

Delivering location-based services using GIS, WAP, and the Web: two applications

Sergio Luján-Mora

Departamento de Lenguajes y Sistemas Informáticos
Universidad de Alicante
Campus de San Vicente del Raspeig
Ap. Correos 99 – E-03080 Alicante, Spain
slujan@dlsi.ua.es

Abstract. The position of a mobile phone can be located using information from the radio network it uses. This paper presents two applications that make use of Wireless Application Protocol (WAP) and mobile positioning technology to provide location-based information to the user in real time. The applications use the user's position to generate dynamic information. Besides, both applications also have a web interface to perform administrative tasks. The first application allows the user to locate the nearest resource (pizza restaurant, theatre, gas station, and so on) to his/her position. The second application is a data acquisition system and it demonstrates how the user can directly introduce data into Geographical Information Systems (GIS) from a WAP phone. Our proposal uses existing radio network and does not need the use of Global Positioning System (GPS).

1 Introduction

The advent of the Web has dramatically changed the way we work. New working methods, services and opportunities have appeared. Internet has proven to be an easy and efficient way of delivering services to millions of users. One of the main advantages of the Web is the 'universal access': users can access the same services and information all over the world as long as they have access to a computer with a browser and Internet. However, users need to be wired to Internet.

On the other hand, mobile phones have spread across the world in the last years. The Global System for Mobile Communications (GSM) [8] has increased the applications of the mobile phones enabling digital communications. Furthermore, this has allowed the development of Wireless Application Protocol¹ (WAP) [10]: a WAP phone is able to communicate with an Internet server, because it is based on the World Wide Web (WWW) technology. Therefore, thanks to WAP, users can really have the benefit of Internet and the 'universal access' from everywhere with no need of using a computer.

¹ WAP 1.0 Specification was released in April 1998. WAP 2.0 has recently been released in January 2002.

In this paper, we present two WAP applications for mobile phones. These two applications use a Geographical Information Systems (GIS) to provide geographical information to the user. GIS have become a leading-edge technology in many fields where people work with spatial data: emergency services, industry, environmental monitoring, etc. A keystone of GIS is the use of Global Positioning System (GPS), that helps to improve the accuracy of geographical data.

The first application we present is a resource searcher and locator: the user can locate the nearest resource (gas station, theatre, cinema, shop and so on) to his/her position. The second application is a data acquisition system: the user can directly upload data to a GIS and the position of the user is automatically recorded in the GIS. In both cases, the system uses the GSM network to establish the position of the user (it does not use GPS). In addition, both applications also have a web interface to perform administrative tasks.

The rest of the paper is structured as follows: Section 2 comments some related work. Section 3 presents WAP and different GSM mobile positioning systems. Section 4 outlines the main components of the architecture of the system used by the applications. Section 5 presents some relevant issues about programming the applications and describes the two proposed applications in detail. And finally, Section 6 summarizes the paper and points out the area for future work.

2 Related work

A number of systems delivering location-based services have recently appeared and they share common problems. We will only make a brief reference to the most relevant projects.

Cyberguide [1] focuses on the presentation of location aware information. It utilizes different kinds of handhelds, but the prototypes have to be reprogrammed for each one. Besides, the information provided is stored locally in every handheld.

comMotion [6] is “a location-aware computing environment which links personal information to locations in its user’s life; for example, comMotion reminds one of her shopping list when she nears a grocery store”. comMotion client is developed in Java on a very particular platform (Mitsubishi Amity Vp).

DealFinder [2] is “a position-aware shopping application for mobile devices that illustrates how collaboration can help consumers make more informed purchasing decisions”. DealFinder currently supports only one mobile device platform (Microsoft PocketPc). In addition, “shopping data is cached on the local device as a text file and new data is periodically downloaded”.

Finally, *Impulse* [12] is “a mobile device which uses location-aware queries to digitally augment and explore the physical world”. Impulse uses a Palm device.

In summary, the chief problem of these systems is that they rely on the satellite-based GPS for obtaining user’s latitude and longitude. This approach presents some problems: the user must have a GPS receiver, GPS signal is lost when entering most buildings and the so-called “concrete canyons” in urban areas make reception difficult. In addition, all of them use particular platforms and therefore, they present a lack

of interoperability among them: the same application has to be programmed for each platform.

On the other hand, a promising new technology for programming mobile phones and other handhelds is Java 2 Platform Micro Edition (J2ME) and the K Virtual Machine² (KVM) [9]. This technology targets small, resource-constrained devices, such as mobile phones and personal digital assistants (PDAs). J2ME promises to standardize the programming of handhelds. However, to the best of our knowledge, J2ME is not currently supported by the majority of mobile phones.

3 Background

The WAP is a group of specifications to develop applications and services that operate over wireless communication networks for wireless devices such as mobile phones, pagers, and PDAs. WAP is the convergence of two rapidly evolving network technologies: wireless communications and Internet.

The position of a GSM mobile phone can be located using information from the GSM radio network. This method is known as Timing Advance³ [4]. It is a server-based solution that allows positioning services to be used with current mobile phones. The accuracy with which the location can be determined depends on the network cell plan and the status of the phone (idle, busy, detached). In general, accuracy is higher in cities and lower in rural areas, because the network cell plan is thinner in cities.⁴

Timing Advance positioning method does not satisfy the accuracy requirements of future applications (person locator, emergency services). The European Telecommunications Standard Institute (ETSI) has been working on the standardization of Location Services for GSM (LCS) [5]. Three positioning methods have been standardized: Time of Arrival (TOA), Enhanced Observed Time Difference (E-OTD), and Assisted GPS (GPS). TOA requires mainly network modifications (modern mobile phones should work), but E-OTD and GPS require both network and mobile phone modifications.

4 Architecture of the system

This section describes the different components that form the system used by the applications we present.

² A compact Java virtual machine whose size is measured in the hundreds of kilobytes.

³ The GSM network knows the cell a mobile phone is currently located at. With the use of Timing Advance, the network can calculate the distance between the base station of a cell and the mobile phone.

⁴ It is not possible to give a specific value for the accuracy since it depends on several factors like: the size of the cell, the kind of the cell (omni or sector cell), the distance to the base station, the topology (reflections), etc. The accuracy usually ranges from some tens of meters to some hundreds of meters.

The positioning system we have adopted is Ericsson Mobile Positioning System [3, 4], which is based on Timing Advance method. We have chosen this system because it can be used with current mobile phones with no further change. Nevertheless, our applications can be easily adapted to any other positioning system.

Figure 1 depicts an overview of the system architecture and the different technologies it embraces. The system is formed by the following components:

- WAP Device (mobile client or mobile station, MS): mobile phones, wireless handhelds, personal digital assistants (PDAs), etc. Interaction with the user is done through a Graphical User Interface (GUI). The WAP Device connects to the wireless network by means of Wireless Session Protocol (WSP).
- WAP Proxy/Gateway (WP): translates WAP requests (from the wireless network) to WWW requests (to Internet) and vice versa, thereby allowing the MS to submit requests to the web server that hosts the Positioning Application (PA). The WP also encodes the responses from the web server into the compact binary format understood by the MS.⁵
- Positioning Application (PA): the PA requests the position of a MS to the Mobile Positioning Centre (MPC) by means of Mobile Positioning Protocol (MPP). These applications can be developed using current web tools: Active Server Pages (ASP), ColdFusion, Common Gateway Interface (CGI), Java Server Pages (JSP), Java servlets, etc.
- GIS Database (GD): stores all the geographical information. The PA uses the position of the MS to query the GD and provide localized services.
- Mobile Positioning Centre (MPC): as a response to a position request, the MPC delivers an answer telling the PA where the MS is located.

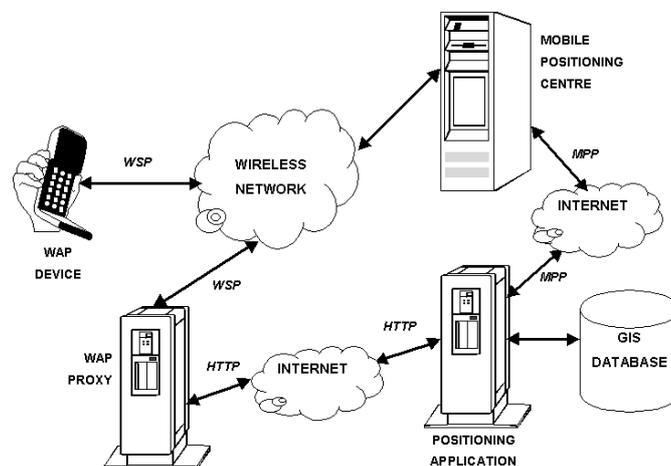


Fig. 1. Architecture of the system

On the other hand, the protocols used by the system are:

⁵ The communication between the WP and the MS is encoded in order to save bandwidth.

- HyperText Transport Protocol (HTTP): the WP converts the WSP request into HTTP requests and forwards them to Internet.
- Mobile Positioning Protocol (MPP) [3]: it is the protocol used to interface the MPC. Through this protocol it is possible to request the position of a MS.⁶
- Wireless Session Protocol (WSP): provides the application layer of WAP with a consistent interface for two session services. The first is a connection-oriented service that operates above the transaction layer protocol (WTP). The second is a connectionless service that operates above a secure or non-secure datagram service (WDP).

5 Application programming

The two applications we have developed are based in the client/server model. They have been programmed by using off-the-shelf authoring-tools:

- The server part of the applications has been implemented in Microsoft ASP running in Personal Web Server or Internet Information Server. The applications are programmed in Visual Basic Script. The geographical information is stored in a Microsoft Access 97 database and the connection between the program and the database is through ODBC. These tools allow content to be generated dynamically.
- The client part of the applications is divided into application and administrative tool. The application is aimed to WAP devices, and it has been implemented in Wireless Markup Language (WML) [7, 11]. Just as HyperText Markup Language (HTML) used on the WWW, WML is used for describing content and user interface, but optimised for wireless Internet access from handheld devices with small displays and limited input facilities. The correct operation of the applications has been proven with the following systems: Nokia 7110/1.0(04.78), Nokia WAP Toolkit/2.0, Ericsson R20/R1A, Ericsson R380 2.0 WAP1.1, and Phone.com UPG1 UP/4.0.10. The administrative tool is aimed to web browsers, and it has been implemented in HTML and JavaScript. The administrative tools works with most browsers (Microsoft Internet Explorer, Netscape Navigator, Opera, etc.).

Due to narrow bandwidth connections, geographical information is a huge problem. GIS files are big, and WAP transmission rate is low (9,600 bauds). In addition, due to limited display, geographical images can be hardly showed on a handheld device. Therefore, our applications provide geographical information based on text. Moreover, common users do not want to know the exact position (e.g., latitude and longitude) of the resource they are looking for. It is much easier to get directions based on phrases (point-by-point or turn-by-turn routing).

We have used two methods to simulate the positioning system. In the first method, the user has to introduce his/her position (the city and the street in the first application, the latitude and the longitude coordinates in the second one). In the second method,

⁶ Thanks to SSL (Secure Socket Layer), the MS and the MPC can share encrypted communications, to prevent access by fraudulent clients or servers.

we have used the Ericsson Mobile Positioning System Software Development Kit 3.0⁷ (MPS SDK 3.0). This development tool includes:

- MPC Emulator. A positioning server that accepts MPP requests and emulates positioning answer from an area. It runs on a web server.
- MPC Map Tool. A mobile network building tool that allows to create geographical areas.

The Positioning Application (PA) requests position information of a Mobile Station (MS) by issuing a POST request towards the Mobile Positioning Centre (MPC). The message body of the request includes an eXtensible Markup Language (XML) formatted request. For example, the following requests the position of the MS 461011334411 and the geographical data to be presented in WGS-84⁸ and Latitude/Longitude with the format IDMS0 (direction indicator –north, east, south or west–, degrees, minutes, seconds, and decimal precision):

```
<?xml version="1.0" encoding="ISO-8859-1" standalone="yes"?>
<REQ ver="3.00">
  <CLIENT><ID>TheUser</ID><PWD>ThePassword</PWD></CLIENT>
  <LIR>
    <GEO_INFO>
      <COORD_SYS>LL</COORD_SYS>
      <DATUM>WGS-84</DATUM>
      <FORMAT>IDMS0</FORMAT>
    </GEO_INFO>
    <MSIDS><MSID>461011334411</MSID></MSIDS>
  </LIR></REQ>
```

The MPC responds with either an error message or with the answer to a successful request. In the following example, the position is described as an arc with an inner and outer radius, and its point of origin:

```
<?xml version="1.0" encoding="ISO-8859-1" standalone="yes"?>
<ANS ver="3.00">
  <LIA>
    <GMT_OFF>+0100</GMT_OFF>
    <POS msid="461011334411">
      <PD><TIME>20020128090000</TIME>
      <ARC>
        <LL_POINT>
          <LAT>N391628.3</LAT>
          <LONG>E010001.5</LONG>
        </LL_POINT>
        <IN_RAD>1200</IN_RAD>
        <OUT_RAD>1500</OUT_RAD>
        <START_ANGLE>120</START_ANGLE>
        <STOP_ANGLE>180</STOP_ANGLE>
      </ARC></PD></POS></LIA></ANS>
```

5.1 Application 1

The first application is a resource searcher and locator: the user can locate the nearest resource (gas station, theatre, cinema, shop and so on) to his/her position. Possible uses of our application are:

⁷ It is free to download from <http://www.ericsson.com/mps/>.

⁸ It is the geodetic datum that is used by the GPS and it is a best fit for the whole world.

- Show the nearest gas station, pharmacy, doctor, bank, etc.
- How to reach a place (street, park, monument).
- A guide to entertainment events. Find the nearest theatre playing a particular movie.

We have called the application ‘*Where is...?*’. The application has a welcome page. After this page, the user can select the city where he/she wants to look for a product or a service⁹ (Figure 2.a). Since then, the searches are restricted to the selected city. However, the user can change this selection whenever desired.

The application main menu contains the following eight options (Figure 2.b and Figure 2.c):

- *Products*: this option offers access to a list of the products (computers, clothes, toys, etc.) ordered by the name (Figure 2.f).
- *Search product*: the products are searched by means of part or the entire name of a product (Figure 3.f).
- *Categories*: this option offers access to a list of the categories (restaurants, book shops, shoe stores, etc.) ordered by the name.
- *Search category*: the categories are searched by means of part or the entire name of a category.
- *Search by name*: the user can enter part or the entire name of the company he/she wants to find.
- *Select city*: this option allows the user to select a city. This selection is used to simulate the user’s position (Figure 2.a) or it is useful when the user wants to look for a resource in a different city.
- *Select street*: this option allows the user to select a street in the selected city. This selection is used to simulate the user’s position (Figure 2.d) or it is useful when the user wants to look for a resource in a different street.
- *Help*: this option shows the *Help* menu. This menu can be accessed directly from every page of the application (contextual help).

If the user decides to find the nearest company that offers a product or a service, or desires to know how to reach a place, he/she can select a street previously. The user can enter part or the entire name of the street (Figure 2.d). Then, the application looks for the street in the GIS database and it shows the matched streets (Figure 2.e). Afterwards, the user can choose a street or return to the main menu.

When the user selects *Products* in the main menu, a list of products is displayed (Figure 2.f). The number of companies offering a product appears in parenthesis. When the user chooses a product, the application displays the companies that sell the product (Figure 3.a).

By default, the companies are shown in alphabetical order. Using *Order by distance*, the application shows the companies order by the distance between the user’s position and the company. In this new display, the distance appears in parenthesis (Figure 3.b).

⁹ When the Ericsson MPC Emulator is used, this step does not exist because the position is automatically obtained from the Mobile Positioning Centre (MPC).

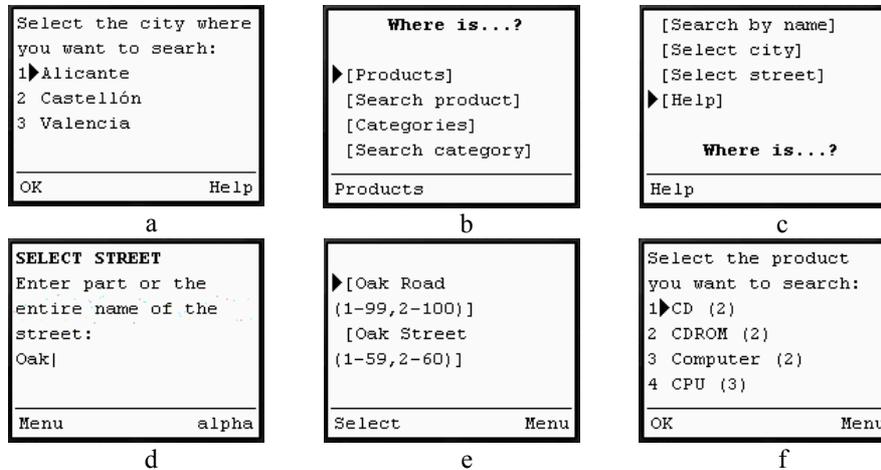


Fig. 2. Device display of Application 1

When the user chooses a company, the display switches to the *company card* (Figure 3.c and Figure 3.d). This card shows the information about the company: address, telephone number, fax number, email, and WAP address (the user can automatically navigate to the WAP address).

The *company card* also contains a description of the company, all the products sold by the company, all the related categories and, if the user has chosen a street, how to get to the company and how far it is (Figure 3.e). The user can also telephone the company thanks to the Wireless Telephony Application Interface (WTAI) (the button *Call* can be seen in Figure 3.c).

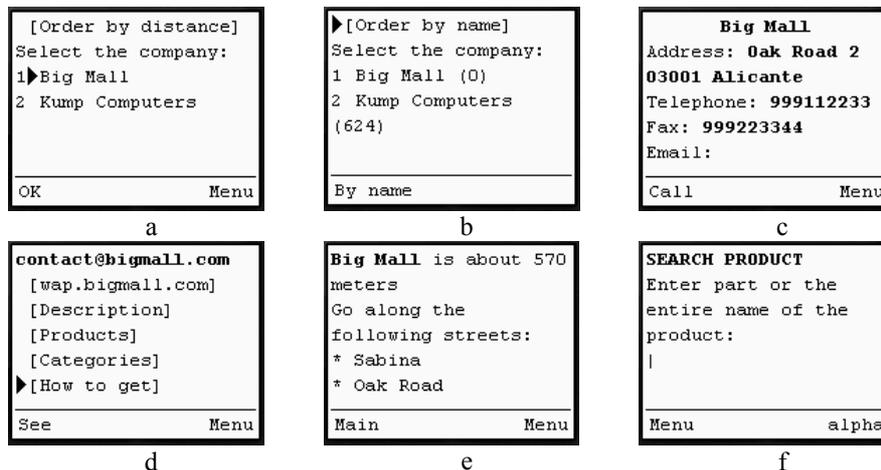


Fig. 3. Device display of Application 1

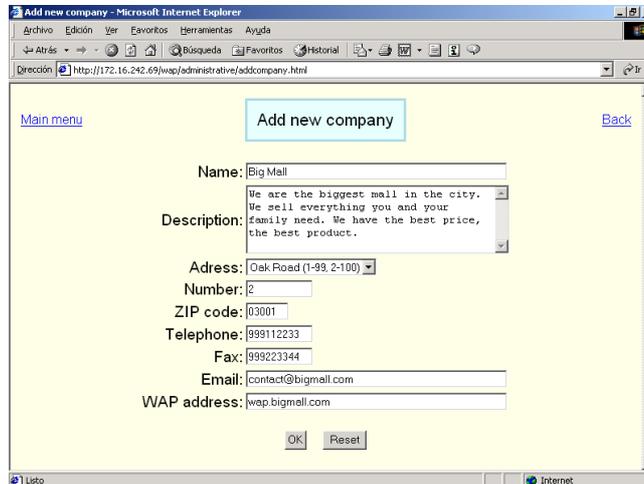


Fig. 4. Application 1 administrative tool: add new company

The administrative tool allows the user to perform administrative tasks, such as insert new data, delete or update data, etc. The administrative tool also provides the application functionality in a web page. Thus, the user can access to the application from a web browser.

In Figure 4, we can see the web form that allows to insert a new company in the GIS database. The user does not need to introduce the position of the company: the position is obtained from the street that the user selects. The GIS database stores the geographical position of every street. If a street is very long, it can be split into different sections with different geographical positions.

5.2 Application 2

The second application is a data acquisition system: the user can directly upload data to a GIS and the position of the user is automatically recorded in the GIS. In this way, there is no need to travel to the office to download or upload geographical data. The applications are multiple for field workers, such as surveyors, pollsters, and so on.

The application we have developed is oriented to gather data about agriculture: terrain quality, plants that grow, size of the grain, etc. Therefore, we have called the application '*Agronomic Data Acquisition (A.D.A.)*'. The application main menu contains the following six options (Figure 5.a):

- *View position*: this option shows the current position of the user (latitude and longitude coordinates) and the nearest recorded position (NRP) if there is any (Figure 5.b). If the user selects the NRP, it will be his/her new position (the NRP replaces the real position of the user).
- *Change position*: the user can change his/her current position and select a recorded position (Figure 5.c). The positions are showed with their name and the latitude and longitude coordinates. The name helps to remember positions.

- *New position*: the user can create a new position (Figure 5.d). The user can assign a name to the position. The latitude and longitude coordinates are obtained from the real position of the user by default, but the user can change them and introduce any value.
- *Current values*: the system shows the current data for the current position (Figure 5.e).
- *New values*: the user can enter new data for the current position (Figure 5.f).
- *Help*: this option shows the *Help* menu. This menu can be also accessed directly from every page of the application (contextual help).

The GIS database stores the positions the user creates. These positions can represent different plots of land, for example. The GIS database stores the following data about every position:

- Owner: the owner of the plot of land that the position represents.
- Terrain: the type of terrain. For example, marsh, rocky, soil, etc.
- Plant: the type of plant that grows in the plot of land (Figure 5.f). For example: corn, rice, wheat, etc.
- Height of plant: the average height of the plant.
- Size of grain: the average size of the grain of the plant.
- Notes: any notes the user wants to make.

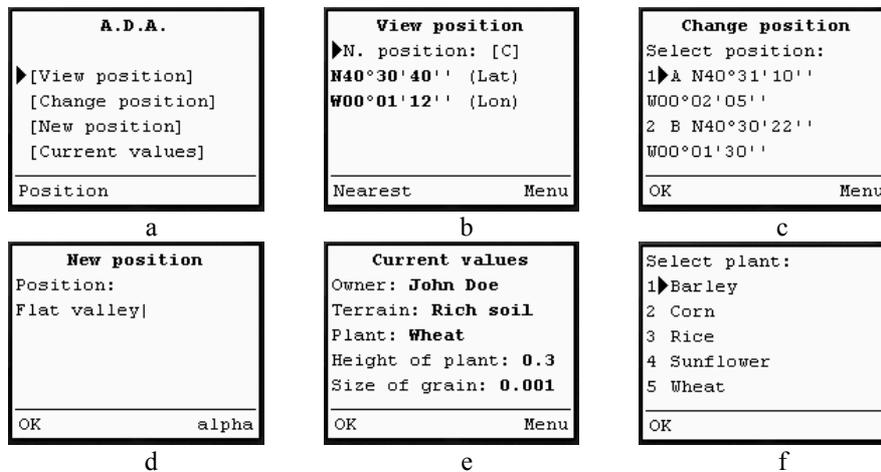


Fig. 5. Device display of Application 2

The administrative tool of this application allows the user to administer all the system from a web page. The administrator can insert, delete or update any data, such as the different types of terrains or plants.

In Figure 6 we can see an example of the administrative tool: the web page that shows the new inputs in a day. The table shows the data and time of the input, the position and the rest of the values that the user has introduced into the WAP device.

The new data is immediately available to be consulted from the administrative tool. In addition, the new inputs can be corrected from the web page.

The screenshot shows a web browser window titled 'New inputs - Microsoft Internet Explorer'. The address bar shows the URL 'http://172.16.242.69/wap/administrative/newinputs.asp'. The page content includes a 'Main menu' link, a 'New inputs' button, and a 'Back' link. Below these is a table with the following data:

D&T	Position	Owner	Terrain	Plant	H&S	Notes
15/06/2001 11:23	Flat valley N39°30'00" W00°30'00"	R. Smith	Soil	Corn	0.02 0.003	Contaminated
15/06/2001 17:35	C N40°30'40" W00°0'112"	John Doe	Rich soil	Wheat	0.3 0.001	Frozen soil
15/06/2001 18:50	C N40°00'40" W00°05'12"	Bill Doors	Rocky	-	-	Burnt

Fig. 6. Application 2 administrative tool: new inputs

6 Conclusions and future work

WAP has become the *de facto* standard for wireless applications and services delivered across a wide range of devices. In this paper we have presented two WAP applications that take advantage of a new technology: mobile positioning system. This technology opens the door to new applications that are known as 'location-based services'.

We have used Ericsson Mobile Positioning System that is based on Timing Advance method, but the Mobile Positioning Protocol (MPP) hides the underlying technology that is used. Therefore, these applications are independent of the mobile positioning technology used. Another advantage of our applications is the low cost of development, since they use commercially available technology and existing wireless data infrastructure, both for delivering data and establishing position. In addition, positioning systems based on GSM present some advantages against GPS: they do not require additional equipment and they can determine the location inside buildings, parking garages and other shielded areas that are inaccessible to GPS.

Our two applications demonstrate how GIS, WAP and the Web can be combined. The majority of the existing location services are read-only: the user can only ask for information. However, our applications have showed that the information can flow two ways, so users can obtain information from the GIS or introduce geographical data into it (it allows to add or update the information stored in the server). Therefore, mobile applications can eliminate the need to travel to the office to download or upload geographical data. Our applications use standard technology: a device only needs

a WAP browser and support for WAP communications in order to use the proposed applications.

WAP applications face serious disadvantages: low bandwidth, high latency and less connection stability. Moreover, applications have to be adapted to handheld devices: limited display, limited keyboard (one-finger navigation), and limited memory and CPU. Mobile phones and the other handheld devices have to increase their transmission speed to manage large geographical information. And in the future, the use of bigger displays with colour will be very common.

We are currently working on new applications: news, weather and traffic reports depending on geographical context, recommendation systems, etc. On the other hand, we intend to use ESRI ArcIMS to generate dynamic Wireless Bitmap (WBMP) images that represent maps from the GIS. Nowadays, sending bitmaps through the current wireless networks is possible but time-consuming due to the low bandwidth. However, new high bandwidth wireless networks such as General Packet Radio Service (GPRS) or the future Universal Mobile Telecommunications System (UMTS) will facilitate to take advantage of this feature.

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