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Research Article

A Review of Wireless Technology for Geographical Information Systems

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Abstract

In the recent years daily routine have new challenges and problems; such as the lack of time, disaster management and on-line management, which GIS can help to overcome. With ever increasing challenges in spatially-related managing and decision making applications, wired GIS cannot meet the demands of users for easy access to spatial data and spatial analysis. Wireless spatial data service is one of the fastest growing areas in the information technology. Most of mobile users tend to access location information via wireless network. Many efforts have been made to reach this goal, and lots of technologies have been introduced in wireless world for serving spatial information.
This paper discusses the technology currently available for use in wireless environments, focusing on Geographic Information Systems.

Keywords: *Wireless Technology, GIS, GPS*

1. Introduction

Networks have become a critical component of all infrastructures in society. In recent years there is a significant rise in the use of small size mobile computers is envisaged: smart phones, tablet PCs and notebooks. These devices are currently reaching a level of development that enables them to support the first practical graphical applications. At the same time, industry is coming up with new, additional equipment embedded into PCMCIA cards: flash memory, hard drives, Wireless Local Area Networks (WLAN), Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) modems and Global Positioning System (GPS) receivers. Also, enormous advances have taken place in GPS technology in the past years. GPS accuracy has improved, the receivers have become smaller and cheaper and the GPS integration with mobile devices as PDAs has been made possible. The cartographic market through Geographic Information Systems (GIS) is one of the sectors, which are interested in such an infrastructure. Moreover, user applications become more functional when they are connected to packet switched networks in order to obtain data from centralized servers, and these networks are broadening their coverage and bandwidth [Jordi Casademont et el- 2004)] GIS is a powerful tool in decision making and managing processes in all affairs that are dealt with spatially-related data. Classical definition of Geographic Information Systems (GIS), which is known by everybody, is a computer based system that collects, stores, edits, analyses and displays spatial data. GIS is a powerful tool to access, analyze and evaluate large amounts of spatial data. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. GIS is considered to be one of the most important new technologies, with the potential to revolutionize many aspects of society through increased ability to make decisions and solve problems.

Stand-alone and wired systems cannot reach life and work demands appropriately, specifically when it is needed to access the system independent from time and location. So, it seems mandatory to move towards ubiquitous systems, which can serve users anywhere and anytime.

Growing wireless capabilities create new horizons for serving innovative application through wireless network. Such an environment imposes a new set of problems for the development and deployment of applications, because it is based on devices far more limited than personal computers. In order to cope with such limitations, several efforts have challenged the construct of complete framework for the transmission of data over wireless network, and into small devices, while removing the restrictions and shortcomings. Additionally, GIS data usually have large volumes, and need modern techniques to be served through mentioned restrictions. Above problems cannot be solved only by providing special

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interface for handheld device onto conventional GIS. Some characteristics are handed down from web GIS to wireless GIS.

2. Wireless access networks

GIS systems can be used in a wide variety of applications of different fields: agriculture, geology, military, urban planning, etc. Wireless GIS builds on the abilities of mobile GIS and is often promoted by the media as a paradigm shift. Wireless GIS builds on the abilities of mobile GIS and is often promoted by the media as a paradigm shift. Although wireless computing is a powerful addition to our ability to use GIS in creative ways, it is simply an extension of what we are accustomed to doing. Wireless GIS provides functionality similar to mobile GIS applications, but utilizes a telecommunications infrastructure to interact with external software and data in a real-time manner.

Applications that run on portable devices will need access to GIS information and can be envisage two ways of doing this: The first one is to store the information in local memory, which has basic limitations because most portable devices have a limited memory capacity. Typical memory devices and capacities are MultiMedia Cards (MMC, capacity up to 16 Gbyte), Secure Digital Cards (SD, capacity up to 4 Gbyte), Memory Sticks (capacity up to 4 Gbyte), Compact Flash Cards (CF, capacity up to 8 Gbytes), SmartMedia Cards (capacity up to 1 Gbytes). A map of a big city, as for example Barcelona (SPAIN), using Geographic Data Files (GDF) format, including information about street and square names, number of lanes of a route, one-way streets, public transports and monument names, has an approximate size of 40 Mbytes. With an external memory card capacity of 1 Gbyte, it is possible to store about 25 maps of this size. Moreover, a map covering the same area, but including only street and square names, has an approximate size of 10 Mbytes. Thereby, with the actual external memory capacities it is possible to store a high number of maps. The second is to download cartographic information on demand. This operation must be carried out in the most transparent way for the user; for instance, when the GIS platform detects that the required map is not stored locally, it tries to download it from the server after requesting confirmation from the user. [Jordi Casademont et el- 2004)] In order to connect mobile devices to a fixed network in which the cartographic server will be set, we can use two kinds of wireless networks: WLAN and Wireless Wide Area Networks (WWAN). WLANs, as the name expresses, have a limited coverage, from few meters to some kilometres. Their main characteristics are that they provide high transmission rates and usually are privately owned. WLAN appeared first as office data networks, then gave coverage to university campus, hospitals or other private and public institutions, and nowadays, there are some operators that give this service in strategic areas as downtown districts.

On the other hand, WWANs are public networks, with national coverage and provide lower transmission rates, up to 2 Mbps for the third generation cellular networks as CDMA2000, UMTS or FOMA. In these networks, the transmission bandwidth is expensive and the network design is focused on the link utilization efficiency. Following Figure (figure 1) shows comparison of various available wireless technologies

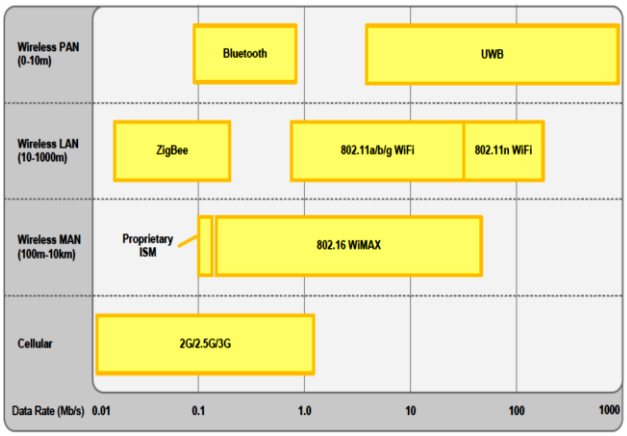

Figure 1 Wireless Technology Comaprison

The following figure (figure 2) shows detail technical description of different wireless technology

	Bluetooth	UWB	ZigBee	802.11a/b/g	802.11n	Proprietary	802.16a	2G/2.5G/3G
Typical Range	< 10m	10-30m	70-300m	100m	100m	10km	50km	Cellular Network
Modulation	Adaptive FHSS	OFDM or DS-UWB	DSSS	DSSS	DSSS	FHSS	QAM	CDMA/GSM/ AMPS
Freq. Range	2.4GHz	3.1-10.6GHz	868/915MHz 2.4GHz	2.4GHz -b/g 5.8GHz - a	2.4GHz	915MHz & 2.4GHz	2-11GHz	869-894MHz
Network	P2P	P2P	Mesh	IP & P2P	IP & P2P	P2P	IP	IP
IT Network Connectivity	No	No	No	Yes	Yes	No	Yes	Yes
Cost of Data	Free	Free	Free	Free	Free	Free	Free	Monthly Charge
Application	Cable replacement	Sync and Transmission of video/ audio data	Sensor networks	LAN, Internet	LAN, Internet	Point to point connectivity	Metro area broadband Internet connectivity	Celular telephones and telemetry

Figure 2 Wireless Technology Comparison

3. GIS Data Formats

There are two basic map formats: raster and vector. In raster, the map is stored as a bitmap image and is sometimes compressed using Joint Photographic Experts Group (JPEG), Tagged Image File Format (TIFF), Geo TIFF, Graphical Interchange Format (GIF) or Portable Networks Graphic (PNG) algorithms. Vector formats are more complex because they store map information as a group of coordinates that are linked by points, lines and polygonal areas when displayed. Moreover, they are able to store points of interest and other kinds of information like street names, number of lanes of a route, one-way

streets, thus making the map navigable for the user. This kind of maps are more interesting, because the correspondent player is not forced to show the information altogether, as happens with raster maps. Information in vectorial maps are stored as layers of information, and they can be displayed independently, so it is possible to show only the map topology or include some additional features as street and square names, public transports or services, at any moment, attending user's requirements. This format is especially interesting for location-based services because it is much more configurable than the former. There are different vector map formats on the market, there are proprietary formats from companies that also provide players and user applications, as AutoCAD, MapInfo or ESRI, and other that are international standards as the European GDF or the American Spatial Data Transfer Standard (STDS) (Spatial Data Transfer Standard (SDTS), Information Site) The GDF format is an open standard used mainly to describe and transfer road-related data. GDF is much more than a generic GIS standard, because it gives rules on how to capture data and how features, attributes and relations have been defined. In Europe, GDF is not only a theoretical standard; the major digital road data suppliers also push it: EGT, Bosch, ETAK and Tele Atlas. These companies have committed themselves to building their databases according to GDF specifications. GDF's main drawback is the fact that it uses text format. This is an inefficient way of storing digital information because it occupies more disk space and takes longer to read. The most immediate solution is compressing GDF files with a standard compression algorithm, which would solve the memory issue but not the reading speed. On the other hand it is important to use this kind of formats in order to guarantee semantic interoperability [OGC].

One more approach used by Open GIS Consortium (OGC), OGC is a non-profit international trade association that is working in the development of open and extensible software applications programming interfaces for GIS. The specifications adopted by OGC are public and available at no cost. Its aim is to provide geographic information and services available across any network, application and platform. Actually, OGD has standardized the Geography Markup Language (GML). GML is an Extensible Markup Language (XML) grammar written language for the modeling, transport and storage of geographic information including both the spatial and on-spatial properties of geographic features. The specification defines the XML schema syntax, mechanisms, and conventions that provide an open, vendor-neutral framework for the definition of geospatial application schemas and objects; allow profiles that support proper subsets of GML framework descriptive capabilities; support the description of geospatial application schemas for specialized domains and information communities; enable the creation and maintenance of linked geographic application schemas and data sets; support the storage and transport of application schemas and data sets and increase the ability of organizations to share geographic application schemas and the information they describe. XML-based languages are suitable for data transfer between distributed, heterogeneous applications and platforms. In this way, XML is appropriate to GIS development and is being used to enable the integration of information from distributed information sources [Cottrell, D.G.]

4. Wireless GIS

Not only GIS experts but also ordinary people tend to access spatial information using wireless environment. With the integration of the new technologies, GISs make new achievements. The development of the handheld devices (such as PDAs, and Java-enabled mobile phones) and internet not only enlarge the applying field of the GIS, but also bring the new opportunity and challenges to GIS. GIS based on handheld devices, Mobile GIS, will become the new branch of GIS and bring the GIS into a brand new world. Despite enormous benefits of using handheld devices; it meets the shortcomings due to wireless network. Mobile devices have restricted memory, less computational power, and there are no clear standards for wireless network, they have also less speed and stability. Additionally, there are no appropriate platform for sending dynamically spatial functionalities in a streaming manner over wireless network, no suitable spatial format due to data program amount restrictions and low capacity of mobile devices. [Terry L. Tarle] [Yong, Lio (2002)].

Wireless GIS applications tend to focus on business operations such as processing service requests, work orders, or inspections with the availability of GIS data as a supplement to the business operation. For the most part, the creation of spatial data remains a mobile GIS function, although this is not true in all cases and will most likely change over time. The primary business drivers behind wireless GIS are the need for real-time data in the field (e.g., retrieval of work order history for a particular asset), the need for real-time access to data provided by the field worker (e.g., inspection results), and the desire to eliminate the need for duplicate data processing. Wireless GIS aims at providing current data to both field workers and in-house staff while simplifying the process of managing such access. There are a variety of notable benefits and concerns to wireless GIS (Table 1) [Paul Braun]

A. Ubiquitous GIS

In many daily scenarios, users can benefit from some aspects of ubiquitous GIS service. They can receive a traffic alert, find the location of a colleague, and search for the closest restaurants. Recently, with the new challenges in the work and life, wired GIS cannot meet the demand of the users in many situations. Eighty percent of the whole information is spatial related data, most of mobile device users tend to access spatial information via wireless network. Wireless GIS is developed under web GIS technology, and there are many similarities between these two. But, wireless GIS has its own characteristics, because of the limitation of the mobile devices and the wireless communication network and technology.

Table 1: Wireless GIS Benefits and Concerns

Wireless GIS Benefits
Provides real-time access to data from the field
Provides real-time access to field-worker data to the in-house staff
Easier application maintenance, with no need to install applications on each device
Data are centrally managed and accessed remotely via the application so there is no need to synchronize data between the mobile devices and the server
Wireless GIS Concerns
Availability and reliability of appropriate telecommunications services
Appropriate bandwidth of the available telecommunications services
Dynamics of the telecommunications industry and assurance that today's offerings will be available tomorrow
Finding a cost plan for the telecommunications service that fits the budget

B. Wireless Characteristics

As the power of phones, PDAs, and other wireless devices grow, the advent of an entire generation of wireless web is finally materializing outside the labs and professional circles and into the mainstream Wireless and mobile devices have restrictions and shortcomings that differ from desktop computers in many fundamental ways. Additionally, GIS data to be served usually have large volumes and need modern techniques to be served through mentioned restrictions. Above problems cannot be solved only by providing special interface for handheld device onto conventional GIS [Takino Shuichi]. To overcome mentioned obstacles, special architecture must be designed.

C. General Wireless Model

There are several significant features in the wireless model, become evident when it is compared with traditional web model (client/server model).The most important features are, Gateway. In this model, the client does not talk to server directly; and gateway is responsible for this task, also client forwards the request through gateway to final server, Encoding and compression of the data. The data are encoded by gateway to be passed to the client; gateway encodes original server response and sends it to client in compressed format better suited to the restrictions, and Type of content. The data provided by server is not of the same type as it is in the web applications (i.e. it is not HTML); for example data content is marked up in WML (Wireless Mark-up Language) (Figure 3) [Hossein Mohammadi].

Moreover, wireless GIS adds its particular characteristics to such model. To overcome low device power, thin client architecture must be implemented that takes most of GIS process burden from handheld device to server machine. Moreover, it is expected that busy transaction will occur as a result of frequent request from enormous number of users. A mechanism to resist heavy transaction load is required on server. In applying to practical use, operation management GIS run on workstation on backend server machine is more required than GIS application itself that is active on mobile device.

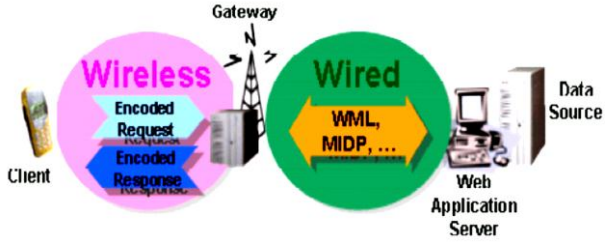

Figure 3 General Wireless Model

D. Spatial Data

XML is going to become an appropriate and reliable data content, in all services working with portable data. XML is a portable, text-based way of representing structured data . More and more applications are using XML to exchange information and wireless technology is going to need to process XML documents. With any XML grammar, consideration has to be given to what exactly is being modeled. For textual formats, modeling is typically at the level of paragraphs and phrases, rather than individual nouns, adverbs, or phonemes. In recent years, standardization activities have been in vigorous progress to define geospatial data standard. The common discussion between these activities is to define GIS data feature as spatial object in real world such as road, river, house and so on. GIS data is a collection of varieties of feature data and it is better to be described in XML or XML Schema, due to its distributed (through Internet) inherent (Figure 4) [Hossein Mohammadi]

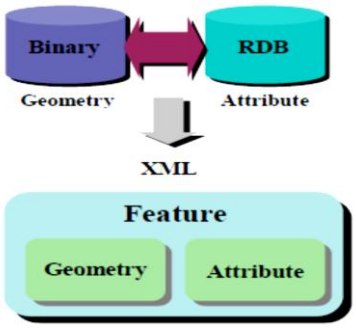

Figure 4 Distributed GIS (Wired and Wireless)

E. Basics of Wireless GIS Network

Internet workstation uses personal computer as a hardware device. This will allow heavy load process to be performed on client side. In other words, Internet workstation will execute user application on client machine based on distributed (Thick client) architecture, and will lower the workload on server machine. But referring to mobile devices restrictions most of process load must be taken by server. On the other hand, mobile device only supports input/output process on the terminal, while application programs are stored on server side (Figure 5) [Hossein Mohammadi].

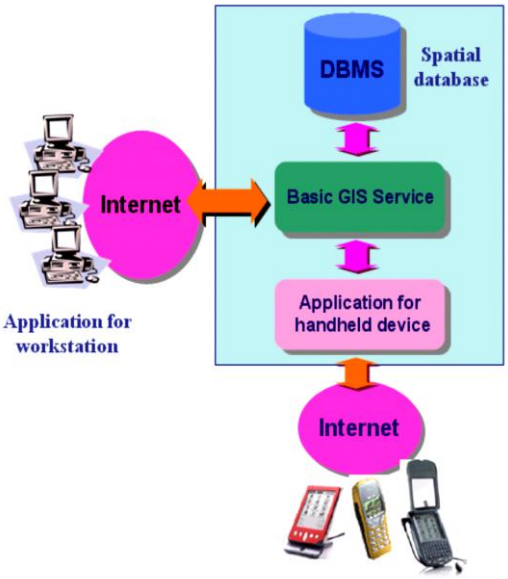

Figure 5 Distributed GIS (Wired and Wireless)

In conventional GIS system, geometry and attribute data are managed separately and linked to each other with unique ID. Although handling vast amount of GIS data, this mechanism enables effective enormous data process, because geometry data processing and text data processing are separately executed on optimized system for special purpose use. In describing feature data, XML encoding is flexible and comprehensible as an advantage point, but XML is weak from the point of data process and data transfer efficiency

F. Portable Code

Java provides a robust programming language and environment. The mobile device is J2ME enabled allowing for the development of intelligent and thin applications for the devices. J2ME is a new akin of Java family and a member of Java 2 platform. It specifically is targeted at applications, running on handheld devices. Many such devices have no option to download and install software beyond what was configured during the manufacturing. J2ME technology addresses the significant number of resource-constrained devices. Unlike desktop and enterprise computers, whose programming needs are addressed by Java 2 Standard Edition (J2SE) and Java 2 Enterprise Edition (J2EE), the devices in the Micro Edition space are significantly varied in many aspects, such as how they perform networking, how they display information to the user and how they accept user input. [Hossein Mohammadi].

Conclusion

Spatial services are going to become the most significant part of wireless applications. With ever increasing speed of wireless technology, spatial systems users want to get more services from wireless system. In this paper, we have presented the technology currently available for use in wireless GIS systems and its capabilities. We have reviewed devices that can run mobile GIS applications, wireless access networks that can be used to connect them to the fixed network where system servers will be located; communication protocols used for these networks; GIS file formats. This paper tries to expose the potential of wireless technology to serve spatial services. Using XML technology, beside the power of Java in network programming made a powerful platform to develop distributed spatial systems. Applying some heuristics can be suitable to increase the performance and efficiency of the system. Making multi-scale data and displaying the data which are restricted to bounding view for each zoom (instead of displaying the whole data) will increase speed and performance efficiency.

Utilizing and parsing GIS-exclusive data handling structures such as GML leads to more capability and functionality in data development, especially in functions (such as querying and network analysis), in which more complex spatial relations and database management are mandatory.

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