Implementation of Sensor Observation Service Prototype for Interoperable Geo-Sensor Networks in Korean Land Spatialization Program

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Abstract Korean Land Spatialization Program (KLSP) is an R&D program of the National GIS Project for developing ubiquitous GIS technologies under the control of the Ministry of Land, Transport and Maritime Affairs (MLTM). The first program of the KLSP, which lasts from 2006 to 2012, initiated with $132 million of national funds and $42 million of private matching funds. Aiming to develop the 'Innovation of GIS technology for ubiquitous Korean land', the KLSP consists of five core research projects and one research coordination project to practically utilize and commercialize the results of core research projects. The Korean Land Spatialization Group (KLSG) is planning the KLSP Test-Bed for testing, integrating, and exhibiting the KLSP's outcomes. About 40% of the outcomes are related products to geo-sensor and wireless sensor network (WSN). Thus, interoperable, scalable and web accessible frameworks like an OGC SWE (Open Geospatial Consortium Sensor Web Enablement) are mandatory because some of the products must be connected to each other in a KLSG Test-Bed. The main objective of this paper is to introduce the KLSP Test-Bed and the SWE SOS (Sensor Observation Service) prototype, which is developed for interoperable geo-sensor networks of the KLSP.

Keywords : Sensor web, GeoSensor Network, Interoperability

1. Introduction

With the ongoing development of smart and miniature computing devices the ubiquitous computing environment has already become established. Among the various ubiquitous computing technologies, wireless sensor network (WNS) technologies affect particularly on GIS fields. With the advent of wireless sensor network technologies, the geospatial system had an opportunity to directly input real time data on geo-related phenomena. The integration of GIS and WSN, usually called ubiquitous GIS, has been expected as the 4th generation GIS technology next to paper map, digital map GIS and mobile/web GIS.

The Korean government is currently pursuing the 3rd National GIS project (2006-2010) for 'establishing spatial data infrastructure for u-Korea (ubiquitous Korea)'. The Korean Land Spatialization Program (KLSP) undertakes the R&D sections of the 3rd National GIS Project for developing core technologies of ubiquitous GIS. The Korean Land Spatialization Group (KLSG), which controls and manages the KLSP, is planning a KLSP Test-Bed for testing, integrating, and exhibiting the KLSP's outcomes. The KLSP Test-Bed will be built so that it would serve as a service provider of ubiquitous GIS using various the KLSP's products[1]. Because the products must be connected to each other in the KLSG Test-Bed for ubiquitous GIS service, interoperable, scalable and web accessible frameworks are mandatory.

Concerns over 'Sensor Web' technology for ubiquitous GIS service have been growing for the past

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several years. Several studies have been conducted on the sensor web frameworks and have focused on the interoperability among heterogeneous sensor systems in WSN. Representative sensor web frameworks (or architecture) include Sensor Web Enablement (SWE) by Open Geospatial Consortium (OGC), Open Sensor Web Architecture (OSWA) by Univ. of Melbourne, and Sensor Map Microsoft. The KLSP selected a framework of them and experimentally developed a prototype in the form of Sensor Observation Service (SOS) in OGC SWE. This paper introduces the design and implementation of the KLSP's interoperable SOS prototype.

This paper is organized as follows. The first chapter presents introductions, including the background and the objectives of this study. The second chapter introduces the KLSP and explains the characteristics of its outcomes, and the third chapter shows the interoperability between WSN related outcomes and necessity of sensor web framework. The fourth chapter explains the design and implementation of the SOS prototype, which was developed in this study, divided into two parts: producer part and consumer part. The last chapter summarizes the result of this study.

2. Korean Land Spatialization Program

2.1 KLSP Overview

The R&D part of the 3rd National GIS project (2006-2010), KLSP, is the largest ubiquitous GIS R&D project and one of the 'Value Creator (VC) - 10 Programs' of MLTM. The primary objective of the KLSP is to take the lead in technological developments for the realization of 'Ubiquitous Spatial Infrastructures for Digital Korea.' The first program of the KLSP, which lasts from 2006 to 2012, initiated with $132 million of national funds and $42 million of matching funds. Consisting of 5 core research projects and 1 research coordination project, the KLSP aims at the 'Innovation of the GIS technology for ubiquitous Korean land' to practically utilize and commercialize the results of core research. The KLSG (Director: Prof. Kim Byung-Guk), which administers the KLSP, was established in INHA university in Nov. 2006.

As shown in Table 1, the five core research projects include (1) geospatial information infrastructure, (2) land monitoring, (3) intelligent urban facility management, (4) Indoor/Outdoor Spatial Information based on Construction Design, and (5) ubiquitous GIS core software technology. The research coordination project organizes (1) Construction of the KLSP Test-Bed, (2) Service modeling and Standardization, and (3) R&D portfolio and business modeling.

Table 1. Organization of the KLSP

Core Projects		Sub-projects
#1	Geospatial Info. Infrastructure	Innovative Management of Geodetic Reference Frameworks
		Constructing Next Generation Digital Maps
#2	Intelligent Urban Facility Management	Data Acquisition of Land Monitoring
		Data Processing and Applying of Land Monitoring
#3	Land Monitoring	Centralized Urban Facility Management Platform
		USN based Monitoring Systems for Urban Facility Management
#4	Indoor/Outdoor Spatial Info. based on Construction Design	Renewal System of Geospatial DB based on Construction Design
		Acquisition and Application of Indoor Spatial DB
#5	Ubiquitous GIS Core S/W Tech.	Processing and Management of u-GIS Geospatial Information
		Customized Land Information

The objective of the 1st Core Research Project, 'Geospatial Information Infrastructure', is to develop technology and management systems for precise and advanced geospatial infrastructures with two main sub-projects: 'Innovative Management System of Geodetic Reference Frameworks' and 'Development of Next Generation Digital Maps'. These technologies are to provide the precise geospatial information infrastructure and to serve future oriented land information demands. The objective of the 2nd Core Research Project, 'Land Monitoring' which consists of 'Data Acquisition of Land Monitoring' and 'Data Processing and Applying of Land Monitoring', is to develop technology for real time monitoring of the Korean peninsula. The 3rd Core Research Project, 'Intelligent Urban Facility Management', is to develop the USN (Ubiquitous Sensor Network) based management systems for the urban facilities of ground and under-ground. The 4th Core Research Project, 'Indoor/Outdoor Spatial Information based on Construction Design', is to develop the indoor spatial awareness technology as well as the conversing and integrating technique between construction CAD data and GIS data for the national digital map updating. The 5th Core Research Project, 'Ubiquitous GIS Core Software Technology', is to develop the GIS software in the ubiquitous computing environment by processing, storing, representing and providing geo-spatial data for a wide variety of users.

2.2 KLSP Test-Bed

In general, R&D products are tested and evaluated in a 'Test-Bed', sometimes called 'Proving Ground', usually including facilities and fields for test. KLSG is planning to construct the 'KLSP Test-Bed' for implementing, testing and evaluating the various the KLSP's products on the field. The 'KLSP Test-Bed' will be a city size field which includes some testing facilities to evaluate the products and technologies. The Test-Bed also will be utilized as the KLSP's showcase with outstanding achievements and will grow into a ubiquitous GIS certification center in the near future.

Fig. 1 Concept of KLSP's Test-Bed

As shown in Figure 1, the KLSP's outcomes will be installed all over a city including roadways, buildings, and common-use channels. The main control center, the heart of the KLSP Test-Bed controls, manages, and administrates the outcomes and information of each core project for integrated services.

The KLSP Test-bed, where all the projects' results are integrated and tested, will have an integrated portal system that shows various research results and services. Actually, KLSP's results in the Test-Bed must be designed and developed to be interoperable with each other to work together well. The five core projects and numerous sub-projects in the KLSP are developed and managed by the different research institutes so that they have to have different properties. Because of these properties, the system integration should be attained as a common systematic frame so that the heterogeneous results may work together well. First of all, a project is regarded as a specific system and divided abstractly into five procedures such as acquisition, transmission, archive, process, and service in the flow of data or information. Then, by clarifying the complicated specifications of each procedure, the structure and infra-structure of the Test-Bed could be designed and proving elements and control center type also could be selected.

Because the KLSP's outcomes are all applicable to land, the properties of the land site are core factors to know and select the type of Test-Bed. Accordingly the KLSG is preparing the master plan for the Test-Bed. The Test-bed site will be selected through an opening bid on May 2009 to local governments which want to offer the site.

2.3 KLSP's R&D Outcones

As mentioned above, the KLSP consists of 5 core research consortiums including about 100 research institutes (R&D institutes, universities, companies). Because each institute has different research which develops different outcomes for its own purposes, the 34 representative outcomes are decided as final outcomes. 29 outcomes of our representative outcomes will be applied to the KLSP Test-Bed site and the rest of the outcomes could not be applied to the Test-Bed, because they could not be tested on the limited Test-Bed, but whole Korean Peninsula.

There are numerous outcomes related to sensors and sensor networks listed in Table 2. About 40% of the KLSP's outcomes are related research to geo-sensors and wireless sensor networks. Each outcome has a different purpose and is equipped with different types of sensor devices, and uses different communication media. All of the systems of outcomes transmit measuring data to the main control center. Because the main control center also has to process, restore, and service the data stream for users, the interoperability among systems should be a prerequisite.

Table 2. KLSP's Outcomes related to Geosensor Networks

Project	Outcome		Purpose	Equipped Sensors	Sensor type		Communication media
					Proximity	Mobility	
1st Core Project	Ubiquitous Geodetic Control Point		Location Service	RFID tag	-	Fixed	CDMA
2nd Core Project	Land monitoring system on UAV		Land monitoring	GPS, IMU, Digital camera, IR camera	Remote	Mobile	RF UHF
	USN based Land monitoring system		Land monitoring	Flame sensor, Ambient Humidity Sensor, Ambient Humidity Sensor Ambient Temperature Sensor, Soil Moisture Sensor	In-situ	Fixed	TRS
	CCTV based monitoring system		Land monitoring	VRS, DVR, Network CCTV	Remote	Fixed	Wire/CDMA
	Mobile USN based Land monitoring system	 	Land monitoring	GPS, CCD, Ambient monitoring sensor	In-situ	Mobile	Wibro/HSDPA
3rd Core Project	Underground Facility Sensor Network Package		Underground Facility management	Ultra sonic Flow Meter	In-situ	Fixed	Zigbee
	Ground Facility Sensor Network Package		Ground Facility management	Thermometer, Hygrometer, Anemoscope, Vibrometer	In-situ	Fixed	Zigbee
4th Core Project	WiFi based RTLS for Construction field		Indoor localization	RTLS	-	Mobile	-
5th Core Project	GeoSensor Date Stream Management System		Geo-sensor data management	-			
	u-GIS Data Integration & Analysis Package		Geo-sensor data analysis	-			
	Customized Spatial Data Provider Platform		Geo-sensor data web service	-			

3. Interoperable Geo-Sensor Network

3.1 Geo-Sensor Network

An article published by Neil Gross (1999) presented that, in the next century, planet earth would don an electronic skin. It would consist of millions of embedded electronic measuring devices. Now his prediction has been realized by conventional sensor systems and the latest WSN technologies. A Wireless Sensor Network (WNS) is a network of sensors, each with an embedded processing unit and wireless communication devices placed into the physical world (Hill et al., 2000).

There are many WSN products called 'Ubiquitous Sensor Networks' in Korea and many WNSs based on monitoring research projects like 'u-monitoring'. Actually sensor devices such as remote sensing satellite and wire or wireless sensor networks are installed to know what happens to the earth. From these sensor systems we can understand the physical phenomena and mutual relations among the objects in the surrounding environment. The data monitoring from the remote or fixed WSN will be used as an important data source in the GIS field. Because these data have all geographical coordination and some geo-content, the sensor network is called geo-sensor network (GSN). In geo-sensor networks the geo-spatial content of the information which is collected, aggregated, analyzed, and monitored by a sensor network is fundamental; this might be performed locally in real-time on the sensor nodes or between sensor nodes, or off-line in scattered or central repositories. Thus, a geo-sensor network may be loosely defined as a sensor network that monitors phenomena in a geographic space (Nittle et al., 2006).

3.2 Interoperability Problem

Interoperability is the ability of two or more systems or components to exchange information and to use the information that has been exchanged (IEEE, 1990). In other words the interoperability is likely to unify a language among human being for communications. The combination of the various and heterogeneous sensor systems can help to more easily understand the geospatial and physical phenomena on specific space. Most of these sensor systems or wireless sensor networks are designed with specialized algorithms, hardware, networking protocols, and operation systems for specific application. They cannot access, interchange, understand and use others' resource without knowledge of the unique characteristics of the sensor network system. Therefore interoperability between heterogeneous systems is essential to work co-operatively in the sensing applications.

As mentioned in Section 2.3 there are a variety of heterogeneous sensor systems in the KLSP outcomes. These sensor systems must be all interoperable in the KLSP Test-Bed, and the main control center of Test-Bed needs to control and collect the data from heterogeneous systems installed in a site. To conduct these functions, the interoperability should be fully guaranteed. In the KLSP's sensor systems there are various sensing devices to measure temperature, humidity, image and so on. Each system must send the measurements from sensor devices to the KLSP main control center for the observation data collection in the same massage format, and the main control center in the KLSP Test-Bed also must have ability to understand the data message.

3.3 Sensor Web

In the previous chapter we realized the importance of the interoperability among heterogeneous systems. Recently the 'sensor web' technology is in the limelight as the good solution to interoperability problem. A Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed with standard protocols and application program interfaces (APIs)[1]. The Sensor Web is achieved by connecting the distributed and heterogeneous in situ/remote sensors by open and interconnected networks to an information center that stores, disseminates, exchanges, manages, displays, and analyzes the sensing information. Interoperability is the key to integrating all of these components and to achieving the vision of Sensor Web(S. H. L. Liang, 2005).

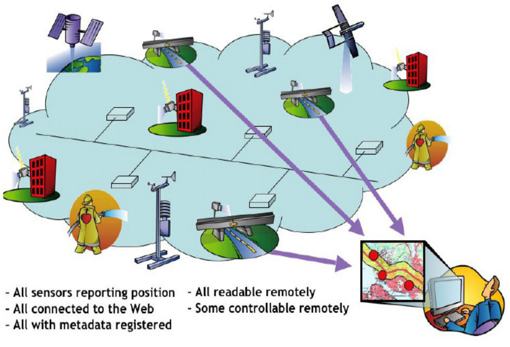

Fig. 2. Sensor Web Concept

The goal of SWE is to enable all types of Web and/or Internet-accessible sensors, instruments, and imaging devices to be accessible and, where applicable, controllable via the Web. The vision is to define the standards foundation for "plug-and-play" Web-based sensor networks. SWE specifications are being harmonized with other OGC standards for geospatial processing. Much as the HTML and HTTP standards enabled the exchange of any type of information on the Web, the OGC's SWE initiative develops standards to enable the discovery, exchange, and processing of sensor observations, as well as the tasking of sensor systems. [3]

Table 3. OGC SWE Specifications

	Specifications	Purpose
Web Services	Sensor Observations Service (SOS)	filtering, and retrieving observations and sensor system info.
	Sensor Planning Service (SPS)	requesting user-driven acquisitions and observations
	Sensor Alert Service (SAS)	publishing and subscribing to alerts from sensors
	Web Notification Services (WNS)	asynchronous delivery of messages or alerts from SAS/SPS
Data Models and Scheme	Observations & Measurements Schema (O&M)	encoding observations and measurements from a sensor
	Sensor Model Language (SensorML)	describing sensors systems and processes
	Transducer Markup Language (TransducerML)	describing transducers and supporting real-time streaming of data

As listed in Table 3, the SWE initiative has established several encodings for describing sensors and sensor observations and several standard interface definitions for web services.

4. Prototype Design and Implementation

This chapter describes work-in-progress development of an SOS-based sensor web prototype to facilitate research in the KLSP. First, this section presents a brief overview of the Sensor Observation Service. Then it describes the sensor web prototype for the KLSP and provides issues for further discussions.

4.1 Sensor Observation Service

As mentioned above, Sensor Observation Service (SOS) is a standard Web service interface for requesting, filtering, and retrieving observations and sensor system information. Web services have a strong advantage on interoperability among heterogeneous systems since they are Web-based application programming interfaces that can be accessed over a network, such as the Internet, and executed on a remote system hosting the requested services.

The OGC's SOS Implementation Specification provides access to observations from heterogeneous sensor networks in a web-based way that is consistent for all sensor networks including remote, in-situ, fixed and mobile sensors. It defines operational profiles for managing deployed sensors and retrieving sensor data. The ability to task, control, and fuse data obtained from heterogeneous sensors can facilitate the discovery of knowledge that is unobtainable from unitary sensor percepts [4-6].

The operations of the SOS are divided into two sections [7]. In the first section the perspective is

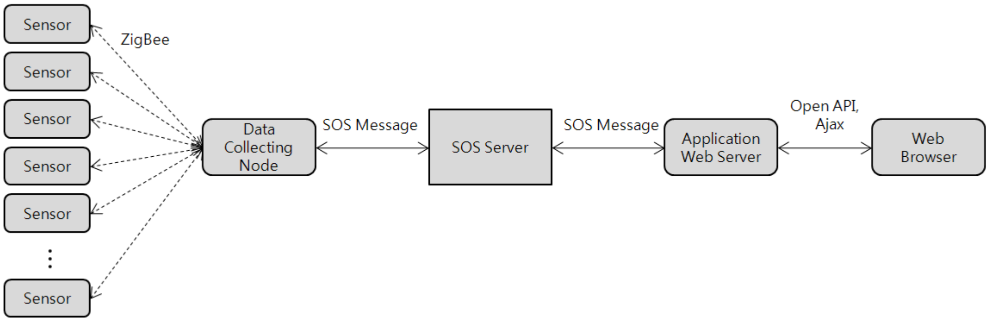

Fig. 3. Structure of the Sensor Web prototype

that of a sensor data consumer who is interested in obtaining sensor observations from one or more sensors. For such sensor data consumers, the SOS has three mandatory core operations: GetCapabilities, DescribeSensor and GetObservation. The GetCapabilities operation provides the means to access SOS service metadata. The DescribeSensor operation retrieves detailed information about the sensors making those measurements and the platforms that carry the sensors. To describe sensor information, the SOS uses Sensor Model Language (SensorML), the general models and XML encodings for sensors. The GetObservation operation provides access to sensor observations and measurement data via a spatio-temporal query that can be filtered by phenomena. To describe the observations and measurements, the SOS uses Observations & Measurements (O&M)-the general models and XML encodings for observations and measurements

In the second section the perspective is that of a producer of sensor observations which is using the services of an SOS that supports the transactional profile. For sensor data producers, the transactional profile allows sensor systems to be dynamically registered (RegisterSensor) and allows sensor observations to be published to the service (InsertObservation). The KLSP's prototype supports these two operation profiles and the development of enhanced operations is a work in progress.

4.2 KLSP's prototype

Figure 3 shows the overall structure of the KLSP's Sensor Web prototype. The prototype of the KLSP consists of 5 parts: sensors, data collecting nodes, a SOS server, application servers, and web browsers as a client. The prototype is based on free or open-source software technologies without depending on any commercial or exclusive ones.

A ubiquitous sensor network is built for the prototype with dozens of sensors including humidity sensors, temperature sensors, and luminance sensors. Each sensor node has a ZigBee network facility to communicate with each other. They can build an ad-hoc network with each other, or can communicate with a certain control node.

Data collecting nodes are Java applications located in between sensors and a SOS server. They are connected with a group of sensors via a ZigBee network, and collect observations from their sensors. Collected observations are encoded into XML messages and published to the SOS server over the Internet using SOS transactional profiles.

The SOS server stores and manages all the observations and measurements into its repository. As a SOS server, the prototype adopts the 52° North SOS Version 3.0.1 [7], an open-source implementation of the OGC's SOS Specification. The 52° North SOS currently supports the complete core profile of SOS (GetCapabilities, DescribeSensor and GetObservation) and a simple version of the transactional profile (RegisterSensor and InsertObservation). The 52° North SOS is implemented as a Java Servlet, which is deployed in Apache Jakarta Tomcat web container.

In the prototype, it is assumed that users desire to monitor a number of sensors in a certain area using their web browser through the Internet. Web-based applications have been widely used in various application domains because they do not depend on a certain computing environment or program. Without any installation of certain software, users can access all the information of sensors using web browsers. The application web server enables this service scenario for the clients, and provides a view for monitoring various sensors on a public map service. Instead of using a custom map server, the prototype utilizes a NAVER map service [8], which is a public internet map service in Korea like Google Map in the USA. It offers a variety of Open APIs, which are freely available for the development of mash-up applications using its map data. The application web server does not store any information about sensors or observations. It communicates with the SOS server by SOS web service messages, and obtains all the information about sensors and observations according to the requests of users. Services in the application web server are developed in PHP, which is a widely-adopted web programming language, and are operated on Apache web servers.

Users can connect to the application web server using their web browsers at anytime from anywhere. The prototype provides an enhanced user experience by using advanced web technologies such as AJAX. The client script programs use Javascript and jQuery framework to manage dynamic contents and AJAX communications.

4.3 Design and Implementation

The KLSP has a vested interest in the establishment of heterogeneous sensing environments due to its potential for monitoring and detecting targets. The interoperability in heterogeneous sensor networks is severely limited by multiple communication protocols in sensor data access implementation. To address this problem, the concept of the adaptor layer is adopted to make data access transparent to the data source tier as shown Figure 4. The adaptor is designed for sensor data producers to be able to plug their data access implementation into the adaptor without modifications of implementation details of the data source tier.

In addition, the ontology for sensor networks has to be adopted to define an ontology that associates sensor information taxonomy for searching and parsing raw sensor data streams. String-matching search techniques for sensor types and its offerings may not retrieve all relevant data because different words/terms are used that do not directly match the name of sensor types and data types.

Due to the recent advantages in sensor technologies and wireless communication, the amount of information generated by sensor networks will increase significantly. In order to efficiently deal with this streaming information, the SOS has to merge with sensor data stream management systems, which filter data streams for signs of abnormal activity and process them for the purposes of aggregation, reduction and correlation. This data stream manager is being designed and implemented to efficiently support a variety of near real-time monitoring applications and to be used in conjunction with other OGC specifications.

Lastly, supporting two-way operations for sensor networks represents another challenge, since SOS does not support operation profiles which are crucial for controlling sensors or pushing messages to sensor networks. To meet challenges, we plan to extended SOS specifications to actuate sensors and deliver messages to sensor networks.

5. Conclusion and Future works

The KLSP is planning the KLSP Test-Bed for testing, integrating, and exhibiting the KLSP's outcomes. The necessity of Sensor web framework for the KLSP Test-Bed has been increased because some of the products related to sensor networks must be connected to one another.

In this paper, a developed OGC SWE SOS prototype is presented to solve interoperability problems in

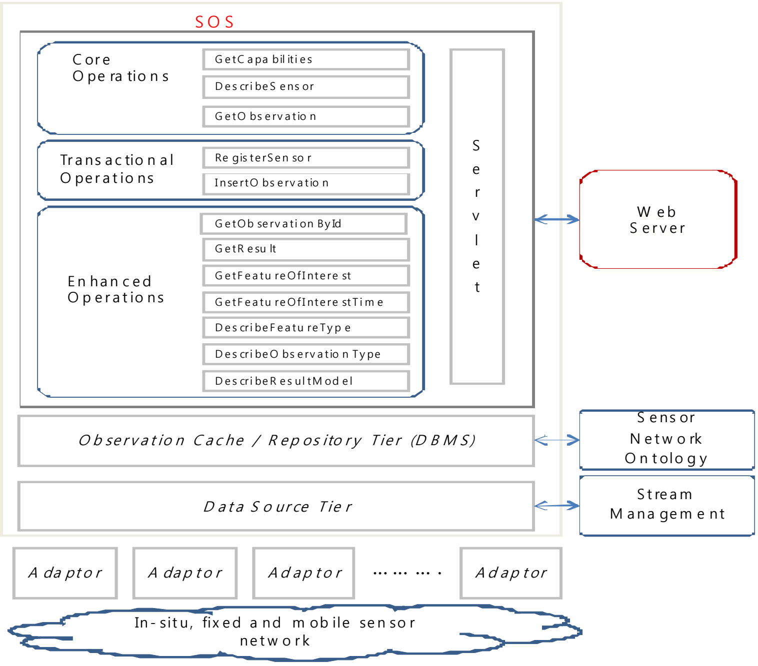

Fig. 4. Architecture of SWE Prototype in the KLSP

heterogeneous sensor networking environments. The prototype consists of two parts which include the SOS producer part and the SOS consumer part. In the SOS producer part, based on the 52° North SOS, three mandatory core operations (GetCapabilities, DescribeSensor and GetObservation) are developed. In the SOS consumer part, the services in the application web server are developed with the NAVER map service. Therefore, the user of prototype can connect to the SOS service using his or her web browser at anytime from anywhere.

The prototype for SOS does not support the operation for controlling sensors or pushing messages to sensor networks. To meet challenges, further studies will be planned to extend the SOS specifications to actuate sensors and deliver messages for sensor networks. The rest of the OGC SWE specifications such as SPS, SAS, and WNS will also be developed and applied to the KLSP Test-Bed.

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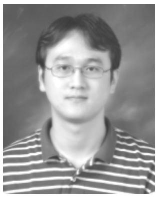

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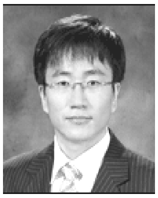

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