Performance Issues of GML Vector Data on Wireless Access Networks

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Abstract
With regarding to web GIS, Open Geospatial Consortium promotes Web Feature Service allowing a client to retrieve geospatial data encoded in GML which is a modeling language to encode the semantics, syntax and schema of geospatial information resources. Even though GML provides benefits for geographic description, it is too heavy for mobile devices to process. In order to address the issue, this paper evaluates a GML service with a WFS server and GML viewers. Through this paper, we analyze properties of GML geospatial data and effects on wireless environments.

Keywords
Geography Markup Language (GML), Wireless Network, Geography Information System (GIS), Web GIS, Web Feature Service (WFS)

I. INTRODUCTION

Geographic information technologies have steadfastly provided tools for collecting, storing, managing, analyzing, and reporting spatial information. Geography Information System (GIS) technology has provided many governments and other organizations with an opportunity to introduce major improvement in traditional methods and procedures of providing services to citizens and customers. With traditional desktop-based GIS, it can be difficult to make your information available to all users - or indeed, islands of data and information may exist due to lack of a central database and visualization capability. However, the Internet and associated technologies are making it possible to design and deploy very affordable and scaleable applications using GIS visualization and analysis. The ability to quickly and easily disseminate spatial data via existing web architectures is enormously powerful and has the potential to minimize many of these limiting factors associated with traditional GIS architectures.

With regarding to standard of web GIS, Open Geospatial Consortium (OGC) has promoted research projects and proposed implementation specifications of web interfaces. A Web Feature Service (WFS) specifies web interfaces for describing data manipulation operations on geographic features. It allows a client to retrieve geospatial data encoded in Geography Markup Language (GML) that is a modeling language to encode the semantics, syntax, and schema of geoprocessing-related information resources. Even though GML provides benefits for the geographic description, it is said that it is too heavy to be processed by mobile devices such as Smartphones and PDAs. In order to address the issue, this paper evaluates a GML service on multiple wireless architectures with a WFS server and GML viewers. Through this paper, we analyze properties of GML geospatial data and effects on wireless network environments. The research results are expected to be fundamental materials onto a design of system architecture for mobile devices.

The rest of this paper is organized as follows. The current status and issues of mobile web GIS, especially service platforms promoted by OGC are reviewed in Section II, Section III and IV describe details on GML and on architectures for wireless networks respectively. The experiments, results and analyses are presented in Section V. Finally, we conclude this paper in Section VI.

II. MOBILE AND WEB GIS

This section presents mobile GIS, web GIS, and their standards on which geospatial services can be implemented and deployed.

A. Mobile GIS

Mobile computing technology comes from the evolutionary changes of computers since 1990s. Mobile phones, laptop computers and personal digital assistants (PDAs) have set high standards for mobile devices, and offer a myriad of options for improving communication across organizations and with customers or trading partners. Because of such mobile gadgets which enable users to access an information network from anywhere and at any time, users are accustomed to getting more done wherever they are and having the latest information available at their fingertips all the time. In geospatial industries, GIS technologies have provided applications, which collect, store, analyze, and process the geographic data on the Earth. They include road facilities, buildings, electric circuits, and water facilities as well as map data or transportation information.

Recent advancements in GIS technologies, wireless

1082-4006/04/1002-129$5.00

communications, and mobile devices have made mobile GIS a reality. Mobile GIS is the use of geographic data on mobile devices, which is an evolution of how the enterprise database is used and managed within an organization. It includes essential components; mobile devices, global positioning system (GPS), wireless networks and GIS applications. A full range of mobile devices can be used for mobile GIS, from mainstream laptop computers with all the computing power of a PC to PDAs or cellular phones with smaller displays, simpler input devices, and limited processing power. Small devices for mobile GIS are usually coupled with GPS and a wireless communication module to facilitate data exchanges from existing spatial servers and satellites. Moreover, network-enabled devices rely on wireless connections to transport information, which gives a significant performance function due to different transmission rates of wireless networks. The GIS applications provide data and services to the user: they may offer location information contents and information processing services. The type of information and services provided varies depending on the type of application being used.

Mobile GIS is a natural expansion of the business system environment. It provides an entire workforce, from office-based analysts to field-based managers, with an immediate access to information. This immediate access to relevant and complete data results in faster solutions and better decisions for the entire organization because it gives field workers the independence to make on-the-spot decisions anywhere at any time. Field technicians can edit and update feature and attribute data onsite. As real-time access becomes more of a reality, mobile GIS will use existing data for more sophisticated query and analysis operations.

B. Web GIS

The use of Internet and related web technologies for accessing spatial data as well as for performing basic spatial query and analysis has opened the world of GIS to the masses. Web GIS means an access to GIS applications/functionality and data via a web browser. The term Internet GIS is occasionally used to describe an access to web GIS applications over the Internet, rather than on an Intranet. The intuitive user interface of a web browser is allowing users with limited technical skills to gain access to large amounts of data and to analyze, interrogate, and use the outcomes of sophisticated queries as a matter of routine. Web-based mapping is the fastest growing segment of the spatial-software industry.

For some applications, web-based applications can provide map visualization and analysis at the lowest possible cost per user. The result is more rapid and informed decision-making, which translates into higher revenue growth and greater cost reduction.

For standards of web GIS, OGC has defined a suite of web service interfaces that have explicit bindings for HTTP [2]. Specifically, there are two HTTP bindings for invoking operations of a service: GET and POST. Thus, the online resource for each operation supported by a service instance is an HTTP Uniform Resource Locator (URL). Only the parameters comprosing the service request itself are mandated by OGC web service specifications. The web services can be implemented and deployed on a layered architecture of technology and standards. The lowest levels of the stack enable connectivity of software components by enabling them to bind, send and receive messages. Higher levels in the stack enable interoperability and allow software components to transparently work together in more integrated and dynamic ways.

C. Web Map Service

A Web Map Service (WMS) produces maps of georeferenced data, where a map is defined as a visual representation of geodata; a map is not the data itself [9]. The maps are generally rendered in a pictorial format such as PNG, GIF, or JPEG, or occasionally as vector-based graphical elements in SVG or WebCGM formats. The WMS specifies the way how maps are requested by clients and how servers describe their data holdings. It defines three kinds of web operations: GetCapabilities, GetMap, and optionally GetFeatureInfo. The *GetCapabilities* obtains service-level metadata, which is a machine-readable (or human-readable) description of the WMS's information content and acceptable request parameters. The *GetMap* obtains a map image whose geospatial and dimensional parameters are well-defined. The *GetFeatureInfo* asks for information about particular features shown on a map.

A standard web browser can ask a WMS server to perform those operations above simply by submitting requests in the form of URLs. The content of such URLs depends on which of the tasks is requested. All URLs include a specification version number and a request type parameter. In addition, when invoking GetMap, a WMS client can specify the information to be shown on the map ('Layers'), possibly the 'style' of those layers, what portion of the Earth is to be mapped ('Bounding Box'), the projected or geographic coordinate reference system to be used ('Spatial Reference System', SRS), the desired output format, the output size, and background transparency and color. When invoking GetFeatureInfo, the client indicates what map is being queried and which location on the map is of interest.

D. Web Feature Service

The Web Feature Service (WFS) proposes HTTP web interfaces for describing data manipulation operations such as INSERT, UPDATE, DELETE, QUERY and DISCOVERY of geographic features on a distributed computing platform [3]. The WFS delivers GML representations of simple geospatial features, where the state of a geographic feature is described by a set of properties that can be thought of as a (name, type, value) tuple. Details on GML are described in the next section. A WFS request consists of a description of query or data transformation operations applied to one or more features. The request is generated on the client and is posted to a web server using HTTP. The WFS then is invoked to read and the request is executed. When the WFS completes processing the request, it will generate a status report and hand it back to the client. In the event that an error has occurred, the status report will indicate that fact.

In order to support transactions and query processing, a WFS defines operations: GetCapabilities, DescribeFeatureType, Get Feature, Transaction, and LockFeature. The *GetCapabilities* describes feature type lists that the WFS can provide and operation lists that are supported on each feature type. The *DescribeFeatureType* generates a schema description of feature types serviced by the WFS. The schema descriptions define how the WFS expects feature instances to be encoded on input and how feature instances are going to be generated on output. The *GetFeature* allows retrieval of feature from the WFS: a request from a client is processed and an XML document containing a result set is returned to the client. The client is able to specify which feature properties to fetch and constrain the query spatially and non-spatially. The *Transaction* supports transaction requests consisting of operations that modify features: they are 'create', 'update', and 'delete' operations on geographic features. The *LockFeature* processes a lock request on one or more instances of a feature type for the duration of a transaction. The WFS can be either a basic WFS, which implements GetCapabilities, DescribeFeatureType and GetFeature operations, or a transaction WFS, which, in addition to supporting all the operations of a basic WFS, implements Transaction operation and optionally LockFeature operation.

E. Web Coverage Service

OGC promotes a Web Coverage Service (WCS) in order to support interchange and storage of geospatial data as 'coverages' in digital information [10]. A WCS provides an access to potentially detailed and rich sets of geospatial information, in forms that are useful for client-side rendering, multi-valued coverages, and input into scientific models and other clients. It returns representations of space-varying phenomena that relate a spatio-temporal domain to a range of properties. It allows clients to choose portions of a server's information holding based on spatial constraints and other criteria.

The WCS supports three different operations: GetCapabilities, GetCoverage, and DescribeCoverage. The *GetCapabilities* returns an XML document describing general information about the service itself, and summary information about the available data collections from which coverages may be requested. Clients would generally run the GetCapabilities operation and cache its result for use throughout a session, or reuse it for multiple sessions. The *DescribeCoverage* lets clients request a full description of one or more coverages served by a WCS server. A DescribeCoverage request lists the coverages to be described, identified by the coverage parameter. The WCS responds such a request with an XML document describing one or more identified coverages. The *GetCoverage* is normally run after GetCapabilities and DescribeCoverage replies showed what requests are allowed and what data are available. The GetCoverage returns a well-known coverage format, properties of a set of geographic locations. Currently, GeoTIFF, HDF-EOS, DTED, NITF, and GML are acceptable for the coverage format.

III. GEOGRAPHY MARKUP LANGUAGE (GML)

A geographic feature, an abstraction of a real world phenomenon associated with a location relative to the Earth, has been a starting point for modeling of geographic information. Recently, the *Geography Markup Language* (*GML*) becomes a new modeling language to encode the semantics, syntax and schema of geospatial and geoprocessing-related information resources [1]. GML is an XML encoding for the transport and storage of geographic information including the geometry and properties of geographic features. GML utilizes the OpenGIS abstract specification geometry model.

A. Feature geometry and properties

Like any XML encoding, GML represents geographic information in the text form. While a short while ago this might have been considered verboten in the world of spatial information systems, the idea is now gaining a lot of momentum. Text has a certain simplicity and visibility on its side. It is easy to inspect, change, and also be controlled.

GML is based on an abstract model of geography developed by OGC. This describes the world in terms of geographic entities called *features*. Essentially, a feature is nothing more than a list of properties and geometries. Properties have the usual name, type, and value description. Geometries are composed of basic geometry building blocks such as points, lines, curves, surfaces and polygons. For simplicity, the initial GML specification is restricted to 2D geometry; however extensions will appear shortly which will handle 2½ and 3D geometry, as well as topological relationships between features. GML encoding now allows for quite complex features. A geometrically complex feature can consist of a mix of geometry types including points, line strings, and polygons. It also supports a FeatureCollection which is a collection of GML features together with an Envelope, a collection of properties that apply to the FeatureCollection and an optional list of spatial reference system definitions.

An essential component of a geographic system is a measure referencing the geographic features to the earth's surface or to some structure related to the earth's surface. GML incorporates an earth-based spatial reference system which is extensible and the main projection and geocentric reference frames in use today. In addition, the encoding scheme allows for user defined units and reference system parameters. GML is going to provide even more flexible encodings in order to handle local coordinate systems such as used for mile logging etc.

B. GML-based encoding

GML becomes an important means of storing geographic information as well as basic encoding rules. There are GML-based encodings for Image and Map Annotations, Styled Layer Descriptors and Location Organizer Folders.

The Styled Layer Descriptor (SLD) encoding specifies the format of a map-styling language for producing geo-referenced maps with user-defined styling [13]. The XML for Image and Map Annotation (XIMA) defines an XML vocabulary to encode annotations on imagery, maps, and other geospatial data. The Location Organizer Folder (LOF) is a GML application schema that provides a structure for organizing the information related to a particular event or events of interest [14]. XML for Location Services (XLS) defines an XML-based application schema that defines the basic OpenLS Abstract Data Types (ADT) used by the OpenLS Core Services, and together, form the Information Framework for OpenLS Services [16]. Service Metadata is an XML vocabulary comprised of several parts for describing different aspects of a service. The units describe the service interface and the data content of the service. Image Metadata is an XML encoding used to adequately describe all types of images handled by OpenGIS Framework services. The Sensor Model Language (SensorML) defines an XML schema for describing the geometric, dynamic, and observational characteristics of sensor types and instances, which are devices for the measurement of physical quantities [15].

C. GML extensions

As GML has been adopted as *de facto* standard for geo-referenced information storing and exchanging, a number of researches utilizing and extending GML has provided advanced technologies and services.

Ahn [17] proposes S-XML (Spatial-eXtensible Markup Language), which extends GML by adding three schemas for mobile and location-based applications: voice schema, tracking schema, and POI schema. It also designs a spatial XQuery language in order to handle the S-XML data effectively. In this research, the geographic data are stored in a spatial database management system and the spatial XQuery constructs submitted by users are translated into spatial SQL programs and evaluated by the spatial database management system. Additionally, a simple form of voice interface for mobile systems is proposed and implemented. Guan [18] proposes a framework for accessing to and integrating distributed GISs by using mobile agent and GML technologies (Mobile Agent and GML based GIS: MAGGIS). In this research, mobile agents are used to overcome the limitations of traditional distributed computing paradigms in mobile Internet context, and GML is used to solve the heterogeneities of various GIS sources. A user submits a query to a server via web browser. Then the query is analyzed and optimized by the server, from which one or more mobile agents are created and dispatched to accomplish the query task cooperatively. Each mobile agent along with its sub-task travels from one remote server to another to gather the related information. All retrieved information is merged and presented to the user. Guo [19] presents a method to efficiently transform GML documents, for storing and exchanging geo-referenced information, to valid Scalable Vector Graphics (SVG) documents, for rendering graphical maps, with attribute grammars (GML-To-SVG Transformation, G2ST). When rendering GML documents in a Web browser, the GML document must be first transformed into a corresponding SVG document: SVG-based GML rendering. In order to support dynamic and interactive geo-referenced information rendering, the method uses Extensible Stylesheet Language Transformation (XSLT), a language for transforming XML documents into other documents recommended by W3C. The G2ST might allow users easily constructing transformation rules from GML to SVG guided by the pre-specified SVG schema.

IV. NETWORK ARCHITECTURE FOR DATA DISTRIBUTION

Wireless technologies represent a rapidly emerging area of growth and importance for providing ubiquitous access to the network. Recently, industry has made significant progress in resolving some constraints to the widespread adoption of wireless technologies. Some of the constraints have included disparate standards, low bandwidth, and high infrastructure and service cost. Wireless is being adopted for many new applications: to connect computers, to allow remote monitoring and data acquisition, to provide access control and security, and to provide a solution for environments where wires may not be the best solution.

A. Wireless Local Area Networks

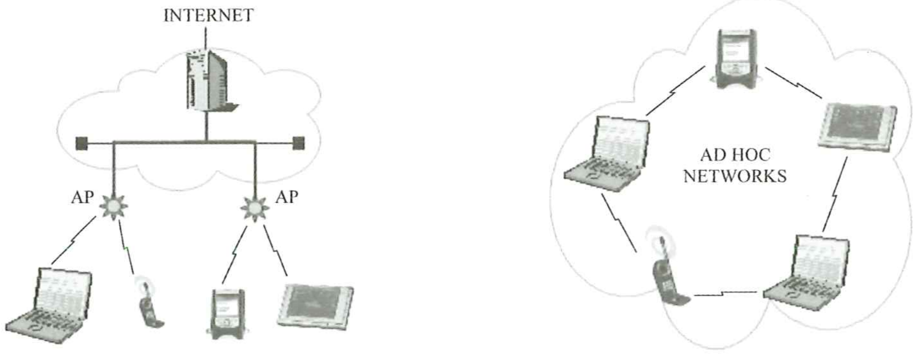
A Wireless Local Area Network (WLAN) is implemented as an extension to wired LANs within a building and can provide the final few meters of connectivity between a wired network and the mobile user. WLANs are based on the IEEE 802.11 standard series [12]. Most WLANs operate in the 2.4 GHz license-free frequency band and have throughput rates up to 11 Mbps currently.

WLAN configurations vary from simple, independent, peer-to-peer connections between a set of PCs, to more complex, intra-building infrastructure networks. There are also point-to-point and point-to-multipoint wireless solutions. A point-to-point solution is used to bridge between two local area networks, and to provide an alternative to cable between two geographically distant locations. Point-to-multi-point solutions connect several, separate locations to one single location or building. Both point-to-point and point-to-multipoint can be based on the 802.11b standard or on more costly infrared-based solutions that can provide throughput rates up to 622 Mbps. In a typical WLAN infrastructure configuration, there are two basic components. An *access point/base station* connects to a LAN by means of Ethernet cable. Usually installed in the ceiling, access points receive, buffer, and transmit data between the WLAN and the wired network infrastructure. A single access point supports on average twenty users and has a coverage varying from 20 meters in areas with obstacles such as walls, stairways, and elevators and up to 100 meters in areas with clear line of sight. A building may require several access points to provide complete coverage and allow users to roam seamlessly between access points. A *wireless adapter* connects users via an access point to the rest of the LAN. A wireless adapter can be a PC card in a laptop, an ISA or PCI adapter in a desktop computer, or can be fully integrated within a handheld device.

B. Mobile Ad hoc Networks

A Mobile Ad hoc Network (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.

The Internet Engineering Task Force (IETF) has a MANET working group that establishes industrial specifications. Under this working group, Corson [11] proposes 4 salient characteristics associated with the MANET. At first, 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 may rely on batteries or other exhaustible means for their energy. The last one is about limited physical security. Mobile wireless networks are generally more prone to physical security threats than are fixed-cable nets. These may give many constraints into the MANET. On comparing to currently-used wireless networks using access point/base station, the MANET does not use infrastructure decreasing dependence on locations. Therefore, a MANET has advantages on deployment of networks; it can be deployed easily and quickly. Figure 1 can give an abstract comparison of a MANET to a current WLAN.



(a) Infrastructure Networking (b) Infrastructureless Networking

Figure 1. Wireless mobile networking

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 MANET are as follows.

- Personal area networking (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)

C. Peer-to-Peer Networks

A Peer-to-Peer (P2P) is a type of network in which each workstation has equivalent capabilities and responsibilities. This differs from client/server architectures, in which some computers are dedicated to serving the others. The P2P technologies and policies, however, are not a new-comer to the field of computing science. The first implementation of the Internet was composed of computers-nodes that were behaving as equals or peers to each-other. Every computer had equal rights in sending and receiving packets. Of course, during those very early days of the Internet (Arpanet), those computers were used by experienced and co-operative researchers. Recently, a new technical definition of P2P architectures has been proposed and P2P systems involve a few key characteristics based on the new viewpoints.

- User interfaces load outside of a web browser
- User computers can act as both clients and servers
- The overall system is easy to use and well-integrated
- The system includes tools to support users wanting to

create content or add functionality
- The system provides connections with other users
- The system does something new or exciting
- The system supports 'cross-network' protocols like SOAP or XML-RPC

In this updated view of peer-to-peer computing, devices can now join the network from anywhere with little effort; instead of dedicated LANs, the Internet itself becomes the network of choice. Easier configuration and control over the application allows non networking-savvy people to join the user community. In effect, P2P signifies a shift in emphasis in peer networking from the hardware to the applications.

D. Mobile devices

Internet-enabled cell phones and PDAs have emerged as the newest products that can connect to the Internet across a digital wireless network. New protocols such as Wireless Application Protocol (WAP) and new languages such as Wireless Markup Language (WML) have been developed and tested specifically for these devices to connect to the Internet. However, the majority of current Internet content is not optimized for these devices; presently, only email, stock quotes, news, messages, and simple transaction-oriented services are available. Other limitations include low bandwidth, low quality of service, high cost, the need for additional equipment, and high utilization of devices' battery power. Nevertheless, this type of wireless technology is growing rapidly with better and more interoperable products.

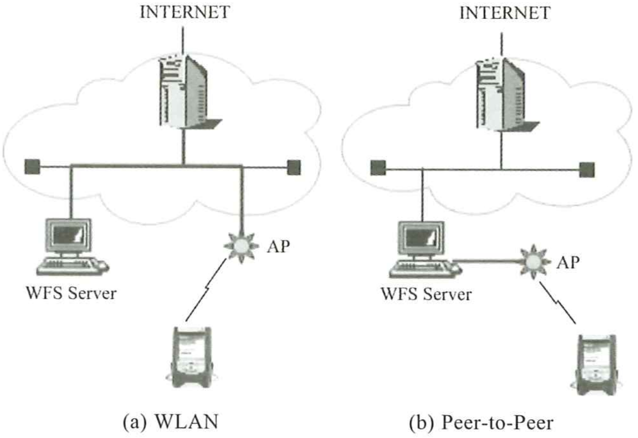
V. SERVICE EXPERIMENT AND ANALYSIS

This section describes details on experimental architecture and elements. Result values are exposed and analyzed for evaluation of GML vector web services.

A. Experimental environment

Even though the GML provides benefits for the geographic description, it is said that it is too heavy to be processed by mobile devices such as laptop computers and PDAs. In order to address the issue, this paper evaluates the WFS on multiple wireless architectures with a *WFS server* and *GML viewers*. In the experiment, we measure network capabilities for getting geospatial data from the server: *the network bandwidth* and *the transmission delay*. Then we measure the processing powers: *the GML loading time*, *the GML parsing time* and *the GML drawing time*. The experimental results are expected to show the performance evaluation of the geospatial application and transmission characteristics of the geospatial data on various mobile infrastructures.

With regarding to the WFS server, we implement a COM model that supports the WFS operations and an ISAPI extension for HTTP web exposes of those operations on a PC-based system [4, 5]. On systems which the GML viewer is run on, we take a mobile device: a laptop computer. The laptop computer has 1.6GHz CPU chip, 1GB memory, and wireless network adapter using 802.11b Wi-Fi card supporting 11Mbps. In experiments, we have two different types of network architectures shown in Figure 2. Figure 2(a) shows a normal wireless network environment: WLAN architecture. There is a server on network and a mobile client is able to access the server through access point (AP) and network. Figure 2(b) shows an environment supporting ad hoc peer network communication: P2P architecture. See the paper [6] for design issues of the P2P architecture.



(a) WLAN (b) Peer-to-Peer

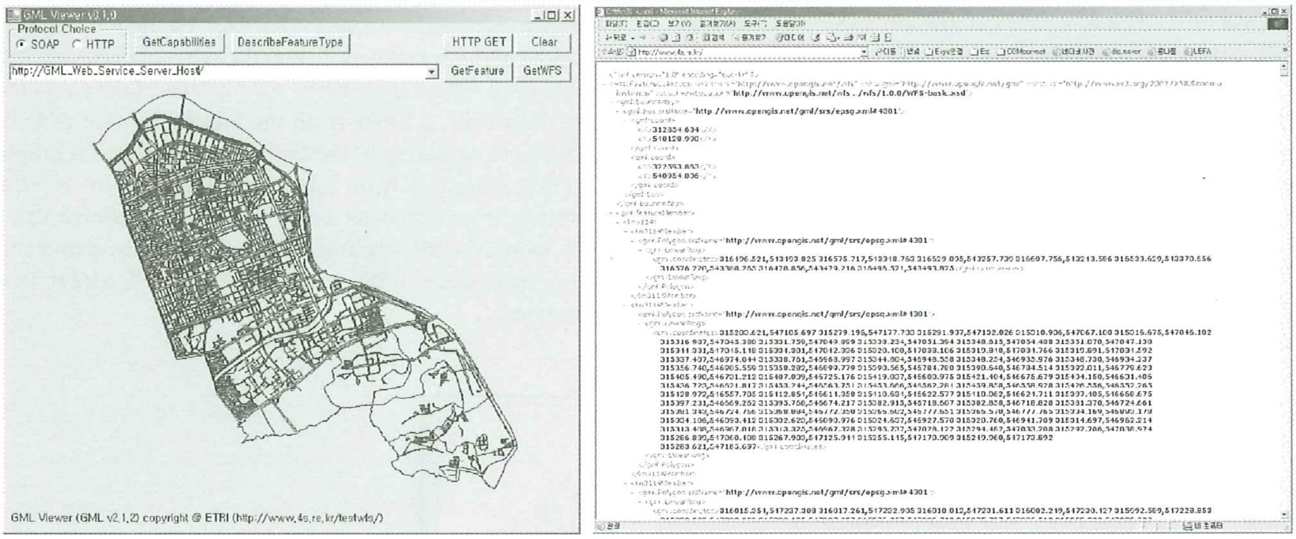
Figure 2. Network architecture for experiments

For experiments, we take 15 different GML data: they have different volume and information such as outlines or road of a district. Figure 3(a) shows a GML viewer, connecting the WFS server and receiving, parsing and drawing GML data. It now displays a part of 'Kangnam' district in Seoul. Figure 3(b) shows raw data displayed on a web browser.

B. Network performance evaluation

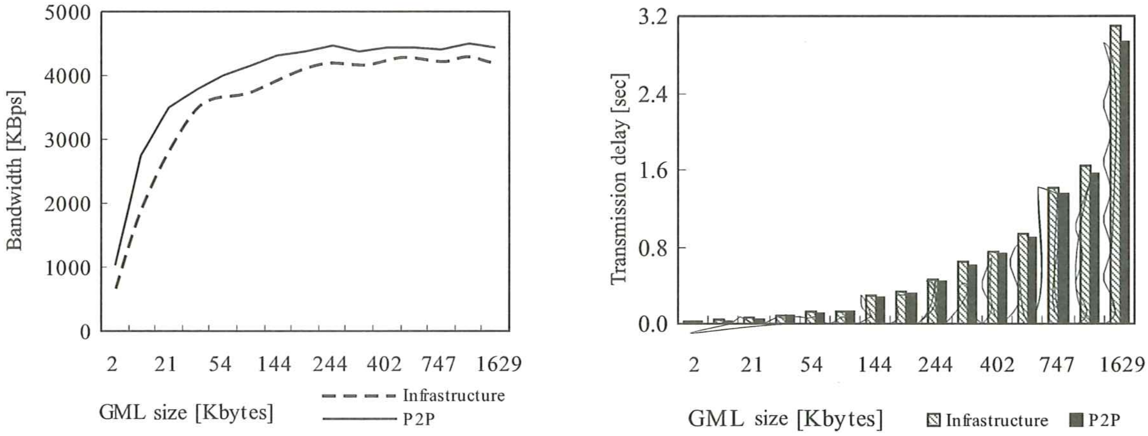
For network performances, this paper has network bandwidth and transmission delay on two types of wireless networks shown in Figure 4. The Figure 4(a) indicates the network bandwidth. P2P architecture, which gives better performance than WLAN architecture, has 3,933 Kbps in average and the difference of bandwidth is more than 300Kbps (about 9%). However, the gap becomes greater on hot spots or networks where lots of mobile devices try to access to the server: in this experiment we do try to reduce network overload as much as possible.

The results for transmission delay are shown in Figure 4(b). In common, the properties of the results are similar to each other: the larger the volume of data is, the longer the time takes to transfer on the two networks exponentially. The average value is 630 milliseconds out of the sample data on P2P architecture and the difference against those on WLAN architectures is about 35 milliseconds, which is shown in Figure 4(c). The

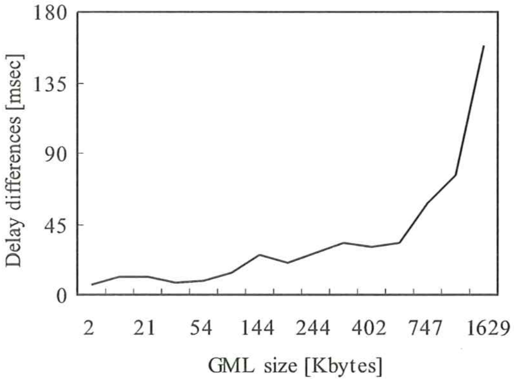


(a) A GML viewer (b) Web browsing of raw data

Figure 3. GML viewers



(a) Network bandwidth (b) Transmission delay



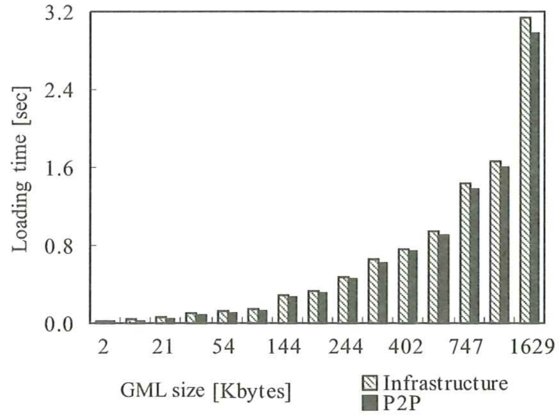
(c) Delay differences

Figure 4. Network performances

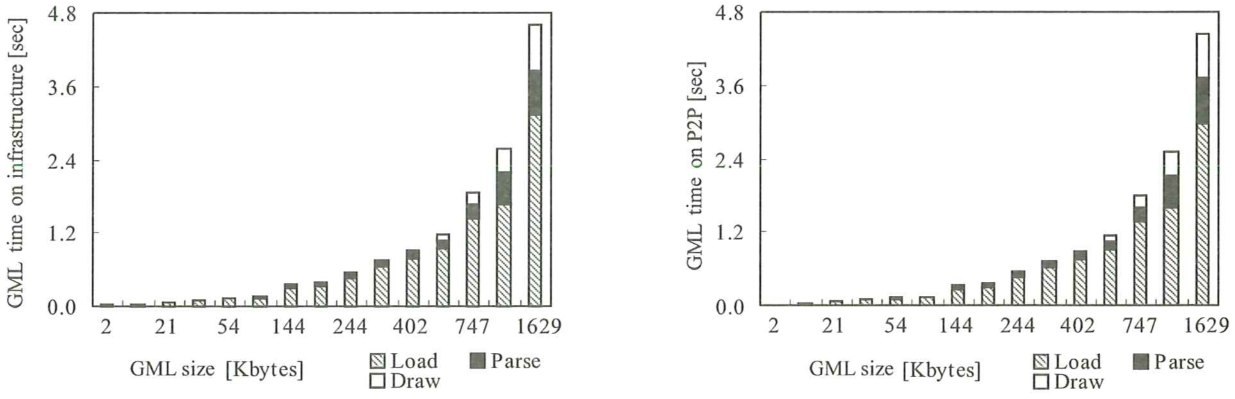
results expectation on hot spots is same to that of network performance. Therefore the difference is expected to become greater.

C. Processing capability evaluation

In order to evaluate the capability to process text-based GML data, we measure a few time parameters: GML loading time, GML parsing time and GML drawing time. Figure 5 shows the time taken to process GML data on the GML viewer. The total processing times, from receiving GML data from the WFS server to displaying it on screen, are shown in Figure 5(a). The time performance on P2P architecture gets 879 milliseconds in average and gets about 4% better than that on WLAN architecture. However, as mentioned, the difference becomes greater as the network overload gets heavier. The total processing time consists of three element values: GML loading time, GML parsing time and GML drawing time. Figure 5(b) and Figure 5(c) show the rates that each element contributes to the time performance on P2P and WLAN architectures. They indicate time values increase as the volume of data becomes heavy. However, a focus is on the increasing rate of GML loading time, which gets the highest percentage on graphs. The GML loading time has close relation to network performance: transmission delay. Therefore, it is expected to hugely increase GML loading time on AP hot-spot architecture and to introduce P2P architecture as an alternative environment.



(a) Total processing time



(b) Processing time on WLAN

(c) Processing time on P2P

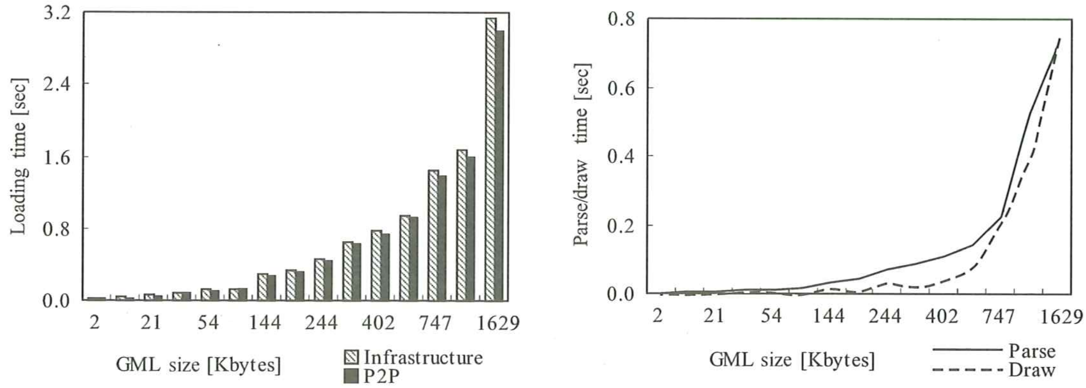
Figure 5. GML Processing Time

In general, the GML loading time has a close relation with transmission delay, which is shown in Figure 6(a). Like the results of transmission delay, as the volume of data becomes larger, the time to take initiative GML data on the two networks increases exponentially The Figure 6(b) shows the time value to parse and draw GML data on the GML viewer. The GML drawing time gets 102 milliseconds in average out of the sample data, which is about 25% lower than that in parsing GML data.

In this experiment, we measure the time when the WFS server processes GML data. The Figure 7 shows the results and the average value is about 10 milliseconds, which is lower than our expectation. However the shape of graph has same properties than others of measured parameters in this experiment.

D. PDA experiment

Figure 8 shows the results of additional experiment for comparison of different mobile devices. In this experiment, a light-weight mobile device, a PDA is used. The PDA has Intel PXA250 applications processor (400MHz) chip and 64MB memory on Microsoft Pocket PC 2002 operating system. It also equips 802.11b Wi-Fi wireless network card supporting 11Mbps. Other experimental environments except for the type of target device are same to those on WLAN architecture



(a) Loading time (b) Parsing and drawing time

Figure 6. Load/parse/draw time

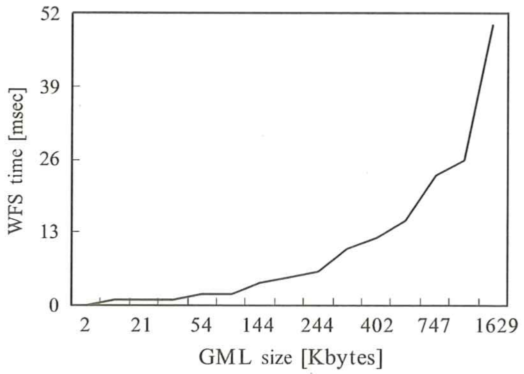
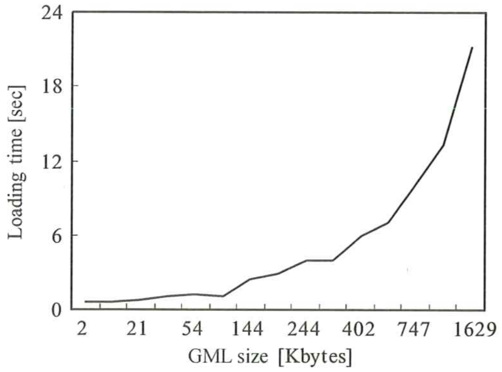
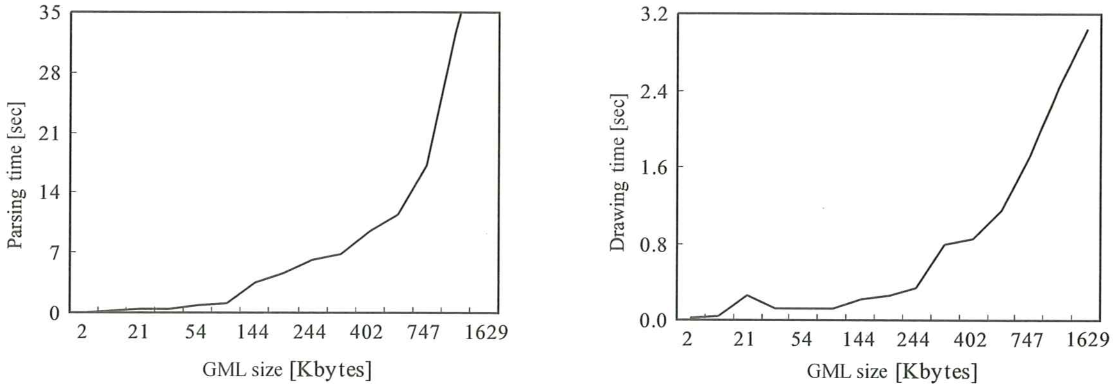


Figure 7. WFS server time

above. Each has values for loading, parsing and drawing time for GML data, too. In general, the larger data volume is, the more the overhead is to process GML data, which is same to the result showed in Figure 6. As volume becomes large, the overhead gets an exponential growth rate. On comparison between two mobile devices, the laptop computer has lower overhead to process the GML service than that of the PDA. Especially we can intuitively recognize the difference of time spent to load and parse the GML data. The PDA takes even more than 40 seconds only for parsing large volume of data: about 1.5Mbytes.



(a) Loading time



(b) Parsing time (c) Drawing time

Figure 8. Processing time with PDA device on WLAN

VI. CONCLUSION AND FURTHER WORKS

The development of GIS has been highly influenced by the progress of Information Technology (IT). Web computing is the single most important current IT trend, with mobile computing following on fast, and GIS has been at the forefront of adopting both technologies to great benefit.

In this paper, we touched the performance issues of a geospatial web service. Especially, we adopted GML, which was a XML-based description model for geographic features on the Earth, and WFS, which was providing GML representations of simple geospatial features in response to queries from HTTP clients. This paper reviewed the concepts and position of mobile and web GIS including standards. Then we studied GML on detail, because it had important properties that become a fundamental format of data transferring on web service architectures. In experiments, we took advantage of a WFS server providing GML notification containing outline and road information of administrative district of Seoul city. See [7], if you are interested in mobile applications.

Through this paper, we analyzed properties of GML geospatial data and effects on wireless devices. The research results are expected to be fundamental materials onto a design of system architecture for mobile devices. An implementation of GML services using SOAP, web transferring protocol taken from World Wide Web Consortium (W3C) is on our next research work.

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