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Standard-Based Data and Information Systems for Earth Observation

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Chapter 2
Use of NWGISS to Implement a Data Node in China's Spatial Information Grid

Dengrong Zhang, Le Yu, and Liping Di

2.1 Introduction

Geospatial data are those that can be associated with location information on the Earth. Because of their importance, both public and private organizations have collected considerable geospatial data (King 1999, King et al. 2003, McDonald and Di 2003). Such data is the dominant form in volume. It has been widely used in many fields of applications. China has accumulated large-scale, heterogeneous spatial resources, among them, continuing to establish a fundamental spatial database, spatial data processing and application software, spatial facilities, and instruments (Guo et al. 2004). Consistent access and sharing of spatial information are generally considered to be challenging problems due to the volume and complexity of processing heterogeneous and distributed data. Technology for extensive GIS application is needed to implement effective access and sharing of the large amount of isomerous and distributed spatial data.

Many approaches have been applied to implementing sharing and integration of spatial information, Grid technology, OpenGIS and Web services are the three most important (Tang and Jing 2004). The Grid technique, first proposed by Ian Foster et al. (2001), is a flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources. It has been a rising research field in recent years (Shao and Li 2005). There have been some studies on integrating grid technology with spatial information applications. The Committee on Earth Observation Satellites (CEOS) started research in 2001 (Tang and Jing 2004) on a prototype system to share satellite data and spatial information in global areas. In China, the National University of Defense Technology (NUDT) first proposed SIG as a system, to integrate grid technology with spatial information applications. It conducted original and fundamental research on SIG architecture. Beginning in

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2002, the National High Technology Research and Development 863 Program of China supported a prototype system.

This chapter concentrates on resource management, because it is fundamental to other SIG services. The data node is designed to be the unit for resource management. Given the requirement of a SIG data node, and using the architecture of the NASA HDF-EOS Web GIS Software Suite (NWGISS) (http://nwgiss.laits.gmu.edu/introduction.htm, Yang and Di), which is a Web-based data distribution system compliant with multiple Open Geospatial Consortium (OGC) standards and the OGC Web Services (OWS) frame, a SIG data service node framework was designed. This paper describes it. Test geospatial data nodes based on the SIG data node prototype have been established for evolution at Zhejiang University and George Mason University.

SIG and OGC standard data interoperability protocols are introduced in Sect. 4.2. Section 4.3 focuses on SIG resources and the SIG data node. Section 4.4 describes the construction of an NWGISS-based SIG data node. An experimental distributed evolution framework and a demonstration of an application are given in Sect. 4.5.

2.2 Related Work

2.2.1 Introduction to SIG

As a novel Web-based infrastructure and technology system of spatial information, SIG integrates and extends information grid technology, spatial information systems and Web services. To implement sharing and integration of spatial information, SIG takes services as its technical core and establishes a unified and intelligent platform to acquire, store, organize, distribute, analyze, aggregate, and apply spatial information.

SIG provides solution to problems in and meets the needs of spatial information application. These problems and needs are focused mainly on (Ren et al. 2004) integrative organization of spatial information resources, sharing large amounts of spatial information resources, high performance collaboration in analyzing and processing spatial information, and integration of geographically distributed spatial information services. Luo et al. (2004) summarized seven major functions SIG should provide:

(1) Ability to process massive amounts of spatial data. Storing, accessing and managing spatial data in amounts from terabytes to petabytes; efficiently analyzing and processing spatial data to produce models, information, and knowledge; and providing 3D and multimedia visualization services.
(2) High performance computing with and processing of spatial information. Solving spatial problems with high precision, high quality, and on a large scale; and processing spatial information in real time or on schedule, with high-speed and high efficiency.

(3) Sharing of spatial resources. Sharing distributed heterogeneous spatial information resources and realizing interlink and interoperation at the application level, so as to make the best use of such spatial information resources as computing resources, storage devices, spatial data (integrating from GIS, RS and GPS), spatial applications and services, GIS platforms (such as ESRI ArcInfo, MapInfo, . . .).
(4) Integration of legacy GIS systems. A SIG can be used not only to construct new advanced spatial application systems, but also to integrate legacy GIS systems, to keep extensibility and inheritance and guarantee the users' investment.
(5) Collaboration. Large-scale spatial information applications and services always involve different departments in different geographic locations, so remote and uniform services are needed.
(6) Support to integration of heterogeneous systems. Large-scale spatial information systems are always synthesized applications, so SIG should provide interoperation and consistency through adopting open and applied technology standards.
(7) Adaptability to dynamic changes. Business requirements, application patterns, management strategies, and IT products for any department are always changing, so SIG should be self-adaptive.

Tang and Jing (2004) first proposed the architecture of SIG. The main components of SIG are systems that acquire spatial information, storing systems, processing systems, application systems, multi-layer users, and computing resources (e.g. PCs, servers). These components are linked and integrated by SIG services (see Fig. 2.1).

There are many reasons why one might wish to have SIG. First, the amount of spatial data is increasing amazingly, so that real time or near real time processing needed by applications confronts difficulties in one single computer. Second,

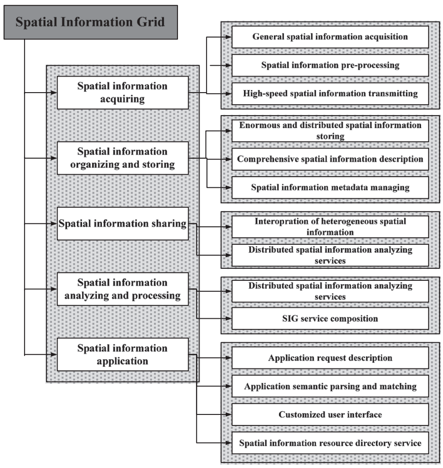

Fig. 2.1 The technical architecture of SIG (Tang and Jing 2004)

data, algorithms, and/or computing resources are physically distributed. Third, the resources may be “owned” by different organizations. Fourth, the use frequency of some resources is rather low. A SIG contains at least (Luo et al. 2006):

(1) A Remote Sensing Information Analysis and Service Grid Node
(2) A data service node: the traditional data base for a Web service
(3) A management center: resource register, finding data and services, services trading, and management;
(4) A portal: an entry for SIG users.

2.2.2 Standards for Geospatial Data Operation

Many international and industry standards have been established to implement Web-based interoperable geospatial information data access and services for GIS research. ISO TC211 (http://www.isotc211.org/Outreach/Overview/Overview.htm) standards and Open GIS Consortium (OGC) specifications (http://www.opengeospatial.org/standards/as) are the most attractive. ISO TC211 is a technical committee with responsibility for establishing the international standards for geographic information. The OGC is a not-for-profit international membership-based organization founded in 1994 to address the lack of interoperability among systems that process geo-referenced data. OGC advances geospatial interoperability technology by developing interoperable interface specifications. Those specifications, tested through interoperability initiatives, are widely accepted by software vendors, the GIS community, and federal agencies in the US. They are also adopted by many different countries and international organizations. The Memorandum of understanding signed by ISO TC 211 and OGC states that OGC will submit its specifications to ISO TC 211 for approval as international standards. TC 211 usually accepts these documents as Committee Drafts.

Among all OGC specifications the most significant kernel specifications for establishing spatial information grid data nodes are Web Coverage Service (WCS) (http://www.opengeospatial.org/standards/wcs),Web Feature Service (WFS) (http://www.opengeospatial.org/standards/wfs), Web Map Service (WMS) (http://www.opengeospatial.org/standards/wms), Catalog Service/Web Profile (CS/W) (http://www.opengeospatial.org/standards/cat), and Geography Markup Language (GML) (http://www.opengeospatial.org/standards/gml). WCS and WMS provides an interoperable way for accessing geospatial overlay data. WFS provides an interoperable approach for accessing geospatial feature data. CS/W defines an interface for Web geospatial data query access. GML provides a tool for describing geospatial data. These kernel specifications form the interoperable bases of geospatial data. WCS, WFS and WMS are three specifications that most related to data sharing and interoperation.

2.2.2.1 OGC WCS

The OGC WCS specification defines the interface between Web-based clients and servers for interoperable access to on-line multi-dimensional, multi-temporal geospatial data (_http://www.opengeospatial.org/standards/wcs). According to definitions by OGC, coverage data include all remote sensing images as well as gridded data such as DEM and land use classification. Three operations are defined in WCS:

GetCapabilities: Client retrieves the XML-encoded capabilities document from a server. The document contains information about the data it serves, as well as about the server capabilities.

GetCoverage: Client requests the server to send data based on client's requirements.

DescribeCoverage (optional): Client retrieves the metadata for a specific coverage.

2.2.2.2 OGC WFS

The OGC WFS specification defines the interfaces between Web-based clients and servers for accessing feature-based geospatial data (http://www.opengeospatial.org/standards/wfs). Examples of geospatial feature data are transportation road networks, coastlines, political boundaries, and utility lines. The WCS and WFS together provide standardized, on-line access to all geospatial data. They form the foundation for Web-based interoperable access of geospatial data. The WFS specification defines three mandatory operations for accessing and manipulation of feature data:

GetCapabilities: A Web feature server must be able to describe its capabilities. Specifically, it must indicate which feature types it can serve and what operations on each feature type are supported.

Get Feature: A Web feature server must be able to service a request to retrieve feature instances. In addition, the client should be able to specify which feature properties to fetch and should be able to constrain the query spatially and non-spatially.

DescribeFeatureType: A Web feature server must be able, upon request, to describe the structure of any feature type it can serve.

2.2.2.3 OGC WMS

The OGC WMS specification defines Web interfaces for dynamically assembling maps over the Internet from multiple sources within a heterogeneous distributed computing environment (http://www.opengeospatial.org/standards/wms). Maps are the visualization of data. A WMS server normally converts the data in its archive to a visualized form (map) based on the requirements of the client. In many cases, a WMS server may talk to a WCS or WFS server to obtain the needed data for making maps requested by a client. In this sense, a WMS server can be considered as a data visualization service for either WFS or WCS servers. The WMS specification defines three operations:

GetCapabilities (required): Obtain service-level metadata, which is a machine-readable and human-readable description of the WMS's information content and acceptable request parameters.

GetMap (required): Obtain a map image whose geospatial and dimensional parameters are well defined.

GetfeatureInfo (optional): Ask for information about particular features shown on a map.

2.3 SIG Resources and Data Node

2.3.1 SIG Resources

The SIG framework can be divided into four layers (Tang et al. 2004): the resource layer, share layer, assembly layer and application layer. The resource layer is composed of the distributed geospatial file server, geospatial database server, remotely sensed imagery server, and sensor simulation node. All distributed resources are packaged and connected to the SIG system by the SIG Resource Package. The share layer is composed of the SIG Resource Management Service and SIG Resource information Service. It organizes, collects, discovers, and selects global spatial information resources. The assembly layer is composed of the SIG Spatial Information Resource Engine and SIG Information Index Engine. The former assembles and combines business logic, the latter searches quickly. The application layer realizes a SIG Portal for spatial users.

To make use of a spatial Web service, the user needs an interpretable and standard description and the means by which the service is accessed. An important goal in managing spatial resources information is to establish a framework within which these descriptions are made and shared. Besides technical support, the framework provides a unified starting point, which is the resources information registry for resources information description, publication, discovery, and employment (Guo et al. 2004).

The resource layer is the fundamental resource environment of SIG. It can be denoted by R (W, S, D), where W= {Image Service, Map Service, Feature Service...} represents the services that can be provided, S= {Data Description and Architecture Protocol, Data Access Protocol, Service Interoperation Protocol} represents the protocols that should be followed and D= {Spatial Data Files, Spatial Database} represents the data that can be provided. Of the three elements, W and D are resources for computing and data, while S is the access rule linking W and D. Figure 2.2 shows the concept model of the resource layer.

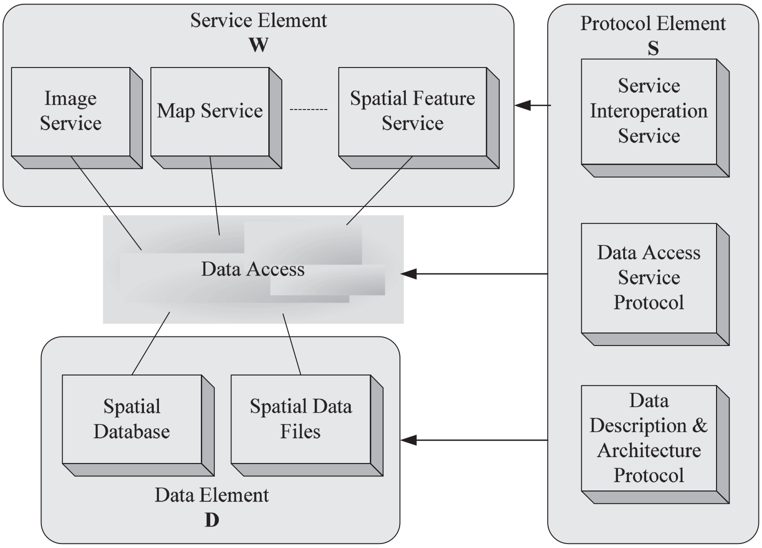

Fig. 2.2 SIG resource layer concept model

2.3.2 SIG Data Node

SIG's resource infrastructure node, which is composed of software, data, hardware, and protocols, can provide spatial data services to Grid. Furthermore, the data node follows OGC specifications in interface and interoperation.

The function of the SIG data node is to organize spatial data from distributed spatial data file servers, spatial database servers, and remotely sensed imagery servers into specific structures for easier managing, access, and use. So there are two requirements for this node:

(1) It should provide coverage services, map services, feature services, and catalog services.
(2) All of these services should comply with OGC specifications.

2.4 SIG Data Node Based on NWGISS

2.4.1 Structure of NWGISS

NWGISS was developed by the Laboratory for Advanced Information Technology and Standards (LAITS) at George Mason University (GMU) to manage the large volume of HDF-EOS format remote sensing data generated by NASA's Earth

Science Enterprise (ESE). LAITS' NWGISS design, a Grid based three-layer structure (Di et al. 2003), significantly improves the accessibility, interoperability of HDF-EOS data. It works with all HDF-EOS files. LAITS's NWGISS is also a Web-based data distribution system, compliant with multiple OGC standards. NWGISS consists of the following components: a Web map server (WMS), a Web coverage server (WCS), a Catalog Service/Web Profile (CS/W) server, a multi-protocol geo-information client (MPGC), and a toolbox (http://laits.gmu.edu/DownloadInterface.html). All NWGISS components can work either independently or collaboratively. WCS and WMS were designed for the distribution of remote sensing data. The CS/W server provides general OGC catalog services. MPGC is a comprehensive OGC client. Currently, OGC WRS, WMS, WFS, and WCS have been implemented in the client. The interaction between MPGC and OGC-compliant Web servers provides interoperable, personalized, on-demand data access and services for geospatial data. The NWGISS architecture can be seen in Fig. 2.3. Functions of five components are listed below (Di et al. 2002):

1) Map Server: The map server enables GIS clients to access HDF-EOS data as maps. Currently, the NWGISS map server complies with OGC WMS version 1.1.0. The OGC specification defines three interfaces: GetCapabilities, GetMap,

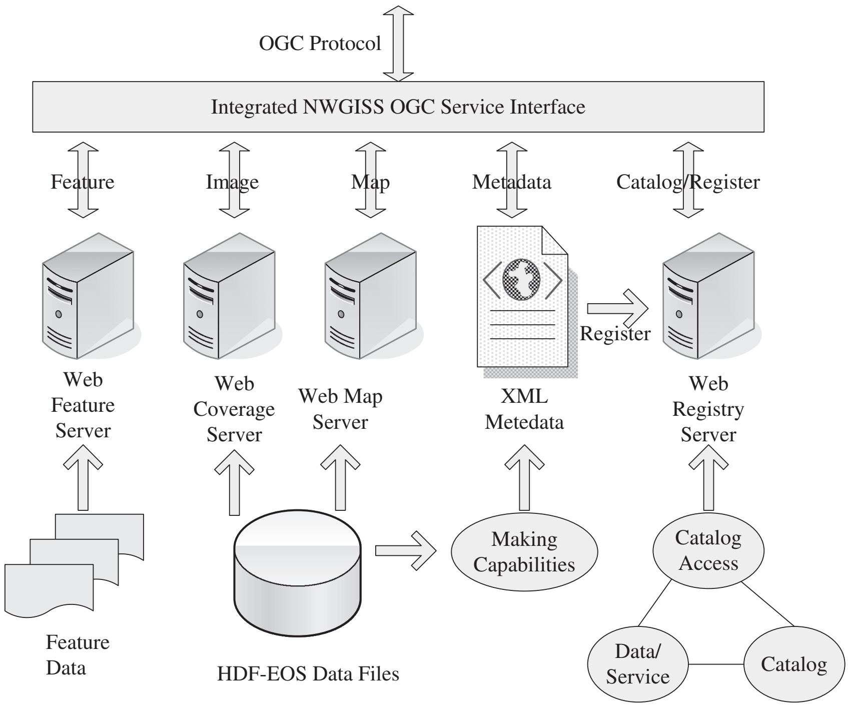

Fig. 2.3 NWGISS interoperation data server layer architechture (Tang and Jing 2004)

and GetFeatureInfo. All three interfaces have been implemented and all three HDF-EOS data models (Grid, Point, and Swath) are supported.

2) Coverage Server: The OGC Web Coverage Service (WCS) specification is designed to enable GIS clients to access multi-dimensional, multi-temporal geospatial data. WCS defines three interface protocols: getCapabilities, getCoverage, and describeCoverageType. The NWGISS coverage server has implemented both versions 0.5 and 0.6 of the draft WCS specification. NWGISS can return coverage in three formats: HDF-EOS (http://hdfeos.gsfc.nasa.gov/hdfeos/he4.cfm), GeoTIFF (http://remotesensing.org/geotiff/spec/geotiffhome.html), and NITFF.
3) Catalog Server: Both the WCS and WMS clients have the GetCapabilities protocol for finding geographic data/maps and services available from servers. This protocol works nicely when a server has a small data archive. If the server has a large quantity of data, the capabilities description, which basically is a data catalog, becomes very large. The catalog server allows GIS clients to search and find available geographic data and services in a NWGISS site following the OGC catalog interoperability specification (CIS). Both state-full and state-less OGC CIS have been implemented in the NWGISS catalog server, which reuses part of the Data and Information Access Link (DIAL) catalog server (Di et al. 1999).
4) Web Coverage Client: The NWGISS coverage client is a comprehensive OGC WCS client. It is able to interactively communicate with all OGC-compliant coverage servers for accessing multi-dimensional geospatial data and handling all three coverage-encoding formats, not only with NWGISS. Besides performing basic WCS client-server communication, coverage access, visualization, and user interaction, the client will also provide georectification, reprojection, and reformatting functions. The user's data requirement and the information about the data in the servers will automatically trigger execution of those functions, when required. The interaction between the NWGISS Web coverage client and OGC compliant Web coverage servers will provide interoperable, personalized, on-demand data access and services.
5) Toolbox: It contains tools for automated data ingestion and catalog creation. Currently, two types of tool are provided: format conversion tools and XML capabilities creation tools. A third type of tool the catalog creation tools, will be provided in the future.

2.4.2 Structure of SIG Data Node

To satisfy the requirements of a SIG data node, a framework of a SIG data service node was designed using NWGISS architecture and the OWS frame in Windows 2000 server and Linux operating system environments. A SIG data node architecture is shown in Fig. 2.4.

NWGISS is the core of the SIG data node. Format transfer is used to transfer other formats (such as GeoTiff) to HDF-EOS. Capabilities in WCS or WMS are generated from HDF-EOS data. These metadata documents will be registered in the

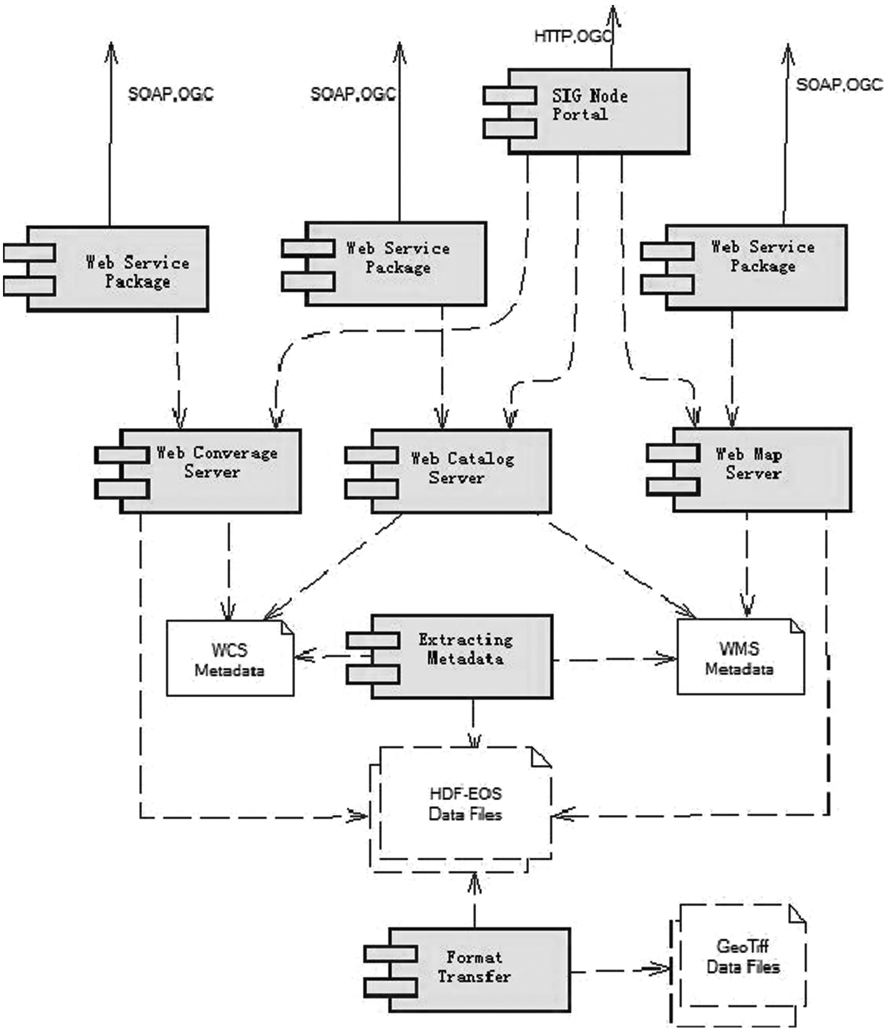

Fig. 2.4 SIG data node architecture

catalog server, available if required by the application layer or resource management layer.

The SIG node portal is a Website gateway for the service node. It is linked to all services by following OGC specifications. Clients from the application layer communicate with Portal by HTTP protocol. Base services, such as WCS, WMS, and CS/W, can interoperate directly with the resource or application layer. In order to satisfy the requirement of applications based on Web services, AXIS (The Apache Software Foundation) is used to convert (package) all services to Web service.

2.4.3 Geospatial Information Index

In order to efficiently support searching of geospatial data by different platforms, a quad-tree index structure was employed with OGC WCS specifications on both the Java and .net environments. Implementation of WCS in .net is based on .Net framework 2.0. It uses the C# 2.0 language to produce a WCS Web Service following the OGC standard. As shown in Fig. 2.5, the .net C# index class is composed of RequestParser.cs, DataIndex.cs, and Image.cs. RequestParser.cs is used to analyze parse Layer, BBOX, Width/Length, Format and to determine the spatial data index and the return data format. The main function of DataIndex.cs is to index the entire document. It first uses the Layer name that the user requested to determine the folder name; under this folder, it then uses the ratio of the Width/Length and the BBOX to determine the corresponding folder of images with the same spatial resolution. It then uses the BBOX to determine the document size and requested scope under this folder. Image.cs is used to splice the images that arrive to the index, return the mosaic image in the format requested by the user. The index process is invoked at GetCoverage time. Part of the analysis is completed in GetCoverage.cs, including request service name, edition.

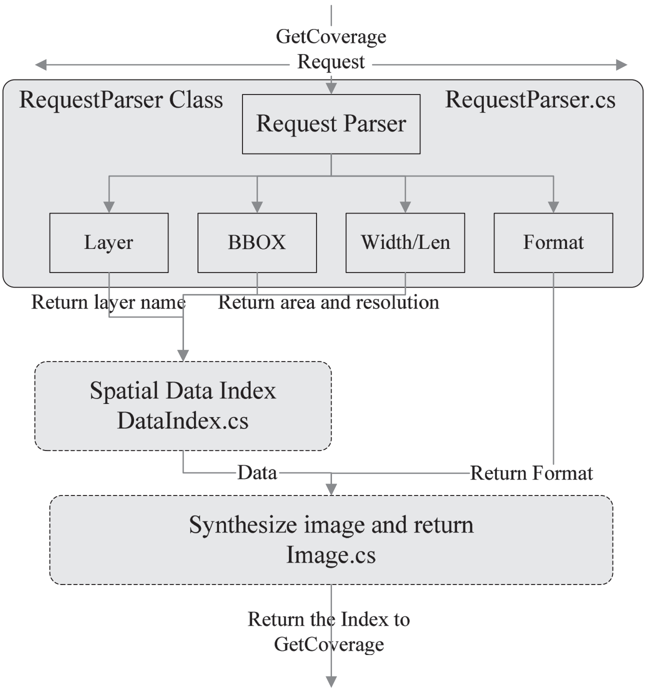

Fig. 2.5 Workflow for data index

On the other hand, implementation of WCS in Java is based on JRE 1.50. The Java development environment has already been installed, with the Web server being Tomcat and Web Service deployment by Apache AXIS. Complete spatial data index frameworks on Java and .net platforms are shown in Fig. 2.6.

This framework demonstrates the WCS flows using JAVA and .NET. The customer first uses GetCapabilities and DescribeCoverage requests to obtain the grid data description. Acting according to this description, the user then invokes the basic spatial data index mechanism, using GetCoverage to obtain the index to the grid document and return the grid image that the user requested.

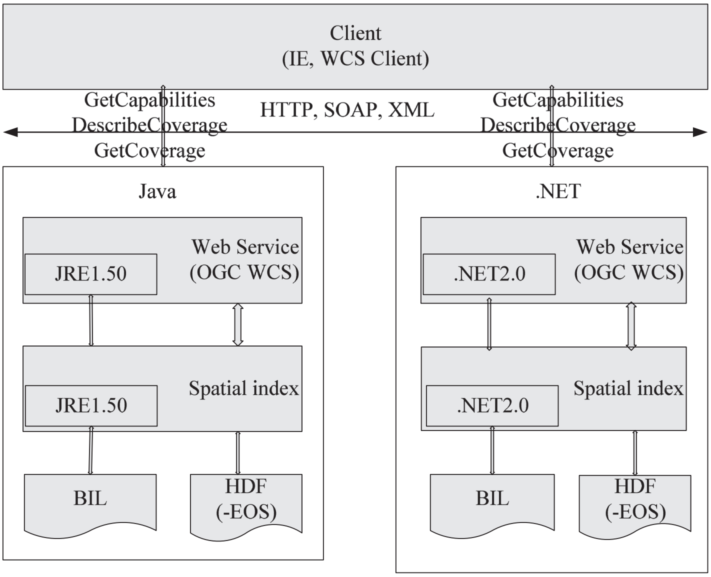

Fig. 2.6 System framework

2.5 Clients Implementation

2.5.1 Experiment Platform

The experiment platform (see Fig. 2.7) for SIG was built on Aparche/Tomcat in the Linux and Windows systems at the Institute of Spatial Information Technique (ISIT), Zhejiang University (ZJU) and GMU LAITS. The experiment concentrated on the resources layer.

ZJU ISIT manages the data node and provides access to the clients. It has responsibility for providing recent MODIS data and stored remote sensing images to SIG. This node server takes GMU LAITS's NWGISS as core software. The OGC WEB Coverage Service (WCS) 1.0 standard was employed as the data service interface. Any WCS1.0-compliant client may get data from the node. All the

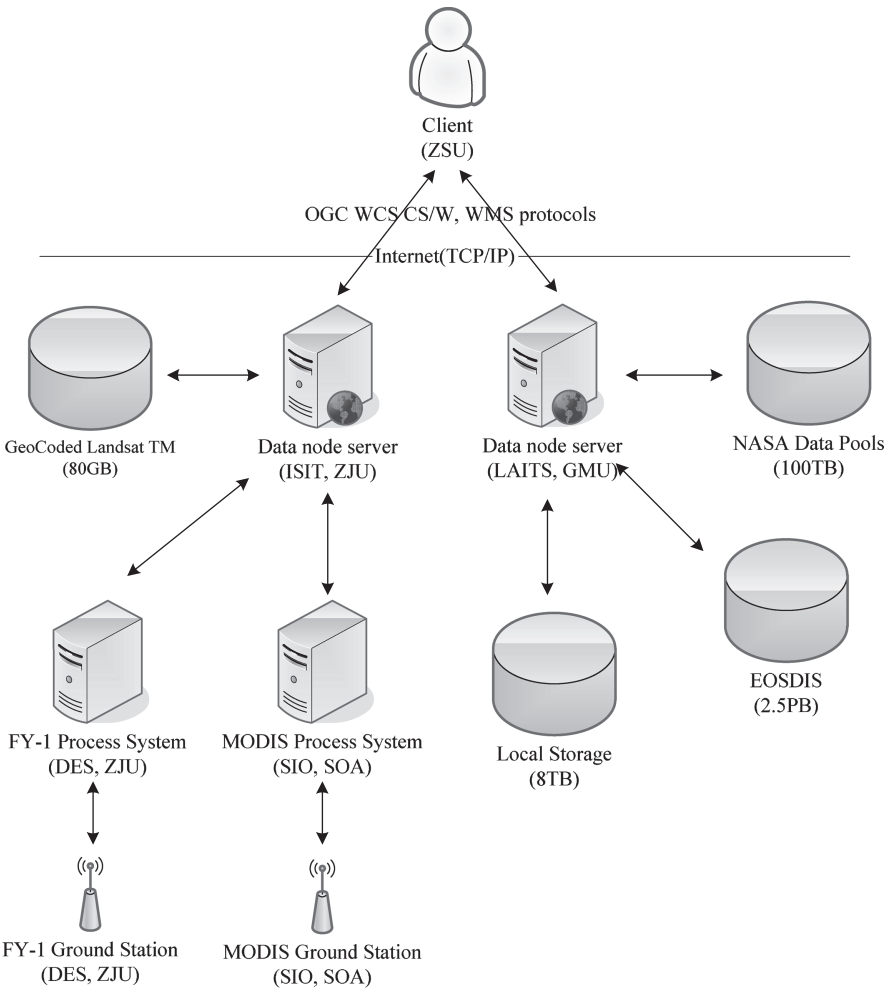

Fig. 2.7 Architecture of experimental system

location, time, projection, resolution, and format can be defined by the client. Three returned formats for coverage, HDF-EOS4, GeoTiff, and NITFF are supported by NWGISS.. WCS can also provide binary format data. The International Standard ISO 19115:2003 (http://www.isotc211.org/Outreach/Overview/Factsheet_19115.pdf) was employed to describe the dataset and ISO 19119:2005 (http://www.isotc211.org/outreach/overview/Factsheet_19119.pdf) was employed to register the data access service in the data node. Some metadata was also provided by the WCS XML Capability document. All the metadata can be obtained though WCS GetCapabilities and DescribeCoverage. The data query service is based on OGC Catalog Service (CS)/WEB (OGC CS/W) specifications. The node can provide almost real-time MODIS Data, which the Second Institute of Oceanography (SIO), State Oceanic Administration (SOA), China receives and processes. MODIS data are available in SIG WCS 1~2 h after the satellite passes over the territory. This SIG data node also connects with the remote sensing data processing system for the FY-1 meteorological satellite, managed by the Department of Earth Sciences (DES), ZJU. A JSP service gate portal that includes all the services provided by the SIG data node was designed in order to provide convenient access to the data node service. The GMU LAITS standards node can directly connect with the NASA EOSDIS system, and it can provide large quantities of NASA EOS earth observation data through the standard interface.

2.5.2 Client Access Mode

All the interfaces of the SIG data node are compliant with OGC specifications. Three access modes were adopted for different applications: Web service mode, Web application mode and desktop application mode.

Web service mode: The Web Service package tool AXIS, is used to package OGC services at each data node. After packaging, three methods, including GetCapabilities, GetCoverage and DescribeCoverage, are designed to interoperate with the client using the SOAP protocol. Parameter formats in these methods are consistent with OGC WCS specification.

Web application mode: An OGC-based request string construct in a specific format is used to get geospatial information through Internet Explorer. "HTTP://3.40.56/cgi-bin/wcs?version=1.0.0&service=wcs&request= GetCapabilities" is the string to get WCS metadata at a data node whose IP is 10.13.40.56.

Desktop application mode: In this mode, OGC specifications are protocols for requests for services and determine application-programming interfaces (APIs). Therefore, in software systems with different purposes, OGC-based codes can be embedded in HTTP requests to get data properly from the node.

Since the WCS service complies with OGC specifications, any methods or client tools compliant with OGC standards can directly access the WCS services. Both Web applications and desktop applications invoke the SIG Web service; they act as clients in Web service mode.

2.5.3 Desktop Application Mode

GMU MPGC is a windows-based Java client, compliant with OGC specifications; it can access geospatial data via desktop application mode (see Fig. 2.8). The client is deployed at Zhejiang Shuren University (ZSU), China, and acts as an instance of the SIG application layer. It uses a friendly user interface to receive user request parameters through an http request that uses internal packaging for SIG services to access the data. The SIG data node at ZJU responds to MPGS, returning information as requested (see Fig. 2.9).

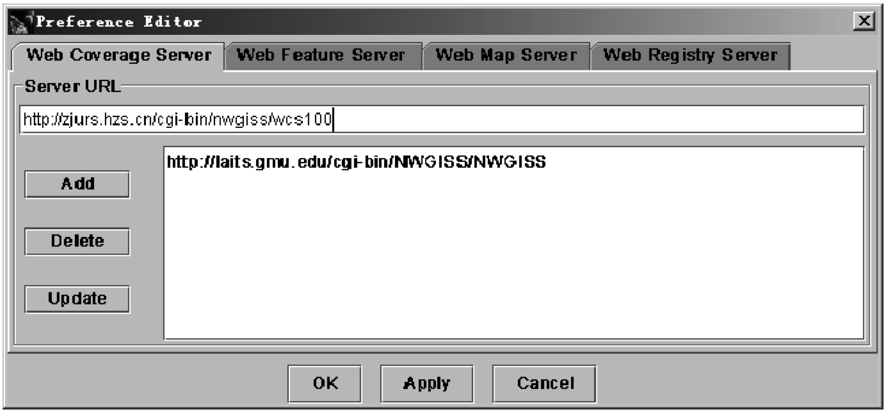

Fig. 2.8 MPGS request interface

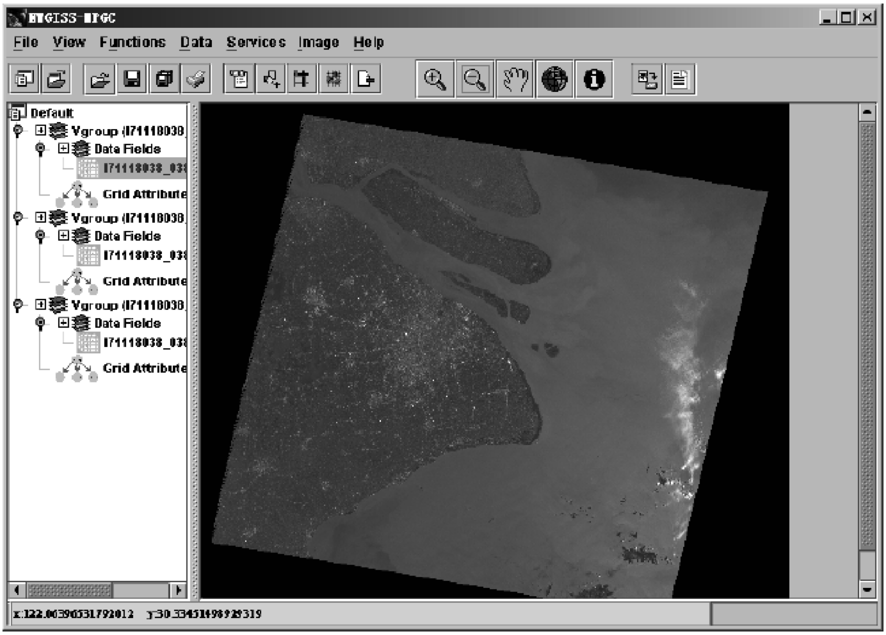

Fig. 2.9 Result from MPGS

2.5.4 Web Application Mode

Another case is a service chain application for water information extraction from Landsat TM. Figure 2.10 shows the framework.

This prototypes the integration of workflow technology, Web services, and the OGC Web Process Service specification (Version 1.0.0. http://www.opengeospatial.

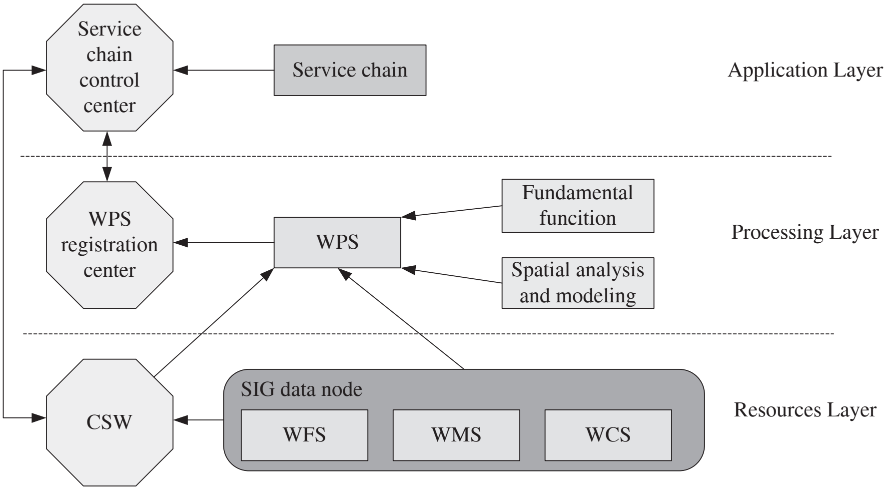

Fig. 2.10 Framework of service chain

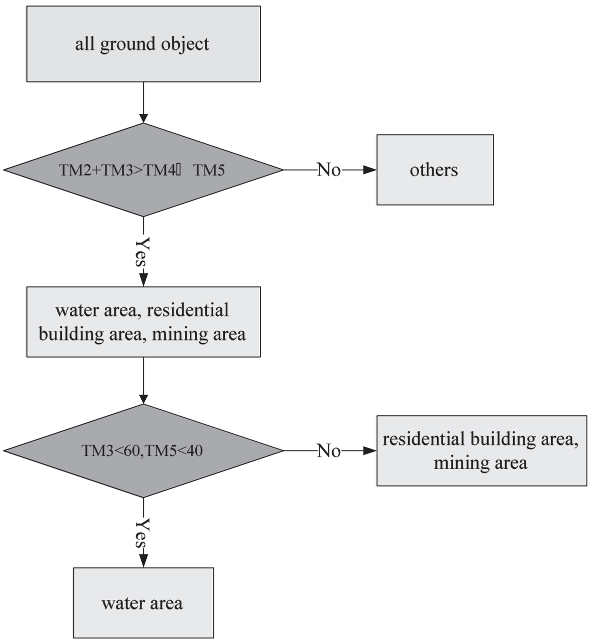

Fig. 2.11 Decision tree

org/standards/wps) (WPS). The WPS interface specifies three operations that can be requested by a client and performed by all WPS servers. Those operations are GetCapabilities, DescribeProcess, and Execute. These operations have many similarities to those in OGC Web Services such as WMS, WFS, and WCS.

In this test, all geospatial data are provided from distributed systems by the SIG data node. Processing functions are packaged as Web services, and can be discovered on line. For complex processing, which involves applying a chain of Web services-based geospatial processing functions, WPS is employed to link data and functions together based on a decision tree (see Fig. 2.11). A Web-based prototype system for extracting water information from TM remote sensing images was developed (see Fig. 2.12). This system shows the efficiency of the SIG data node and the ability to organize and execute a designed services chain. Furthermore, it has the advantages of being independent of platforms and program languages, and complying with OGC specifications.

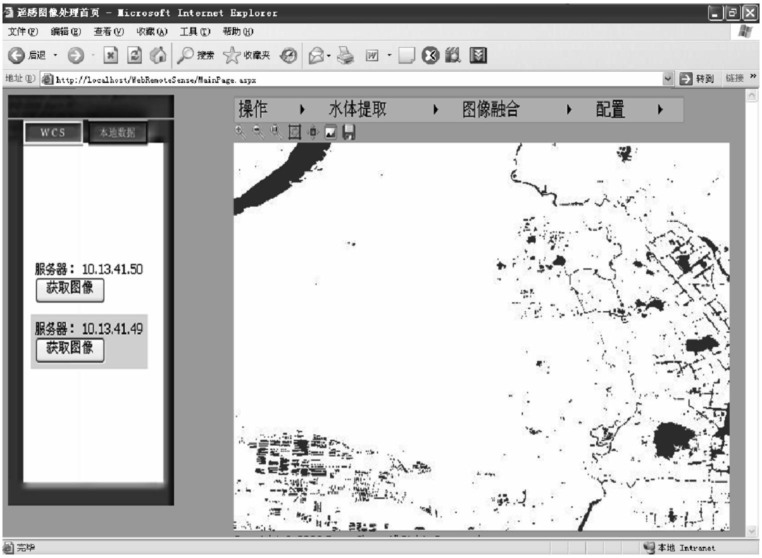

Fig. 2.12 Application interface

The experimental results indicate that these service nodes can successfully respond to requests compliant with OGC standards and return specific spatial data under different network environments. Any OGC WCS1.0-compliant geospatial information analysis system's client can access the data nodes distributed at different locations and locally retrieve geospatial data and complete comprehensive analysis. It shows that the SIG data node designed here can share distributed data. The Interoperable Access between the Windows data node and the Linux data node also shows that data can be shared under a heterogeneous operation environment.

2.6 Conclusions

Construction of the spatial information service node is fundamental for developing an infrastructure. This chapter discussed the design of a SIG data service node based on NWGISS, which implemented WCS, WMS, CS/W, tools for transforming relevant data format, and several node instances. To satisfy demands from different applications, AXIS packages OGC Web Services and provides services to clients in three different ways. Several major OGC specifications are implemented. Concurrent with the development of OGC specifications, adding additional OGC specifications and managing of larger volumes of data will be investigated.

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