A Distributed Geo-Spatial Infrastructure for Smart Sensor Webs

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Key words: Internet GIS, web services, sensor web, GIServices.

SUMMARY

The confluence of rapidly evolving sensor, computation, telecommunication and real-time positioning technologies introduces a new instrument concept: Sensor Web. A sensor web is generally composed of multiple science instrument/processor platforms and intelligent sensors that are interconnected by means of a communications fabric for the purpose of collecting measurements and processing data. This new earth observation system opens up a new avenue to fast assimilation of data from various sensors (both in situ and remote) and to accurate analysis and informed decision makings. One of the critical components in developing sensor webs is to build a geospatial information infrastructure, a backbone that connects the heterogeneous in-situ sensors and remote sensors over the wired or wireless networks. This paper describes a distributed GIServices architecture, which utilizing a new service-oriented architectural approach, Web Services, to build a gateway that timely integrates and fuses observations from spatially referenced sensors.

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1. WHAT IS SMART SENSOR WEBS?

"A system composed of multiple science instrument/processor platforms that are interconnected by means of a communications fabric for the purpose of collecting measurements and processing data for Earth or Space Science objectives."

This is the definition of Sensor Web from NASA Sensor Web Applied Research Planning Group. Sensor Web can be seen as an advanced smart sensor network.

Business week provide a vivid and easy understanding description of smart sensor web (Gross, 1999): "In the next century, planet Earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies -- even our dreams."

Sensors are able to "think" and "talk". Because of the advances of semiconductor technologies, microprocessors become cheaper and faster than ever. According to Moore's law (Moore, 1965), the number of transistors on a given piece of silicon would double every couple of years. In fact the growing rate of computation power today is even faster than that and the price of computing processors has a massive drop in a short period of time as well. With those cheap and powerful embedded computing processor, the small sensors become small intelligent agents. Those sensors equip brains and are able to "think". With the integration of computing processors, wire/wireless communication and embedded operation system, these sensors even can "talk" with each other (Delin et al., 1999) (Delin and Jackson, 2000) (Delin and Jackson, 2001).

Sensors can be mobile. With wireless communication and real-time positioning technologies, sensors don't need to be fixed at a certain location and carrying those annoying wires. Sensors will be mobile and installed everywhere as tiny moving agents monitoring our planet restlessly. Wireless communication is a consequential trend of the way which devices communicate with each other in the near future. In one or two years, we will no more see those disordered lines behind our machines, because wireless protocols like Bluetooth, 802.11a and 802.11b will replace those virtual lines and cords. 2.5G and 3G mobile phone technology will also largely increase the bandwidth of mobile phone network. Internet connection will exist everywhere. Real time location is an essential property for the sensors as well. A measured value must be observed at a particular geospatial location at a particular time. Real-time positioning technologies, such as GPS, RFID, RTLS and cell-phone positioning make it is possible to acquire accurate real-time location of the sensors with low cost and low power consumption. By integrating both wireless communication and real-time positioning technologies, sensors can collect data without spatial boundary and time constraints.

The concept of sensor webs is exciting. Sensor webs can perform as an extensive monitoring and sensing system that provides timely, comprehensive, continuous and multi-mode observations. This new earth observation system opens up a new avenue to fast assimilation of data from various sensors (both in situ and remote) and to accurate analysis and informed decision makings (Teillet et al. 2002).

2. CHALLENGES TO CURRENT TECHNOLOGIES

One of the critical components to implement the goal of sensor web concept is to build a geospatial information infrastructure, a backbone that connects the heterogeneous sensors or sensor webs over the wired or wireless networks.

A sensor web consists of a large number of sensors which link with each other and the concept is just like the concept of World Wide Web today. Sensor webs might have the similar problems which today's WWW has. How to find the sensor which meets exactly user's interest definite will become a challenging issue. There are mainly three basic components of sensor web information required in order to discover the needed sensors (Botts, 2002). First component is the properties of physical entities and the phenomena that are capable of being measured and quantified. These properties can be temperature, count, rock type, chemical concentration, or radiation emissivity. Second part is the sensors that are capable of observing and measuring particular properties. These sensors have particular response characteristics and in addition to the response characteristics, the sensor system also has properties that allow one to associate the measured values with a particular geospatial location at a particular time. Third component is the data values that are returned by a sensor system or are derived from sensor measurements (Cox, 2003). A sensor discovery mechanism which meets users' needs should fully support these three components and an infrastructure, which supports an effective sensor discovery mechanism and bridges the sensors together, is a necessity.

Different sensor webs deployed by different organizations may have different communication protocols, different data formats, and other proprietary standards. Collaborations between different sensor webs become very difficult or need to be considered at the designing stage. Moreover, there are already many sensor networks existed and collecting measurements for Earth or Space Science objectives. They were designed and deployed even before the birth of sensor web concept. These sensors were not designed for the purpose of collaboration. Deployment of a sensor network is very expensive and a lot of work. If we can upgrade the existing older sensor networks to sensor webs, a lot of resources and time could be saved. An infrastructure which connects existing older sensor networks and newer sensor webs has the necessity and urgency.

3. A DISTRIBUTED WEB GISERVICES ARCHITECTURE FOR SMART SENSOR WEB

3.1 A Web Services Approach

We use a new technology framework, Web Services, to build the architecture of the proposed geospatial infrastructure for smart sensor webs.

Web Services represent the convergence between the service-oriented architecture (SOA) and the Web (W3C, 2002). SOA has evolved over the last 10 years to support high performance, scalability, reliability, and availability. However, traditional SOA are tightly coupled with specific protocols. Each of the protocols is constrained by dependencies on vendor implementations, platforms, languages, or data encoding schemes that severely limit interoperability. The Web Services architecture takes all the best features of the SOA and combines it with the Web. The Web supports universal communication using loosely coupled connections. Web protocols are completely vendor-, platform-, and language-independent. (Systinet Corp., 2002) Web Services support Web-based access, easy integration, and service reusability. Web Services satisfies our requirements to build a geospatial infrastructure for Sensor Webs with openness, interoperability, and extensibility. Web Services now are developing as standards in W3C group and will become future standards for World Wide Web. Due to these reasons, Web Services serve a perfect foundation to build such an open infrastructure for Sensor Webs.

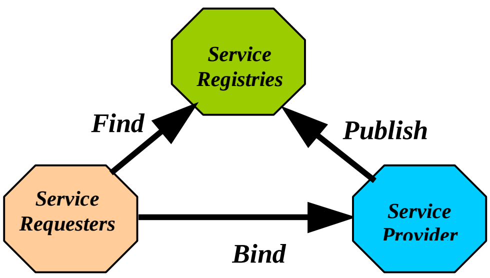

Figure 1. Basic Web Services Architecture

3.2 A distributed GIServices for smart sensor webs- GeoServNet

GeoServNet is designed with the architecture of GIServices (Mueller, 1999) (Tao, 2000) and is developed by GeoICT Lab, York University, Canada. Figure 2 illustrates the components architecture of GeoServNet.

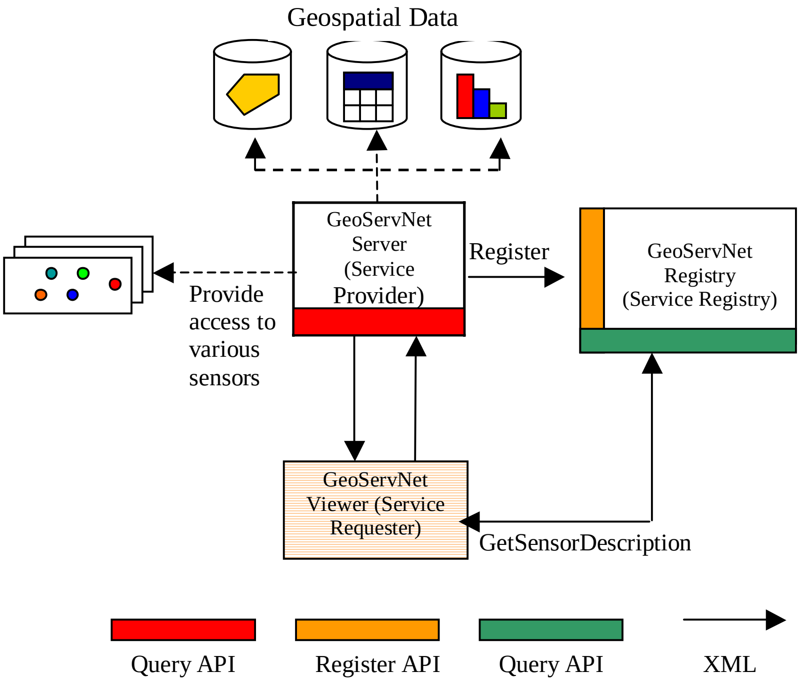

Figure 2. Components Architecture of a geospatial infrastructure for Sensor Webs

3.2.1 <u>Service Registry – GeoServNet Registry</u>

The ability to locate, access, and use arbitrary sensors is one of the most challenging and practically relevant objectives in the design of open, distributed infrastructure for smart sensor webs. And in dynamic, heterogeneous environments it is advantageous to allow late binding between sensors and clients; that is, a client will generally not know in advance where a desired sensor is located. GeoServNet Registry is the component that supports the run-time discovery and evaluation of available sensors offers.

GeoServNet Registry provides a common mechanism to classify, register, describe, search, maintain and access information about Sensor Webs and other Web Services. Such offers play a central role in publishing, finding, and binding to network-accessible services. GeoServNet Registry is a key component in such a service-oriented architecture that manages shared resources and facilitates service discovery. GeoServNet Registry allows:

- Sensor providers (such as GeoServNet Server) to publish descriptions about sensors
- Clients to discover information about sensors which meet clients' interest.
- Clients to access (bind to) sensor providers.

The Registry Service defines a common information model and standard operations that allow clients to interact with registry instances, regardless of their role or content, in order to discover, access and manage sensor observation data, geospatial data and services (Martell, 2002).

3.2.2 Service Provider - GeoServNet Server

The role of GeoServNet Server is to provide a web-enabled interface for sensor systems and other geo-spatial information as well. GeoServNet Server acts like a wrapper which hides the different communication protocols, data formats and standards of sensor systems behind the server and provides a standard interface for clients to collect and access sensor observations and manipulate them in different ways. In this way, various clients only need to follow the standard interfaces which provided by GeoServNet Server, and don't need to deal with the annoying protocols of various sensors. In order to accommodate various sensors in a sensor web, the standard interfaces play a key role to keep the whole architecture efficient, extensible, and interoperable. Thanks to W3C and OpenGIS, they provide interoperability standards and interfaces, such as XML, SOAP, WSDL, UDDI and OGC Web Services Specifications. In the GeoServNet, we implemented the OGC simple feature specification and OWS interfaces are adopted as well. As a member of OGC, GeoICT Lab is actively involved in the development and implementation of OGC specifications as well.

3.2.3 Service Requestor – GeoServNet 2D/3D Viewer

GeoServNet 2D/3D viewer plays a service requestor role in the whole service-oriented infrastructure for linking smart sensor webs. A service requestor first asks the service registry, such as GeoServNet Registry, whereto find a suitable service provider, for example GeoServNet Server, and then binds itself to the provider. After the service binding, service requestor sends requests to the service provider, and provider send responses back according to the requests. After the responses are received, then client can perform the analysis and processing.

Sensor Web comprises a large number and different type of in-situ and remote sensors which will produce massive and diverse data that can challenge our ability to process and manage the data. How to accommodate various sensor types in a viewer and deliver valuable information to the end user becomes a challenging task. The great density and diversity of these data, however, offers the opportunity to take advantage of interactive 3D visualization techniques that can improve the efficiency and accuracy of processing, and provide an unprecedented perspective of sensor observations.

GeoServNet Viewer is an interactive 2D/3D visualization web-based GIS client, and was specifically designed to facilitate the interpretation and analysis of very large, complex, multi-component geospatial data sets through Internet (Tao, 2001). The services-oriented design gives it the capability to dynamically accommodate diverse sources of geo-spatial data rather than limited with its proprietary system and its own standard.

GeoServNet Viewer fuses both 2D and 3D interactive visualization and fully supports the standard functions in a desktop GIS. It is built based on Java and Java 3D technology which means platform independent and no software installed needed. Figure 3 and Figure 4 shows the GeoServNet 2D and 3D viewer respectively.

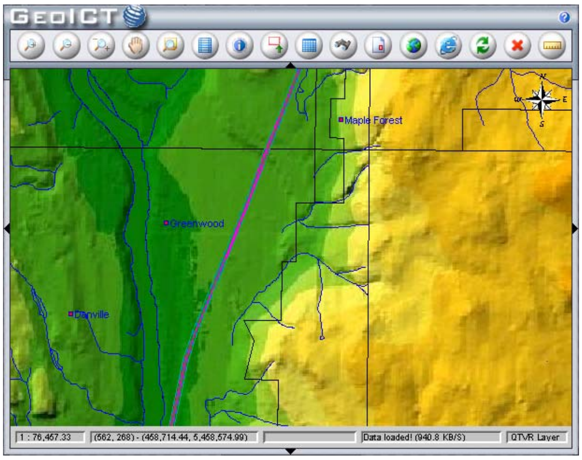

Figure 3. GeoServNet 2D Viewer

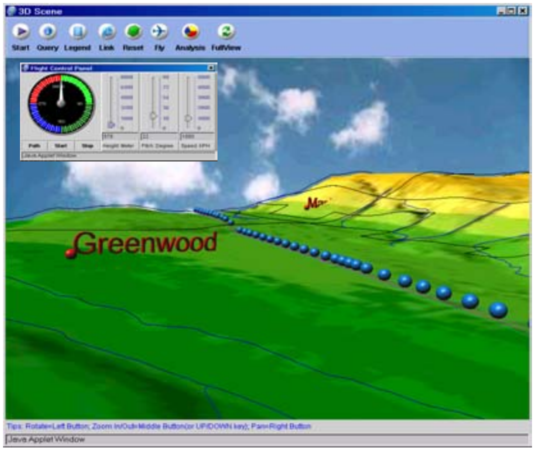

Figure 4. GeoServNet 3D Viewer

4. CONCLUSION AND FUTURE WORK

The web service based architecture is designed to accommodate various platforms, data formats in the hybrid IT world. Diverse types of sensor data formats, geo-spatial data sets could circulate within this open infrastructure; this architecture also supports dynamically and late binding between sensors and clients. The proposed architecture also provides great extensibility. Sensors could be added into existing sensor web after the designing stage, and old existing sensor network can be linked to new sensor webs as well.

GeoServNet serves a solid foundation to build such a sensor web infrastructure. GeoServNet platform was built for the purpose of interoperability and extensibility; it is implemented by following OGC Web Service standards and Java standards. GeoServNet serves a very good platform for an open distributed geo-spatial infrastructure for smart sensor webs. In the future, we will try to integrate the very fast evolving IT based web services technologies, such as SOAP protocol, UDDI registry and WSDL into GeoServNet platform. It is believe that porting OWS services to the IT standard Web Services will offer the following advantages (Sonnet, 2002):

- Distribution – It will be easier to distribute geospatial data and applications across platforms, operating systems, computer languages, etc.
- Integration – It will be easier for application developers to integrate geospatial functionality and data into their custom applications.
- Infrastructure - The GIS industry could take advantage of the huge amount of infrastructure that is being built to enable the Web Services architecture – including development tools, application servers, messaging protocols, security infrastructure, workflow definitions, etc.

The next step for the GeoServNet development work is to integrate those technologies into our platform and make this sensor web infrastructure more universal and interoperable.

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BIOGRAPHICAL NOTES

Steve H.L. Liang completed his B.Sc. in Surveying Engineering at National Cheng Kung University, Taiwan and is now working on a M.Sc. in Geomatics at GeoICT Lab, York University. His research interests are Internet GIS, GIServices, Sensor Webs and Location Based Services. Steve currently is also the Coordinator of GEOIDE Student Network and a member of the GEOIDE board of Directors.

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