SERVICE ORIENTED ARCHITECTURE (SOA) BASED WEB SERVICES FOR GEOGRAPHIC INFORMATION SYSTEMS

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ABSTRACT:

Geographic Information System (GIS) has long been essential tool for governments, environmental institutions, military and others who depend on geographic information. GIS combines layers of data about a location to create a fuller and more accurate picture of that location. These data are obtained from different sources in different formats, datum and coordinate systems. The problem of traditional GIS is to gather all up-to-date data and to process them in the same format and datum. The Internet has changed rapidly the transfer and dissemination of geographical information. This rapid and enormous development of the Internet technology resulted in usage of the Internet as a tool for data access, data transmission and access to GIS analysis tools. The combination of GIS and the Internet offers great possibilities, such as the interactive access to geospatial data, enhancement of the functions of geographic information, and the access to GIS analysis tools. As a result of advancements in both technologies, Web services come into view based on Service Oriented Architecture. Web services let applications share data and even use other applications' capabilities, without regard to what operating system or platform those applications run on.

1. INTRODUCTION

A Geographic Information System (GIS) is a computer-based information system designed to efficiently capture, store, update, manipulate, analyze, and display many forms of geographically referenced and associated tabular attribute data (Fischer and Nijkamp, 1993). GIS are used extensively in various applications such as environmental monitoring, disaster management, land-use mapping, transportation mapping and analysis, urban development planning, and natural resource assessment, etc. (Sadagopan, 2000) and huge volumes of geospatial data have been produced and collected. Although these seem to be relatively independent and different areas there is a need for the system to relate information from different sources.

For example, a GIS can be used to help planning adequate response in case of a natural disaster such as an earthquake that would require latest information about the strength of the earthquake, detailed information of the affected areas with and inhabited places marked, the names of these places, usable roads, information about the energy and natural gas lines, hospitals, buildings.

With the development of internet technology, access to distributed geographic data and geo-processing applications become much easier. Today widely known online mapping applications such as Google Maps and Yahoo Maps provide GIS services to ordinary Internet users (Aydin, 2007a).

GIS introduce methods and environments to visualize, manipulate, and analyze geospatial data. These methods and environments have some interoperability problems. The nature of the geographical applications requires seamless integration and sharing of spatial data from a variety of providers. Interoperability of services across organizations and providers is a main goal for GIS. Different organizations and commercial vendors develop their own data models and storage structures. If GIS services are not interoperable, they cannot interact with each other even though they are in the same organization or they belong to same commercial vendor. To solve the interoperability problems, the Open Geospatial Consortium (OGC) has introduced standards by publishing specifications for the GIS services.

GIS services, such as defined by the OGC, are part of a larger effort to build distributed systems around the principles of Service Oriented Architectures (SOA). Such systems unify distributed services through a message-oriented architecture. Web Service standards are a common implementation of SOA ideals (Sayar et al, 2005).

2. GEOGRAPHIC INFORMATION SYSTEMS

2.1 Evolution of GIS

Until the mid-'90s, organizations utilized geographic information systems that closely tied applications to a native, proprietary spatial data model. These early file structures were highly optimized for fast access to data and were relatively easy to distribute between sites using the same GIS vendor software. Data sharing between organizations with different GIS vendor

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systems was limited to data converters, transfer standards, and later open file formats.

Gradually, GIS models evolved into geo-relational structures where related attribute data could be stored in a relational database that was linked to the file-based spatial features. In the mid-'90s, new technology emerged that enabled spatial data to be stored in relational databases, opening a new era of broad scalability and the support of large data layers.

As GIS technology continues to evolve the best long-range solution for data sharing and interoperability is Web services. This gradual on-going transformation is primarily fueled by the growing role of GIS in today's organizations, the increasing availability of spatial data and its inherent conduciveness to reuse (ESRI, 2003).

2.2 The Need for GIS Interoperability

GIS technology is evolving beyond the traditional GIS community and becoming an integral part of the information infrastructure in many organizations. The unique integration capabilities of a GIS allow disparate data sets to be brought together to create a complete picture of a situation. GIS technology illustrates relationships, connections, and patterns that are not necessarily obvious in any one data set, enabling organizations to make better decisions based on all relevant factors. Organizations are able to share, coordinate, and communicate key concepts between departments within an organization or between separate organizations using GIS as the central spatial data infrastructure. GIS technology is also being used to share crucial information across organizational boundaries via the Internet and the emergence of Web Services (ESRI, 2003).

With the universal availability provided by the Internet for both data and online processing/visualization tools, today we have access to a number of high-quality online mapping web sites along with many other types of publicly available geographic data analysis or visualization applications. As more geographic data and related applications become available organizations have been formed to answer the problem of interoperability between geographic data and services (Aydin, 2007b).

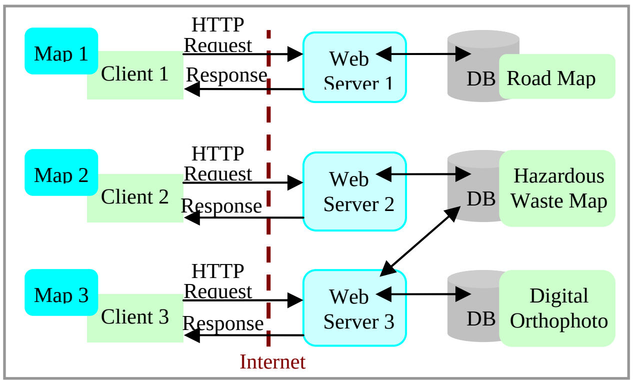

Figure 1. Client/Server Lack of Interoperability

Online mapping services from different providers cannot, in most cases, interoperate or communicate with one another. Thus, it is seldom possible for a user to get a hazardous waste map from one Web site and a street map from another site and overlay them in the same composite map. Figure 1 shows a scenario in which a user must run three different Web applications to access the data and functionality provided by three server implementations. The result is three different maps. In this situation, there is very little interoperability (or reuse) of the Web client and server implementations. Because data are often accessible only through one particular server, there is also very limited ability for a user to transparently access data from other map servers (Kolodziej, 2004).

To fully realize the capability and benefits of geographic information and GIS technology, spatial data needs to be shared and systems need to be interoperable (ESRI, 2003). Without a corporate or enterprise commitment to interoperability and a concept of open systems, an organization cannot effectively integrate geospatial data, services, and processes into their overall business processes (Reed, 2004).

3. WEB SERVICES

3.1 Service Oriented Architecture

In recent years the technology trend within information technology has made it possible to move towards service oriented architectures and distributed computing.

There are lots of services available over the internet. However it is not possible for individual standalone service to meet all the service requirements of many users. As the number of geospatial services increased rapidly, an emerging need has also appeared for methodologies to locate desired services that provide access and data mining capabilities to geospatial data. The Service Oriented Architecture (SOA) recognizes this and tries to construct a distributed, dynamic, flexible, and re-configurable service system over Internet that can meet information and service requirements of many different users (Aydin, 2007a).

Service Orientation is the result of the natural evolution of current development models. Object-oriented models were used in the 80s; then they were replaced by the component-based development models in the 90s. And now we have service orientation. Service orientation retains the benefits of component-based development (self-description, encapsulation, dynamic discovery and loading), but there is a shift in paradigm from remotely invoking methods on objects, to passing messages between services.

One of the key benefits of service orientation is loose coupling. The principle of loose coupling is that of using a resource only through its published service and not by directly addressing the implementation behind it. This way, changes to the implementation by the service provider should not affect the service consumer. By maintaining a consistent interface, the service consumer could choose an alternative instance of the same service type without modifying their requesting application, apart from the address of the new instance. The service consumer and provider do not have to have the same technologies for the implementation, interface, or integration when Web services are used (Linthicum, 2008).
SOA is an architectural style for building software applications that use services available in a network such as the Web. SOA is a principle concept underlying beneath Web Services implementation. It promotes loose coupling between software components so that they can be reused.

The key component in the SOA is services. A service is well defined set of actions. It is self contained, stateless, and does not depend on the state of other services.

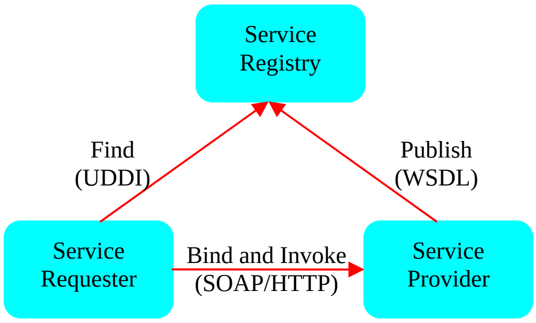

Figure 2. The basic operations in SOA

SOA concept has three components (Figure 2): service provider, service registry, service requester and three operations: publish, find, and bind. A SOA relates the roles of the three components with the three operations to maintain automated discovery and the use of services. The three essential components mentioned above can be described as following:

- **Service provider** publishes services to a registry and makes it available on the Internet for the requests of the consumers.
- **Service requester (client)** performs service discovery operations on the service registry in order to find the needed service; then accesses services.
- **Service registry** helps service providers and service requesters to find each other by acting as a registry of the services (Sayar, 2008).

3.2 Benefits of Service Oriented Architecture

The benefits of SOA are several. From users' perspective, a SOA setting is an open and interoperable environment, which is based on reusability and standardized components. Basically a SOA creates an infrastructure for application development. Development is focused towards concrete applications (and thereby specific requirements and needs) and in contrast to standard GIS applications where normally only a small percentage of the functionalities in the software are used, applications based on SOA provide users with just the functionality they need. Another prominent intention of the design of a SOA is that data used for a given processing activity are not stored locally, but rather decentralized close to the source of production. This means that inconsistency in local copies and repositories of data are avoided and, hence, the quality of the output is possibly increased in cases where data from various different sources are used. Furthermore, redundancy in the algorithms used for specific processing tasks are also avoided. The SOA approach to system development can produce systems that can be flexibly adapted to changing requirements and technologies, and offers easier maintainable and more consistent systems of data and functionality (Aydin, 2007a).

3.3 Web Services

The SOA can be implemented at many different network environments. The implementation of SOA in Web environment is called Web Services. The concept of Web services is based on service oriented architecture paradigm where a complete application can be constructed from various services which provide different functionalities.

Web services are self-contained, self-describing, modular new breed of Web applications that can be published, located, and dynamically invoked across the Web. Web services provide access to sets of operations accessible through one or more standardized interfaces. A Web service is simply an application that exposes a function that is accessible using standard Web technology and that adheres to Web services standards (Doyle and Reed, 2001).

One significant aspect of the Web Services is that they allow program-to-program communications. With the help of several Web Services specifications a complete cycle of describing, publishing, and finding services can be made possible (Aydin, 2007b).

Web Services reflect a new service-oriented architectural approach, based on the notion of building applications by discovering and orchestrating network-available services. The Web Services architecture is the logical evolution of object-oriented analysis and design. It is also the logical evolution of the architecture, design, implementation, and deployment of e-business solutions. Both approaches have been proven in dealing with the complexity of large systems. As in object-oriented systems, some of the fundamental concepts in Web Services are encapsulation, message passing, dynamic binding, and service description and querying. Fundamental to Web Services, then, is the notion that everything is a service, publishing an API for use by other services on the network and encapsulating implementation details (Doyle and Reed, 2001).

Properties of web services in the literature: First, web services are for application-to-application communication. Second, web services are accessed over Internet. And finally, web services are XML based and not for proprietary solutions (Akinci, 2004).

3.4 The Standards for Web Services

Web services are XML (eXtensible Markup Language) software systems designed to support interoperable machine-to-machine interaction over a network. This interoperability is gained through a set of XML -based open standards, such as WSDL, SOAP, and UDDI. These standards provide a common approach for defining, locating, publishing, and using web services.

These standards are a series of protocols that support sophisticated communications between various nodes in a network. The Web service protocol stack (Figure 3) is a collection of these protocols that are used to make Web services interact with each other.

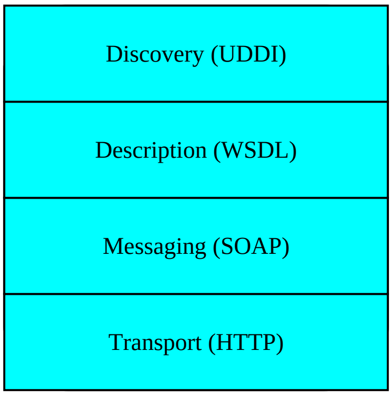

Figure 3: The four-layer model of the Web services stack

- **Transport Protocol** is responsible for transporting messages between network applications. HTTP (HyperText Transfer Protocol) is the low-level protocol used by the Internet for the transport layer.

- **Messaging Protocol** is responsible for encoding messages in a common XML format so that they can be understood at either end of a network connection. Simple Object Access Protocol (SOAP) is the specific format for exchanging Web Services data over HTTP.

- **Description Protocol** is used for describing the public interface to a specific web service. Web Service Definition Language (WSDL) is used to describe what type of message a Web Service accepts and generates.

- **Discovery Protocol** centralizes services into a common registry. Universal Description, Discovery, and Integration (UDDI) specification can be used by the service providers to advertise the existence of their services and by requesters to search and discover already registered services (Aydin, 2007a; Josuttis, 2007).

The important thing about the service interface is that it hides the implementation logic from the users, which allows the service to be used on different platforms than which it was implemented. Also any application capable of communicating through the standard XML messaging protocol and regardless of with which programming language it was developed in can use the service through the standard interface. These properties allow Web Services based frameworks to be loosely coupled and component oriented. Because of the standard interfaces and messaging protocols the Web Services can easily be assembled to solve more complex problems.

The main advantage of Web services is that the service can be used remotely without the user's actual knowledge and intervention and by multiple users at the same time, eliminating the need for constant updates to locally installed software. Moreover it minimizes the network traffic, since data do not need to be transferred to the client in every step of the operation (Kotzinos and Chrysoulakis, 2003).

4. GIS WEB SERVICES

4.1 GIS Web Services

Geographic information comes from different and diverse sources and in different formats. This is especially true for areas such as environmental, disaster management related information which has to combine data from different sources having different data model and formats.

The SOA approach also applies within the GIS domain where several standards have been launched. This has created a technology evolution that moves from standalone GIS applications towards a more loosely coupled and distributed model based on self-contained, specialized, and interoperable geospatial web services. In order to create SOA architecture for the GIS services it is necessary to create Web Service correspondences of each GIS services. GIS services can be grouped into three categories (Sayar, 2008):

- **Data Services** are tightly coupled with specific data sets and offer access to customized portions of that data. Web Feature Service (WFS), Web Feature Service-Transactional (WFS-T), Web Mapping Service (WMS) and Web Coverage Service (WCS) can be considered in this group. WMS produces maps as two-dimensional visual portrayals of geospatial data. WCS provides access to un-rendered geospatial information (raster data). WFS provides geospatial feature data (vector data) encoded in Geography Markup Language (GML) whereas WFS-T enables editing feature coordinate geometry (i.e position and shape) and related descriptive information (i.e. attribute values), as well.

- **Processing Services** provide operations for processing or transforming data in a manner determined by user-specific parameters. They provide generic processing functions such as projection and coordinate conversion, rasterization and vectorization. Coverage Portrayal Service (CPS), Coordinate Transformation Service (CTS), and even WMS can be considered in this group.

- **Registry or Catalog Service** allows users and applications to classify, register, describe, search, maintain, and access information about Web Services. Web Registry Service (WRS) and Catalog Service for the Web (CS-W) are considered in this group (Alameh, 2003).

4.2 GIS Web Services Architecture

The Open Geospatial Consortium, Inc (OGC) is an international industry consortium of 357 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications (OGC, 2008).

The OGC has developed the OGC OpenGIS Web Services Architecture to improve the interoperability among geospatial system. This document is a specification and description of a common architectural framework for the design and implementation of Open Distributed Processing applications based on the Web Services specification. In this specification, some fundamental components are identified:

- **Web Features Service (WFS)**, defines web interfaces for accessing feature-based geospatial data (vector data like administrative and political information, streets, cities, etc). WFS allows a client to retrieve and update geospatial data encoded in GML from multiple Web Feature Services. The specification defines interfaces for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform. Via these interfaces, a Web user or service can combine, use and manage geospatial data -- the feature information behind a map image -- from different sources.
- **Web Map Service (WMS)** produces maps of spatially referenced data dynamically from geographic information. This service defines a "map" to be a portrayal of geographic information as a digital image file suitable for display on a computer screen.
- **Web Coverage Service (WCS)** represents a web interface for supporting electronic retrieval of geospatial data as "coverages" – that is, digital geospatial information (like remotely sensed imagery, ortho-photos, etc) representing space-varying phenomena. A WCS provides access to potentially detailed and rich sets of geospatial information, in forms that are useful for client-side rendering and input into scientific models and other clients.
- **Web Registry Service (WRS)** specifies web interfaces for finding data or services from registries.

GML is widely accepted as the universal encoding for geo-referenced data. GML is an XML grammar written in XML Schema for the modelling, transport, and storage of geographic information. GML provides a variety of kinds of objects for describing geography including features, coordinate reference systems, geometry, topology, time, units of measure and generalized values.

The fundamental components of Web Services Architecture are related with components in SOA concept as shown in Figure 4.

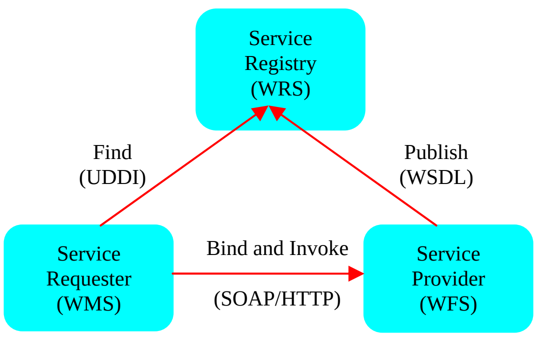

Figure 4. Web Services representation with three major functionalities.

In the GIS context, the UDDI plays the role of a metadata server of registered Web services. A user can search a UDDI directory and find other distributed service providers that exist on a network. Web services communicate through an XML-based SOAP protocol. This is an XML API to the functions provided by a Web service. Each Web service "advertises" its SOAP API using WSDL, allowing easy discovery of any service's capabilities.

Web services can be accessed with devices such as browsers, mobile devices such as telephones, desktop clients, and other information appliances. To discover these services, a broker is provided. The discovery protocol is referred to as a Universal Description, Discovery, and Integration.

4.3 Interoperability in GIS Web Services

Interoperability means openness or the ability to exchange data freely between systems. According to Open GIS Consortium Interoperability is the "capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units." i.e. interoperability enables the integration of data between organizations across various disciplines and industries, resulting in the generation and sharing of information and reduces redundancy (Ummadi, 2008)

Interoperability enables the integration of data between organizations and across applications and industries, resulting in the generation and sharing of more useful information.
Web services provide an open, interoperable, and highly efficient framework for implementing systems. They are interoperable because each piece of software communicates with each other piece via the standard SOAP and XML protocols.

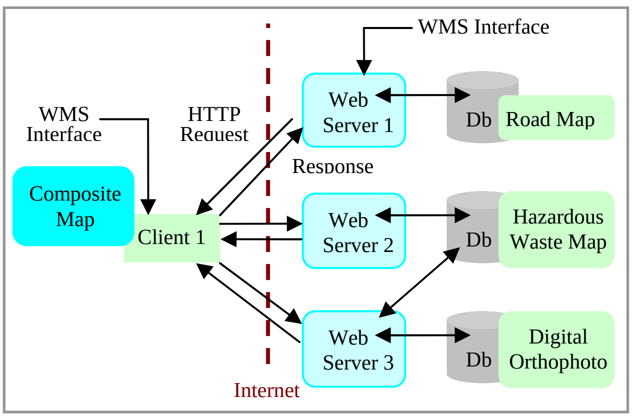

Figure 5. The portrayal of the concept of interoperable, distributed mapping systems in which the user runs a single Web client to access all the capabilities of each server.

With OpenGIS standards-based interoperable Web mapping, each map server implements a common interface for accepting requests and returning responses. Now, the same client in Figure 1 has Web access to potentially all available map servers and multiple data sources, in which each map server is accessed by the same Web client through the common interface. Figure 5 portrays this concept of interoperable, distributed mapping systems. The result is one composite map instead of three, as portrayed in the Figure 1 scenario. This approach allows, among other things, the user to run a single Web client that accesses all the capabilities of each server (Kolodziej, 2004).

The future of GIS technology depends on the interoperability with Web services. Web services are accessible with browsers, telephones, PDA's and most of the upcoming information devices (Ummadi, 2008).

5. CONCLUSIONS

GIS fundamentally involves the integration of data from different and diverse sources and in different formats. With the advancements in Geographic Information Systems and Internet technologies, it is becoming easier for anyone to access to geospatial data and geographic data analysis or visualization applications. As more geographic data and related applications become available organizations are confronted with the problem of interoperability between geographic data and services.

As GIS technology continues to gradually develop the best solution for data sharing and interoperability is Web services. This interoperability is gained through a set of XML-based open standards which provide a common approach for defining, locating, publishing, and using web services. The concept of Web services is based on service oriented architecture paradigm where a complete application can be constructed from various services which provide different functionalities. An important aspect of SOA is the separation of the service interface from its implementation.

The specifications for GIS web services initiative are specified by the Open Geospatial Consortium. The OGC Web Services Architecture improves the interoperability among geospatial systems. The OGC Web services architectures and collaboration tools will allow users to work together in new ways and deliver more shortcut solutions to problem solving.

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