# Managing a Geographic Database From Mobile Devices Through OGC Web Services*

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**Abstract.** We present in this paper a system for the management of geographic databases from mobile devices. The architecture of the system is extensible in the sense that it can be adapted to the particular characteristics of a wide variety of heterogenous mobile devices. This is achieved by the incorporation of an extensible middleware between the limited GIS applications running at the Mobile devices and the general purpose web services used at the data tier. The interfaces of these web services are compliant with the well-known Web Map Service(WMS) and Web Feature Service (WFS) specifications proposed by the Open Geospatial Consortium (OGC). A first prototype of the system for a specific PDA hardware with a specific software configuration was also implemented. We believe that the system has many practical applications in wireless environments with connectivity problems.

**Key words:** Mobile GIS, Data management, Web Geo-Services, Open Geospatial Consortium, WMS, WFS

## 1 Introduction

Traditionally, tools devoted to the management of geographic data use client-server architectures composed of desktop clients and either conventional or spatial Database Management Systems (DBMS) at their servers. Many examples of such desktop clients and DBMSs exist already in the market, both commercially available and derived from open source initiatives. However, the broad bandwidth of the computer networks currently available enables the access to spatial data sources through the web with reasonable delays, even through wireless physical communications. Thus, GIS tools have already appeared that

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enable the publication on the web of geographic data, both in the form of maps for data visualization purposes and in the form of spatial objects and spatial coverages for spatial data editing and analysis purposes. Examples of such tools exist both with proprietary interfaces [6, 2] and with well-known open interfaces [1, 9, 4] based on the standard specifications developed by the Open Geospatial Consortium (OGC) [12, 10]. The data published by these tools can now be consumed by both GIS desktop and GIS web applications. The OGC goes beyond these ideas proposing a general architecture for GIS applications based on standard Geo-services. A generic framework for GIS applications based on such an architecture was already proposed in [8].

Regarding mobile environments, GIS vendors already provide tools [3, 7] that enable remote access to geographic data sources, generally through proprietary formats and interfaces. The availability of Java Virtual Machines (JVM) for mobile platforms (based on Java ME specification) enables also the use of some Java-based open source GIS initiatives [5, 14]. However, these solutions have difficulties to be installed in platforms with limited hardware and software capabilities.

In this paper, we present a system for the management of geographic databases using mobile devices. The architecture of the system uses web services compliant to well-known OGC standard specifications, namely the Web Map Service (WMS) specification [12] and the Web Feature Service (WFS) specification [10]. On top of them, an extensible *Geographic Data Access Middleware* adapts the heterogenous characteristics of a wide variety of mobile devices to the OGC standard interfaces. This is achieved by the incorporation of *Data Access Plug-ins* in the Middleware, one such plug-in for each different type of mobile device, which may range from powerful portable computers and Personal Digital Assistants (PDA) of various types to limited mobile phones. To test the viability of the system, a prototype implementation was also undertaken for a specific type of PDA with a specific software installation.

The rest of the paper is structured as follows. In Sect. 2 the architecture of the system is briefly described. The prototype implementation is shown in Sect. 3. Finally, Sect. 4 provides the conclusions and issues of further work.

## 2 System Architecture

The proposed architecture for the developed system is next briefly described. As it is shown in Fig.1, the architecture is organized in three tiers. The *Mobile Tier* consists of the client desktop GIS software installed in each of the mobile devices supported by the system. The *Middleware Tier* consists of a *Geographic Data Access Middleware*(GDAM), whose objective is to adapt the heterogeneity of the aforementioned tier to the standard interface of the OGC web services available at the *Data Tier*. This is achieved by extending the GDAM with a *Data Access Plug-in* (DAP) for each different type of mobile configuration. Finally, the *Data Tier* consists (at this stage) of web services implementing the well-known Web Map Service (WMS) and the Transactional Web Feature Service specification

(WFS-T) both defined by the OGC. We briefly describe now the functionality of each of the tiers.

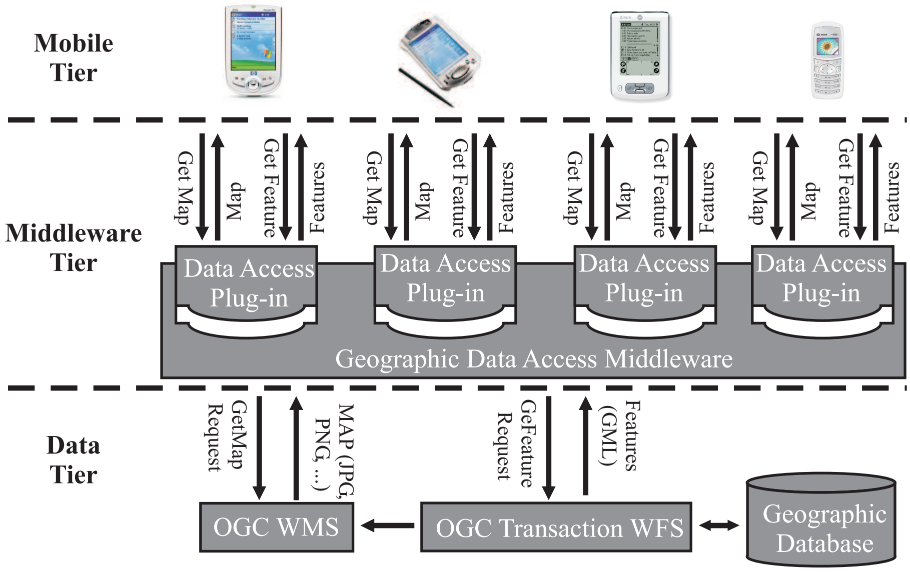


**Fig. 1.** Architecture of the system.

***Data Tier:*** The functionality of this tier is the one provided by the well-known OGC WMS [12] and WFS-T [10] interfaces. These services are accessed through the HTTP protocol, either by a GET or by a POST request. The interfaces define operations for retrieving service metadata and for retrieving a map (in a raster image format) or a collection of features (in GML). In the case of a WFS-T service, an operation for updating the information in the database is also defined.

***Middleware Tier:*** The functionality of the extensible GDAM enables mobile devices with limited capabilities to invoke the operations of well-known OGC web services and assists them in processing the results. This tier supports two tasks: First, downloading *maps* and *features* from the WMS and the WFS services, and second, updating the geographic database through the *Transaction* operation of the OGC WFS-T according to the changes reported by the client PDA GIS application.

The interface between the GDAM and each different type of mobile device is provided by a different Data Access Plug-in. This interface is specifically developed for the specific capabilities of the mobile device. The requests sent by the mobile device are translated to standard requests to the appropriate OGC web services. Similarly, the responses obtained from the OGC services are transformed to formats supported by the specific capabilities of the mobile device. In particular, a *map* obtained from a OGC WMS in some raster format has to be transformed to a raster format supported by the mobile device. Similarly, a collections of *features* encoded in Geography Markup Language (GML)[11] returned by a OGC WFS service have to be transformed to adapt them to the specific capabilities of the XML parser used by the mobile device.

***Mobile Tier:*** The GIS software installed in the mobile devices supports the rendering and edition of the existing geo-data and the insertion of the new one. In particular, it gives support for the following tasks:

1. Invoking the DAP to download both *maps* and *features* (spatial objects in OGC terminology). The specific DAP accessed is designed and implemented to take into account the particular capabilities and limitations of the mobile device.
2. Rendering both the *maps* and the *features* on the screen of the device, offering the typical GIS navigation functionality (zooms, movements, etc).
3. Selecting *features* and enabling the edition of both their geometries and their conventional properties.
4. Creating new *features*, enabling both the digitation of their geometry and the insertion of the values of their alphanumeric properties.
5. Incorporating the positions retrieved from a GPS device both in the navigation task and also as part of the geometry of new and edited *features*.

## 3 A Prototype Implementation

A system prototype for a specific mobile platform was implemented based on the architecture proposed in the previous section. The mobile device chosen was a Pocket PC Fujitsu-Siemens Pocket Loox 420 with an Intel XScale PXA 255 processor, 64 MB of RAM and 32 MB of ROM, and a screen of 280x320 pixels and 65536 colors. The operating system of the PDA is Windows CE first edition. Regarding the GPS device, a Fortuna Clip-on BT was chosen, which uses the NMEA protocol and Bluetooth communications. Finally, the GIS client software was developed with the free edition of the SuperWaba [13] virtual machine. The Graphical User Interface (GUI) of the application is shown in Fig.2. A summary of the hardware and software limitations is next given:

– The maximum file size supported is 64 KB. Therefore, both map images and GML documents retrieved from the WMS and the WFS must be broken by the Data Access Plug-in into pieces of an appropriate size.
– Only bitmap images (BMP) of 8 bits per pixel are supported. To the best of these authors knowledge, none of the available tools that implement the WMS specification support such a limited format for the maps.

– An XML parser is not part of the free edition of SuperWaba. An existing parser was adapted to enable the processing of GML documents. However, a couple of limitations had to be assumed. First, the maximum length of an XML element is restricted to 512 Bytes. Second, many special characters cannot be processed by the parser.
– HTTP POST requests cannot be issued from the PDA.

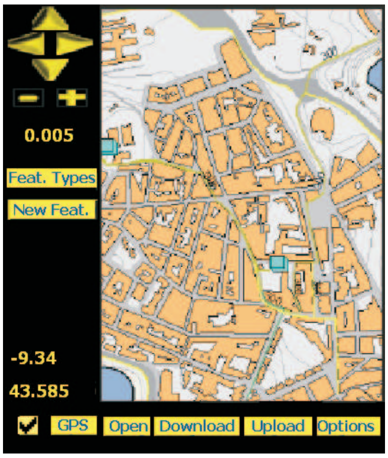


**Fig. 2.** Graphical User Interface of the GIS Application.

The implementation consists of a Middleware Tier and a Data Tier that can be used with many different mobile devices. The limitations of our particular case were solved by a Data Access Plug-in specific to our hardware and software configuration.

Regarding the map downloading funcionality, the map returned by the Data Tier has to be transformed by the DAP before it is sent to the GIS PDA application. For example, due to the file size limitation, the map has to be split (by the DAP) into tiles of the same size and shape and an XML document with metadata describing this transformation has to be sent to the PDA GIS application to enable the reconstruction of the map there. A similar process occurs when the user of the PDA GIS application asks for features to download. Now, the result format of the relevant *GetFeature* operation of the WFS is GML. Such format has to be adapted to the functionality of the XML parser of the PDA GIS application. Thus, for example, the size of the <coordinates> element of GML is likely to exceed the 512 bytes supported by the parser. To solve this problem, the DAP transforms each <coordinates> element to a collection of <coord> elements, also supported in GML.

In the case of the updating functionality, a *Transaction* operation of the OGC Transaction WFS is invoked by the GDAM, according to the GML passed by the PDA GIS application through the DAP. Now the <coord> elements of such GML are transformed back to <coordinates> elements.

## 4 Conclusions and Future Work

We designed a system for the management of a geographic database from mobile devices and we undertook a prototype implementation. The use of an extensible *Geographic Data Access Middleware* in the architecture of the system enables it to be used from a wide variety of mobile devices with different capabilities. Thus, the incorporation of a new kind of mobile device requires only the development of an appropriate *Data Access Plug-in* to enable its communication with the middleware. At the *Data Tier* of the system, web services compliant with the standard Web Map Service and Web Feature Service specifications of the OGC are used.

Future work include the incorporation of other types of mobile devices to the prototype implementations (mobile phones for example), the improvement of the SuperWaba PDA GIS application and the incorporation of other OGC web service interfaces in the Data Tier (Web Coverage Service, Sensor Observation Service, etc.).

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