Transference and Storage of Spatial Data in Distributed Wireless GIS

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Abstract. There has been a great development in Wireless GIS (WGIS) new century. Spatial data transferring and storage in GIS are developed from wired to wireless network. This paper first briefly introduces the technologies and strategies of spatial data transferring and storing in distributed Wireless GIS. Secondly, the schemes of spatial data transferring modes in wireless GIS for improving the network transfer rates are introduced emphatically, and the distributed transferring process technology of GIS spatial data are also discussed. Based on these, we present the storage strategies in wireless database, and introduce mobile computing conception and three-tier wireless replication database. Here, we emphasize on dynamic replication strategies and methods in wireless environment. Finally, we compare several data storage strategies in WGIS databases and the dynamic multi-tier replication strategy is proposed for wireless database storage…

1 Introduction

Stand-alone and wired GIS may not meet the requirements of all the GIS (Geographical Information Systems) applications appropriately, especially when users need to access a GIS, time and location independently. Therefore, there is a need to move towards ubiquitous GISs, which can serve users anywhere and anytime.

These days, not only GIS experts but also ordinary people tend to access spatial information using wireless equipments. With the rapid development of new integrated techniques, there are also many new achievements in GIS. The development of the handheld devices, such as Personal Digital Assistants(PDA), Java-enabled mobile phones, laptop and Internet techniques, and the application field of GIS has been enlarged and furthermore, lead to the new challenges to GIS techniques. GIS based on wireless devices -- wireless GIS (WGIS), will become new branches of GIS and bring the GIS into a new stage of development. The technology of spatial data trans-

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ferring and storage in GIS is developed from wired to wireless network at present. It is feasible for itinerant or peripatetic users to travel from one place to another by using the wireless network.

However, in the applications of wireless network, the speed of transaction is getting faster, and the capacity of storage is getting larger. However, there are limitations in wireless GIS.It is a challenge task to connect network elements by radio waves instead of wires. [1, 3, 4, 5, 6] For example, GIS spatial data transfers and storage based on wireless LAN are restricted to spatial data capacity and transferring distance. Therefore, there exists deficiency on the data processing. It is potential to solve the problem by using distributed dynamic multi-tier spatial data transferring.

Wireless GIS technologies offer a lower time-to-market comparing too many wired technologies, which require the deployment of large amounts of new network equipments. The wireless GIS, not only satisfy the network demand of various personal digital assistants (PDAs),portable computers at anytime and anywhere, but also be regarded as the compensative means for traditional wired GIS. The data process is promoted by improving the transferring rate.

2 Characteristics of WGIS

In the mobile communication area, GIS network were usually divided into two types according to the wireless connection technologies. One is based on the Cellular Infrastructure connection technique, which is also used for Mobile GIS.The other is based on wireless LAN techniques. Wireless network is a network, which is built, in a mobile environment, or the environment-combined wireless with wired. It is quite convenient for data-transferring network. Therefore, we first need to consider the characteristics of wireless GIS that will likely affect our way of working and thinking on the current GIS technology.

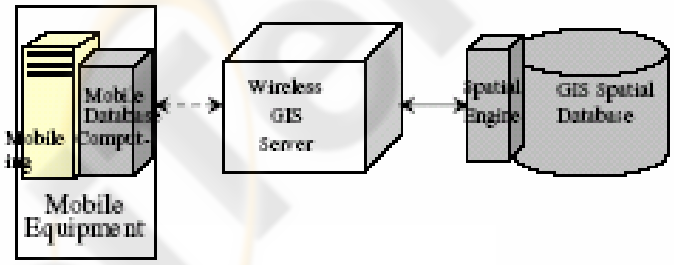

Fig.1. Wireless GIS Framework

As illustrated in Fig.1, WGIS is composed of mobile equipments, wireless GIS server and GIS spatial database. The mobile equipments, i.e., PDA, laptop, and mobile phones etc. should be comprised with mobile databases and mobile computing environment. Wireless GIS server is the main part of WGIS, it deals with all kinds of

processing in wireless transfers, including ‘read’, ‘write’, ‘delete’, ‘update’ and ‘commit’ etc.

As the wireless communication the factors considered are, for example, communication cost, communication time, power supply etc., so the wireless server should take into account the problems mentioned above and should provide an optimal search for wireless users.[2,5,7,8,9] GIS spatial database (DB) is used to manage all types of massive GIS data, while the conventional DBMS could fit the function. Between the GIS DB and wireless server, a spatial database engine, which could be ODBC or SDE, should be produced in order to provide services for users.

The wireless GIS is the management and application system of functional and wireless Geo-spatial data. In this system, we can realize tremendous Geo-spatial data storage and management in GIS, fast queries of multi-dimensional spatial data and search in wireless network, wireless station over switch, wireless vendor’s authentication and management, encrypted wireless data transferring etc.

Being compared with the conventional LAN, the wireless network technology is possessed itself with overwhelming predominance.However, wireless couldn't be absolutely replaced by the wired environment and is used to make up the restrictions of wired, with it’s purpose of the extension of the wired. [10]The Geo-science is now facing a shift in the way for GIS development in human works and in their access.So the question becomes how to give GIS clients accessing any type of Geo-Information quickly, securely, at anytime and in anywhere.

The development of Wireless GIS is served the first and top priority to the development of the mobile computing technology. Mobile computing technology is a revolutionary technology, born as a result of the remarkable advance in the development of computer hardware and wireless communication. It enables us to access information at anytime and anywhere even in the absence of physical network connection. It is essential in a mobile computing environment to serve mobile clients to access remote information at anytime and at any place. In the process of accessing files on remote servers by the clients, requests are sent by them to mobile support stations from where the files are thus received from the remote servers and are then are delivered back to the clients. The high mobility of mobiles for mobile hosts and the narrow bandwidth in the wireless network may cause certain delay in accessing files. Also, because mobile clients may request the services of accessing file too often and give rise to bandwidth contention among them, latencies can be caused on the whole.

The important characteristics in wireless GIS transfer and storage that are needed to be considered are as follows:

(1) The environment, in which wireless GIS is deployed, is the mixture of two different networks, the fixed and the wireless networks. The fixed network is characterized by the fixed hosting location, relatively high capacity, high reliability and low connection cost. In contrast, the wireless network is to support dynamic network topology but with relatively low capacity, low reliability and high connection cost. In order to avoid compromising database performance due to the use of the wireless network, recently some techniques have been proposed, including:

- Reducing the number of data exchanged via mobile network;

- Reducing the response time of accessing data via mobile network;
- Providing data cache on mobile host;

(2) The resources available to mobile users are generally very limited. As a result, mobile hosts will tend to be highly personalized. From the data management's point of view, mobile users will likely and solely bring the fraction of data they need to access frequently in mobiles. A new challenge arises for coping with the requirement of consistency on databases (both on mobile and fixed hosts) especially when those fractions are not completely independent to each other. Actually many techniques have already been proposed to address this problem, including:

- Transaction management for wireless transfer;
- Allocation of mobile database replication (materialized view) on the fixed network;

(3) In general, wireless communications are consisted of low security. The worst case is, for example, that our data on the mobile hosts would be completely lost if the mobile hosts become the subjects of thieves.

The consequence of the above characteristics is concluded that wireless GIS, in general, contains a high degree of unavailability. It is not to say that most data management issues in mobile information systems are related, directly or indirectly, to the problem of low data availability. Thus, data availability is the central issue in transferring mobile spatial data. Accordingly, addressing the problem of low data transferring speed and management would have significant contribution in the establishment of wireless GIS technology.

3 Distributed Data Transferring Strategies

Wireless GIS impulses Geo-science and wireless communication technique to a new era through enlarging the network's carrying capacity and application domain. Nowadays, since the application of wired network is gradually saturated, the wireless application has become wider and wider. Meanwhile WGIS provides some newly hot spot applicable strategy.

The data is the most unvigorous segment in GIS, whereas spatial data, which is related to GIS, is multi-original and complicated, in terms of data types and formats, i.e., gigantic grid image data, spatial vector data, metadata, etc. It is an essential matter in WGIS operation for constructing geographic entity objects, organizing and transferring spatial data, and realizing data share in the Internet. Integrating the character of wireless transferring, WGIS spatial data transferring strategy should consider the following facts:

(1) Unrestricted by time and location. It is also the predominance for wireless network to realize WGIS from preventing disturbances from outside conditional environment and atrocious weather. In the area where the wired is untouched, for example, in a hard, badly, dangerous environment, the WGIS could still work well.

(2) Wireless applicability. Being compared to the wired network, the wireless network has a more comprehensive employment and configure mode; otherwise, it isn't involved in the situation of stations. Thus, the use of GIS becomes more flexible. Wireless GIS could be realized as the convenient GIS by clients as it is applied to the traditional GIS and prevalent mobile GIS contemporarily.

(3) WGIS should provide a more extensive GIS service for users. Location Based Service (LBS) and Mobile Based Service (MBS) provide a realistic model for our practical world. At different times and in different locations, the model dynamically offers distinct information service.

(4) WGIS should improve the security for data transferring. The wireless GIS is utilized an electromagnetic wave transferring in the air instead of cables, to dispatch spatial data. The frangibility of transferring medium makes the data transfer easily to be disturbed by the outside environment. Meanwhile the uncertain factors of a transferring process make wireless data easily to be listened and captured to enough packets by hackers. Hence, the increase of the wireless security for data transfer is an important factor for our design.

(5) Transferring velocity of WGIS is restricted by the existing standard. Although the wireless velocity has been made a great progress in 21st century, for example the new standard for wireless, i.e. CDMAX, IEEE802.11a and IEEE802.11g, is protrusive recent. The velocity of wireless couldn't be exactly and completely compared with the wired network. From considering the wired cable transferring, the gigantic GIS data transferring velocity is hard to satisfy the demands. Therefore, improving GIS transferring velocity is a persistent requirement for WGIS.

(6) WGIS should solve the low efficiency of the visits of spatial database exchange. Data organization is still the GIS bottleneck for accesses of users. In the wireless environment, there also exist the factors for confining exchange visits, for example restriction of data access and uncertainty of client location. Considering the interoperability of GIS data, it is important to enhance the efficiency of data transfer.

As a consequence of the above strategies, in the wireless GIS, there is generally a high degree of unavailability; thus, data transferring is the central issue in this field. Accordingly, there will be a significant contribution in the establishment of WGIS technologies from solving the problem of low data availability and velocity depending not only on spreading software protocol standard, but also on improving hardware technology.

4 Spatial Data Storage for Mobile GIS

As we all know, the character of GIS data including vector data, grid data and image data is gigantic and multi-resource. In mobile environment, for the limitation of trans-

ferring velocity, we should consider appropriate strategy to storage and manage GIS data in the wireless server.

4.1 Mobile Computing

Mobile Computing and wireless networks are fast-emerging technologies to make an environment conducive for ubiquitous computing. In this environment, mobile users equipped with compact battery-powered palmtops or laptops need to access the large volume of GIS data stored in the fixed network through Mobile Support Station (MSS) by the wireless communication. In order to realize the GIS data storage in MSS, it is essential to adopt mobile database technology.

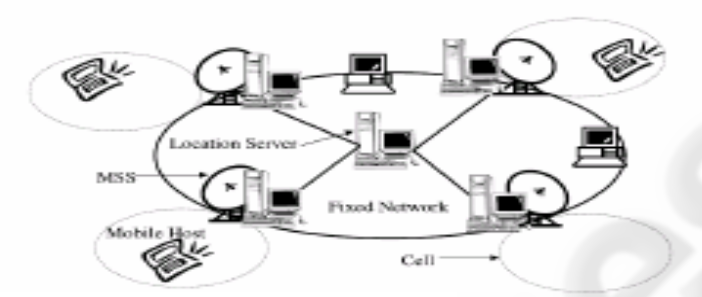

Fig.2. The model of Mobile Envinment

Fig.2 presents the model of a mobile environment. A mobile environment consists of two distinct sets of entities: mobile hosts and fixed hosts. Some of the fixed hosts, called MSS, are augmented with wireless interfaces to communicate with mobile hosts, that are located within its radio coverage area called a cell. Mobile hosts are connected by wireless connections to the MSS of the cell where they currently exist. A mobile host can move within a cell or between two cells while retaining its network connection. Further, every host and cell in the system is assumed to be associated with a unique identifier.

The mobile computing environment is a distributed computing platform with the following differences: the mobility and access devices of users, frequent disconnection, limited bandwidth and the mobile resource constraints - limited computational and power sources.

As a part of a mobile database system, a mobile host acts as a data client and a data server at the same time. A mobile host, as a data server, is to support basic transaction operations such as ‘read’, ‘write’, ‘commit’ and ‘abort’. WGIS should deploy mobile database as data management, and the use of multi-ties, dynamic replication technology is available.

4.2 Three-Tier Replication Model in Mobile Database

In mobile computing environment, users can access information through wireless connections regardless of their physical location. In mobile database systems, new features, such as mobility, disconnection, low bandwidth, high bandwidth variability, heterogeneous networks and security risks, make traditional database processing schemes no longer well suitable.

Replication is one of the key technologies in promoting the performance of mobile database systems. In WGIS mobile database system, the three-tier replication architecture, which is shown in Fig.3, is used to solve the synchronization problem, as

Fig.3. The three-tier architecture of wireless GIS database

Fig.3 and Fig.4 shows, WGIS mobile database is utilized as a synchronization server to promote the efficiency of spatial data synchronization. It provides a replication model for database server (DBSVR) and WGIS. Besides, it ensures serializability and consistency of the mobile database system through the reconciliation of transaction-level conflict.

The function of Sync Server which is connected wireless communication interface is making distributed processing, controlling spatial data exchange with WGIS and database server, and sustaining a wireless cell. Mobile client conserves a database duplicated copy, and through the GIS manages local geographic database. With the ODBC interface, sync server could exchange spatial data with database server.

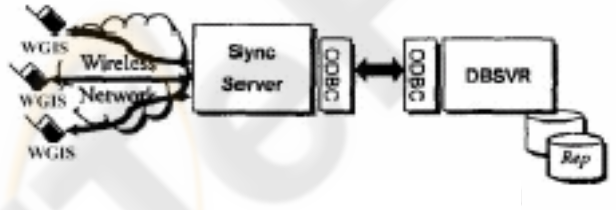

Fig.4. The three-tier WGIS replication model

4.3 Replication Dynamic

Replication is a general technique to increase the data availability. However, the generally available replication technologies assume the deployment on a fixed distributed environment.

According to the behavior of replicas in replication schemes, we can categorize the schemes into two replications, static replication and dynamic replication. In this paper, dynamic replication for wireless GIS database is considered.

In static replication schemes, the location and the number of replicas are chosen prior to the deployment. For example, traditional replication schemes, fall into this category. Manual recalculation of the access cost and redistribution of replicas are necessary to reflect newly accessing patterns. However, in a mobile environment, static replication schemes may not perform well since the assumptions about fixed locations and static accessing patterns are no longer held.

On the other hand, in dynamic replication schemes, the location and/ or the number of replicas are changed to follow the accessing patterns to data being replicated. Dynamic replication schemes try to overcome the problems mentioned above by continuously maintaining statistics about accessing patterns and/or system workload so as to dynamically recalculate access cost and reconfigure the replication structure to adapt to the changes in accessing patterns. In general, this is desirable for a mobile environment.

In a mobile environment, however, mobile hosts are dynamic. They could move to anywhere and for unpredictable length of time. Furthermore, the users of replicas may need to work at several ‘well-known’ sites. In such cases, it may be more advantageous to deploy multi-replication, i.e., placing a replica on each ‘activity centre’ of its users.

In a mobile computing environment, however, mobile hosts can move anywhere and anytime, resulting in a highly dynamic system. Accordingly, the centre of activity of replica readers is not static in general. Not only that, the ability of mobile users to move can also make it more costly to find current location of mobile users and of course the replicas if they are dynamic. In this sense, it is necessary to take a balance between the cost of finding location and replica maintenance.

5 Comparisons of Various Data Storage Strategies in WGIS

In this section, we compare the dynamic multi-tier replication and dynamic-single replication strategy strategies for wireless databases, which combine the two aspects of replication policies mentioned above. We intend to show how some important parameters related to the characteristics of data access in wireless environment affect the performance of these strategies.

As the performance measure, the average access cost of data is used. In a network environment, cost is mostly associated with the number of network packets transferred to do an activity which is observed until it is completed. In a mobile computing environment, generally, network packets can be divided into two classifications, i.e., the data packet and the signal packet. The data packet consists of user data transferred from the server to the client and vice versa. On the other hand, the signal packet consists of data such as routing information, location lookup, and location update used by the system,. However, for the reasons mentioned below, we simply ignore the signal packet from our model.

Generally, the size of the signal packet is much smaller than that of the data packet. Thus, when considering both of them, ignoring the signal packet will improve the clarity of analysis and the resulting observation on the characteristic of each strategy. In a mobile environment, signal packets are exchanged using a separated channel from data packets. Therefore, separating the analysis of these two kinds of packets is more logical and makes our model closer to the real situation in mobile computing environments.

Without losing the generality, 50 mobile users are assumed to be sharing their databases with each other. The accesses include both ‘read’ and ‘update’. Access requests arrive according to the Poisson distribution and the access configuration, i.e., the portions of ‘read’ and ‘update’, are determined by the ‘write’ ratio. We assume that an ‘update’ operation will be preceded by a ‘read’ operation.

As for dynamic replication strategies, the implementations are as follows. As indicated by the name, the dynamic-single replication strategy is implemented by making each master database to only have single replica. In this strategy, each replica is initially allocated on the home location. As the simulation runs, mobile users start to move and access the shared data. The replication manager in the registration area where the user resides currently records every ‘read’ request from a mobile user. Periodically, the access statistics from all registration areas are collected and compared. Based on the comparison result, the system makes a replica relocated to the registration area where the ‘read’ accesses to it are requested mostly, and the statistics is reinitialized. In this way, the dynamic-single replication strategy is equal to user’s major replica allocation.

As for the dynamic multi-replication strategy, the adaptive data replication (ADR) with some modifications is adopted. The original ADR, metaphorically, forms a variable-size that stays connected at all times, and constantly moves towards the 'centre of read–write activity'. The replication scheme expands as the ‘read’ activity increases and contracts as the ‘write’ activity increases. In our model, we have assumed that the replicas are allocated on the replica servers associated with registration areas. That means, the dynamic multi-replication strategy does not assume any connected situation.

However, as in the original ADR, ‘read’ the closest replica serves requests and all access requests (including the updates) are recorded. In each registration area, the access statistics are periodically tested. A replica of data is made available in a registration area, if during the access statistic evaluation period, the number of its ‘read’ is greater than the number of its ‘write’. Otherwise, the registration area will cease keeping the replica. In this way, the replication level changes dynamically following the read–write patterns but it is guaranteed that at least one replica for each data exists in the fixed network. In general, the average access cost increases in all strategies when the network scales up. However, the way the access cost increases in each strategy is slightly different, depending on the ‘move’ and ‘update’ frequencies.

6 Conclusions

In a wireless GIS environment, it is possible to access data anytime and anywhere without a fixed network. In this paper, we discussed distributed spatial data transfer-

ring strategies and the replication strategies of the wireless GIS.It is possible to improve the availability of wireless GIS which such a technology. Due to the use of wireless network, WGIS may have very low availability without the effectively transferring scheme and data storage strategies. This may lead to inefficiency in data sharing and interoperation among mobile users.

In this paper, we introduced the characteristics of wireless GIS transferring and storage. The basic framework and the environment of WGIS are deployed in an integrated network. By analyzing the distributed wireless data transferring scheme, it was found that it depends on both software and hardware technologies in order to improve WGIS transfers and increasing transferring velocity. The possible solutions may include for example, spreading software protocol and employing new mobile equipments.

The performance of replication strategies depends on many factors, such as network scale, mobility, access ratio and access concentration. It was found that in most circumstances, dynamic replication strategies excel to static replication strategies, and the performance of the dynamic multi-tiers replication strategies is the best.

Nowadays, the wireless equipments become more and more excessive and wireless GIS has been applied in many fields, like business, retailing, medicine, etc. Spatial data transferring and storage in distributed wireless GIS is a challenge area to be further developed. More and more comprehensive GIS application with 'wired velocity, infinity freedom' will be realized.

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