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A 4S Design on Mobile Ad hoc Networks

Eun-Kyu Lee, Mi-Jeong Kim, Byoung-Woo Oh, and Min-Soo Kim

Tangible GIS Research Team, Spatial Information Technology Center,
Electronics and Telecommunications Research Institute (ETRI)

Abstract : A provision of spatial information is expected to make a market explosion in various fields. A distribution of spatial data on wireless mobile environments indicates a huge expansion of mobile technology as well as a spread of geospatial applications. For high-qualified spatial information, the 4S technology project that is integrating four kinds of spatial systems is currently being executed with the goal of nationwide integration of spatial data and spatial information systems. In terms of network environments, a mobile ad hoc network where mobile terminals communicate with each other without any infrastructures has been standardized for the next generation mobile wireless network. With respect to the future technologies for spatial information, it is necessary to design 4S applications on mobile ad hoc networks. This paper addresses the issue, which is proposing design concepts for distributing 4S spatial data on mobile ad hoc networks and for ad hoc styled 4S applications.

Key Words : 4S, Spatial Data, Mobile Ad hoc Network, Mobile GIS.

1. Introduction

Mobile wireless computing is expected to have large scope of its application and frequent utilization with fast technological development of personal computers and wireless networks. A distribution of spatial data on wireless mobile environments indicates a huge expansion of mobile technology as well as a spread of geospatial applications.

As the demands for high-qualified spatial information are increased, a lot of attention is being focused on spatial information system and related technologies. 4S technology project is currently being executed with the goal of nationwide integration of spatial data and spatial information systems. 4S represents four systems that are commonly related to spatial information: GIS (Geographic Information System), GNSS (Global Navigation Satellite System), SIIS (Spatial Imagery Information System), ITS (Intelligent Transport System). 4S also means a new technology that integrates the four systems by supporting interoperability. The main goal of 4S technology is to integrate the four systems and to remove the redundant time and effort of developing each system separately, which is expected to bring in synergy effect to each system.

Telecommunication industries have tried to

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standardize and develop GIS related services based on communication systems. A mobile terminal on those mobile systems plays a client that gets geospatial data throughout infrastructures such as switches, routers, and gateways. Recently, the infrastructureless networking, commonly known as an ad hoc network, has been considered as a candidate for the next generation wireless mobile environment. Without any infrastructure, mobile terminals communicate with each other through intermediate terminals in their network and cooperatively maintain network connectivity. Therefore, there exist no special routers, switches, or gateways for communications.

In ad hoc networks, a mobile terminal works both as a host and as a router. They are likely to communicate with peer terminals rather than a 4S server with open security and limited power. Therefore, it is necessary to take a new design concept that is fitted to ad hoc networks. Moreover, 4S spatial data has a complicated characteristic that comes from each feature of spatial data. For 4S data, it is necessary to define the communication method and applications on various network environments. This paper addresses the issue, which is proposing design concepts for a distribution of 4S data on mobile ad hoc networks and ad hoc styled 4S applications.

This paper is organized as follows. Section 2 describes the 4S integration technology including 4S applications on mobile environments. Section 3 reviews mobile ad hoc networks; the characteristics and the application area. In Section 4, we analyze the properties of 4S spatial data and propose a new architecture where 4S spatial data is distributed. In Section 5, we touch the general 4S applications and their extensions on mobile ad hoc networks. We also show simple application examples of the extensions. Finally, this paper is concluded in Section 6.

2. 4S Integration Technology

(Joo *et al.*, 2002) designs and constructs the integrated 4S system based on component paradigm that is one of the promising trends in software development field. It studies about the extension of the OpenGIS Component software technology to the 4S project.

1) 4S Component Systems

For the design and implementation of the component system that handles spatial data, the basic and core functions required for four systems are defined, specified, categorized, and developed as a component named as a 4S kernel component. Developing common functions as the 4S kernel component, the integration of 4S can be achieved. With the components developed, the redundancy of four systems can be reduced and the interoperability among four systems can be increased.

The 4S data provider component enables accesses to the heterogeneous spatial data over a common interface. The 4S kernel component has basic and core functionalities, which spatial information systems should have, such as display, analysis, and basic process of spatial data. The GIS component contains database, spatial reference system, rendering, data format, spatial

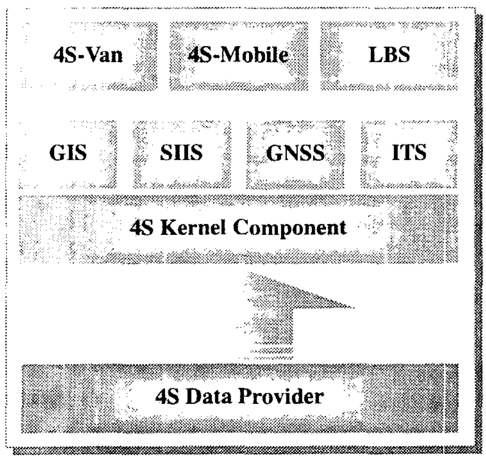


Fig. 1. Component-based 4S system.

analysis and operation, Web GIS, mobile GIS, 3D GIS, etc. The SIIS component is related to satellite imagery including preprocessing, rendering, image analysis, and so on. The GNSS component contains location determination, network assisted GPS, real-time and post-processing survey, communications, and error correction. The ITS component is corresponding to transportation technology such as traffic control, communications and messaging, electronic billing, and routing. The whole architecture of the 4S component system is illustrated in Fig. 1.

2) 4S Application Areas

The 4S technology can be applied to many application areas. Based on the 4S kernel components, corresponding application and service components are being developed, which help services provision and easy construction of application systems.

The 4S-Van is a vehicle for the acquisition and construction of spatial data, that is equipped with GPS, CCD camera, IR sensor, IMU, etc (Oh *et al.*, 2001). It collects and acquires real-time position data and image in an automated method. The 4S-Van application component by assembling functionalities is developed for the 4S-Van functionality. The 4S-Mobile combines 4S technology with the state-of-the-art mobile communication technology and infrastructure. The 4S-Mobile component supports functions and interfaces that are related to the 4S technology in a mobile environment. For services of 4S data and information, the web server and client applications for mobile device such as PDA are developed. The LBS (Location-Based Service) component is for application area that services location or location-related information to moving terminals through wire or wireless communications.

3) 4S-Mobile Framework

Spatial applications can process vector map such as building boundary, raster map such as satellite image, road information using ITS, location information obtained from GPS (Global Positioning System), etc. They consist of construction of data, clearinghouse, and applications. Spatial data for mobile environment are constructed from existent spatial data sources, managed by a server for distribution, and used by application systems as shown in Fig. 2.

The 4S-Mobile data construction system that uses data provider components creates spatial data that is optimized to mobile environment via the process of coordinate conversion, map integration from distributed 4S spatial data. The created spatial data can be stored in clearinghouse server and used whenever users want by accessing to the server through wireless modem or wireless LAN. The application system on 4S-Mobile environment can be classified to 3 groups: web browser using ActiveX component or Java applet, dedicated client/server architecture, and standalone system.

(Oh *et al.*, 2002) developed four application systems: the mobile event application, the parking management system, the fire report application, and the spatial data construction system for car navigation system. It also designed a web pad for 4S-Mobile hardware that is suitable for public LBS such as the national disaster management system. The characteristics of the 4S-

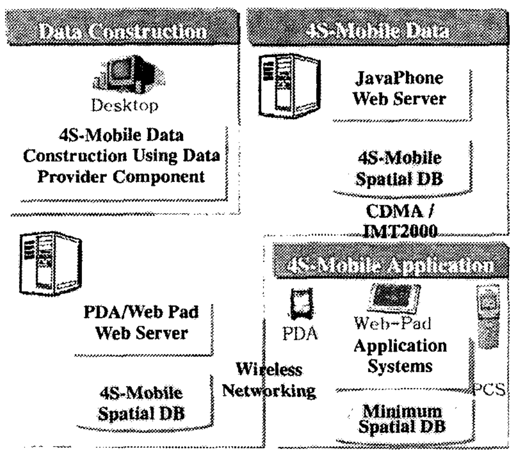


Fig. 2. 4S-Mobile framework.

Mobile hardware are as follows.

- Wide touch screen display LCD for map manipulation in outdoors
- Portable device with long-lasting battery (or extra batteries)
- Large amount of built-in memory
- GPS for acquiring current location
- Wireless communication for spatial data transfer anywhere
- USB master for accessories such as external hard disk, camera, etc.
- USB slave for data synchronization between desktop computer
- PCMCIA slots for future extension

3. Mobile Ad hoc Networks(MANET)

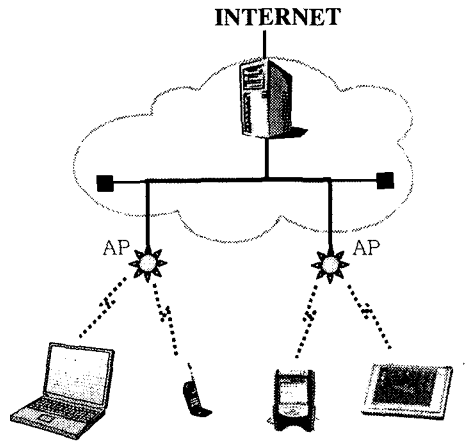
In this section, we review the characteristics of the MANET. A MANET is an autonomous system of mobile terminals that are free to move around arbitrarily. The terminals may be located in or on vehicles, small devices, even on people. The system may operate in isolation, or may have interfaces with a fixed network. In general, terminals in a MANET are equipped with wireless transmitters and receivers using antennas. Terminals can make wireless connectivity depending on their positions, coverage patterns of signals, transmission power levels, and interference state via channels at a given time.

The IETF (Internet Engineering Task Force) has a MANET working group in which establishes industrial specifications related to MANET routing protocols. Under this working group, (S. Corson, 1999) proposes 4 salient characteristics associated with the MANET. At first, the MANET has dynamic topologies. Terminals are free to move arbitrarily; thus, the network topology may change randomly and rapidly at unpredictable times. Secondly, bandwidth-constrained or variable capacity links are considered. Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In the third place, mobile terminals in a MANET do energy-constrained operation. Some or all of the terminals in a MANET may rely on batteries or other exhaustible means for their energy. For these terminals, the most important system design criteria for optimization may be energy conservation. The last one is about limited physical security. Mobile wireless networks are generally more prone to physical security threats than are fixed-cable nets. The increased possibility of eavesdropping, spoofing, and denial-of-service attacks should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. These may give many constraints into the MANET. There has been lots of endeavor to solve constraints involved in the MANET.

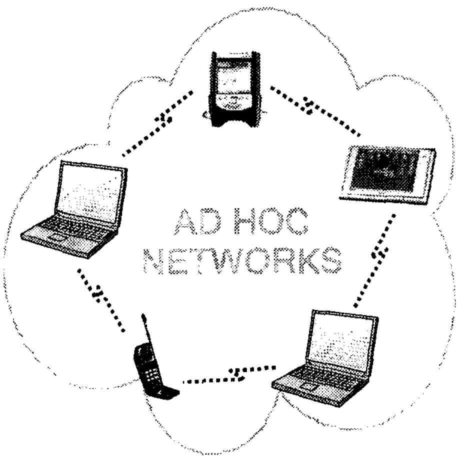
On comparing to currently-used wireless networks using networks infrastructure, the MANET does not use infrastructures decreasing dependence on them. The MANET has advantages on the deployment of networks; it can be deployed easily and quickly. Fig. 3 can give an abstract comparison a MANET to a current wireless network.

A MANET can be deployed into many kinds of field. However its characteristics and requirements must be considered before deploying it because it has quite different type of structure. Application areas of the MANET are as follows.

- Personal area netwo rking (cell phone, laptop, ear phone, wrist watch)
- Civilian environments (taxi cab network, temporary conferencing, sports stadiums)
- Military environments (soldiers, tanks, planes)
- Emergency operations (search-and-rescue, policing and fire fighting)



(a) Infrastructure Networking.



(b) Infrastructureless Networking.

Fig. 3. Wireless mobile networking.

4. Distribution of 4S Spatial Information

1) 4S Spatial Data

A GIS is a spatial data in forms of vector such as a building boundary, road, and natural objects. In the 4S technology, the GIS data can be transformed into WKB (Well-Known Binary) format from OGC. The ITS spatial data contains database of road information gathered from sensing equipments on streets and map data used to distribute the information efficiently. The GNSS spatial data contains location information including navigation, surveying, vision obtained from GPS. The SIIS contains and processes visual images captured on satellites. The 4S technology takes advantage of Grid Coverage specification of OGC as a SIIS component.

Each spatial data is normally used in conjunction with others as shown in Fig. 4. The ITS can provide car navigation services and traffic information with the GNSS. It can also provide a collecting technology of traffic information by processing high accurate image with the SIIS. The GIS can provide real-time mobile GIS applications with the GNSS. The SIIS can provide a technology of automatic correction of spatial data and make maps for spatial data with the GIS.

Because the 4S spatial data includes four types of spatial data, the characteristic representing the 4S spatial data includes various indexes for various types of data. And it is necessary to make relationship between each spatial data appropriately. From the viewpoint of network, the 4S spatial data is expected to be large in its size. This can put a burden on network overload. On understanding data transmission is limited on the Internet, the data size should be considered on its design procedure. The 4S spatial data is sensitive to data loss during transmission. 4S applications may fail to work with a loss or error of a bit of data. Because the current

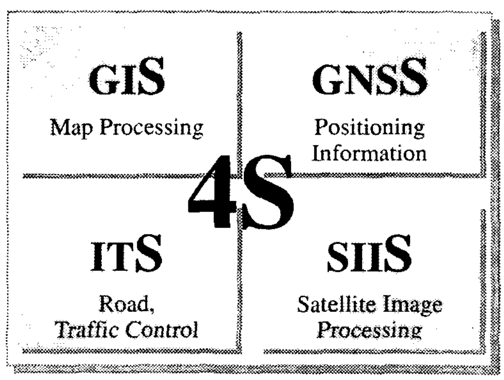


Fig. 4. Integration of 4S spatial data.

Internet is unconcerned with quality of data transmitted, it is considered to guarantee a data that is transmitted without loss. A security issue should be touched because the 4S spatial data contains private information such as location information of a user, vector information that should be protected from redistribution, and spatial information charged.

2) Web Distribution of 4S Spatial Data

The 4S application systems on mobile environments can be classified to three groups: web browser using ActiveX component or Java applet, dedicated client/server architecture, and standalone system. ActiveX component and Java applet executed in web browser can be used to access web. In order to meet specific requirement, dedicated client approach can be adopted. Socket communication is widely used in client/server architecture. If wireless communication is not convenient, standalone system that stores necessary spatial data in its own memory can be used.

The OGC Web Services architecture (General Service Model, GSM) consists of service requestor, service provider, and service broker (OGC, 1999). The architecture follows the publish/find/bind paradigm to actualize the 4S applications with support of dynamic binding. The service provider publishes services to a broker (registry) and delivers services to the service requestor. The service requestor performs service discovery operations on the service broker to find the service providers it needs and then accesses the service provider for provision of the desired service. The service broker helps service providers and service requestors to find each other by acting as a registry or clearinghouse of services. The Fig. 5 shows the architecture and scenario.

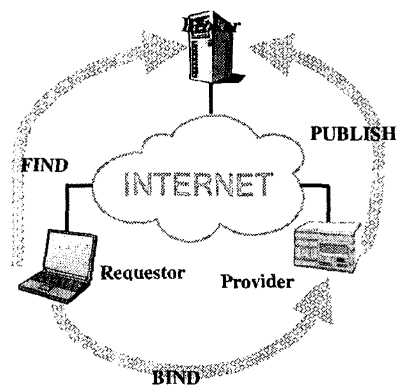


Fig. 5. OGC Web service architecture.

3) Distribution of 4S Spatial Data On *Mobile Ad hoc Networks*

The most outstanding point on 4S application systems on mobile ad hoc networks is its architecture. Mobile ad hoc networks do not have any provider; there are only requestors. Therefore, it is necessary to change the architecture for data transmission. All mobile terminal works as requestor in a mobile ad hoc network. They work as provider and broker at the same time. When a terminal wants to get 4S spatial data from others, it can become a requestor. When it provides data, it can become a broker and a provider. Fig. 6 shows this scenario.

In mobile ad hoc networks, it is necessary to distinguish a data type of 4S applications. The data transmission in mobile ad hoc networks can be subdivided into two parts according to the transmission distance; single hop data transmission and multi hop

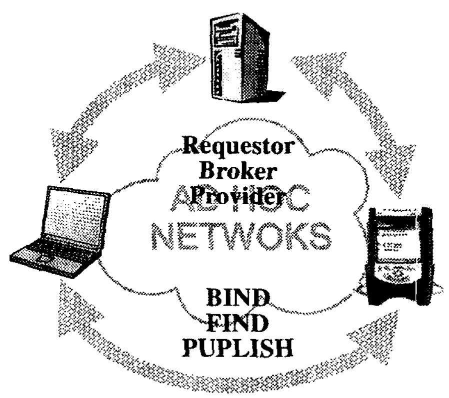


Fig. 6. Service architecture on ad hoc networks.

data transmission. In single hop data transmission, 4S spatial data is exchanged with neighbor terminals because a terminal can identify neighbors and their links easily. In multi hop data transmission, however, an overhead is burdened to intermediate terminals forwarding data. On considering the energy-constrained characteristic of ad hoc terminals (see Section 3) and large size of 4S spatial data, intermediate terminals may consume more energy than others. This is because they forward others data. These properties should be considered when designing the 4S applications. For example, 4S spatial data can be exchanged in single hop data transmission. On the other hand, meta data containing information of 4S spatial data can be exchanged in multi hop data transmission.

A mobile terminal in a mobile ad hoc network can be a standalone 4S application system. It may need to update 4S spatial data from servers that are located over the Internet. It may also request 4S spatial data to others that are connected with wired networks. In order to actualize these scenarios, it is necessary to communicate with wired networks like current Internet environments. Therefore, we should consider the integration mobile ad hoc networks with wired networks.

The design of 4S architecture should consider the place where a 4S application is actualized. An outdoor 4S application is likely to be affected by exterior condition such as propagation interference, network partitioning, and lack of data. It can take advantage of a GPS receiver gathering its location information from satellites and utilize the information. An indoor 4S application, however, cannot use the GSP system. It can exchange 4S spatial data under more stable network environment. It is necessary to consider these properties when designing the 4S applications.

4S spatial data should be compressed. A mobile terminal generally consumes much energy in sending, forwarding, and receiving data. A compression technology can decrease the size of 4S spatial data, which cannot only reduce the energy consumption of a terminal, but also its corresponding terminals. This can also decrease the amount of data on mobile ad hoc networks, which lightens the network load.

A security issue should be considered because mobile ad hoc networks are open and public and 4S spatial data should be protected. Traditional encryption technologies or security and authentication methods fitted to mobile ad hoc networks can be applied. It is needed to develop a security technology for handling spatial data.

5. 4S Applications on Mobile Ad hoc Networks

In this section, we identify the use cases of 4S applications and 4S applications appropriate for mobile ad hoc networks.

One type of the 4S application is a client invocation of location services. User actions on a mobile or stationary terminal, or actions initiated by a service provider, will lead to the invocation of 4S application service. Event notification by an ad hoc user or a provider can give location information as well as the contents of the event. Directories are interested in the nearest business or a specific place, product, or services that could be any place. Ad hoc users can request information to neighbors that have the required data or a gateway that can contact to the data resources through wired networks. Route services are provided. Given two or more known user specified locations, the user wishes to compute the optimal route between the locations and then display the route and/or turn-by-turn driving directions. A taxi cab network based on ad hoc paradigm can provide route services with ad hoc communications between taxies. 4S applications support map/feature display and interaction. It fetches a map or collection of features, displays them on the user terminal, and allows the user to 'pinpoint' a map feature and obtain its properties. Ad hoc users can get the map/feature data or meta information of the map/feature data from his neighbors or a gateway. The users can get location. Given a user with a mobile terminal and a provider with a Mobile Positioning Server and various sources of location-based information at their disposal, a user wants to know its location. Users are likely to have data for location where they are working, so ad hoc users can access to the location information easily. Ad hoc users can also take advantage of a gateway to request positioning data from Mobile Positioning Server. The users can also be provided traffic services. Traffic services provide the conduits for traffic feeds. Basically, the user is given the traffic conditions along his route or in his area. With respect to the taxi cap network, ad hoc users can be also given traffic information additionally. Persons and assets can be tracked down. The user is interested in locating a specific or the nearest person(s) or asset(s) of a known type. The subscriber and the service provider basically enter into a lightweight agreement concerning how the service provider will use subscriber location data, as well as other private data.

4S application with ad hoc paradigm can be applied to military environments. Soldiers on battle fields are equipped with 4S application systems and communicate with colleagues to execute their operation. The communication messages include a plan, an objective, order, and map of the operation. Search-and-rescue can take advantage of a 4S application. Rescuing in the place where network infrastructures cannot be set up can be safely accomplished with 4S spatial information. One of the 4S applications is related to tourism. A tour guide can let tourists watch their courses at the fields by broadcasting the tour map to them. The map may contain additional information of the target attraction, which tourists can get real time information of it.

6. Conclusions

In this paper, we reviewed the 4S technology integrating four kinds of spatial systems; GIS, GNSS, SIIS, and ITS. The 4S technology is expected to be able to remove the redundant time and effort of development and bring in synergy effect to each system. We also showed the mobile ad hoc network highlighted for the next generation mobile wireless network environments and its characteristics. The 4S spatial data were analyzed for the adaptation onto the mobile ad hoc networks. We proposed design concepts when the 4S applications are applied on the mobile ad hoc networks. They contained the distribution architecture, the communication method, the distinction of services, and the data processing such as compression and security issues. The 4S application is expected to be prevailed with maturity of spatial information and popularization of mobile wireless networks.

This paper suggested a new integration on which the 4S technology and ad hoc networks are considered. They are under standardization and development, and result in many constraints and solutions. Therefore, we are going to adopt their endeavors in order to keep developing our work.

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