Mobile Devices as Personal GIS Client Platforms

Dejan Rancic[1], Bratislav Predic[2], Dragan Stojanović[3], Aleksandar Milosavljevic[4]
Computer Science Department
Faculty of Electronic Engineering, University of Nis
Nis, Serbia
{ranca[1], bpredic[2], dragans[3], alexm[4]}@elfak.ni.ac.yu

Abstract— Proliferation of powerful and feature rich mobile devices during recent years has caused increased need for professional grade mobile applications that are to aid fieldworkers in their everyday activities. Apart from obvious technical limitations mobile computing/telecommunications devices pose like reduced processing capabilities and small memory capacity changing usage conditions in open space while user is moving and completing other primary task present mobile applications developers with additional challenges and opportunities to exploit user's environment in order to create applications that are capable of adopting to changing environment conditions they are being used in. Mobile GIS is enabling field work personnel to always have access to most accurate and up to date spatial data. Also, this system automates the process of updating central enterprise GIS with data acquired in the field, process which has been up to date tedious and error prone.

Keywords— mobile devices, geographic information system, fieldwork, PDA, context-aware

I. INTRODUCTION

Geographic information systems (GIS) have been around for a number of years and all benefits of their implementation and everyday usage are well known and have been target of thorough research. Spatial data visualization and analysis concepts have been thoroughly tested in applications in various fields of application like climate and geology changes analysis, maintaining cadastre information, social phenomena tracking or managing fleet of mobile objects [1]. The development and implementation of Internet technologies in organizations and companies that utilize in their work process some aspects of geographic space and spatially referenced objects inevitably led to development of Web based and mobile GIS solutions. Concepts of distributed computing and databases implemented in GIS allowed spatial data to be physically located at the site where the data is collected or generated and updated yet to be available for use to distant, road-warrior type, users wirelessly connecting to data storage [2]. These technologies present support for field work at locations remote to company or organization headquarters simultaneously increasing productivity and efficiency of business processes and procedures performed on site where objects spatial data is modeling are located. Data acquisition in the field generates significant organizational problems, requires time, and is also error prone. Even in the case where centralized GIS exists it is used solely as paper maps generation tool. These, generated, thematic maps are then used during field work. Upon field work completion newly generated or updated spatial data is manually entered into central GIS. Integration of data generated during field work requires engagement of field personnel that performed field work, GIS administrators as well as domain experts in order to minimize possibility of error or data misinterpretation.

Second section of this paper presents characteristics and functionalities of mobile GIS imposed by introducing mobility into classical GIS. Third section gives top level and detailed component architecture view of GinisMobile, proposed component framework for development of Mobile GIS. Fourth section presents GinisED Mobile, an example application based on proposed framework and implemented in public power company in department of power distribution network maintenance. Fifth and final section concludes this paper and gives directions for further development.

II. MOBILE GIS – CHARACTERISTICS AND FUNCTIONALITIES

Considering the fact that mobile GIS is targeting services that have field work as part of their work process we need mobile hardware platform with significant processing power and memory capacity that simultaneously retains mobility characteristics. In this usage scenario, when mobile GIS is used by professionals as a tool for their on site activities personal digital assistant (PDA) is a perfect match for everyday usage requirements [3]. Hardware and software limitations of this class of mobile devices as well as limitations imposed by fieldwork usage style considerably influences architecture and other usage characteristics of future mobile GIS solutions.

Hardware limitations are probably the first obstacle development team will face. The most obvious attribute of this class of devices is low resolution display. PDA devices usually have vertically oriented displaus with resolution up to 640x320 pixels. These displays are usually TFT type so their readability in bright daylight conditions should be considered. These, display, limitations primarily have impact on mobile GIS user interface design. Since visual representation of spatial data in the form of some sort of map is primary source of information to mobile GIS user it should be assigned with maximum available space on the screen. Page based user interface organization fulfills this requirement most successfully.

Processing power available in typical PDA is not very restrictive factor as it may seem at first glance. Processors used are usually from Intel *XScale* family [4] and are operating at 300 – 500MHz frequency range. This enables comfortable work with processing intensive applications.

Attributes of wireless network interfaces built into PDAs available today vary significantly and require somewhat more thorough analysis. Implemented network adapter can be compliant to 802.11b/g standard. From mobile GIs development viewpoint this type of network interface requires no special attention in regard of latency, transfer speed or reliability. It's shortcoming is that it requires WLAN access points network implemented by the company utilizing mobile GIS or some third party. This infrastructure must cover the whole area field work may occur in. This area is in most cases vast and sites requiring field work are not densely packed. This is both technologically difficult and economically inefficient. Second alternative is to use packet data services provided by cellular phone operators. This approach solves the problems like the need for independent access points network. On the other hand it introduces problems of high connection latency, transfer speed and selective service availability and coverage. Cellular phone operators implementing 2.5G and 3G technology offer GPRS speeds of 54-115Kb/s and EDGE, up to 384Kb/s [5]. Considering all these characteristics of cellular packet data transfer services network subsystem of mobile GIS should be designed to minimize the amount of data being transferred as well as to be able to adapt to temporary unavailability of network service [6].

Application usage restrictions imposed by usage style in the field, where noise and light levels as well as other distraction factors can not be predicted require separate attention. Furthermore, mobile GIS is only auxiliary means for field personnel performing tasks on site. This means that user's attention is divided, she doesn't want to be required to perform complex user interface tasks. User interface development process should take into account the fact that the users will not be primarily focused on the application and user interface should be able to predict user actions as much as possible. User's environment, namely context, in the case of mobile GIS has increased impact on development and exploitation process. The manner the data is entered and visualized can vary significantly depending on the context and the application should be able to automatically adapt itself and therefore free user of some actions that are secondary in respect of primary task. Context aware applications concepts are separate research area and are addressed in more detail in [7].

III. USAGE ASPECTS OD MOBILE GIS CLIENTS

Recent developments in wireless telecommunications, ubiquitous computing and mobile computing devices allowed extension of geographic information system (GIS) concepts into the field. Contemporary mobile devices have traveled a long way from simple mobile phones or digital calendars and phonebooks to powerful hand held computers capable of performing majority of tasks until recently reserved only for desktop computers. Advancements in wireless telecommunications, packet data transfer in cellular networks, wireless LAN standards are only some of technological advancements GIS is profiting from. This mobile and ubiquitous computing environment is perfect incubation grounds for a new breed of GIS applications, mobile GIS. Advances in mobile positioning have given a rise to a new class of mobile GIS applications called Location-based services (LBS). Such services deliver geographic information and geo-processing services to the mobile/stationary users taking into account their current location and references, or locations of the stationary/mobile objects of their interests.

But the location of the user and the time of day of the application's usage are not the only information that shapes the features and functionalities of a mobile GIS application. As other mobile and ubiquitous applications, mobile GIS completely relies on context in which the application is running and used. The full potential of mobile GIS is demonstrated when used in the geographic environment they represent (Raento, 2005). Thus, development of mobile GIS applications requires thorough analysis of requirements and limitations specific to mobile environment and devices. Practices applied to traditional GIS are usually not directly applicable to mobile GIS applications. Limitations shaping future mobile applications, including mobile GIS, are ranging from hardware limitations of client devices to physical and logical environment of the running application. Considering the fact that mobile applications are used in open space and in various situations the ability of the application to autonomously adapt itself to user's location and generally, user's context significantly increases application's usability. Regardless of the type of the LBS and mobile GIS application the part of the system that is handling context is fairly independent and can be separately developed and reused. The proper management of contextual data and reasoning about it to shape the characteristics and functionalities of mobile GIS applications leads to a full context-aware mobile GIS.

Even though the concept of mobile GIS is in its infancy, technologies that were prerequisite for development of this niche of GIS applications are today widely available and well known to GIS developers. It is reasonable to expect that there are prototypes available demonstrating all the advantages mobile GIS offers to field fork personnel. ESRI, as one of the leading companies in the GIS field in its palette of products offers mobile GIS solution targeting PocketPC platform. It is called ArcPad (ArcPad). This is general type of mobile GIS solution with open architecture allowing easy customization and tailoring according to specific customer's needs. It therefore offers a set of basic GIS functionalities and tools that are used to extend application with functionalities needed for specific usage scenarios. ESRI bases its ArcPad on four basic technologies and those are mobile computing device (PocketPC), basic set of spatial analysis and manipulation tools, global positioning system (GPS) and wireless network communication interface.

Basic GIS functionality understandably supported by ArcPad is geographic maps visualization in the form of raster images. In order to avoid the need for maps conversion into some highly specialized proprietary raster map format ArcPad supports usage of all today widely used raster image formats, like JPEG, JPEG 2000, BMP as well as MrSID which is common in GIS applications. Thematically different maps in the form of raster images can be grouped into layers. Apart from raster type, layers can also contain vector data. Also, standard vector type data formats are supported, most importantly shapefile format. That is the most common vector data format in use in GIS today and is also well supported by other ESRI GIS software like ArcInfo, ArcEditor, ArcView, ArcIMS and others. Other optimizations which enable sufficient speed in handling spatial data include spatial indexing schemes. Spatial indexing significantly increases speed of spatial objects visualization and search, especially on portable devices with limited processing power. Indexes are prepared on other desktop type ESRI applications and afterwards transferred to a mobile device and used by ArcPad. In order to support usage of ArcPad throughout the world majority of map projections are included.

ArcPad is conceived as integral part of ESRI GIS platform consisting of other products, so there is the possibility of ArcPad functioning as a client for ArcIMS or Geograpy Network (Geography Network). Data is transferred to ArcPad using TCP/IP protocol and any sort of packet based wireless networking technologies (Wireless LAN, GSM, GPRS, EDGE, 3G, etc.). Possibly the strongest advantage of ArcPad is its extensibility and adaptability. Forms used for thematic data input and manipulation are created and customizes independently using ArcPad Studio and Application builder development tools. Application toolbars can be adapted to specific user needs. More importantly specific interfaces can be developed and added to ArcPad enabling it to acquire data from different database types and sensors (GPS location devices, laser rangefinders, magnetic orientation sensors, etc.).

One of academic projects that encompasses the development of mobile GIS is “Integrated Mobile GIS and installed. Customization includes components developed specifically for testing on campus. PocketPC is connected with external GPS device and therefore has constant access to user location information. Considering wireless communications, campus grounds are covered with Wireless LAN and all client PocketPCs are equipped with WLAN adapters. Server side of this system includes typical set of servers and tools from ESRI including ArcIMS and ArcGIS.

When this system is employed by campus security service, field units use mobile GIS component to locate reported incident location more easily and swiftly. Mobile GIS is also used to report new incident to central. Following report-in, information about new event taking place is momentarily available to all units. Therefore, reaction time is shortened and all patrolling units within campus are synchronized more easily.

Demonstration use case shows the field unit receiving warning about fire reported at the specified site. Closest field unit is being notified. Using campus WLAN it is contacting central ArcIMS server and acquiring map of that part of the campus as well as blueprints of buildings endangered by fire. Central server contains also thematic data about estimated number of people in these building, evacuation plans and similar. Simultaneously, units on site can update fire reports with more detailed information and therefore shorten response time of other units enroute. The ArcPad application customized for this use and being used in this scenario is shown in figure 1.

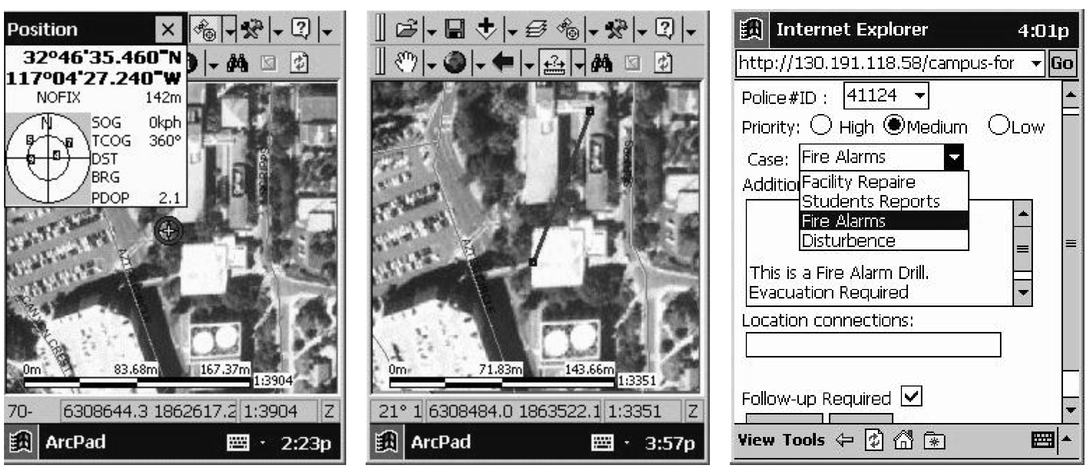

Figure 1. Mobile GIS implemented in San Diego State University campus security

Wireless Image Servers for Environmental modeling and Management” developed at San Diego State University (San Diego, 2002). The project includes integrated GIS platform where in the field data collection must be performed using mobile GIS client platform. Effectiveness of the developed system is tested in three different services: campus security, national park preservation service and sports events. Development group’s decision was not to develop mobile GIS solution from scratch but to upgrade and customize ArcPad. Similarly to other mobile GIS solutions this project is based on modified client/server architecture. Fieldwork personnel are using PocketPC device with customized ArcPad version

Beside the location of the user, contemporary mobile GIS applications, such as previously described one, lack the support for context awareness. Such support must be developed and integrated in the basic framework or platform on top of which mobile GIS application is developed. But firstly, we must define the context and the basic principles of context awareness.

In interpersonal communication, significant amount of information is transmitted without explicit communication of such information. If we take verbal communication as an example, nonverbal signs will significantly influence completeness of verbally communicated data. We are referring to facial expressions, body postures, voice tone, nearby objects and persons including past history of communications. All this is helping the process of interpretation of verbally transmitted data. In a typical human-machine communication there is very little context information available in a form that can be interpreted by machine. Therefore our first step should be to define the context. No matter how obvious this may seem, the definition of the context influences significantly all the decisions in the further process of context-aware application development.

Different authors in literature [8], [9] give definitions of context that are influenced either by pragmatic approach or theory of human computer interaction:

> *"We define context as any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object."*

or

> *"Context refers to location, identity of spatially nearby individuals and objects and changes that are relevant to aforementioned individuals and objects."*

Summarizing numerous definitions of context we can notice three aspects of context that are standing out:

- Technical characteristics of the environment: Hereby we are mainly referring to technical characteristics of the client device, processing power, available memory capacity, display characteristics as well as characteristics of network connections available to the device (bandwidth, latency, price…).
- Logical characteristics of the user's environment: This group contains geographic location, identity of individuals and objects nearby and generally social situation.
- Physical characteristics of the user's environment: This group contains levels of noise, light, movement parameters (speed, direction, etc.).

In the process of context modeling and management, the system can use information that is both, automatically collected or manually entered by the user. Although the first approach is attractive and seems to be the only true manner of handling contextual data we believe that manual input should not be excluded. Also, some characteristics of the context (e.g. user preferences, history and predictions of actions) are much easily acquired by manual input at the current level of advancements in context management algorithms.

The important step in development of context aware LBS and mobile GIS is to define the set of functionalities the application should provide to the user, implicitly or explicitly. Numerous types of contextual information produce adequately numerous potential functionalities. We can group them as follows:

- Display of information and services – In order to reduce user workload the system adjust the set of offered information and functions according to detected and deduced environment of the user. For a typical mobile GIS, a section of the map surrounding the current user's location is displayed. According to user's speed and heading, central point of the map view is chosen and speed vector displayed. Also, font and color scheme is adjusted to situation user is in (e.g. user is steering a vehicle at night).
- Automated execution of commands – Example would be a navigation GIS application that detects the user has missed the intersection and automatically initiates rerouting to find new shortest path to destination.
- Storage of contextual information – Potential use of stored contextual information would be to enable application to autonomously extract user preferences from previous actions using data mining techniques.

The user context that is of interest in LBS and mobile GIS applications is classified into specific classes. Each class of contextual information is assigned a context variable. Usually, in other papers published by researchers in this field authors have noticed hierarchical structure of context information so some sort of graph structure is used for context representation. Since one class contains contextual information of various levels of generality the most appropriate data structure for representing contextual information is directed acyclic graph. This data structure is the closest match to human cognition of structure and connections existing within a context data class. Another advantage of hierarchical context model is the possibility to narrow the choice of possible actions induced by detected context. In this manner, a set of rules used by rule based expert system is kept to a minimum of candidate rules. Rule based expert system is used to perform generalization of raw contextual data acquired from sensors and contained in leaf nodes. In this manner a "vertical" structure within each context class is built. As an example of rule based expert system that is widely used in literature we have opted for CLIPS (C Language Integrated Production System). The main advantage of CLIPS in our case is the existence of jCLIPS, library that enables Java programs to use CLIPS engine embedding it in a Java code.

The typical context data flow path in a context aware application is as follows: raw data is collected by connected sensors; software interface associated with each of the sensors converts the data into facts and stores the facts into the expert system. After each modification of a rule set, CLIPS executes generalization process and generates the new facts at higher levels of generality. Also, the possibility of performing action is tested. The action is represented by forming a XML file containing configuration parameters for the client device. This XML file generally describes a profile that a context aware application will use as a response to a context change. The XML scheme of such profile is shown in figure 2.

The particular profile transferred to the client is represented as an XML file described in the following listing.

```
<?xml version="1.0" encoding="UTF-8"?>
<ContextProfile
xmlns="http://gislab.elfak.ni.ac.yu/bpredic"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://gislab.elfak.ni.ac.yu/bpre
dic:\Dragan\CONTEXT\sema.xsd">
```

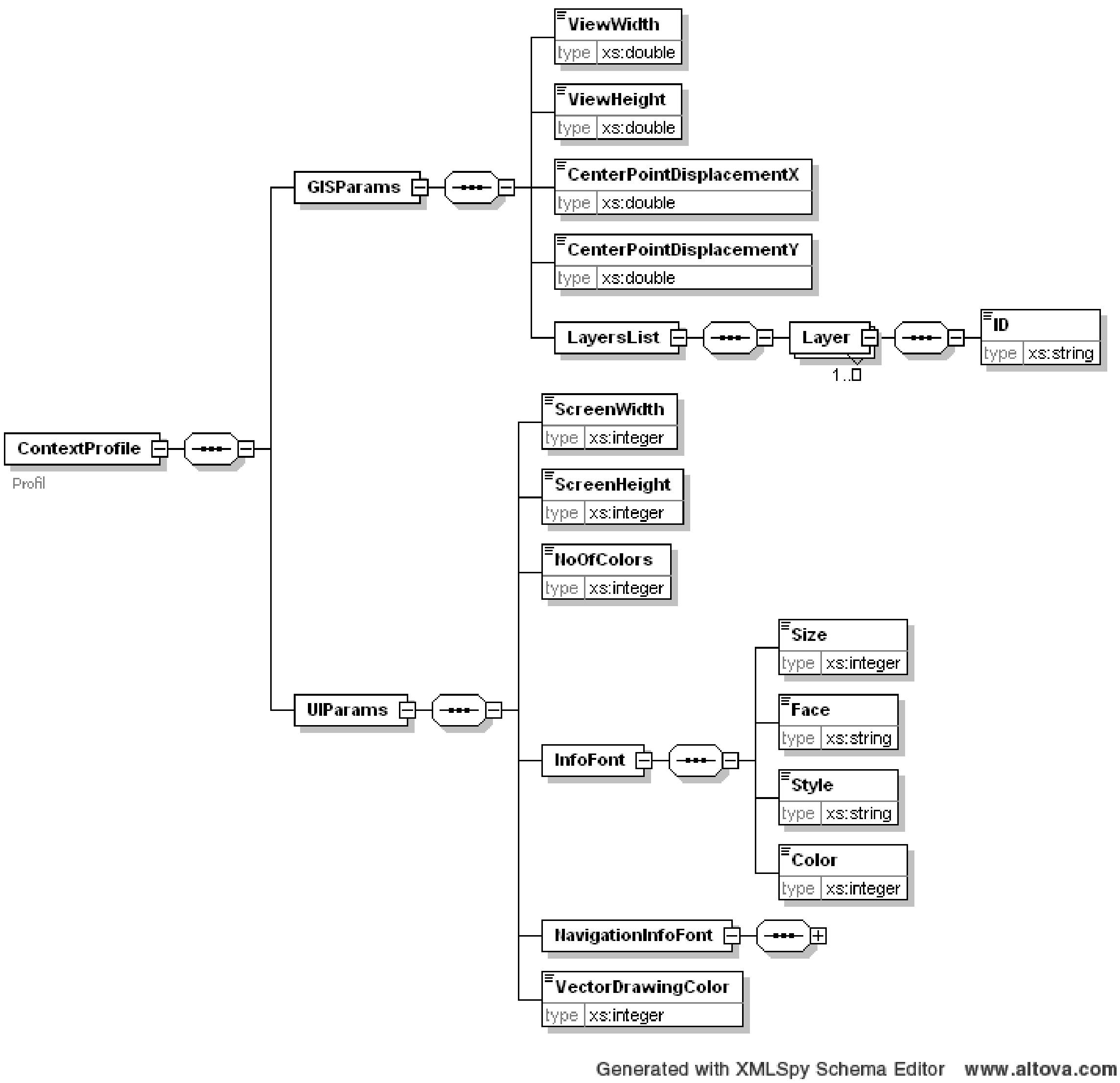

Figure 2. XML scheme describing profile

```
<GISParams>
  <ViewWidth>1000</ViewWidth>
  <ViewHeight>700</ViewHeight>
  <CenterPointDisplacementX>850
    </CenterPointDisplacementX>
  <CenterPointDisplacementY>0
    </CenterPointDisplacementY>
  <LayersList>
    <Layer>
       <ID>Gas_Stations</ID>
     </Layer>
     <Layer>
       <ID>Fast_Food_Restaurants</ID>
     </Layer>
   </LayersList>
   </GISParams>
     <UIParams>
       <ScreenWidth>200</ScreenWidth>
       <ScreenHeight>320</ScreenHeight>
       <NoOfColors>4092</NoOfColors>
       <InfoFont>
         <Size>12</Size>
         <Face>Courier</Face>
         <Style>Normal</Style>
         <Color>Yellow</Color>
       </InfoFont>
               <NavigationInfoFont>
                      <Size>24</Size>
                      <Face>Arial</Face>
                      <Style>Bold</Style>
                      <Color>Red</Color>
               </NavigationInfoFont>

       <VectorDrawingColor>Blue</VectorDrawingColor>
     </UIParams>
   </ContextProfile>
```

IV. GINISMOBILE – COMPONENT FRAMEWORK FOR DEVELOPMENT OF MOBILE GIS

Researchers in Laboratory for Computer Graphics and Geographic Information Systems (CG&GIS Lab), Faculty of Electronic Engineering, University of Nis, developed component framework GinisMobile as support for development of mobile GIS solutions. This framework represents the result of continuous development and advancement of GIS frameworks intended for rapid development of desktop and Web GIS applications (Ginis and GinisWeb). Well tested GIS concepts of Ginis and GinisWeb have been supplemented with application components from mobility domain [10].

Mobile GIS architecture is somewhat similar to architectures used for Web or WAP GIS solutions [11]. Extended client/server approach is used as basis. The most frequent modification of this architecture which is used in commercial solutions is three tier model. It consists of presentation layer, GIS logic layer including mobile database components and external GIS services layer. Third layer encompasses GIS services like Web Map Server (WMS), Web Feature Server (WFS) etc. The main advantage of this approach is clear separation of functionalities into independent modules, easily upgradeable and substitutable. Grouping of layers in the case of mobile GIS is shown in figure 3.

Presentation layer is tasked with information visualization (spatial data in the form of maps and attributes in

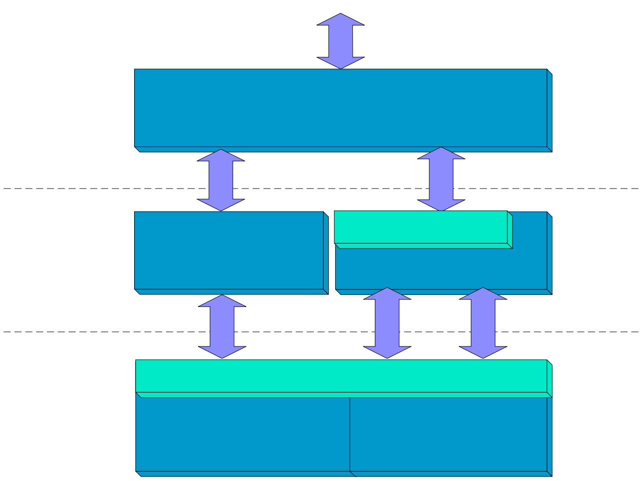

Figure 3. Layered architecture of mobile GIS

alphanumerical tabular form). This layer also receives user's requests and queries, interprets them and activates corresponding functions in application logic layer. Using adapted HTTP protocol client is supplied with static sections of maps in the form of raster images and vector type spatial data which is XML encoded. XML encoding also contains attribute data. All data the user interacts with and can change is classified and transferred in the vector form. All other data, regardless of its form when stored on the server side, is rasterized and transferred to the client in the form of raster images. Since its role is only auxiliary this is the most appropriate form of visualization.

Database component has to contain the functionality of partial replication of the data subset that is of interest to the individual user and data synchronization with local data storage located on mobile device [12]. In our usage scenario (mobile GIS) client possesses significant processing power and memory capacity which can therefore be used for performance improvement of this typical layered architecture. That is the reason the client side component in the case of mobile GIS is named usually called rich [13].

Mobile database and application logic layer is physically located at the client device accordingly to its significan processing capacities. Application logic which is also physically located at the client device contains portion of GIS functionalities, basic functionalities which can be performed on the client side solely without data transfer to/from server side.

Stationary database and third party GIS services layer (eg. Web Map Server) is physically located on the server side. Stationary database contains the complete set of data available. Mobile GIS client is supplied only with subset of available data, subset that is of direct interest of individual client (fieldwork team). Determining the scope and volume of this subset is the task of GIS functionalities component located in this layer. Other GIS services belonging to this layer (WMS, WFS) are also controlled by GIS functionalities of this layer. WMS is tasked with supplying raster map segments which are used at the client to form continuous georeferenced map.

More detailed overview of the mobile GIS architecture shown in figure 4 with Components *Integrator* and *interpretator* represent software interfaces with external devices, mainly sensors. In our scenario these are usually positioning devices (GPS). This component enables field personnel to use GPS to either directly input coordinates of spatial objects or to orient themselves on displayed digital map. Specific class of applications is Location Based Services (LBS) which automatically use information about users geographic location to adjust its functionality [13, 14].

For the optimization purposes spatial data that is supplied to mobile clients are classified in two groups: spatial data that is static in nature in regard to individual user in question and spatial data that user interacts with, modifies, adds and deletes. Data from the first group are auxiliary in nature and their primary role is user's orientation in space. That is the main reason this class of data is rasterized on the server and separately transferred to the client. Whole continuous raster map consists of regular rectangular matrix of raster map segments. Regarding static nature of these map segments it is optimal to maintain local cache of raster map segments already used at the client. This caching mechanism significantly increases performance of map visualization. The caching mechanism is realized as two level cache. First level is using secondary memory medium to store raster map segments. This is usually some sort of memory card. Since secondary memory has relatively slow transfer time second level of caching is introduced. If we rely on locality characteristic of spatial data it is expectable that the user will request map segments adjacent to map segment that was the last requested. Second level cache keeps last N map segments in client device RAM. The number N is dynamically calculated and depends on currently available amount of memory. Secondary caching algorithm adapts to currently available RAM on the client device. When the amount of available memory becomes critically small it removes from secondary cache raster map segments that

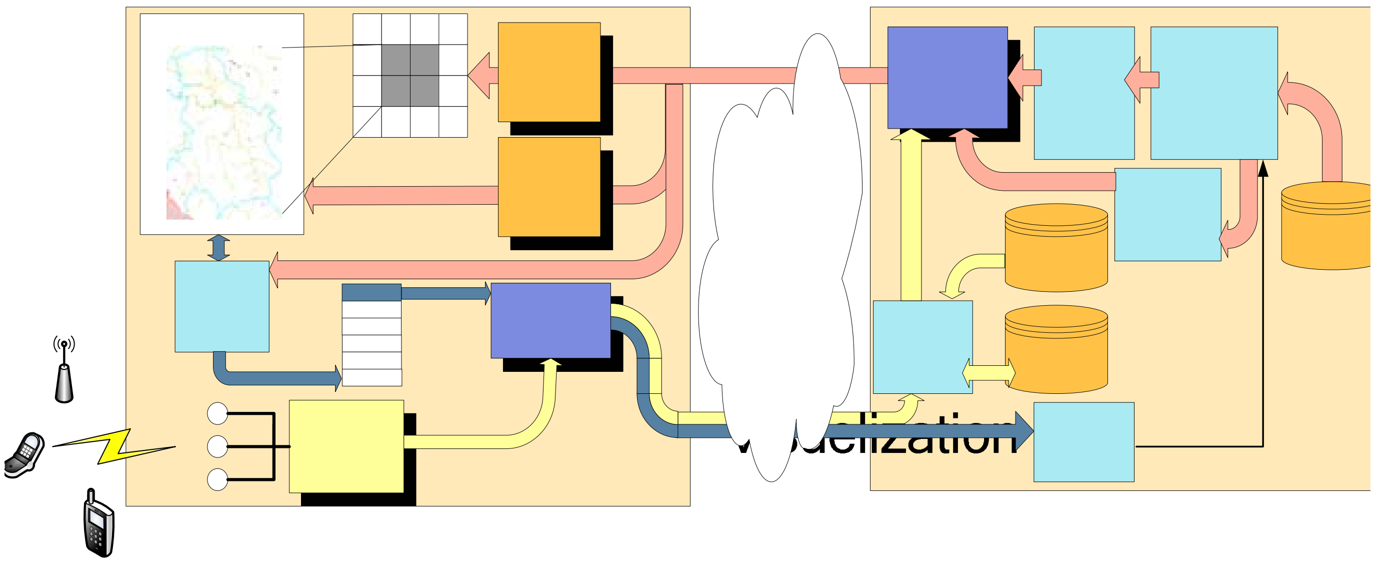

Figure 4. Detailed component view of mobile GIS architecture

haven't been used recently. Statistics of map segment usage is maintained and decision which segment is to be removed from the cache is made according to *Least Recently Used* (LRU) algorithm.

Another layer of visualization on the client device screen is vector type. Vector type spatial entities are stored into mobile database local storage on the mobile device. Visualization and manipulation of this type of spatial data is handled separately from raster layer.

Another important part of mobile GIS architecture is component handling user requests and queries. Regarding implemented caching mechanisms some of the user commands require communication with the server side using HTTP protocol. Nature of wireless network connection (802.11b/g or GPRS/EDGE) doesn't guarantee network availability at every time instant. This requires introduction of command queue. Frequently, the command queue multiple sequential translation or zoom-in/zoom-out commands. Since the user is almost always interested only in the final result of such an array of commands sequential commands aggregation mechanism is implemented. This caused significant decrease in system response time and generally improved user experience. Furthermore, by eliminating N-1 unneeded commands out of N HTTP traffic over slow and expensive wireless network connection. HTTP protocol is used only to transfer final result of aggregate user command.

On the server side of mobile GIs it is possible to isolate three groups of components: Web server (Internet Information Server - IIS) which is tasked with network communication with mobile clients by interpreting HTTP requests and forming valid HTTP responses, spatial database enabling partial data replication and synchronization including context interpretation machine and WMS and WFS services with integrated GIS analysis functionalities. We should point out here that the associated GIS functionalities component in this model is somewhat different in comparison to paper [13]. In accordance with significant processing power available in modern PDA devices there is no need for coordinates conversion on the server side into client screen coordinate system. Complete mobile client performs all analysis and data manipulation in real world coordinates in defined reference system. Mobile GIS for *Smartphone* devices which was elaborated in [13] did not have this characteristic. GIS functionalities component's task is to interpret user's request and acquire appropriate section of the raster map from Web Map Server. This map segment is combined with rasterized vector type spatial data that is of secondary value to the specific user or that is not changing over time. HTTP response to the mobile client apart from this combined raster image also contains vector data and thematic attributes encoded in XML spatial data encoding standard.

V. GINISED CONCEPT DEMONSTRATION APPLICATION

In municipal public works companies (waterworks, public power companies etc.) or other companies dealing with telecommunication, transportation and distribution of goods significant part of the business process consists of efficient management and maintenance of network infrastructure. These activities support quality of service offered to the customers and increase productivity. Most of mentioned companies include GIS in their IT strategy. But, whet it is required to support infrastructure maintenance and construction in the field classical GIs is of little use. Mobile GIS is supposed to bridge this gap and provide field personnel with most up to date data and critical functionality that is essential for completion of their field tasks. In the case of electrical power distribution maintenance fieldwork mobile GIS provides maintenance teams with efficient navigation to the point of interruption in the network and better overview of power distribution network affected by the malfunction.

Figure 5. Map visuelization with combined raster and vector layes

Public power corporation Niš uses mobile GIS for electrical power distribution network management, analysis and overview. Mobile GIS is realized as a complement to centralized desktop GIS and Web GIS solutions. Centralized system enables input of data about distribution network [15], but provides no efficient means for input and usage of spatial data in the field. All this influenced the decision to include in the system mobile GIS client named GinisED Mobile. Using this system fieldworkers can request subset of spatial data describing electrical distribution network that is of interest to them, perform needed changes, update data at the time of changes and merge data changes with the central database while still in the field. Georeferencing of distribution network elements can be performed automatically using GPS sensor attached to PDA od manually by drawing on the screen.

Due to unified geospatial data model users of GinisED Mobile in preparation phase of fieldwork use centralized data storage to extract subset of data that covers the area field work is located in. Every change performed on data subset or generation of reports is automatically merged with central database. The result is central database that is always up to date and synchronized.

Figure 5 shows user interface of realized GinisED Mobile application demonstrating concepts presented in this paper. As it was pointed out in chapter two user interface is page oriented giving map display most available area. Other important pages include GPS sensor configuration controls. Concrete example shown in figure 3 client application is displaying various raster maps with different vector layers overplayed on top. As displayed, vector layers could include locations of mobile objects if GinisED Mobile is used for tracking vehicle fleet [14], or distribution network installations.

VI. Conclusion

In accordance with the trend of ubiquitous computing and development of wireless telecommunication technologies [16] GIS extended its application into mobile domain. It is expected that mobile GIS applications will completely substitute thematic maps which are today widely used in departments that have fieldwork in their business processes.

The most important issue in understanding mobile GIS concept is that mobile GIS is operating as an extension of the centralized GIS. Only system administrators will have the need for accessing central system directly, and the whole process of entering new data into the system or modifying existing data can and will be performed directly on site during field work using mobile GIS clients. Consequently, implementation of mobile GIS solution is reducing expenses, shortening data input and modification procedures and finally producing more accurate and up-to-date data.

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