A Mobile Spatial Information Service framework based on Mobile Computing and Middleware technology

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Abstract: In this paper, a new mobile spatial information service framework based on mobile computing and middleware technology is proposed. Unlike the traditional mobile spatial information service framework, which applies partially mobile communication to send mobile user's requirement, receive and display the query result about spatial information, this new type of mobile spatial information service framework integrate the mobile computing technology, mobile communication technology, middleware technology, web services technology and spatial information technology etc. in order to raise the application level and Qos (quality of services) of mobile spatial information service, make it to be more convenient to both mobile users and stationary users, and be equipped with capability of inosculating spatial information with other non-spatial information, such as multimedia, various report forms etc . Even the new ones have the character of better mechanism in aspects of reusability, extensibility, interoperability.

Keywords: Mobile Spatial Information Service; Mobile Agent; Middleware; XML

1 Introduction

Mobile spatial information service can be defined as applications which provide spatial information and associated services accordingly on mobile devices (Personal Digital Assistants, smart phones, in-car computers, palmtop computers and so on.) or fixed devices by analyzing the position of their uses firstly. For the lastly decades, many mobile spatial information service system (commonly known as mobile GIS or location based service) has been built up for providing the real-time location service on any time, at any places, to any things and for any bodies. The Strategies Group of MapInfo is already predicting that take up rates for mobile location services will reach 480 million by 2005, and Sun Microsystems analysts predict that mobile location services will grow to 25 million consumers in the U.S. alone by the end of 2005. The enormous market stimulates some large companies and research groups to further their efforts to integrate key technology to form mobile location service solution——mobile spatial information service architecture, and obviously will be promoted to a high application level in reverse.

The efforts to architectures for mobile location service are the following:

◇Sun[sun Microsystems,2002], Oracle and MapInfo company have developed Java Location Services platform[3]， which is composed of client layer, application service layer and data service layer. This platform has adopted MapXtreme middleware to access data server for meeting the need of application service layer, and the application service layer, including location application server, Oracle database server and mobile location server together, act as coordinators between multi-type of terminals.

◇ OGC has introduced Open Location Services Initiative — OpenLS[Harry Niedzwiadek,2002] for LBS system. OpenLS comprises of an open location service platform——GeoMobility Server and several OpenLS Abstract Data Types (ADTs), and has adopted the specifications of OGC, ISO, W3C, IETF, OMA/LIF, 3GPP, AMIC,MAGIC, WAP, JAIN and Parlay。

◇ESRI also has proposed ArcLocation solution—Spatial Server、Connector、Toolkits and ArcPAD, which make full use of the advantage of GIS platform(i.e. ArcGIS)，Spatial Server integrates spatial database engine ArcSDE, location middleware and mobile application service based of SOAP and OpenLS XML API.

◇Mapinfo corporation [MapInfo 2001] have built MapInfo miAware^{TM} platform for LBS according to mobile location services conception framework. MapInfo's location based solutions allow wireless service and content providers to offer personalised wireless Internet services dynamically based on customer location. miAware is designed to allow network operators, infrastructure vendors, application service providers and content providers to deliver new revenue generating location enabled applications.

◇Oracle Corporation[Oracle Corporation2002] has brought forward LBS framework based on Oracle9iAS Wireless.Oracle9i AS' extensible framework supports a full spectrum of wireless and mobile applications, making it easier and more cost-effective to develop and deploy mobile solutions. Oracle9iAS Wireless provides application developers independence from the underlying wireless infrastructure - underlying networks, protocols, devices, gateways and other wireless complexities.

◇In 2000 Motorola, Ericsson and Nokia had built LIF（Location Interoperability Forum）aiming to develop common LBS solution, now LIF is a membership of Open Mobile Alliance(OMA).

◇Intergraph's IntelliWhere LocationServer[Intergraph 2002] integrates the industrial criterion of OGC, Open Location Services Initiative, LIF, XML, Web Services, Microsoft and Oracle, which is a Spatial Query Engine that acts as a Web Service, taking Spatial Queries in XML format, answering the query and sending the result back to the calling application via XML, acts as an interface between GIS and other mainstream applications to provide mobile spatial information service based on XML.

◇Professor Li Qingquan also has introduced a mobile spatial information service solution, in which spatial information application service is independent of spatial data and spatial information service platform is of independence with professional oriented platform. Data source, service platform and application service are three logic layers in this mobile location service architecture. Data source layer manages spatial data in relational/object-oriented database and different format files, as blood in human body. Service platform construct basic components such as runtime management, communication, naming service, transaction, security, message, log service, email service and so on for application service platform. And application service platform is field-oriented application service built on infrastructure—service platform in reverse.

In conclusion, mobile spatial information service has constructed its communication platform via mobile communication and Internet technology, commonly being three-tiers layers (representation layer, middle layer and data layer) system. The application areas are navigation service, mapping service, public information service and government management, as yet the main functions of these are:

- Geo-Coding;
- Analysis query: neighborhood query, context query, clicking query, naming query, route planning and geo-statistics;
- Navigation;
- Mapping service, data visualization;
- Flow work management, allocation resource;
- Real-time information publishing, etc.

However, current mobile spatial information service exists several disadvantages:

- Unintelligent service way: it cannot adjust service pattern (online and offline) dynamically, once in disconnected way, it can only furnish fewer and limited service;
- Waste bandwidth consumption: because it always move large amount of data to another server, on the same time this transaction processing will waste communication link and computer resources;
- Simple representation: mobile terminals often represent spatial information very simple due to mobile terminal platform or hardware;
- Deficiency of analysis ability: the analysis ability is weak thanks to mobile communication network and low capacity mobile terminal;
- Lack of extension mechanism for new service;
- Absence of the capacity of mobile computing.

In this paper, a mobile spatial information service (MSIS) framework based on mobile computing and middleware technology will be presented. Some issues like communication approach and protocol, terminal hardware and software OS, GIS based application, optimization rules and strategies in this framework are considered in the following section.

The paper will be structured as follows. Section 2 presents a mobile spatial information service framework, starting with brief introduction of mobile agent, then expatiates on the overall framework and individual components, the roles which plays in mobile spatial information service system and their relationships to each other. Next it shows the implementation events in sequence and layered architecture, lastly depicts the ascendant application feature and implementation character of the framework based mobile computing and middleware technology. Section 3 illuminates a mobile spatial information service through the framework based mobile computing and middleware technology in a scenario that an employee, on his way to office, wants to purchase a land for his further investment projects, triggering the graphical evaluation of this land and the finding shortest path from here, with the results being printed by printer on his office desktop, and sending it to his own cellular phone in the form of SMS message and geographical map around the land. Section 4 concludes the related works about mobile spatial information service or LBS, sums up the aspects of the new framework in this paper and gives some advices for further works and points out that we treat the framework as an attractive one at the direction of pervasive computing or ubiquitous computing and the basic and essential exploration for the promising computing mode.

2. mobile spatial information service framework

2.1 why mobile agent ?

An agent is a program that is autonomous enough to act in independently even when the user or application that launched it is not available to provide guidance and handle errors [Robert Gray, David Kotz, et al.1996]. Mobile Agents are computing entities that act on behalf of a principal (user, group, organization) and can autonomously migrate during the execution from one host to another one to continue their operations there [Paola Bellavista, et al.2001].Mobile agent technology is considered an enhancement of distributed technologies as it provides powerful and efficient mechanisms to develop application for distributed and heterogeneous systems [Claudia Raibulet, Claudio Demartini.2000].

Mobile agent technology has become so popular primarily because of the reasons:

■Providing efficient way for access and manipulation of remote information[Claudia Raibulet, Claudio Demartini.2000].

■Enhanced flexibility, Reduced bandwidth consumption, improved fault tolerance, support for disconnected operation[Gian Pietro Picco.2001];

Reduced Network Load (advantage of the code on the same host or the network as the target objects);

■Overcoming network latency;

■Encapsulate protocol[Gian Pietro Picco.2001];

■Executing asynchronously and autonomously, Flexible Remote Execution;

■Adapting dynamically;

■ Naturally heterogeneous(mostly developed in Java).

2.2 mobile spatial information service framework

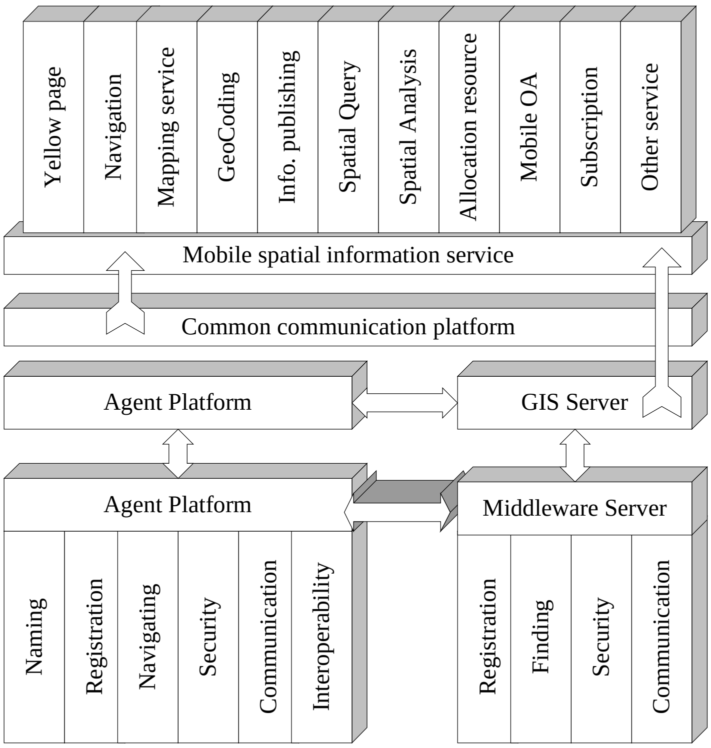

Fig 1. mobile spatial information service framework

The framework (see Fig.1) relies on a three-tier architecture comprising three main layers, namely service representation layer, application server layer and network communication layer. All communications between the service representation layer and application server layer are conducted through the network communication layer. The application is executed on the service representation layer using a static agent that running in lightweight agent platform or in Java Virtual Machine (JVM). The agent communicates with application server using the existing HTTP, RMI/IIOP networking protocols and ATP (Agent Transfer Protocol).

The service representation layer is in charge of receiving spatial information and related information, displaying map the user is interesting, organizing and expressing data inquired about, gathering user's intention and then encrypting it into agent code, dispatching agent to remote host and retracting agent from remote host. A wide spectrum of applications of the service representation layer provided for user include yellow page, navigation, mapping service, geo-coding, information publishing, spatial query, spatial analysis, resource allocation, mobile OA, information subscription, and others.

The application server layer contains several server groups described in the following. GIS server group is responsible for all GIS based transaction. As it is a core server group, at the fewest one of this type should supplies the shear volume of geo-data including raster, vector, attribute and other data, and furnishing GIS function components or middleware for spatial analysis, spatial query, transmission and displaying. And one group or a server also updates itself indexes values on the fly aiming at servicing mobile agent or other transaction efficiently and fleetly.

Agent platform server group comprises of several agent platforms running IBM agets2.0 respectively. Aglets are Java objects that can move from one host on the network to another, that is, an aglet that executes on one host can suddenly halt execution, dispatch to a remote host, and start executing again [Aglets Specification1.1, 1998]. The agent platform aglets provide an easy and comprehensive model for programming mobile agents without requiring modifications to Java VM or native code, and offer the basic functionalities of agent creation, agent cloning, agent dispatching, agent retraction, agent disposing and killing, removing registry and so on in a life cycle. The dynamic class-loading mechanism are developed for meeting the demands of calling the classes of an agent need to be available at the server. In the platform security mechanism for these security services: authentication of sender, the manufacturer, and the owner of the agent, authorization of the agent (or its owner), secure communication between agent systems, non-repudiation and auditing, is designed to protect agent and agent platform against masquerading, unauthorized disclosure and unauthorized modification. Some security techniques including partial results encapsulating, execution tracing, computing with encrypted functions and time limited black box [V. VARADHARAJAN and D. FOSTER,2003] can also be designed and added in the agent system.. The extended naming services are appended to support: location-independent names, services for name creation and name resolution, protection of name registry entries, protection of name-spaces delegated to different users and entities [Anand R. Tripathi, et al. 2002]. Agents of this system can communicate with remote application server, agent platform, and other agents using the existing HTTP, RMI/IIOP networking protocols and ATP (Agent Transfer Protocol). The interoperability solution in this paper like those Paola Bellavista [Paola Bellavista,et al. 2001] discussed to permit the inter-working between MA platforms and other systems, even non-MA-based, via compliance with either accepted or emerging interoperability standards. In particular, it focuses on compliance with CORBA, the accepted standard for object-oriented components, but also with MASIF（Mobile Agent System Interoperability Facility）and FIPA（Foundation for Intelligent Physical Agents）, respectively , the OMG specification for the support of agent mobility and management, and the framework for standard agent platform and communication languages, the details can be found in [Paola Bellavista, et al. 2001].

Middleware, performing a variety of functions on behalf of applications running on mobile and fixed internet-connected clients, becomes more critical due to proliferation of wirelessly connected mobile computing devices [Steffen Lipperts, Anthony Sang-Bum Park.1999; RAJIVE BAGRODIA, et al.2003]. Middleware server group integrates the middleware service mechanisms of registration, finding, security and communication to implement a number of problems to the world, for instance complex topologies, scalability, heterogeneity and increased complexity due to parallel execution paths. The profile service, registration service and telecommunication services of middleware service center facilitate the mobile spatial information service between the application server, agent platform server, and users working on heterogeneous mobile and fixed clients.

In the mobile spatial information service framework, shown in figure 1, we have interpositioned the GIS application server, and middleware server between the mobile or fixed clients and agent platform server to provide a number of benefits. The eventual design goal called for service group to contain a number of geographically located servers that would best service the clients at the nearest path and in the fewest time, in addition, service groups can also be appended to the whole service network easily, further more the topology of service network could be adjusted dynamically to optimize location based service rules and enhance the quality of service (Qos).

2.3 framework implementation

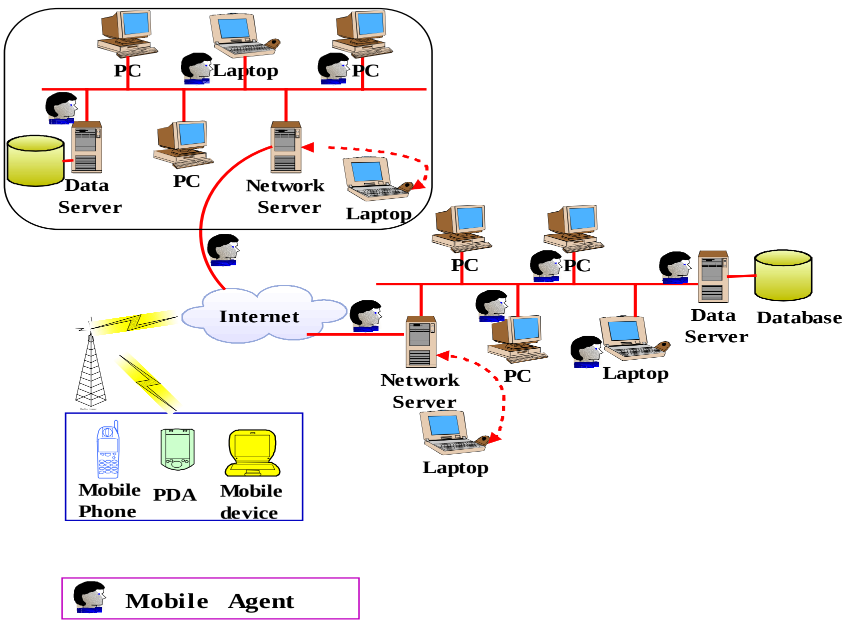

Fig 2. mobile spatial information service implementation

Fig.3 depicts the basic implementation approach and hardware environment of mobile spatial information service. The terminal of this service, consisting of different hardware with a wide range at price, can be classified into two categories, one is mobile device (mobile phone, PDA, laptop, in-car computers, palmtop computers and so on), the other is fixed device (desktop PCs, TV set, control systems etc.). The server groups can be divided into GIS based application server, middleware service server, mobile agent server and mobile communication server. Mobile communication network and Internet are two main communication ways in mobile spatial information service framework, acting as many road networks between all terminals and application servers.

Here is a sequence of a few events that occurs in the framework.

1. First, the user gives an instruction associated with spatial information service via terminal. This is done by static agent or terminal interface communicating with user to understand intention and goals of the spatial information services . The agent or terminal program analyze this service, encrypt it and other data including migration route list, limited lifetime, time stamp, identification and inner status value by using public key certification and sign it with digest value. After successfully encryption the agent is cloned and send the cloned one to destination server using ATP, or migrate to it directly. The other way is that the terminal sends the service request in the form of XML to the destination through Internet or mobile communication network using HTTP and WAP.

2. If the destination server receives immigrated mobile agent, the server push it into agent platform—aglets2.0 and transfer the privilege to aglets. Then the aglets platform decodes the immigrated agent, checks the digest of it according to predefined security rules. If no tempering is detected, it allows the immigrated agent to regale itself on agent environment to the full extent of corresponding security permission, and check the privilege of the agent in determining whether the operation requested by the agent is to be allowed or not. Else if the destination server receives XML requests, it decoded the XML requests for intentions of user according to predefined rules.

3.If the server has the capability of providing the corresponding middleware or components to handle requests, it will accomplish the user’s purpose immediately and return the result to terminal by same means the server having accepted. Otherwise, the agent terminates its execution, serializes itself and then migrates to middleware server or GIS application using ATP for making full use of corresponding middleware, components or functions of them, and finally carry the result to the terminal via nearest server, but to XML requests they send handling requests to middleware server or GIS application server, and run it locally, also return the result back to terminal in terms of XML using HTTP and WAP.

4. The terminal decodes returned results and feeds them back to user via geo-map, message, text or table and so on.

2.4 layered architecture and characters of the Framework

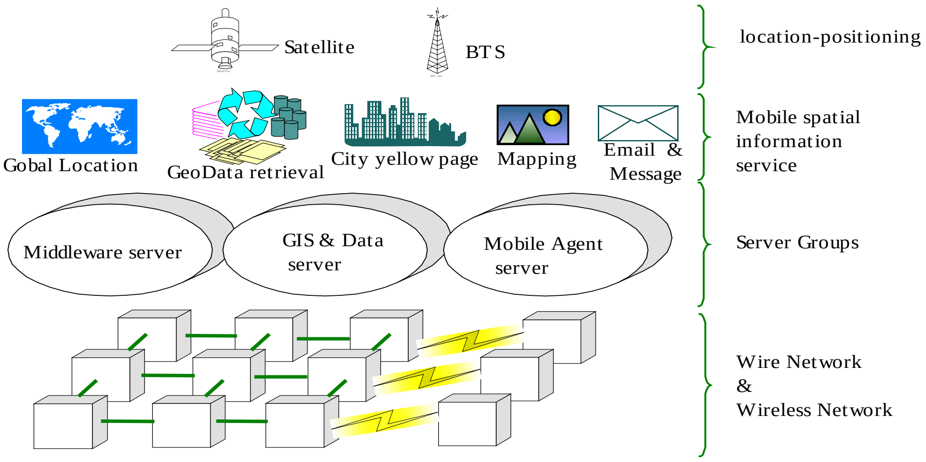

Fig 3. Layered architecture of mobile information service

The framework proposed in the paper can be layered as Fig.3. The location-positioning layer and wire network & wireless network layer provide essential and synergic communication infrastructure for users or terminals to obtain location information, which is the precondition of providing mobile spatial information service. Server groups layer is in charge of the spatial information amalgamation, extracting spatial information and processing related data, encapsulating and encrypting correlative data into XML files or mobile agents in running system. Mobile spatial information service layer is the representation layer to users, which acts as some assistant tools dig unknown gold in a broad gold mine efficiently, and becomes the interface between terminal users and spatial information in remote hosts. All of them form an organic and high-powered service system.

Table 1. Characters of the framework

Network	wire network and wireless network
Positioning	GPS positioning and BTS positioning
Mobility	mobile computing, mobile service
Bandwidth consumption	low according to mobile agent technology
Ability of spatial analysis	strong
Server distributing	distributed, centralized or both
Operation	support for disconnected and connected
Executing	asynchronously and autonomously
Protocol	WAP,HTTP,XML,SOAP,ATP
Security	access control and service control
Potential	promising thanks to append new middleware

Out of all peradventure, the mobile spatial information service framework here, combining mobile agent technology, middleware technology, mobile communication technology and spatial information technology, therefore is in possession of effective and multi service characters shown in Table1. Mobile agent technology enriches the power of expression of mobile spatial information service and spatial information analysis in distributed environment, and reduces the bandwidth consumption on account of flexible mobility ability, even makes it possible that program segment execute itself in disconnected ways. Wire network and wireless network including Internet and commercial mobile communication network are used to transfer encrypted information via WAP, HTTP, XML, SOAP, and ATP protocols.

3. An Example

In a scenario that an employee, on his way to office, wants to purchase a land for his further investment projects, triggering the graphical evaluation of this land and the finding shortest path from here, with the results being printed by printer on his office desktop, and sending it to his own cellular phone in the form of SMS message and geographical map around the land. Firstly a program segment in cellular phone asks the owner to specify the preference and conditions of purchasing land. Then the received preference information is encrypted into binary data together with other environment parameters as xml elements in XML format file, and request is sent to remote server groups through commercial communication network and Internet via WAP and HTTP protocols. Commonly mobile GIS or LBS system receive the request and extract related spatial data or files to GIS server for this service, thus GIS server waste time, network bandwidth consumption and other

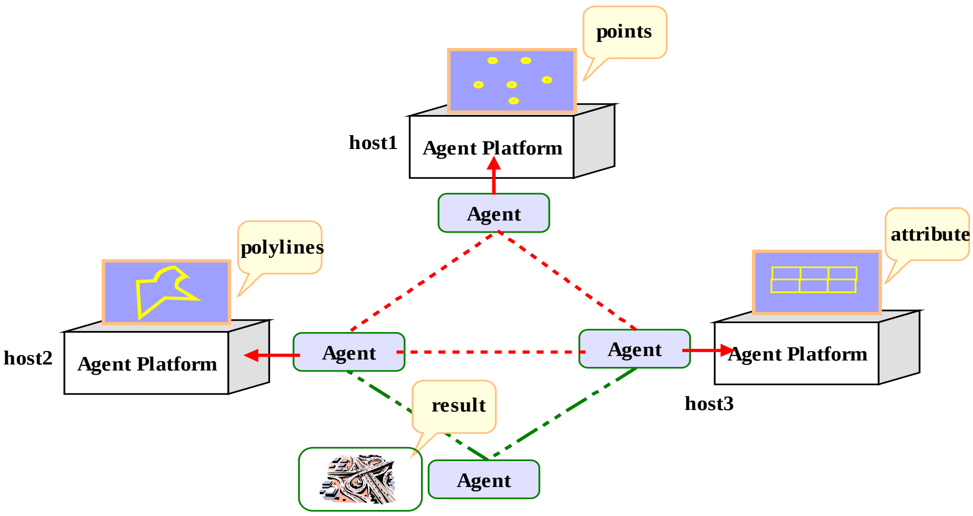

Fig 4 . an application example between three hosts

computer resource to transfer the large amount of data and analyze the data with GIS middleware and interface. But now we solute this problem by virtue of mobility technology of mobile agent in mobile agent system, just as Fig 4, the points, polylines and attributes of prerequisite for spatial analysis reside in host1, host2 and host3 respectively for GIS application demonstration. Firstly an agent, assigned to above mission, is created by one of agent platforms, and also is initialized the itinerary, inner code, inner status and credentials by the agent platform. Then the task-oriented agent dispatch itself to the remote hosts in sequence of predefined itinerary (for instance: host1-host2-host3), after arriving at host1, it authenticate itself in agent platform in host1, if it succeed the authentication, the agent search the boundary points of target land and serialize them in inner code, next the agent terminate itself and release any consumed resources by it and migrates into host2. If the mobile agent's migration is successful, the agent platform in host2 reconstructs an agent from the content of a request of mobile agent and start executing the agent, and the reconstructed agent search related polylines in road network and geographical map according to boundary points found in host1, then calculate the route to the object. Analogously the agent migrates into agent platform in host3 to find important information such as transaction and amalgamation or segregation history of this land, and evaluated price and so on. As a result the agent have fetched all information about this service, lastly the agent send the result to employee's cellular phone with text message and pocket geographical map, simultaneously a copy is sent to employee's office computer, which will be triggered to print all results if corresponding program in computer have received it successfully.

4 Conclusion and current work

The design, implementation and deployment of mobile spatial information service motivate the flourish of mobile GIS, LBS(Location Based Service) or MLS(Mobile Location Service), capable of providing people with various service under the help of GIS application service and mobile communication network. Mobile computing is a basic and absolutely necessary character to mobile spatial information service. The paper has introduced mobile agent technology—a flexible mobile computing programming paradigm, to mobile spatial information service framework, therefore the framework inherits several merits of mobile agent paradigm such as low bandwidth consumption, distributed and centralized server arrangement, supporting for connected and disconnected operation, asynchronous and autonomous executing, rigorous security management, and so on. In addition to characters of mobile agent, is also support wire network and wireless network, GPS positioning, various protocols (WAP, HTTP, XML, SOAP, ATP, etc.). Particularly mobile agent and middleware technology enable the special mobile spatial information service with the capability of service negotiations among huge amount of resources over Internet and spatial information server (H Lee, M A Buckland and J W Shepherdson.2003).

The paper has introduced the overall framework based mobile computing and middleware technology in the aspect of implementation, layered architecture, qualities of application. Here we don't claim that we have provided a complete solution to mobile spatial information service, rather we treat it as an attractive one at the direction of pervasive computing or ubiquitous computing and the basic and essential exploration for the promising computing mode. Further work, on one hand, will focus on the integration of mobile agent with CORBA and CORBA-based standards, which will play an important role in interoperability between different agent platforms that are compliant to MASIF or FIPA, and the interoperability of heterogenous GIS application server. On the other hand more mobile information service (see Fig 1. mobile spatial information service framework) will be developed excluding the current mobile spatial information services: in-car navigation and handheld devices like PDA, Pocket PC and WAP phones for flood prevention and mobile OA.

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