MOBILE COMPUTING IN NATURAL RESOURCES: A CONCEPTUAL MODEL*

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ABSTRACT

Rapid developments in mobile computing offer unique opportunities to private and public agencies for handling data in a timely and cost-effective manner. Recent advances in wireless network, Internet, handheld computers, and global positioning system (GPS) have paved the way to mobile applications in natural resources. Such applications may be broadly classified into emergency dispatch and field data collection systems. Relevant data is stored on a server in a centralized spatial database. Users with a mobile application are able to access the central repository anytime and from anywhere. This approach reduces considerably network traffic, allows easy access to information sharing, and prevents data entry redundancy. Organizations using such a system save time and money.

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INTRODUCTION

New advancements in wireless networks and portable computers are paving the way for a new paradigm known as *mobile computing*. It allows users to carry portable computing devices anywhere in the world to access shared information at any time. Often the term mobile computing is misunderstood for nomadic computing. The main difference is the type of network used, which in the case of nomadic computing does not allow mobility while computing. Even though nomadic computing uses a portable device such as a laptop, access to a network is through DIAL-UP lines or via a Wireless Local Area Network (WLAN) within the confines of a building and is not truly mobile (Helal et al 1999). Users of mobile computing depend on small portable computers, hand-held units, and other similar wearable devices to run stand-alone applications and to access remote ones via wireless networks such as GSM, CDPD, and satellites. Mark Weiser, one of the pioneers in the field of mobile computing, envisioned the computing trend as depicted in Fig. 1. Recently, a new term, *ubiquitous computing*, appeared in the literature. It encompasses both, mobile and nomadic computing. With increasing use of personal computers and laptops in the late nineties, the trend will continue in the foreseeable future. Mobile computing will add to the existing infrastructure for better and timely dissemination of information, thus putting data right at our fingertips wherever they may be.

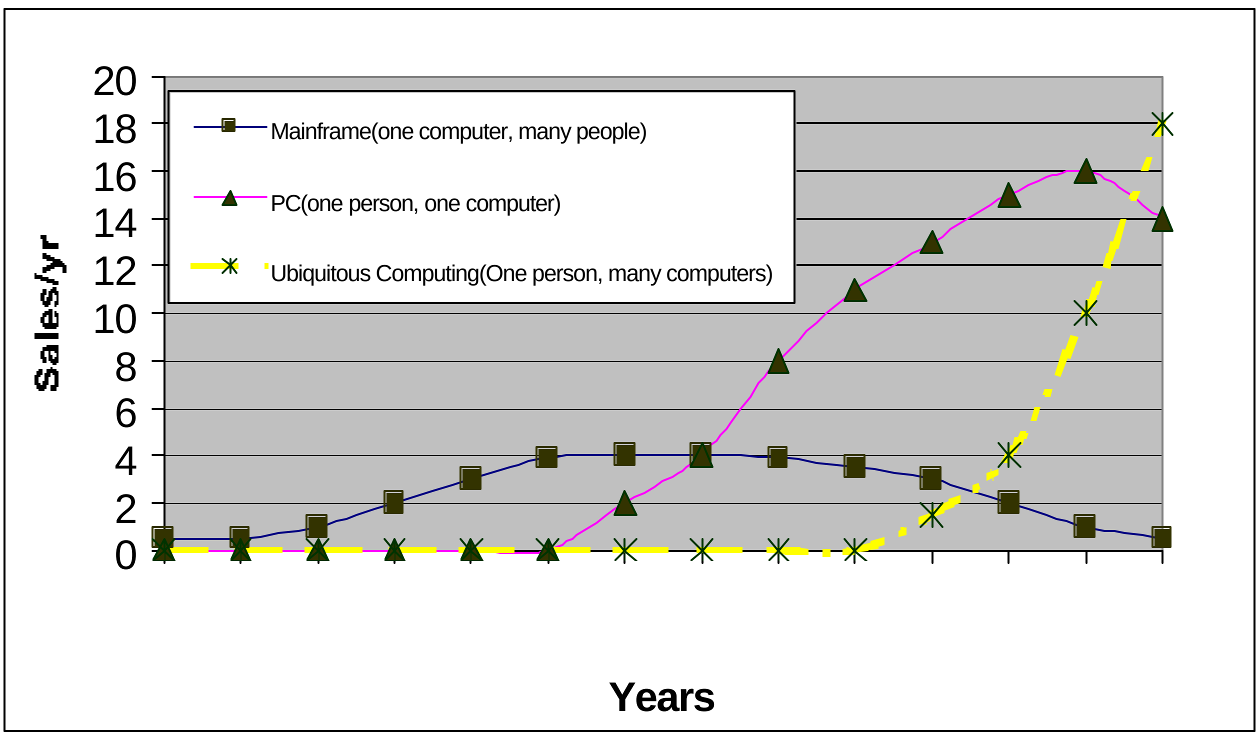

Figure 1. The major trends in computing

MOBILE COMPUTING ENVIRONMENT

The mobile computing environment has added challenges to the development of applications. These challenges stem from the following three areas: wireless communication, mobility, and portability.

Wireless communication

When a person with a portable computer is in the office or at a meeting, the device may be physically attached to the network to gain a better and/or less expensive connection. However, to be truly mobile, a computer or portable device requires wireless network access. Disconnection is of greater concern to mobile applications than to applications in the fixed network. A mobile application needs to be ready to operate even when disconnected. Limited communication bandwidth is another major consideration when designing mobile applications, compared to stationary ones. Wireless communication provides much lower bandwidth than wired networks, which are orders of magnitude slower than fixed network (Forman and Zahorjan 1994).

Mobility

As the mobile user moves, he/she will use different network access points or addresses. Currently, there are no widespread dynamic addressing capabilities. A computer cannot be moved from network to network seamlessly and still maintain a communication channel while moving across networks. Most of the ongoing research is focused on developing reliable Mobile Internet Protocols (Johnson and Maltz 1996). Also, lack of mobility awareness by applications is a major hurdle. There is no set of application programming interface (API) together with a testing environment. Similarly, there is also a lack of mobility-awareness by the system. Existing transport protocols are inefficient to use across a heterogeneous mix of fixed and wireless networks. Operating systems lack location related conditions and signals.

Portability

To make units portable many concessions are made in component size and design. This leads to short battery lifetime (max ~ 5 hours), since network connectivity hardware demands a large portion of available power. Units need to be disconnected to save power or recharged. Most portable units do not have the same architecture. They range from simple organizers and communicators to handheld computers and laptops. Most of the devices are resource poor in displaying capability, memory, input devices, and disk space (Satyanarayanan, 1995). The advantage of such a variety of devices is that one can develop custom applications based on the requirements for a specific project. This imposes many restrictions on the overall design of a mobile computing model. To meet these and other obstacles, one either needs to invest time to minimize the effect of constraints or to design relevant applications.

NEED FOR MOBILE COMPUTING IN NATURAL RESOURCES

Advances in geographic information systems (GIS), the global positioning system (GPS), and remote sensing (RS) led to geospatial databases. Previously, most of the tasks were performed with hardcopy maps, aerial photographs and paper forms for most of the transactions in government agencies as well as big and small private organizations. This meant poor quality service for the general public, low productivity and too much redundancy. Even though these technologies have the advantage of processing and manipulating data for better management, the data that goes into such systems is still recorded first on paper forms and later transcribed into digital format. In natural resource disciplines there is a need for timely and reliable data for making intelligent decisions.

Some applications require direct access of information for quick implementation in the field. A good example is that of forest fires in Florida during the summer of 1998. Fire fighting personnel urgently needed the location of wetlands and other water bodies to develop a strategic plan to combat the fire. Most of the time was lost in generating maps of the relevant features in the office. In such a scenario a mobile computing solution could have alleviated the situation. A common concern one often hears in natural resources is "*lack of mobility*".

Progress in Client/Server computing models and desktop GIS software brought some mobility to geospatial information systems (Arvanitis et al. 1999, Wang et al. 1996). This generated a large array of stand-alone client applications. Advances in GPS receivers and reduced cost brought true mobility to GIS mapping systems and paved the way for portable systems. Previously, spatial layers were very static and served only as a substitute to hardcopy maps with the exception of spatial analysis. Many of the applications require real time coordinate information.

One of the major changes that occurred with the availability of the GPS is the way data is captured for GIS. Initially, laptops with desktop GIS software brought the capability of mapping new features with differential GPS in the field. This proved to be convenient as it short-circuited the whole process of digitizing hardcopy maps and reduced the cost associated with such processes. The GIS community faces the same hurdles as mobile computing systems, namely, short battery life for continuous daily operation, ruggedized devices to suit the environmental conditions, disk space etc. The acceptance and spread of mobile solutions were adversely affected due to the initial cost in changing the infrastructure and the reluctance to change from conventional methods. Recent advancements in technologies like Internet, wireless network, and miniature GPS receivers (OEM, Embedded systems etc.) have stimulated research and development of mobile systems in geospatial information systems. Mobile computing applications in Natural resources can be broadly classified into two categories: a) Emergency and dispatch systems and b) Field data collection and navigation applications.

Emergency and dispatch systems

In case of natural disasters like hurricanes, flooding, forest fires etc., immediate response and recovery is required. Fire fighting crews, paramedics and ambulances with GPS tracking receive dispatched information about the latest weather and road conditions, traffic volume and others, for better response time and more efficient handling. In these types of applications, users will have access to computer-displayed maps, the status of the near-by units, and their respective locations. For hurricanes, post-flooding and fires, this application is useful for estimating the damage as well as for navigation since most of the landmarks, such as road signs, manholes, sewer lines may be damaged.

Field data collection and navigation applications

Data collection serves a variety of applications such as forest and other natural resource inventories, mapping, and ground truthing for remote sensing. One of the earliest attempts to implement a mobile application was a "*fieldwork assistant*" developed keeping in mind the various limitations of the mobile computing model (Ryan et al 1997). An important theme of this study was context awareness, the ability of a computer to receive and act upon information about its environment such as location, time, temperature, or user identity. It was based on the assumption that the combination of an inexpensive hand-held computer or Personal Digital Assistant (PDA) with a GPS receiver will provide a suitable platform for data collection, authoring and delivering of field exercises, as well as student field experiments.

The application model is based on the simple concept of stick notes as reminders. The hand held computers or PDA's act as field notes on which information, may be taken to the field, created or modified in the field, or analyzed after returning from the field. In their simplest form, these notes are plain text. This approach still needs further refinement to be easily integrated with a highly sophisticated system like GIS. Similarly, stand-alone pen based and hand held computer applications are developed, which store the data in the most generic text format. Once in office, this may be exported to the required format to be compatible with their system. Any loss or corruption of data in the processes will totally defeat the main objective of mobile computing.

In applications requiring navigation, GPS provides real time coordinate information. For example, navigation is critical to precision agriculture. A tractor may follow a predetermined path in the field specified by remote sensing imagery. It applies proper amount and type of fertilizer, insecticide or water. Navigation is also important in mapping crop yield. Location information is needed for predictive models. This approach assists farmers to combat crop diseases, use fertilizer more effectively and enhances profits.

DYNAMIC CLIENT-SERVER MODEL

Since mobile computing implies communication, the prevailing models for designing mobile applications are predominantly based on client-server architecture. Currently, there are less than ten models available in the market (Helal et al, 1999). Our focus is on applications that require intensive field data collection procedures for forest and other natural resource inventories. The approach we have taken is a dynamic client-server model with disconnected operations to support mobile computing. The spatial and descriptive components of the geospatial database are treated separately. This model links both the application and the system to adapt to a mobile environment. It is ideal for storing and accessing data in a centralized database by multiple users and agencies. Two mobile client applications will be developed in parallel to address the spatial and descriptive needs. In the first application, issues related to organizations involved in intensive inventory data collection will be addressed. The second application will deal with limited navigation and retrieval of locational data from the centralized database server. This solution is suitable for large and small organizations alike.

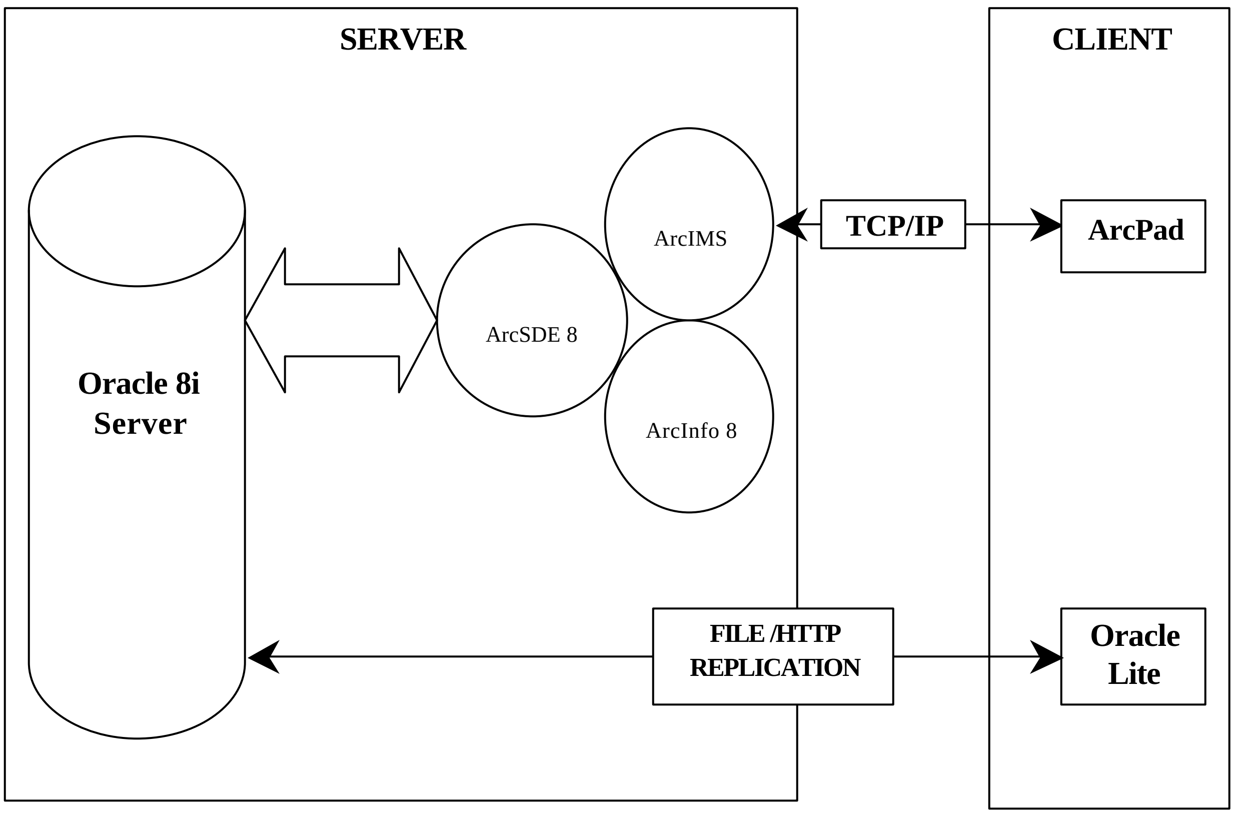

Figure 2. Dynamic client-server model

Such an approach is suitable for data stored in a robust database management system (DBMS). In our case, Oracle Corporation's *Oracle8i Enterprise* server for SPARC Solaris with replication manager is on the server side. In addition, Environmental Systems Research Institute's (ESRI) *ArcSDE 8*, *ArcInfo 8* and *ArcIMS* are used. *ArcSDE* is a gateway between GIS software and DBMS. It spatially enables data stored in an external relational database management system, like Oracle database. The new object data model of *ArcInfo 8* provides flexibility in creating and sharing GIS datasets in a multi-user environment. *ArcIMS* based on Internet map server technology provides features to exchange, integrate and analyze data. ArcSDE in conjunction with *ArcInfo 8* and *ArcIMS* helps in distributing spatial data to the mobile units. The clients reside on the same unit but perform different functions depending upon the scenario. The architecture of the model is depicted in Fig. 2.

The advantages of using DBMS in a geospatial information system are numerous. One of the features that make DBMS superior is its replication capability. Replication is the process of copying and maintaining database object properties in multiple databases. This facilitates handling of distributed data management systems. Replication can improve the performance and protect the availability of applications because of the existence of alternate data access options. For example, an application might normally access a local database rather than a remote server to minimize network traffic and achieve maximum performance. Furthermore, the application continues to function while the local server may experience a failure, provided that other servers with replicated data remain accessible (Oracle 1997). It supports bi-directional replication.

The mobile client, which is a Microsoft Windows CE handheld device, uses Oracle Corporation's *Oracle Lite 3.5* and ESRI *ArcPad 5.01. Oracle Lite* is an object-relational database designed to be embedded inside distributed client applications. It provides a full client and a thin version of the server on the mobile platform. It is a small footprint of the server with all the performance benefits that can run on desktop and portable systems. Oracle's advanced replication option for Windows CE supports data replication over any connection using HyperText Transfer Protocol (HTTP), Mobile agents, or file-based replication. At this stage, the focus is mostly on file-based replications. Mobile clients upon reconnection, updated replicas are synchronized with the local database or the central server. On synchronization with the central database, a conflict resolution strategy will be performed to determine whether there are any collisions in the transactions based on the timestamps. If found, it would be resolved according to the rules with which the database was designed. In the future, the other two methods will be tested in scenarios where the users are required to transfer or retrieve data from the field using wireless network or access through Internet connections. This will further enhance the productivity of the field force.

ArcPad similar to Oracle Lite provides lightweight mapping capabilities on Windows CE devices. But it lacks the robust replication and conflict resolutions supported by Oracle in a multi-user editing environment. Currently, *ArcPad* is suited for applications that require retrieval of base images and map layers for aid in real time navigation and location information in the field. It also supports National Marine Electronics Association (NMEA – 0183) protocol for integration with GPS units. A combination of *Microsoft's Windows CE Tool Kit for Visual Basic (VB) 5.0* and *Avenue* scripting language will be used for developing custom applications.

SUMMARY

Mobile computing is still in its infancy. However, it offers great possibilities to private and public agencies in handling spatial and descriptive data in a timely and cost-effective manner. Mobile applications are designed to address specific requirements of a project due to the various limitations imposed. This approach reduces considerably network traffic, allows easy access to information sharing, and prevents transcription errors as well as data entry redundancy.

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