.

The results from testing A-GPS implementations from two suppliers are compared to see if any differences in performance are found.

1.3.2 Hosted mapping service
For the investigation of the possibility to launch internationally available A-GPS services, TeliaSonera has formulated some requirements for the mapping service to be used.

These requirements are:
- Compatibility with TeliaSonera’s current services
- Server reliability
- Response times similar to the current server
- A good visual presentation of the map information

These requirements are used in this thesis, to ensure a good customer experience.

1.3.3 Alternative positioning methods
To see if the same, or a better, customer value can be gained from other positioning methods, the most commonly suggested improvement strategies for the currently used GSM and WCDMA positioning methods are investigated and related to the customer value found in the A-GPS evaluation.
Chapter 2 Theoretical framework

2.1 GPS

To have an understanding of the GPS system is essential to identify the benefits gained by A-GPS. Here the GPS system is described both by an overview and in detail where the differences introduced by A-GPS are the greatest.

2.1.1 Principles of the GPS system

Introduction to GPS

The GPS system, which is an example of a Global Navigation Satellite System, GNSS, is owned by the US military and was developed mainly for military use. It is also open for civilian use, but with less precision. The available precision is, however, enough for most civilian services. The GPS system structure is often divided into the following three segments. (FAA, 2006)

- The space segment consists of the satellites orbiting earth.
- The user segment, which are the users receiving the satellite signal.
- The control segment monitoring satellite orbits and transmitting control data back to the satellites.

The theoretical part of this thesis will concentrate on the communication between the space and user segments.

Trilateration

By using the satellites as references and finding the distance from these known points in space it is possible to calculate the position of the receiver. This procedure is called trilateration.

Normally trilateration involves three reference points, but as described by Kaplan (1996) a GPS receiver needs to receive ranging signals from at least four satellites to find its position. The reason for this is that, a part from the three dimensional location, the time offset of the receiver is also unknown. If only three satellites are available, the receiver can only calculate a two dimensional position estimate.

As described above, the receiver needs to know the precise position of the satellites and be able to calculate the distance to each of the satellites in sight. This is done by the use of ephemeris data and pseudo range measurements.
Ephemeris data

For the receiver to be able to use the satellites as reference points it computes their precise position using the ephemeris data (Kaplan, 1996). The GPS Interface Control Document, ICD, (NAVCEN, 2000) specifies ephemeris data contents describing the satellite orbit. This is complemented by clock and health status of the satellite. Each satellite transmits these data every 30 second and they are considered to be valid for about four hours before it needs to be updated (Kaplan, 1996).

Almanac data

The ICD (NAVCEN, 2000) also specifies a more general version of the ephemeredes in the form of almanac data. Every satellite broadcasts almanac information about every other satellite. Because of the amount of data to be transmitted it is a time consuming process which needs 12.5 minutes for a complete copy of almanac data to be transmitted. In (Kaplan, 1996), this is found very useful since the receiver can use this to calculate the approximate position of all satellites and use this when acquiring signals. This procedure will be described later on.

Signal structure

A key component in any GNSS is the signal broadcasted from the satellites. In the public GPS system this 1575.42 MHz signal consists of a Binary Phase Shift Keying, BPSK, modulated coarse-acquisition (C/A) code which is mixed with a data stream using modulo-2 addition. This signal structure is also specified in the ICD. (NAVCEN, 2000)

Figure 2-1 GPS signal structure (Bertelsen & Rinder, 2004) shows the signal structure with the carrier frequency, C/A code, data stream and modulated signal.
C/A code
The C/A code is the identity of a satellite. This implies that every receiver that detects this code also can identify the transmitting satellite. To make this possible, every satellite is given a unique pseudo random noise, PRN, code which is a bit sequence that appears to be random, but follows a predetermined sequence. All these sequences are chosen from the so called gold codes to ensure minimum correlation between each of them. If there would be any cross correlation between two codes the receiver would not be able to tell them apart and this would lead to incorrect position computations. (Kaplan, 1996)

Every bit in the PRN sequence is called a chip, rather than a bit, since it carries no information other than its value. Every sequence consists of 1023 chips repeated every millisecond. (ibid.)

Data stream
To transmit the ephemerides and almanac information, a data stream containing this information is broadcasted from each satellite in the form of a bit sequence at 50 bits per second. This bit sequence is modulo-2 added with the chip sequence. The data is ordered according to the GPS navigation (NAV) structure consisting of 25 frames of 1500 bits each. Every frame is divided into five 300 bit sub frames. This frame structure can be seen in Figure 2-2. (ICD, 2000).

As seen in the figure above, the first three 300 bit sub frames contain clock, health and ephemeris data and are repeated on every 1500 bit frame. Each occurrence of sub frame four and five, which holds the almanac data, is part of a 25 frame data set. The complete 25 frame data set repeats every 12.5 minutes as mentioned earlier. (ibid.)
Pseudo range measurement
The real distance from the satellite to the receiver is the geometric range, but the GPS receiver will not be able to calculate this distance. The reason for this is that the measurements are biased by some non-measurable conditions such as atmospheric delays, multipath and receiver hardware. Some of these can be accounted for by approximations and some of them can be considered to be negligibly small. To distinguish the difference between the geometrical and the calculated range, the latter is referred to as pseudo range. (Kaplan, 1996)

The method for calculating the pseudo range is based on finding the propagation delay from the satellite to the receiver. The propagation delay is derived by replicating a copy of the known C/A code in the receiver and finding relative displacement against the received signal. (Ibid.)

![Figure 2-3 C/A code propagation delay](image)

Figure 2-3 shows the displacement of the received and locally generated codes. This propagation delay is used to calculate the pseudo range by multiplying with a factor equal to speed of light. (Ibid.)

2.1.2 Signal Acquisition
The process of finding the satellite ranging signals and synchronizing them with the locally generated code is called signal acquisition and is essential for the calculation of pseudo range. This process has to be carried out for each satellite that is to be acquired and is a 2-dimensional problem in the sense that both the exact carrier frequency and the propagation delay of the C/A code are unknown. This is shown in Figure 2-4 Acquisition search space for one satellite channel (Kaplan, 1996). Even if the transmitted carrier frequency is fixed at 1575.42 MHz, the received frequency is greatly dependent on Doppler effects since the satellite is orbiting the earth at high speed. The maximum Doppler for a stationary receiver is ±4.2 kHz based on the maximum relative user-satellite velocity. (Abraham & van Diggelen, 2001)
In the commonly used sequential search engine, for every frequency bin in the Doppler dimension, all delays in the propagation delay dimension have to be tested to find out if one of them coincides with the received C/A code. This is done by correlating the received signal with the locally created and delayed version. This is a time consuming process, since all possible Doppler frequencies and propagation delays have to be searched until correlation is found. This is often done in parallel for every satellite that is to be acquired. (Kaplan, 1996)

There are techniques used to speed up this process by reducing the number of cells to be searched. The most common is to use last known position and up to date almanac data to determine the satellites most likely provide a navigation solution. By doing this, the acquisition process can be narrowed down to only the C/A codes of satellites in sight. To further improve the acquisition time, almanac data can be used to predict Doppler effects on the satellite signals to find a starting frequency bin for the acquisition process. This reduces the Doppler dimension and, if very precise user position and orbital data is available, the process will be reduced to a nearly one dimensional problem. This is the case when the GPS unit reacquires the satellites after passing through a shorter tunnel. (ibid.)

After finding the right Doppler frequency and propagation delay, the GPS receiver extracts the navigation message including the ephemeris data. If up to date ephemeris data is already available, decoding it from the navigation message is not necessary and the acquisition time will be decreased. This is the case when the receiver has been shut down for less than four hours. (ibid.)

Bryant (2005) states, that to be able to acquire satellite signals and decode the navigation message in an acceptable time frame the receiver needs at least -142 dBm signal strength.
This is 12 dB below the minimum expected signal strength with a clear view of the sky specified in the ICD (2000). If the receiver has an up to date copy of the ephemerides, the navigation message does not have to be decoded and the demands on signal strength is about 3 dB less (Lachapelle, 2004).

2.1.3 Tracking
After acquiring the ranging signals, the receiver enters a tracking mode, in which the propagation delay is monitored to detect any changes in position. This is, however, not in the scope of this thesis since A-GPS is only intended to optimize the acquisition process.

2.1.4 Integrity
The UK Civil Aviation Authority (2004) defines the term integrity in the following way when used in the area of navigation systems. “Integrity relates to the level of trust that can be placed in the information provided by the navigation system.”

In the GPS system, this is accomplished by knowing the satellite health status and calculation of dilution of precision, DOP, and pseudo range standard deviation. Satellite health status is distributed in the first sub frame of every frame in the navigation message. If the control segment, which monitors the satellite orbits, detects any deviation in the satellite orbit, the status parameter is changed to indicate that the ranging signal is not reliable. DOP is calculated from the satellite constellation geometry. When multiplied by the standard deviation of pseudo range measurements this gives the standard deviation on the position calculation. The standard deviation of pseudo range measurements depends on variables including clock stability, receiver noise and multipath. (Kaplan, 1996)

2.2 A-GPS
A-GPS, which in this thesis refers to Assisted GPS on the Secure User Plane for Location, SUPL, platform, is aimed at decreasing the satellite acquisition time by using a standard TCP/IP communication channel to distribute information normally decoded from the navigation message. In this section, the A-GPS system will be described and the theoretical performance will be investigated.

2.2.1 Principles of the A-GPS system
The ideas of an assisted, or aided, GPS was formulated by Sennot and Taylor (1981). They introduced the theory that if a receiver is provided with the information needed to estimate the Doppler frequency before acquiring a signal, the Doppler dimension of the search space is reduced and, hence, the acquisition time is shortened (ibid.). This principle has been extended to include all ephemeris and almanac data as well as approximate receiver position. By supplying the receiver with the full contents of the GPS navigation message, the need for decoding the data stream is eliminated. (Bryant, 2005)
2.2.2 User plane A-GPS
Burroughs and Gum (2006) identify that location based services, like A-GPS, can be categorized into two groups with different focuses. There are the emergency services where demands on availability and precision are high, whereas investment costs are secondary. In countries where there are no government regulations on emergency positioning accuracy, the focus is, instead, on commercial services. Here, the investment costs are very important while availability and precision have to be related to the price that the customers are willing to pay for the services. For this reason, two different A-GPS implementation strategies have been formed. The control plane implementation, specified by 3GPP, ensures the availability needed for emergency services, while demands on modifications in the operator network are high and dependent on network type. For more commercially focused services, the Secure User Plane for Location, SUPL, platform was specified by the Open Mobile Alliance, OMA. Here, all information exchange uses standard TCP/IP communication channels. By using standard TCP/IP communication, there is almost no demand for network modifications. Other commercially interesting characteristics of the SUPL platform are positioning services internationally in roaming networks and easy implementation across both GSM and WCDMA networks. Only the user plane implementation strategy is in the scope of this thesis and the term A-GPS will refer to the SUPL implementation, if not stated otherwise. (Burroughs & Gum, 2006)

Figure 2-5 GSM/WCDMA user plane and control plane

2.2.3 Messaging call flow
The A-GPS messaging structure is specified by OMA, and the most important messaging is presented as a call flow diagram in Figure 2-6. Specification of each message type is found in (OMA, 2005b) and (3GPP, 2005b).
Worth noting is that the SUPL INIT message is sent through a WAP-push message using SMS as a bearer. All assistance data is contained in the RRLP message included in SUPL POS. RRLP is specified by 3GPP for control plane A-GPS (3GPP, 2005b), but as seen here the same message is used, but contained in a SUPL message in the user plane (OMA, 2005b).

2.2.4 A-GPS performance in theory

The advantages achieved by supplying satellite data through the mobile network, instead of in the satellite data stream, are all related to the acquisition process. The most obvious advantage is, not having to wait 30 seconds until recent ephemeris data have been decoded from the data stream. A less obvious one is that having this information in advance gives a choice of increased speed or sensitivity when searching for satellite signals. (Abraham & van Diggelen, 2001)

Advantages gained by knowing the Doppler frequency

In section 2.1.2, the acquisition process was discussed and the Doppler frequency domain was described. It was also found that by knowing its approximate location and having recent satellite ephemeris data, the receiver could reduce the Doppler domain of the search space. Abraham and van Diggelen (2001) extend this reasoning by stating that if the Doppler domain is reduced by a factor of ten, this would lead to up to ten times faster acquisition or, as will be discussed below, be ten times more sensitive while keeping the same acquisition time.
In a traditional GPS receiver, the received and the locally generated signals are correlated by integration in every cell of Figure 2-4 *Acquisition search space for one satellite channel* (Kaplan, 1996). If the level of correlation is above a predetermined threshold, the right Doppler frequency and propagation delay is considered to be found and, consequently, the search continues if the value is below this threshold. (Kaplan, 1996)

The calculated correlation follows a stochastic process with corresponding probability density functions (PDFs). When the right Doppler frequency and propagation delay is found, a signal is considered to be present and the PDF follows a Ricean distribution, while all other cases is considered to consist of noise only and are described by a Rayleigh distribution. (ibid.)

Figure 2-7 *Probability of correct signal detection* shows the probability distribution of the case when a signal is present and the predetermined threshold. If a signal is present, the stochastic process follows the Ricean distribution and if a correlation higher than the threshold is found this is considered a correct detection. Figure 2-8 *Probability of false signal detection* shows the case when no signal is present and the stochastic process follows the Rayleigh distribution. If the level of correlation is above the threshold even if only noise is present, this is considered a false detection. The grey areas in both figures represent the probability of correct and false detection respectively. (ibid.)

![Figure 2-7 Probability of correct signal detection at a given threshold](image1)

![Figure 2-8 Probability of false signal detection at a given threshold](image2)

The Ricean distribution of the case where a signal is present is defined as follows (Kaplan, 1996):

\[
p_s(z) = \frac{z}{\sigma_n^2} e^{\frac{z^2}{2\sigma_n^2}} I_0 \left( \frac{z\sqrt{2s/n}}{\sigma_n} \right)
\]  

(2.1)

While the Rayleigh distribution of the case when only noise is present is defined as follows:

\[
p_n(z) = \frac{z}{\sigma_n^2} e^{\frac{z^2}{2\sigma_n^2}}
\]

(2.2)
where

\[ z = \text{integration variable} \]
\[ \sigma_n = \text{root mean square noise power} \]
\[ I_0 = \text{modified Bessel function of zero order} \]
\[ s/n = \text{predetection signal-to-noise ratio} \]
\[ s/n = 10 \log_{10} \left( \frac{s}{n} \right) \]
\[ S/N = \text{predetection signal-to-noise ratio in dB} = \frac{C}{N_0} + 10 \log T \]
\[ C/N_0 = \text{Carrier-to-noise ratio} \]
\[ T = \text{coherent integration time [ms]} \]

Equation (2.3) indicates that the signal-to-noise ratio is a function of carrier-to-noise ratio and coherent integration time. From this relation follows that an increase in integration time acts as an amplification of signal strength, hence increasing the probability of signal detection at a given threshold. If the integration time is increased 10 times, this acts as a 10 dB gain (Kaplan, 1996). This is illustrated by Figure 2-9 Short coherent integration time and Figure 2-10 Long coherent integration time.

The theoretical maximum coherent integration time is the bit duration of the data stream, which is 20 ms and gives a gain of 13 dB, according to equation (2.3), in relation to 1 ms integration time which is often used as a reference value. When this maximum is reached, a non-coherent method can be used to get a higher gain. Non-coherent integration means that many coherent integration intervals are accumulated. This method is not as effective as coherent integration since it also increases the noise. (Lachapelle, 2004)

As a result of this it is seen that it is possible to choose between decreasing the acquisition time and increasing the sensitivity when the Doppler domain is reduced, as stated earlier in this section.

**Advantages gained by knowing the navigational message**

By having the full navigational message in advance, there is no need of decoding it from the received satellite signal. As mentioned in 2.1.2 *Signal Acquisition*, decoding the navigation data stream needs -142 dBm, while pseudo range measurements can be determined from much weaker signals. (Bryant, 2005)
Knowing the navigation data stream also provides the possibility to expand the coherent integration interval past the 20 ms limitation. This is done by prediction of bit transitions in the data stream. (ibid.)

For this to be possible, precise time aiding is important. This is not available in GSM networks, as will be discussed in the following section. (Agarwal, 2002)

**Time aiding**

There are two types of time aiding available. These are precise time aiding, which is on the microsecond level and coarse time aiding, which is within a few seconds. Using microsecond timing helps the acquisition process greatly and should be used if possible to implement. Since the GSM and WCDMA networks are not synchronized to GPS time, this is not possible. Instead coarse time aiding is used. (Bryant, 2005)

There are methods to find a precise timestamp even if only coarse time aiding is available. This is discussed by Agrawal et al. (2002). There are also methods proposed to make microsecond timing possible even in unsynchronized networks. One of these is the Matrix method, where many phones work together and share timing information throughout the network (Duffett-Smith & Hansen, 2005). This will be discussed further in Chapter 3 *Alternative positioning methods.*

**Enough for location based services?**

To be suitable for location based services a GPS receiver must work under heavy multipath and with signal strengths well below those found where GPS receivers traditionally have been used (Dedes & Dempster, 2005). These signal conditions is studied further in section 4.1.4 *Test locations.* Is the performance increase found in the previous sections enough to make a GPS receiver perform well even under those conditions?

Abraham and van Diggelen (2001) have found that increasing integration time will, in practical implementations, give about 10 dB gain if a 10 times increase in coherent integration time is used. Indoor signals are often much more attenuated than this and signal strengths seen inside are about 20-40 dB below what a standard GPS receiver can acquire.

To achieve 30 dB of integration gain, the coherent integration time has to be increased by a factor of 1000 giving 1 second of integration time, compared to the often used 1 ms. When trying to increase integration time there are a number of problems that have to be overcome. For example, the demand on the quality of the time source as well as the demand for computing power increases. (Agrawal, 2002)

Acquisition time also increases heavily by increasing the integration time. As seen in Figure 2-4 *Acquisition search space for one satellite channel* (Kaplan, 1996) integration is done in every cell and even if precise Doppler aiding is present, integration has to be conducted for all cells in the remaining one dimensional problem. A traditional GPS...
receiver uses three correlators per satellite channel and searches three cells in parallel. With this receiver implementation and a 1 second integration time, the acquisition time is up to 682 (1023/1.5) seconds even with precise Doppler aiding no data stream decoding. (Kaplan, 1996)

Precise time aiding would decrease the need of integrating over all possible propagation delays (Bryant, 2005). As described earlier the precise timing issue is not solved for GSM networks, even if some approaches to solve this has been proposed.

Another problem is that the traditional GPS receiver is not suited for the multipath and highly varying signal conditions it is exposed to inside a building. In heavy multipath and fading conditions, the signal can often be lost for a short while, which is something that traditional GPS receivers are not designed to handle. (Dempster & Dedes, 2005)

This leads to the need for further improvements of sensitivity and adaptation to multipath conditions in combination with A-GPS to be suitable for location based services, LBS. This is discussed in the following section.

2.3 Further improvements of the GPS chip

As found in the previous section, a traditional GPS receiver is not suited for LBS services, even with the help of assistance data. To solve the problems described above, the massively parallel correlating receiver was introduced. This receiver has a separate correlator finger for each propagation delay, leading to the possibility of integrating all possible propagation delays in parallel instead of in a serialized fashion as has been done before (Abraham & van Diggelen, 2001). Figure 2-11 Reduced search space shows the search space with precise Doppler aiding and massively parallel correlating engine. The figure is somewhat ideal, since the exact Doppler is hard to predict in real environments.

![Reduced search space with A-GPS and massively parallel correlators](Figure 2-11 Reduced search space with A-GPS and massively parallel correlators)

By implementing the improvements discussed above, this kind of receiver has a great potential of suiting the needs of LBS services. It handles both fading and multipath signals more effectively than traditional receivers. The ability of increasing the integration time beyond the limitations of a traditional receiver gives the possibility of detecting signals attenuated up to 30 dB. (Abraham & van Diggelen, 2001)

It is this kind of massively parallel correlating receiver that is usually referred to as high sensitivity receivers. There are other approaches to reach higher sensitivity which are based
on smart algorithms (Agarwal, 2002), but so far the receiver type discussed above are
dominant on the high sensitivity receiver market.

High sensitivity receivers in combination with assistance data open for the possibility of a
GPS receiver for LBS services.

2.4 Cartographic design

Cartographic design is the science of how to present geographic information in a way that
focuses on the readability and getting the user to focus on the information that is most
important. In short it is the matter of good or bad maps. This matter can often be discussed
almost to infinity. There are, however, some guidelines that are agreed upon among
cartographers and it is a selection of these guidelines that is relevant in this thesis and will
be described in the following section.

Robinson et al. (1984) write, “Regardless of the positional accuracy or essential
appropriateness of the data, if the map has not been carefully designed it will be a poor
map.” This means that even if the diversity on the market for international map data is very
limited and many maps use the same data source, there will still be a great difference of
quality due to good or bad cartographic design.

2.4.1 Cartographic guidelines

According to (Brodersen, 2002), the task of a cartographer can be brought together in three
points. These can be closely related to (Robinson et al., 1984).

- What information should the map contain? (Brodersen, 2002)
  o Generalization (Robinson et al., 1984)
- How should this information be sorted, filtered and organized? (Brodersen, 2002)
  o Hierarchical organization (Robinson et al., 1984)
- How should the information be graphically presented? (Brodersen, 2002)
  o Graphic map design (Robinson et al., 1984)

To make a good map, it is important to know how the map will be used and what
information is important to the users (Brodersen, 2002). A user at sea has, for example,
different needs than one that use the map for land navigation. In a similar way, a user that is
familiar with the area covered by the map often has different needs than a user that visits
for the first time.

Generalization

The aim of the generalization process is to present only the information needed to
communicate the intended meaning of the map. There are two levels of generalization to be
made. The first stage is to decide what information to include. The other is to decide the
level of detail to use, when describing the information geographically (Brodersen, 2002). The information that is displayed is dependent on size, scale and intended usage and can only be done in a satisfying way if these variables are known (Robinson et al, 1984).

Hierarchical organization
Organizing the information hierarchically, means that objects are ordered according to a variable, for example size or importance. This ordering will be used when representing objects with symbols on the map. A common way of ordering objects is to order roads by road classes and cities by size, but sometimes importance of an object is not necessarily only dependent on the size. (Robinson et al., 1984)

Graphic map design
In the map design stage, the information from the generalization and hierarchical organization stages are used to produce an easily readable map. The map design stage primarily involves choosing symbols and colors to represent the information that should be presented on the map. (Robinson et al., 1984)

Colors
The primary task of the color is to show the qualitative differences (Brodersen, 2002).

- Color conventions
  - There are color conventions that are based on the perception of different colors. For example, blue are associated with water, green with vegetation and red with roads and cities. (Brodersen, 2002)

- Contrast
  - The contrast between colors has to be chosen with care and, as with all other factors, with consideration of the intended user. If the map is to be used on a small screen in varying light conditions, color contrast has to be given extra care. (Magnusson, 2006)

Cartography for LBS
New types of media like mobile phones and PDAs have introduced new demands on cartographers when it comes to making maps suited for small screen sizes. (Lantmäteriet, 2005)

When designing maps for use in LBS services, the cartographer has to take extra care, since the map is often used for quick assessment and interpretation of the presented information. Often the map should contain only the information needed for orientation and some navigational needs.
Chapter 3  Alternative positioning methods

3.1  Currently used methods

3.1.1  In the GSM network

The accuracy of the GSM positioning method currently used in TeliaSonera’s network, is determined by cell type and cell diameter or measured distance. The two cell types defined for positioning purposes are omni cell, meaning that the coverage area of the cell is 360 degrees, and sector cell that only covers an area that is 120 degrees wide. (Magnusson, 2006)

The distance measurement is derived from the Timing Advance, TA, value that is responsible for adjusting the transmissions to arrive at the base station synchronized to the time slot allocated for that user. The resolution of the TA values, which refers to round trip time, is 3.7 μs and is specified in the GSM standard. These TA values can be converted to time by multiplication by speed of light, giving a geographical resolution of 550 m when converted to the one way distance (3GPP, 2005c). GSM accuracy in urban environments tends to be better than in rural areas, thanks to more base stations giving smaller cell areas, as shown in the figures below.

![Figure 3-1 GSM positioning example in urban area](image1)

![Figure 3-2 GSM positioning example in rural area](image2)

3.1.2  In the WCDMA network

In the TeliaSonera WCDMA network only cell type and size, without distance measurement, is used for positioning. Thanks to the smaller cell areas, this method result in similar positioning accuracy as GSM positioning with TA measurements, as shown in the following figure. (Magnusson, 2006)
3.2 Improving GSM and WCDMA positioning

The method of trilateration in both GSM and WCDMA networks looks very promising in theory, giving high accuracies. Network implementations using trilateration, however, are rare. The reason for this is most probably the fact that the needed investments are much greater than the value this type of services adds to the user experience. This will be discussed in the following sections.

3.2.1 Trilateration and TA

By using the current technique with TA-values and sector cells, the positioning estimate would clearly be improved by using trilateration. Since a TA value is only available from one base station, BTS, at the time, handovers would have to be carried out to retrieve TA values for at least three BTSs. This method has been investigated, but is not possible to implement due to the lack of support for handover for positioning purposes (Willassen, 1998 & Magnusson, 2006). If the network would be modified to support this kind of handovers, or to support TA values of multiple BTSs, the precision would still not be very good since the resolution will never be better than 550 meters for each of the respective measurements, as mentioned earlier (3GPP, 2005c). Another issue is that for trilateration to be possible, the phone has to be able to reach at least three different BTSs (Zhao, 2002). In rural areas with great distances between BTSs this is often not possible to achieve.

3.2.2 Unsynchronized network

Other measurement methods than TA values have been proposed, which do not have the handover and measurement resolution problems. The most commonly mentioned is Time Difference Of Arrival, TDOA. This method measures the difference in time of arrival at different BTSs of the signal transmitted from the mobile phone. Due to the fact that GSM and WCDMA networks are not synchronized to a common time source, measuring this time difference is not possible (Zhao, 2002).

A method for synchronizing GSM and WCDMA networks, without large infrastructural investments that have been proposed, is the Matrix method. This method uses information
exchange between users to learn the time offset between different BTSs. This method needs new software in the handsets, but since no new network infrastructure is needed, this method could be a very attractive alternative (Duffett-Smith & Hansen 2005). There is, however, a need of getting a high market penetration of Matrix compliant devices for this method to be effective.

3.2.3 Using signal strength measurements for positioning

In the GSM standard, it is specified that every GSM phone should keep a network measurement report, including signal strength measurements of the surrounding BTSs. (3GPP, 2006)

Since the propagation loss in free space can be modeled quite accurately, these measurements would give good position estimates. The problem with signal strength measurements is, that signals are attenuated by obstacles as trees and walls. This results in a lower received signal strength than if the signal path was through free space only. The consequence is that the user is thought to be further away from the BTS than he really is. (ibid.)

To compensate for this, signal strength measurements can be collected and added to a digital map. This is possible only in small areas due to the need of collecting measurements by hand. (Gunnarsson & Gustafsson, 2005)

3.3 Cell phone with GPS

There have already been phones with GPS receivers available on the market for some time. Among some users, these receivers have been much appreciated, but the success on the mass market has so far been limited. From the mobile operator’s point of view, a problem has been that to make services that use GPS positioning available, there is a great need of a standard for requesting position information from the device. In the early GPS devices, non-standardized SMS communication has been used to request position information. This makes integration with current positioning services hard and consequently it has not been performed. (Magnusson, 2006)

3.4 SUPL without assistance data

To overcome the standardization issue, a GPS receiver can be used in autonomous mode even on the SUPL platform, giving easy integration with current services (OMA, 2005b). For the mobile operator, this will reduce the investment cost compared to A-GPS, since there is no need for assistance data. None of the advantages found in section 2.2.4 A-GPS performance in theory is, however, available without the use of assistance data.
Chapter 4  Evaluation of A-GPS performance

4.1  Method

4.1.1  Field testing

There are results available from a number of studies on the performance of A-GPS in lab environments and setups, where an ordinary GPS receiver has been loaded with assistance data from a computer and with an external GPS antenna (Carver, 2005; Abraham & van Diggelen, 2001). In this project, TeliaSonera is interested to see the real performance when implemented in their real GSM and WCDMA networks and with real user equipment.

Ackermann (2006) points out that there are some issues with repeatability and control over the test environment in field testing, since A-GPS performance will change with the location of satellites as well as weather conditions. In this study, the most important objective is finding an indication of the real performance in a live network. This means that the repeatability and control problems have to be accepted and accounted for when interpreting the results.

TeliaSonera have, in earlier studies, used field testing as a method and found very important results not published in results from laboratory studies. (Magnusson, 2006)

4.1.2  Network initiated

TeliaSonera is mainly interested in the performance of network initiated positioning request, since most of TeliaSoneras current LBS services are accessible through WAP, SMS or through a web browser. In these cases, the positioning request is network initiated even if the service request can be initiated via the user equipment. The network initiated performance is also a very useful indicator of the performance of positioning requests initiated in the user equipment. The reason for this is that the user equipment performs the same operation in both cases, but in the network initiated case, it has to wait for an initiation message to arrive before the positioning request is handled.

4.1.3  Cold start/Hot start

The definition of cold start and hot start used in this report is knowledge of coarse position and up to date ephemerides when the GPS receiver is started. For details about the impacts on acquisition performance, see section 2.1.2 Signal Acquisition.

As discussed in section 2.1.2, the acquisition performance of an ordinary GPS receiver differs greatly between cold start and hot start. The usage pattern of most LBS services does not imply that the user requests a position with less than a four hour interval and thus
do not have up to date ephemerides. Because of this, the case of cold start performance is of interest for TeliaSonera. As with network initiated requests, cold start performance will never be better than hot start. It is therefore, a performance indicator of a worst case scenario. Theoretically, this difference should not exist in an A-GPS system as found in section 2.2.4 A-GPS performance in theory.

To test the cold start performance, all compatible terminals must have the capability of resetting all available satellite information. Whether this option is made available for the user or not is not specified. (3GPP, 2005d)

In the terminals that are used for this project there is a software application installed, where this option is available as an “Always Cold Start” option, for evaluation purposes. All the tests in this thesis are done with this option activated.

4.1.4 Test locations
Tests are carried out in seven different signal environments, ranging from very good to very poor. The majority of the locations are chosen inside an office building to be applicable to the signal environment LBS users are likely to be exposed to.

Signal environment
The signaling environment was characterized with the NordNav indoor truth reference system, which measures signal strength and multipath along with other characteristics. (NordNav, 2005)

Figure 4-1 GPS indoor signal strength measurements
Figure 4-1 GPS indoor signal strength measurements shows the signal strengths found inside the office building where the testing are performed. The strongest signals are outdoor signals that each corresponds to an indoor signal which is shown with the same color.
this figure it is found that difference between the outdoor and indoor signals are about 10-40 dB.

Inside an office building, the signal environment will be characterized by lots of multipath signals that is reflected by walls and furniture. The figures below exemplify three different cases of multipath. The horizontal direction represents time and the vertical can be interpreted as received signal strength.

Figure 4-2 No multipath shows a signal without reflections. This kind of signal is desired for accurate positioning results, but is rarely found in urban areas.

Figure 4-3 Reflected signal shows two signal components. The component that arrives first has travelled the shortest way, but is attenuated by passing through walls and furniture. A reflected signal, with a slightly longer way travelled, has higher signal strength. In this case, the latter is reflected on a nearby house and received through a window.

Figure 4-4 Heavy multipath shows a signal that has been reflected multiple times and finding the true signal is very hard. This kind of signals is often found under indoor conditions.

4.1.5 Time aspect

As Ackermann (2006) pointed out, the satellite constellations will have impact on the results. To ensure that different satellite constellations are represented in the test, all seven testing locations are visited at four occasions at different time of the day. By doing this, the mean values represent “normal” conditions in some sense.

4.1.6 Saving results

All test results are saved on the server for later analysis. Along with the positioning response, the real location is saved. The real location is estimated by the use of a digital map. This method is only accurate within a few meters, but this is compensated by the fact that the expected accuracy of the A-GPS is far worse than this when used indoors.
4.1.7 Error sources
What to consider an error has to be defined before discussing error sources. Since the object of this thesis is to evaluate real performance in real conditions, individual results impacted by bad weather and satellite constellations is considered an error. If all results are biased in the same way by weather and satellite constellations, this is, however, considered an erroneous result since it does not correspond to normal user conditions. Results biased by SUPL implementation details that are not applicable on a commercial A-GPS implementation is considered an error source, since these results does not correspond to the performance of the commercial implementation.

4.2 Equipment
The equipment used for evaluating the A-GPS performance can be divided into three categories. These are network, terminal and server application.

4.2.1 Network
We are using fully hosted implementations of the SUPL platform from two different suppliers. This means that there are no changes at all made in the TeliaSonera Network and that all server hardware are hosted by the suppliers. All communication between the mobile phone network and the hosted SLPs are carried out using TCP/IP over internet and GPRS. The mobile network used is TeliaSoneras GSM network.

4.2.2 Terminal
The terminal used for the evaluation of both suppliers is the HP6515 smartphone with a built in GPS-receiver.

The GPS chip is developed by Global Locate with the objective to be able to detect extremely weak signals in indoor conditions, while having very low power consumption. According to the specifications, it should be able to track signals as low as -160dBm. This chip is considered a high sensitivity chip and has the improvements mentioned in section 2.3 Further improvements of the GPS chip implemented. (Global Locate, 2005)

The fact that the antenna size on this device has been minimized to fit in the smartphone might have a negative impact on the results.

The terminal has been complemented with SUPL software to gain A-GPS possibilities and compatibility with the SUPL standard.
4.2.3 Server application

For the purpose of initiating the positioning requests and logging the results, a server application running in Java Server Pages, JSP, is used. The application is an enhancement of an application used to supervise and evaluate mobile positioning systems in the GSM and WCDMA networks at TeliaSonera. This application forms a request that is sent to the location server. The reply is decoded and presented graphically on a map. The positioning result can also be saved in shape format for further analysis using GIS tools.
Chapter 5 Evaluation of hosted mapping services

As discussed in the introduction, TeliaSonera has formulated some requirements to be used in the evaluation of the hosted mapping service.

TeliaSonera has previously done an assessment of the market and briefly investigated a number of hosted mapping services. The conclusion from this investigation was that the service that best complied with the requirements was ESRI’s ArcWebServices. This conclusion was based on information from the mapping service providers. (Magnusson, 2006)

5.1 Method

5.1.1 Compatibility

Today TeliaSonera uses XML requests following the OpenLS specification (OGC, 2005) for communication with the map server. For easy integration with the currently available services it is important that the hosted mapping service supports this kind of request. (Magnusson, 2006)

The evaluation of compatibility is done through an investigation of the modifications of the XML request needed when using the hosted mapping service instead of the in house server.

5.1.2 Reliability and response times

Service reliability is evaluated through an investigation of server redundancy stated by the service provider.

To perform a reliability test with a one sided confidence interval with a 95% degree of confidence for 99.9% service availability at least 10,000 test would have to be carried out. In discussions with TeliaSonera (Magnusson, 2006) it was decided that this is not in the scope of the thesis.

Response times are investigated by the use of a specially designed server application that sends requests at a specified interval and saves response times in a log file. This log is analyzed using a software for statistical analysis to find any differences between the two servers.

5.1.3 Cartographic design

The starting point of the evaluation of cartographic design is a mobile LBS user that has a device with a relatively small screen and often at lightning conditions that are not optimal.
The map from the hosted mapping service is compared, side by side, with a map of the same area from the current in house mapping server, where a lot of work has been put into adapting the cartographic design for LBS users.

Similarities and differences are discussed and related to the cartographic guidelines presented in the theoretical framework. By the nature of determining the quality of cartographic design it is of course a partly subjective matter. To ensure that this evaluation is as objective as possible, the statements in the discussion will be related to theory.
Chapter 6  Results and analysis

6.1  A-GPS

As described earlier, testing was conducted at seven different locations. First, the summarized results and mean values are presented and discussed. Then two of the seven locations are presented and discussed in detail, while the complete test results are available as appendices. The two locations to be discussed in detail are chosen to represent the complete results quite well. In the summarized values presented below, results from all locations are considered.

In the summarized results, the two suppliers are differentiated and compared to see if any differences in performance are found. In the results from the individual test locations, the number of tests is small and as a result of this the degree of confidence in any differences found would be very low. Therefore results are not presented per supplier.

6.1.1  Summarized results

These results originate from seven different locations, consisting of a majority of locations in very bad signal conditions. All these locations were visited four times with varying weather and satellite constellations. The consequence is high variances in response distributions and the analysis is adapted accordingly.

Response types

There were four different response types received during these tests of which only one is considered to be a successful positioning response. From the A-GPS testing point of view, only a GPS based positioning response was considered a success. Hence, a cell based location response from the GSM network was considered to be a failure. The reason why not all failed requests reported a cell position is not known, but it was probably due to a server error.

As seen in Table 6-1 Summarized A-GPS response types, 88% of the requests were successful for both suppliers while 12% failed. No difference could be found, except from the type of positioning failure response returned.

Table 6-1 Summarized A-GPS response types

<table>
<thead>
<tr>
<th>Supplier</th>
<th>OK (88%)</th>
<th>Cell ID (6%)</th>
<th>Position method failure (6%)</th>
<th>Absent subscriber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>74</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>74</td>
<td>0</td>
<td>0</td>
<td>10 (12%)</td>
</tr>
</tbody>
</table>
Response times

For analysis, the response times were divided according to the response types above. These response times are presented as dot plots in Table 6-2 Dot plot of response times, below. This choice of presenting the results are based on the desire to present all individual responses, since these often are more easily interpreted than means and sigmas.

Table 6-2 Dot plot of response times

<table>
<thead>
<tr>
<th>OK</th>
<th>Supplier 1</th>
<th>Supplier 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell ID</td>
<td>Supplier 1</td>
<td>Supplier 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position method failure</td>
<td>Supplier 1</td>
<td>Supplier 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent subscriber</td>
<td>Supplier 2</td>
<td>Supplier 2</td>
</tr>
</tbody>
</table>

As seen in the plot of response times, there is a difference between the suppliers both in successful and failed positioning responses. To further investigate the source of these differences, the call flow chart in Figure 2-6 SUPL call flow diagram for network initiated case using proxy (OMA, 2005a) was studied to identify differences in the SUPL implementations from the two suppliers.

The three time consuming parts that were identified are WAP-push delivery (C), GPRS session initiation (D) and satellite acquisition (F). These were identified by studying log files and measuring WAP-push delivery times. The only difference that is applicable on a commercial launch is a difference in satellite acquisition. Because of this the two suppliers were compared with the difference in WAP-push delivery and GPRS session initiated compensated for. See section 4.1.7 Error sources for a further discussion of what was considered an applicable difference.

To find out if there is any difference in acquisition time, a confidence interval with differences in WAP-push and GPRS connection time subtracted was calculated as follows:

\[
\left( \bar{T}_1 - \bar{T}_2 \right) - \left( \bar{P}_1 - \bar{P}_2 \right) - \left( \bar{C}_1 - \bar{C}_2 \right) \pm 1.96 \sqrt{\frac{s_{T_1}^2}{n_{T_1}} + \frac{s_{T_2}^2}{n_{T_2}} + \frac{s_{P_1}^2}{n_{P_1}} + \frac{s_{P_2}^2}{n_{P_2}} + \frac{s_{C_1}^2}{n_{C_1}} + \frac{s_{C_2}^2}{n_{C_2}}}
\]

with the values presented in the table below.
Table 6-3 Variable values for calculating confidence interval

<table>
<thead>
<tr>
<th></th>
<th>Mean (s)</th>
<th>Number of tests</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push: Supplier 1</td>
<td>$P_1 = 3.442$</td>
<td>$n_1 = 86$</td>
<td>$s_{P_1} = 1.269$</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>$P_2 = 10.774$</td>
<td>$n_2 = 77$</td>
<td>$s_{P_2} = 1.099$</td>
</tr>
<tr>
<td>Connection: Supplier 1</td>
<td>$C_1 = 8.1955$</td>
<td>$n_{c_1} = 22$</td>
<td>$s_{c_1} = 0.24$</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>$C_2 = 11.445$</td>
<td>$n_{c_2} = 22$</td>
<td>$s_{c_2} = 0.286$</td>
</tr>
<tr>
<td>Total: Supplier 1</td>
<td>$T_1 = 34.78$</td>
<td>$n_{t_1} = 78$</td>
<td>$s_{t_1} = 10.76$</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>$T_2 = 48.48$</td>
<td>$n_{t_2} = 78$</td>
<td>$s_{t_2} = 13.62$</td>
</tr>
</tbody>
</table>

The resulting confidence interval is (-7.1;0.9) seconds which includes zero. Based on this, no difference in repose times that is applicable to a commercial implementation was found for successful positioning responses. The fact that the interval is mainly negative is an indication that supplier 1 might have a little shorter response time, even if it is not significant enough to be concluded with a 95% degree of confidence.

Accuracy

The definition of accuracy used in this thesis is the measured distance between the real position and the centre point of the geographical area returned by the positioning system.

Table 6-4 Summarized accuracies shows a dot plot with the measured accuracies for all successful positioning responses.

Table 6-4 Summarized accuracies

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier 1</td>
<td>0 100 200 300 400 500 600 700</td>
</tr>
<tr>
<td>Supplier 2</td>
<td>0 100 200 300 400 500 600 700</td>
</tr>
</tbody>
</table>

To investigate if a difference in accuracy between the two suppliers is present, a graph showing accumulated percentage as a function of accuracy of the positioning response was studied. This graph is presented in Figure 6-1 Accuracies versus summarized percentage. The graph should be interpreted such that 50% of the responses from supplier 1 had accuracy better than or equal to 50 meters, while 50% of the responses from supplier 2 were better than or equal to 75 meters. These values are equal to the median value for each supplier.

Note that only accuracies up to 400 meters are presented in the graph, even if they were included when calculating the percentages.
of the positioning. This is concluded due to the fact that the graphs are separated in a majority of the percentage scale, and supplier 1 has a higher accuracy at these percentages.

Integrity

For every positioning result, a radius describing an uncertainty circle was reported. As discussed in the theory, it is important to know the level of confidence in the positioning result. In this case, it means that the reported uncertainty radius should correspond to the real accuracy. Most importantly, the reported radius should never be allowed to be smaller than the real accuracy.

In Figure 6-2 a straight line divides the response region into two areas. The area in the upper left corner is considered to be ok, whereas the area to the right should be avoided, according to the discussion above. Neither of the suppliers has a satisfying estimation of accuracy, but a clear difference between them is that supplier 2 always reports an uncertainty radius of about 30 meters, independent of the real accuracy as seen in the figure.

Figure 6-1 Accuracies versus summarized percentage

Figure 6-1 indicates that supplier 1 has a better accuracy in a majority of the positioning responses. This is concluded due to the fact that the graphs are separated in a majority of the percentage scale, and supplier 1 has a higher accuracy at these percentages.
From this figure it is concluded that supplier 1 provides a higher grade of integrity than supplier 2. The integrity provided is, however, not considered acceptable for services where integrity is critical. (CAA, 2004)
6.1.2 Open sky conditions

In open sky conditions, the signal strength is expected to be about -130dBm. This was confirmed by Figure 4-1 GPS indoor signal strength measurements. Under these conditions an unassisted GPS receiver works very well, but the assistance data should decrease the acquisition time noticeably.

![Figure 6-3 Positioning responses in open sky conditions](image)

Table 6-5 Summary of results in open sky conditions

<table>
<thead>
<tr>
<th></th>
<th>Min: 13 s</th>
<th>Max: 41 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Min: 1 m</td>
<td>Max: 139 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-6 Dot plots of response time and accuracy in open sky conditions

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>0</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accuracy (m)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As seen from *Table 6-5 Summary of results in open sky conditions* and *Table 6-6 Dot plots of response time and accuracy in open sky conditions* the real accuracy was not as good as expected. A reason for this might be that the A-GPS receiver returns the first valid position fix and does not increase accuracy by filtering tracking results and return the mean value, as a GPS in tracking mode.

When studying the dot plot of response times in Table 6-6 the impact of differences in WAP-push delivery times found in section 6.1.1 *Summarized results* must be accounted for and the plot clearly shows two different distributions of response times.

The red triangle in Figure 6-3 *Positioning responses in open sky conditions* indicates the real position of the A-GPS receiver and the dark circles indicate positions returned by the A-GPS. This figure shows that the accuracy in open sky conditions is enough for most LBS services.
6.1.3 Indoor conditions (10 meters from window)

Under indoor conditions, the signal strength is far below those found outside. The measurements from Figure 4-1 show that the signal strengths found were from -140 dBm down to -160 dBm and lower. It is also a heavy multipath and fading environment. At such conditions, a traditional GPS receiver would not be able to track any satellites. A high sensitivity receiver might be able track satellites, but acquiring them without up to date ephemerides and coarse position would not be done within a reasonable time frame.

Figure 6-4 Positioning results from an indoor environment

Table 6-7 Summary of results in indoor conditions

<table>
<thead>
<tr>
<th></th>
<th>Min: 29 s</th>
<th>Max: 66 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Min: 29 m</td>
<td>Max: 224 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>71%</td>
<td></td>
</tr>
</tbody>
</table>
Table 6-8 Dot plots of response time and accuracy in indoor conditions

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>.</th>
<th>.</th>
<th>.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Accuracy (m)</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>130</td>
<td>230</td>
</tr>
</tbody>
</table>

From Table 6-7 Summary of results in indoor conditions and Table 6-8 Dot plots of response time and accuracy in indoor conditions it is found that response times increased compared to response times in open sky conditions. This was probably due to the challenging signal conditions giving a longer acquisition time.

Figure 6-4 Positioning results from an indoor environment shows that the positioning errors can have an important impact in services where accuracy is critical. Compared to the positioning systems available today which were presented in section 3.1 Currently used methods, this still shows a great increase in accuracy. The lack of integrity, as discussed earlier, is however a concern when used in critical services.

6.2 Hosted mapping services

6.2.1 Compatibility

The XML request modifications needed were found to be small and often related to the fact that the hosted mapping service follows the OpenLS specification (OGC, 2005) more accurately. Two map requests, which show these modifications, are presented in the appendix. One modification is the need to specify the coordinate system used for map projection. This is done by using the srsName property in the XML tags where coordinates are specified.

A modification that is not related to the specification of OpenLS, is the need of requesting a token to be used in the map request. The use of a token is implemented for security reasons, to be used for user authentication by HTTPS, instead of supplying the password in the XML request sent by HTTP. The token is valid for 60 minutes, but for easy implementation it is possible to request a new token for every map request sent.

There is also a need of specifying the map database to be used. This is done by supplying a “ServiceGroup” variable as a request property for the connection. In Java this is done in the following way:

```java
URLConnection conn = url.openConnection();
conn.setRequestProperty("ServiceGroup","XLS.TA.EU");
```
6.2.2 Reliability

According to ESRI, the server structure is redundant by the use of two complete sets of servers at two geographically separated locations. As discussed in section 5.1.2 Reliability and response times this will not be investigated further.

To find out if there is any difference in response time a confidence interval was calculated as follows:

$$\left(\bar{R}_H + \bar{R}_T\right) \pm 1.96 \sqrt{\frac{s_{R_H}^2}{n_{R_H}} + \frac{s_{R_T}^2}{n_{R_T}}}$$

with the values presented in the table below.

<table>
<thead>
<tr>
<th>Map Response</th>
<th>Mean (s)</th>
<th>Number of tests</th>
<th>Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hosted</td>
<td>$\bar{R}_H = 1.4109$</td>
<td>$n_{R_H} = 120$</td>
<td>$s_{R_H} = 0.0987$</td>
</tr>
<tr>
<td>TeliaSonera</td>
<td>$\bar{R}_T = 1.1223$</td>
<td>$n_{R_T} = 120$</td>
<td>$s_{R_T} = 0.2915$</td>
</tr>
</tbody>
</table>

The resulting confidence interval is (0.23;0.34) seconds which does not include zero. Based on this, a difference in response time was concluded. This difference grows if a new token is requested for every map request. The mean response time for token requests is 0.39 seconds.
6.2.3 Cartographic design

Small scale map

Figure 6-5 Small scale map from the in house map server

Figure 6-6 Small scale map from the hosted mapping service

Generalization

As discussed in section 2.4.1 Cartographic guidelines the aim of the generalization process is to present only the information needed and nothing else.

In the map which is generated by the in house mapping server, and presented in Figure 6-5, the included information are major roads and towns as well as smaller villages. This is an example of a map with a adequate degree of generalization.

Figure 6-6, shows the map from the hosted mapping service. On this map the number of roads included is far greater and all roads are shown with a great detail. This does, however, not make the map more easily interpreted. By studying the map in detail it is found that a number of important roads are not included, such as E4 and road 51. The town of Söderköping is also not included even if it can be considered more important than other villages that are included in the map.

Hierarchical organization

In Figure 6-5 roads are organized by road class in four different classes. This is very helpful when distinguishing between expressways and smaller roads. Towns and villages are presented according to their geographical size and thus hierarchical organization is not needed.
On the map in Figure 6-6, roads are not organized by road class and all roads are represented with the same line width. Towns and villages are presented according to their geographical size as in Figure 6-5.

**Graphic map design**

The map from the in house server has a good presentation with easily readable labels and contrasts making identifying objects easy. Colors are chosen to correspond to color conventions.

The background is not as neutral as suggested by literature to support contrasts with the full color spectra. The color choice can be a result of generalization as most of the area is covered by forest.

Figure 6-6 has less contrasts and mostly grey colors. This corresponds to theory, if other information, such as routes, is presented on the map and the map shown here act as a background. Then only neutral colors should be used. These low contrasts make the map less suited for interpreting the geographical information presented. Especially labels are hard to read.

**Large scale map**

![Figure 6-7 Large scale map from the in house map server](image1)

![Figure 6-8 Large scale map from the hosted mapping service](image2)
Generalization

In Figure 6-7 buildings have been included to help users familiar with the area to find easily recognizable objects, while the user unfamiliar with the area can use the buildings to find tourist attractions etcetera. This is a part of the generalization process since it, in a wide sense, includes decisions about what information not to present as well as what to present. In this case, the difference is due to the fact that the supplier of map information, used in the hosted mapping service, does not provide information about buildings (Magnusson, 2006).

Hierarchical organization

As in the previous example it is clear that an adequate hierarchical categorization by road class greatly helps easy interpretation of the map information. In this case it is also needed to be able to separate the narrowest roads from each other as seen in Figure 6-8 where this is not possible.

Graphic map design

As discussed in the theoretical framework, the contrast of the map is very important in LBS services, since the map is used under varying lighting conditions. In this case the background color in Figure 6-7 does not give enough contrast against the road network for the map to be easily distinguished from the background.

The map in Figure 6-8 has the same problem with labels as in the previous example. Including labels for Stockholm and Mälaren does, however, help interpreting the map for a user that does not know from which geographical area the map is taken. Such an example is fleet management services.
Chapter 7  Discussion

7.1 A-GPS performance

After studying the performance of the A-GPS system, I have come to the conclusion that the performance nearly represents what is to be expected from the technology. For a successful launch of A-GPS services, there are, however, some areas that have to be addressed, including receiver and antenna performance, as well as system stability. I think that the system stability will increase rapidly since the equipment in this test was first generation A-GPS servers and receivers.

To get more accurate and reliable performance, the GPS hardware and algorithms have to be further adopted for indoor environments with multipath and fading. The need for receivers to be adapted for indoor use is also addressed by Lachapelle (2004). Heinrichs et al. (2006) state in their article that the future GPS and Galileo signal structure will enhance signal processing under these conditions. Companies like NordNav (NordNav, 2006) and SigNav (Bryant, 2005) introduces new types of receivers with software algorithms that adopt according the state of the receiver as well as signal conditions. Following from this development, I think that A-GPS performance will increase greatly with new hardware and new satellite signals.

The differences found between the two suppliers were not clear, but numerous indications point to the conclusion that supplier 1 performed slightly better than supplier 2. This conclusion is supported by indications of better accuracy, shorter response time and better integrity when studying the summarized results, but is not statistically established.

7.2 Customer value

The customer value added by A-GPS has to be seen from two perspectives depending on the positioning system currently used. The current GPS users will see a decreased startup time, decreased power consumption, decreased demand for signal strength, access to positioning and communication in one device as well as the possibility of network initiated positioning requests and the use of GSM/WCDMA positioning as a fallback. The current user of GSM/WCDMA positioning will see the possibility to get more accurate positioning results, positioning in roaming networks and continuous tracking capabilities as well as standardized personal integrity management.

From this, it is clear that A-GPS has the potential to give a great customer value, but start up times and accuracies found in this thesis show that the quality of the user plane A-GPS implementations available today limits the customer value in applications that have high demands on reliability. An example of such a service is emergency services, where both
response time and accuracy is essential. This issue is further discussed by Borroughs & Gum (2006).

7.3 Alternative positioning methods

As found in Chapter 3 Alternative positioning methods, some of the proposed improvements strategies for current GSM/WCDMA positioning technologies have obvious advantages compared to A-GPS when it comes to both reliability and availability in bad signal environments. The great demand for infrastructure investments in the network will, on the other hand, reduce the interest from the mobile operators’ point of view. As stated by Borroughs & Gum (2006), as well as many others, this is the key advantage with user plane A-GPS. It is easily implemented with minimum requirements on infrastructure investments. Borroughs & Gum (2006) state this as an important difference of focus between positioning systems aimed at emergency or commercial services.

7.4 Hosted mapping services

The evaluation of cartographic quality in Chapter 5 Evaluation of hosted mapping services found that the compatibility and reliability, as well as response times, were good. The problem found was that the quality of the cartographic design is not good enough for a successful launch of internationally available location based services. This shows the importance of good cartographic design and adaptation to local conditions, as well as user device and environment. The most important issues to be addressed are what Brodersen (2002), as well as Robinson et al. (1984), refers to as generalization and map design.

Because of the use of a price plan based on payment per request, this service is very well suited for services with map requests that are spread over a large geographic area and with relatively small volumes. Internationally available location based services is an example of such a service.

If good enough cartographic design quality is achieved, the hosted mapping service could entirely replace the current in house server even for areas where map information is currently available. In this case, the number of requests are, however, much higher and the cost per request has to be put in relation to server maintenance costs based on estimated usage.
Chapter 8  Recommendation for TeliaSonera

8.1  A-GPS

My recommendation for TeliaSonera is to start by using a hosted SUPL service and add A-GPS support to the current fleet management service “Närmaste Resurs”. The users of these services are often mature LBS service users that can see the advantages with A-GPS compared to GSM positioning. These users also have the possibility to choose A-GPS compatible devices. If the services are well received by these users, the A-GPS support can be extended to more services. Since there are currently no possibility to know if the device to be located is an A-GPS capable device, a GSM position should always be requested as a backup. This position can be shown as a course estimate before the A-GPS positioning response is delivered. There should be an assessment of the changes needed to add A-GPS support for TeliaSonera’s current LBS services so that a fast, and successful, launch is possible if the customer demand increases quickly and new SUPL compatible phones are introduced on the market from one of the major brands.

8.2  Hosted mapping services

For a successful launch of A-GPS services, international map information is important. Adding this map information to the current server means large investment costs that are not justified by the predicted demand for this information. For this reason, the hosted service is a very interesting alternative, but an improvement of the cartographic design is necessary. My recommendation for TeliaSonera is, therefore, to be an active customer and try to influence the service provider to adapt the cartographic design to Swedish conditions and the demands introduced when used for LBS services. The current mapping service should be kept and used for maps in the Nordic countries.
References


[http://www.webmapper.net/thesis/] 2006-05-05

Magnusson, L. (2006). *Oral communication with Lars Magnusson, TeliaSonera Sweden AB*


Navsync (2004). *Network Assistance* [www].  


Appendix I – Test results

Window towards north

<table>
<thead>
<tr>
<th></th>
<th>Min: 28 s</th>
<th>Max: 92 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Min: 23 m</td>
<td>Max: 314 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>88%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accuracy (m)</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
2 meters from windows towards north and east

<table>
<thead>
<tr>
<th></th>
<th>Min: 27 s</th>
<th>Max: 62 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Min: 7 m</td>
<td>Max: 284 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>92 %</td>
<td></td>
</tr>
</tbody>
</table>

Response time (s)

<table>
<thead>
<tr>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Accuracy (m)

<table>
<thead>
<tr>
<th>0</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
 Inside a desk drawer

Response time
Min: 31 s
Max: 62 s
Accuracy
Min: 6 m
Max: 730 m
Total tests 24
Success rate 96 %
10 meters from the nearest window

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min: 29 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max: 66 s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>71%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Min: 29 m
Max: 224 m
Entrance of an office building

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td>20 s</td>
<td>62 s</td>
</tr>
<tr>
<td>Accuracy</td>
<td>8 m</td>
<td>169 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>83 %</td>
<td></td>
</tr>
</tbody>
</table>

Response time (s)

Accuracy (m)

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (m)</td>
<td>29</td>
<td>70</td>
<td>120</td>
<td>170</td>
<td>220</td>
<td>270</td>
<td>320</td>
<td>370</td>
</tr>
</tbody>
</table>
Urban canyon-like conditions

<table>
<thead>
<tr>
<th>Response time</th>
<th>Min: 24 s</th>
<th>Max: 84 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Min: 7 m</td>
<td>Max: 429 m</td>
</tr>
<tr>
<td>Total tests</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Success rate</td>
<td>88%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response time (s)</th>
<th>24</th>
<th>34</th>
<th>44</th>
<th>54</th>
<th>64</th>
<th>74</th>
<th>84</th>
<th>94</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy (m)</td>
<td>0</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Open sky

Response time
Min: 13 s  
Max: 41 s

Accuracy  
Min: 1 m  
Max: 139 m

Total tests 24
Success rate 100%

<table>
<thead>
<tr>
<th>Response time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accuracy (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>80</td>
</tr>
<tr>
<td>140</td>
</tr>
</tbody>
</table>
Appendix II – GML-requests

Current server

<Output width='150' height='150' format='jpg'>
  <BBoxContext>
    <gml:pos> (UTM-coordinates) </gml:pos>
    <gml:pos> (UTM-coordinates) </gml:pos>
  </BBoxContext>
</Output>

<Overlay>
  <POI>
    <gml:Point>
      <gml:pos> (UTM-coordinates) </gml:pos>
    </gml:Point>
  </POI>
</Overlay>

<Overlay>
  <Position>
    <gml:Polygon>
      <gml:exterior>
        <gml:LinearRing>
          <gml:pos> (UTM-coordinates) </gml:pos>
          <gml:pos> (UTM-coordinates) </gml:pos>
          <gml:pos> (UTM-coordinates) </gml:pos>
          <gml:pos> (UTM-coordinates) </gml:pos>
        </gml:LinearRing>
      </gml:exterior>
    </gml:Polygon>
  </Position>
</Overlay>
Hosted service

<?xml version='1.0' encoding='UTF-8'?>
<XLS version='1.1'>
  <RequestHeader srsName='#32633' clientName='userName' clientPassword='token'/>
  <Request methodName='MapRequest' version='1.1' requestID=''>
    <PortrayMapRequest>
      <Output width='150' height='150' format='image/jpg' content='URL'>
        <BBoxContext srsName='#32633'>
          <gml:pos> (UTM-coordinates) </gml:pos>
        </BBoxContext>
      </Output>
      <Overlay>
        <POI>
          <gml:Point srsName='#32233'>
            <gml:pos> (UTM-coordinates) </gml:pos>
          </gml:Point>
        </POI>
        <Overlay>
          <Position>
            <gml:Polygon srsName='#32633'>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:pos> (UTM-coordinates) </gml:pos>
                  <gml:pos> (UTM-coordinates) </gml:pos>
                  <gml:pos> (UTM-coordinates) </gml:pos>
                  <gml:pos> (UTM-coordinates) </gml:pos>
                  <gml:exterior>
                    <gml:Polygon>
                      <gml:exterior>
                        </gml:Polygon>
                      </Position>
                    </Overlay>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </Position>
        </Overlay>
      </Overlay>
    </PortrayMapRequest>
  </Request>
</XLS>
På svenska

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