THE CHANGING ROLE OF THE GEO-DATA INFRASTRUCTURE: FROM A DATA DELIVERY NETWORK TO A VIRTUAL ENTERPRISE SUPPORTING COMPLEX SERVICES

M. Radwan, L. Alvarez, R. Onchaga, J. Morales

International Institute for Geo-Information Science and Earth Observation (ITC)
(radwan, alvarez, onchaga, jmorales)@itc.nl

Commission VI, WG VI/4

KEY WORDS: Geo-data Infrastructure, Geo-Information Market, Geographical Services, Service Broker, Workflow Management Service, Quality of Services

ABSTRACT:

The geo-data infrastructure (GDI) has for long been developed as a network for spatial data discovery and access. As a result spatial data, in distributed and heterogeneous databases, are readily accessible and sharable. Spatial data abundance notwithstanding, a rapidly growing segment of the geoinformation market comprises non-expert GIS users who seldom seek raw data but rather demand value-added information products and services of varying complexity. Increasingly, traditional geo-data infrastructures fail to fully meet the needs of emerging markets. Further, increased competition, demand for lean enterprises, pervasive e-commerce and rapid gravitation towards Internet GIS all compound to motivate the concept of a novel service-centred infrastructure that enables delivery of geo-information services and products typically beyond the capability of any single organization. Such a service-centred infrastructure has variously referred to as the Geographical Services Infrastructure (GSI).

The GSI operates as a virtual enterprise comprising dynamic collaborations of many organizations partnering on the basis of core competencies and shared business objectives. The development of such an enterprise requires the design of an integrated platform that enables interoperability and inter-working of functional entities within heterogeneous environment. To facilitate access to GIS services over the Internet (Web GIS Services), mechanisms are needed to coordinate and control the execution of identified services. Workflow management services are suited for the latter set of functions while service brokers support the former. Service brokers maintain registries containing relevant service metadata to aid the discovery of required services. Workflow management services control and coordinate the execution of service chains, both intra- and inter-enterprise, negotiate and enforce adherence to quality of service specifications (service level agreements) while shielding the client from the complexities of the chaining process. The service broker and WFMS are thus central components of a GSI. The paper proposes a GSI system architecture in which the service broker and workflow management systems enable the delivery of services illustrating the interactions between these key components. An example for implementation is presented.

1. THE VIRTUAL ENTERPRISE: THE ROAD TOWARDS COLLABORATIVE WORK

Today's dynamic business environment forces industrial and service sectors to work beyond their boundaries and operate in a more tightly coupled mode, forming integrated 'virtual' enterprises, to seize business opportunity. A Virtual Enterprise (VE) is a temporary network of independent organisations (legally autonomous companies), that join functions with a particular objective. A VE is structured and managed in such a way that it is seen by third parties as an identifiable and complete organisation (one enterprise). The principles of the VE are: better customer satisfaction, reduced time-to-market and adaptation to changes in the surrounding environment.

These principles are applied mainly with the aim of having a share in a wider global market. This approach provides an organization with enough flexibility to handle an uncertain changing environment. These enterprises are called "virtual" because of their temporary nature, seizing certain, often short-lived, business. The products and services provided by VEs are dependent on innovation and are strongly customer-based.

Current developments in the industrial and service sectors are focusing on the concept of VE and in the issues that have to be addressed to achieve inter-organisational integration. The development of an integrated platform that enables interoperability and inter-working of functional entities within heterogeneous environment is required to make such an enterprise feasible. Further, special computer-based tools are required to manage cross-organisational information, processes, and workflows as well as the quality of services of such distributed enterprise [2], [3], [4], [5], [6].

2. IMPACT ON GIS MARKET: GOING BEYOND THE TRADITIONAL BOUNDARIES OF ORGANIZATIONS

2.1 New Trends in GIS Advances

The implementation of these new ideas of virtual communities, collaborative work, etc. and integrating processes and information from different organisations, for the delivery of products or services on the basis of common business understanding is an inevitable future characteristic of the GIS market worldwide. These developments lead to several consequences, such as:

- Collaborative work: it has become evident that satisfying the needs for a large variety of geo-spatial datasets and services, mostly in near-time mode, is beyond the capacity of a 'single' organisation. As organisation start to collaborate, they develop a need for new mechanisms, tools and ideas as to how to define, execute and manage collaborative processes, [6], [9].
- Interoperable, distributed GIS functionality, the growth of the Internet and the accompanying advances in communication technology are pushing the interoperability efforts to facilitate the sharing and distributing geodata. Furthermore, these technological advances are leading to the boom in Web mapping and Internet GIS. New GIS models emerge, based on the concept of unbundling functionalities in the current stand-alone systems to be delivered over the Internet, as independently developed, yet interoperable autonomous services, [2], [11].
- Web services: there exists increasing interest in Web Map Services, as commercially available ready to use services delivered across the Internet, and the on-going OGC developments of standards for such services and their access via standard, interoperable, interfaces, [12].

2.2 The Emerge of 'Virtual' Mapping Organization

Geo-information and mapping organisations have been affected by economic and technical developments in the way they perform their job, creating new ways to do business, being partnership and collaboration an important business strategy. This is to satisfy the needs for varieties of geo-spatial data sets and services, mostly of large volumes and in near-time mode, and beyond the capacity of single organizations. The partnership collaboration can be improved by applying a new business paradigm: the virtual enterprise. By taking this approach, more tightly integration and communication is achieved through a common mission, strategy and use of ICT, with mechanisms to establish clear responsibilities improving the production relation-ships and thus improving success for the organisations. The virtual enterprise is a new business practice that is emerging, [9].

The operational model of such an enterprise is based on the concept of unbundling of the functionalities of current stand-alone systems in the traditional Geo-organisations, including mapping agencies, to make them available as independently developed, yet interoperable autonomous services. These functionalities include processes from different data sources, processes to create databases and manage their access, processes for map visualisation, GIS functionality for spatial data analysis, etc. Such services are essentially processes that run on Web services. Adding to these functionalities, the commercially available Internet-based services (Web Map Services), ready to use via standardised access interfaces and delivered across a wide area network; the OGC Application Service provider is an example [12].

An infrastructure, with institutional and technical arrangement will be required to support the networking and chaining of these functionalities and services to create customised solutions and achieve common business goals. Integration is not limited to data exchange capabilities, but also concern with the rest of the enterprise by connecting all necessary functions and heterogeneous functional entities: business processes, information systems, application packages, organization units, resources, etc. The infrastructure will manage information, processes, control and workflows across the boundaries of the participating organisations. Basic functionalities and services are processes that run on Web services, made accessible via standardised, interoperable, access interfaces, semantic unification must be assured to support data exchange and need to be registered in order to be located in a distributed environment; all these are the main requirements to utilise such an infrastructure. Further, special services will be developed to provide the option of combining and chaining of services (a kind of broker/mediator), also to manage inter-organisational workflows and manage the quality of services in such wider network of services, operating under different rules and constraints, [2], [6], [9].

3. THE CHANGING ROLE OF GEO-SPATIAL INFORMATION INFRASTRUCTURE: FROM DATA TO SERVICE DELIVERY

Geo-information Data Infrastructure (GDI) provides access to geographical data by networking geo-information databases ruled by sharing mechanisms, defining technological as well as organisational aspects for the exchange of data.

The role of the GDI is currently changing, from it being a simple data discovery and retrieval facility to become an integrated system suitable for the provision of customised information and services. For the sake of simplicity we use the term services to denote geo-information services. Normally developers address the issue of designing complex services by stringing together groups of functions in an ad-hoc manner. This approach may satisfy a particular need but doing this separately for different services hampers reusability. Moreover, lack, of descriptions of the solutions obtained makes it hard to aggregate solutions to execute complex tasks.

From the 'virtual enterprise' perspective, a GDI is viewed as a mechanism that facilitates collaborative work, where it is possible to link autonomous, distributed, geo-information centres (data providers, value added service enablers, service providers and control units) to achieve business goals, [8],[9].

Such a service-centred infrastructure has variously referred to as the Geog-information Services Infrastructure (GSI).

The objective of our research is therefore focusing on the development of mechanisms to describe, combine and manage independent collections of services. Here we introduce a concept that aims at facilitating the generation of sophisticated value-added services, (see Figure 1). The idea of the GSI is that elementary services can be described, accessed, combined and managed to deliver complex content. Within the GSI a common method is used to describe elementary services and their interfaces, and then these services are made available for users to create service chains that perform complex geo-processing tasks [6], [7], [9].

A GSI is a system from which specialised geo-information products and services can be obtained by exploiting the artefacts of an infrastructure of interconnected nodes that include, among others, data repositories, data brokers, service providers, service brokers and clients.
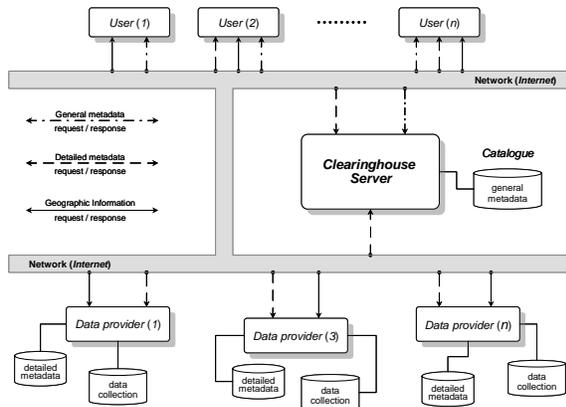
Figure 1. Geoinformation Service Infrastructure

Large geo-processing tasks are achieved by combining or chaining artefacts located along the distributed nodes. Such combinations of artefacts provide diverse functionality that satisfies particular sets of requirements. Every artefact has an economic value; these artefacts are assembled to perform operations within the infrastructure, resulting in a specialised artefact that has a value equal or larger than the value of the artefacts used. This architectural approach can be regarded as a "value-added system". By chaining these artefacts one can provide a service. A service is defined as a behaviour of value to the user, which is accessible or instantiated through interaction points. This behaviour is exhibited through an appropriate combination of elementary artefacts.

In order to bind multiple artefacts into a chain that accomplishes a large geo-processing task, a proper description of the participating artefacts is required. These descriptions focus on exposing the artefact's internal behaviour, its intended effect and its interaction points or points of composition. These descriptions, which are presented as instances of well-defined models, make it possible to interchange and reuse artefacts. We call these descriptions system metadata and they are stored and accessible through a service repository.

The GSI system enables Geo-Service Providers (GSPs) to make use of each others functionality to supply a wide range of services and possibly to reach larger groups of users. Figure 1 illustrates the interactions that take place as GSP nodes provide services to their users.

Users interact with the different GSP-nodes to request their specific services. Figure 1 shows these interactions as dashed-lines. GSP-nodes may make use of artefacts available in other GSP-nodes in order to realise a particular service. These interactions between GSP-nodes are shown in Figure 1 as solid lines running from Node to Node. All connections mentioned here are established through a network.

At the bottom of Figure 1 we can see that additional data collections located at non-GSP nodes may still be accessed, if needed, either by users or service providers. This is achieved by making use of the conventional data discovery functionality, of the clearinghouse server. These interactions appear in the Figure 1 as dashed-dot-lines.

4. MODELING THE GSI AS VIRTUAL ENTERPRISE

Looking at the GSI as a VE facilitates its development and maintenance as it can be seen as an enterprise entity to be analyzed, modelled and executed with concepts from enterprise modelling and engineering where an enterprise is described by different inter-related models to describe its various essential aspects.

The integrated enterprise model of VE (and associate specifications) will describe the system from various perspectives (viewpoints) in order to provide the focal point, around which the business operations in VE are designed, implemented, managed and improved and/or business opportunities are identified. It will also support the assessment of its performance in 'totality' along the various operational dimension, i.e. quality, time of delivery, cost, optimum use of resources, monitoring of changes in the surrounding environment as well as the capability to adapt to such changes at both organization's business and operational levels. The model plays a vital role in enterprise integration and managing virtual enterprises. It represents the common semantic to insure interoperability and knowledge sharing between its functional entities for the execution of business processes.

The Geo-spatial Industry can benefit from the various models and tools that are developed in other industries, as well as the vast opportunities offered by ICT, to make such a 'virtual' enterprise VE feasible. These models define a set of abstractions (viewpoints) of an enterprise with the associate viewpoint languages defining the concepts of each viewpoint [3], [9].
With respect to the computational viewpoint (as the most relevant to our discussion), it provides functional decomposition of the system into a set of services that accessed through interfaces (set of operations that characterize the behaviour of an entity). Processes are modelled by their properties (content, behaviour, environment of a service), also describing the technology, information and enterprise aspects of the service (the process Model). Services can be classified according to several schemes [2], [11].

- Stakeholders perspective: processes performed by Service Provider, Service Requestor, Service Broker;
- Functionality perspective: Data Services (to access to databases), Registry Services (to document and/or locate data and processes), Map Services (perform basic mapping operations such as georeferencing, visualisation), Application Services (value added services);
- Hierarchy and Chaining Perspective: Simple Services, Aggregated Services (bundle pre-defined chain of services, to be presented as one), chaining services (design interfaces between chain of services), Mediator (smart) Services (support chaining of services according to user requirements), Workflow Management Services (pre-defined chain of services, managed by computer-based workflow management system).

5. THE GSI BROKER

In a virtual environment, with enterprises not knowing each other, there must be a mechanism to facilitate their cooperation. For that the broker can be used. A broker in the VE context is the facilitating mechanism to find partners to cooperate with

and to provide a complex product to fulfil a client demand. The GSI broker will serves as the mechanism supporting the searching for products by users, the selection of partners and the creation and control of the workflow [1], [5], [6].

Table 1: OGC service taxonomy

Service Categories
Human Interaction
Information Management
Workflow
Processing
Communication
System Management

Following the OCG service taxonomy categories (Table 1) [10], the broker will support the workflow with additional capabilities for control and management that can be placed into the System Management OGC categories [11]. The main components of the GSI architecture are the user (client), the broker and the GSI nodes, arranged in client/server architecture using Internet as the network environment (see Figure 2). The client (organisation) is one of the GSP nodes, looking for partnership to fulfill a demand. The client defines the objective of the VE to be created, organises and looks for partners. The client designs, implements, operates and owns the service via the service broker, which will link the participating enterprises.
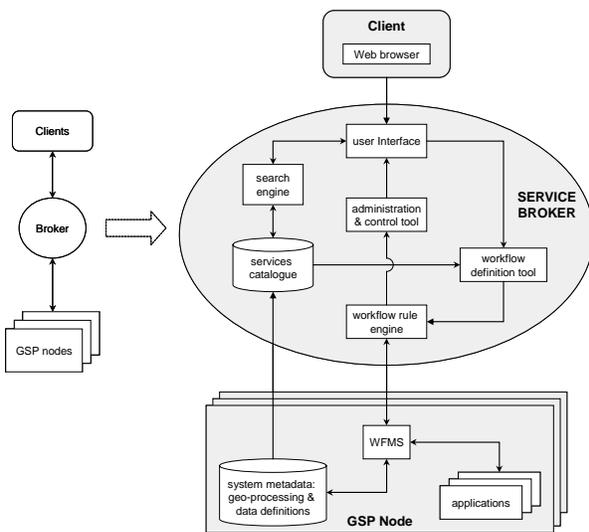
Figure 2. GSI Enterprise Conceptual Architecture

The service broker supports the creation, execution, control and management of business virtual processes. It is composed of:

- User Interface: gives access to the different services provided in the broker;
- Search Engine: This service allows users to find the business services they need. To find individual products or services the search engine has access to the Workflow Services Catalogue;
- Workflow Services Catalogue: in a virtual environment, enterprises advertise their services in this component. It should contain the business services definition (which includes simple services like data supply) and the

workflow definition. This functionality can be inside or outside the broker and is represented by a dashed line;
- Workflow definition tool: provides tools to define a virtual business process made up of building blocks from the workflow services catalogue (chaining enabler), which is feed by the enterprises participating in the GSI. The workflow definition tool creates a single definition of the virtual business process, facilitating its enactment;
- Workflow rule engine: the full virtual business process definition will be passed to the workflow rule engine for enactment and control of the execution. It communicates with the WFMS of the GSI nodes to trigger the activities when corresponding. However, the participating nodes not necessarily need to own a WFMS in which case the trigger to start the process is not automated. The enactment service of the workflow engine takes care of security mechanisms for data transmission over the network;
- Administration and control tool: it is responsible for keeping track of the progress made in the execution of the virtual business process, provides status of all active components in the system and keeps a log history file with performance data like duration of the activities, that can be consulted by the membership organisations participating in the GSI via the user interface.

6. CASE STUDY: IMPLEMENTATION OF THE 'VIRTUAL' LAND AGENCY

The Egyptian Government has the need of a modern Land Information System (LIS) to improve Local Real Estate market and encourage foreign investments as some of the main reasons. The tasks and data needed for the LIS are distributed in three different organizations from the government:

- The Egyptian Survey Authority in charge of the rural an urban parcel surveying
- The Registration Estate Office: in charge of the parcel registration
- The State Owned Land Office: in charge of managing the State-owned land and responsible for the development of land use scenarios for investors in real estate.

A possible solution is to use the existing government agencies as nodes of a GSI system and the concepts of VE as outlined above. By linking them, their workflows and data, the three agencies behave as a 'virtual' Land Information Agency.
The participating agencies require a service orientation attitude, clear business process definitions, high commitment for collaboration and ICT infrastructure to create and maintain the LIS which will support the land market players and other organizations as it participates in the National GDI (NGDI). A prototype was developed at ITC, in the framework of the TMS/ESA Project for capacity building in the Egyptian Survey Authority, [14]. Figure 3 depicts the participating organizations and the services they provide in the 'Virtual' Land Agency. In addition to the above mentioned organizations, is the Information and Communication Technology (ICT) supply information service which interact with the main users of the LIS. The other components which support services such as finance, user interface, etc. are left out as they are of the scope of this paper.

The tool used for the agencies, or enterprises to interact with each other, is the GDI broker or, as we prefer to call it, the GSI

broker, as in this infrastructure, not only data but services are to be provided. The service broker for the Virtual Lang Agency (Figure 4), supports the creation, execution, control and management of business virtual processes. It is composed of the components explained in Section 5; the *Workflow Service Catalogue, Workflow definition tool, Workflow rule engine* and *Administration and control tool.*
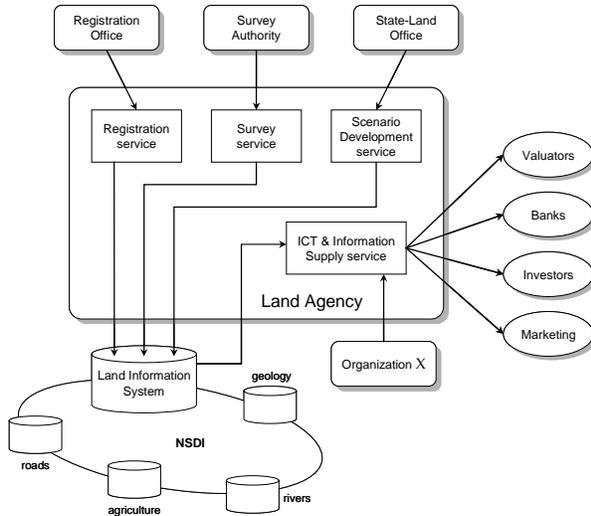
Figure 3. Virtual Land Agency and
its participating organizations

The proposed GSI broker is an Inter-workflow Management System based on the work of Hayami and Katsumata, [4] and the interoperability standards developed by the Workflow Management Coalition (WfMC), [1], with the main components of a regular WFMS: a process definition tool, a workflow engine and the administration and monitoring tool. Using the inter-workflow method, the process is defined in hierarchy. One top-level definition of the cooperative process is made in the Inter-workflow definition tool and internal process definitions are made in the enterprises.

The communication can be achieved using gateways as described in the WfMC Interoperability, [1]. A gateway is a mechanism that allows specific workflow products to move work between each other.

7. QUALITY-AWARE SERVICE CHAINING

The previous sections have outlined the eminent evolution of the GDI into a to take advantage of ICT advances and novel business paradigms. The GSI is rooted in web services technology, particularly dynamic chaining of geographic information services to deliver functionality of value to the user.

Dynamic chaining of services presents a novel model for delivering geospatial solutions, products and services to diverse communities of users. With state of the art standards for business-to-business integration, GI services offer a real opportunity for disparate GI enterprises (service nodes) to dynamically discover each other, negotiate innovative business propositions and collaboratively execute common business processes to address a market opportunity and meet strategic mission.

However, as the technology becomes mundane, the services will proliferate and the number of users will explode. Furthermore, the emergence of exciting but quality sensitive applications like wireless and mobile location-based services, and increased integration of GI services in mission critical business processes, quality of service (QoS) emerges as a critical concern and a major factor of competition on the geographic services infrastructure.

Sustainable exploitation of GI services therefore demands careful consideration of diverse user requirements and the quality related constraints of service chaining in view of the limitations of Web computing. Given the potentially large number of services, each with distinct non-functional quality characteristics, a first and necessary step towards providing QoS guarantees in service chains will thus be to enforce QoS-aware discovery and composition of services, in which services are selected from a community to participate in a business process based on their non-functional quality properties. Once selected, the services can then be choreographed in their correct sequence and their execution managed by a QoS-aware workflow management system to ensure adherence to QoS specifications.

Clearly, mechanisms to enable QoS-aware discovery and composition of services, orchestration and execution service chains in workflows become necessary. Similarly, a QoS model defining important non-functional quality characteristics is needed. These constraints can be imposed and managed by the service broker shown in Figure 3.

Its notable however, that the notion of quality being advanced here is beyond classical spatial data quality and extends to include systemic and business process quality criteria like cost, performance, reliability etc. QoS-aware service chaining, while not providing hard QoS guarantees, will greatly enhance the quality perceived by the user or Internet GI applications, [13].

8. CONCLUDING REMARKS

Geo-information production services can be offered in a market place, using the Web and Internet as the network environment that can reach more customers at lower prices and taking advantage of the efforts and advances on existing GDI concept which will be improved to a Geo-information Service Infrastructure (GSI), that as its name suggest, can offer data plus services for all the geomatics players, including direct contact with customers and their requirements, all together in a virtual environment, composed of a collection of independent enterprises offering their core competences and joining together in a dynamic way to offer and produce complex products.

By using the concept of the virtual enterprise, the GSI has been outlined. Such an enterprise can extend its share in the ever-growing information mark by providing access to a variety of GIS services and to be a tool to support the generation of 'complex' products/services. Such view will enhance the existing geo-spatial data infrastructure concept. The geo-information 'service' infrastructure opens new business opportunities for service delivery, facilitating service search and execution, and increasing the interest of organisations to participate in geo-information infrastructure initiatives. It also provide huge entry opportunities for 'small niche players to enter the market with specific offering. However, these opportunities are limited by the availability of data/service repositories and catalogues in the market.
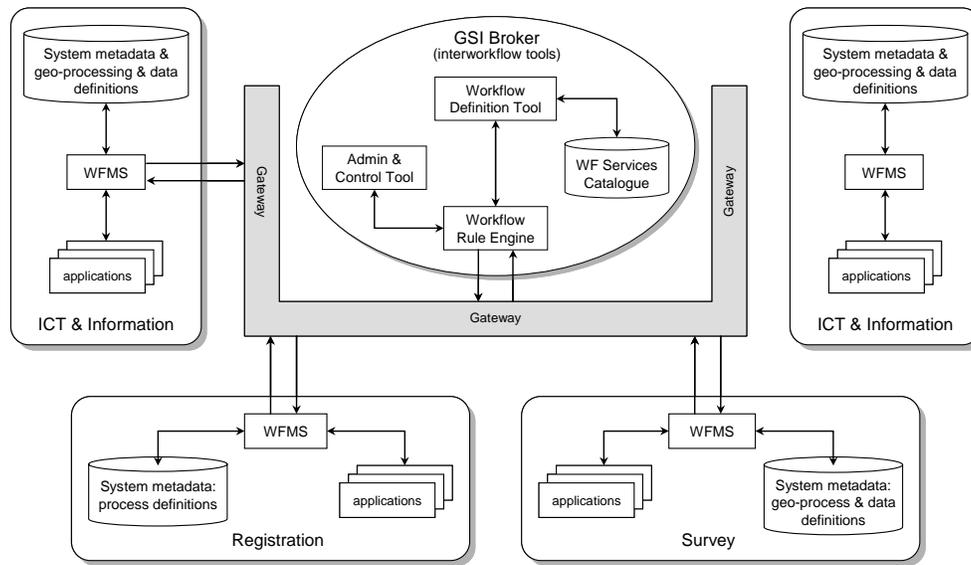
Figure 4. GSI broker conceptual architecture for the Virtual Land Agency

A client/server architecture that supports the GSI virtual enterprise has been defined, with special attention to the GSI broker, which will provide the services and functions required to link the clients and the enterprises data and processes. The client can be an individual looking for data as in the case of traditional GDI concept or it can be a geo-information production organisation looking for partners to extend its production. The second client is the focus of the broker services. The GSI broker supports searching for services, definition, control and execution of workflows from different enterprises to supply a demand by using an inter-workflow management system.

The Inter-workflow management system is an appropriate tool to create and manage virtual enterprises supporting the design, integration, operation and control of processes which are provided as services by multiple enterprises.

References

[1] T. Adams and S. Dworkin. WfMC Workflow Handbook, chapter Workflow Interoperability Between Businesses, pages 211–221. John Wiley & Sons, 1997.

[2] N. Alameh. Scalable and Extensible Infrastructures for Distributing Interoperable Geographic Information Services on the Internet. PhD thesis, Massachusetts Institute of Technology (MIT), Massachussets, United States of America, 2001.

[3] Peter Bernus and Laszlo Nemes. Modelling and methodologies for enterprise integration. In Proceedings of the International Federation for Information Processing (IFIP) Conference on Models and Methodologies for Enterprise Integration. Chapman & Hall, 1996.

[4] H. Hayami and M. Katsumata. WfMC: Workflow handbook 2001, chapter Interworkflow: A challenge for Business-to-Business Electronic Commerce. Future Strategies Inc., Florida, United States of America, 2001.

[5] J. Kanet, W. Faisst, and P. Mertens. Application of information technology to a virtual enterprise broker: The case of bill epstein. International Journal of Production Economics, 62:23–32, 1999.

[6] L. Alvarez. Geoinformation virtual enterprises: design and process management. Master Thesis, International Institute for Geo-Information Science and Earth Observation ITC, Enschede, The Netherlands, March 2003.

[7] J. Morales J. Model-driven design of geo-information Services, Ph.D Thesis, ITC, 2004

[8] J. Morales J and M. Radwan. Extending geoinformation services: A virtual architecture for spatial data infrastructures. In Proceedings of the Joint International Symposium on GeoSpatial Theory, Processing and Applications of the ISPRS Commission IV, Ottawa, Canada, July 2002.

[9] M. Radwan, L. Alvarez, R Onchaga, and J Morales. 'Designing an Integrated Enterprise Model to support Partnerships in the Geo-information Industry', Map Asia 2003, Malaysia, October 2003

[10] The openGIS Abstract Specification Topic 12: OpenGIS Service Architecture. Version 4.3, Open GIS Consortium, Inc., January 2002. Editor: George Percivall.

[11] OpenGIS Reference Model. Version: 0.1.2, No. OGC 03-040, Open GIS Consortium Inc., March 2003. Editor: Kurt Buehler.

[12] OpenGIS Web Services Architecture. Discussion paper, Version: 0.3, No. OGC 03-025, Open GIS Consortium Inc., January 2003. Editor: Joshua Lieberman

[13] R. Onchaga. Modeling for quality of services in distributed geoprocessing. ISPRS proceeding, Istanbul 2004.

[14] M. Nasr, M. Radwan. Capacity Building in the Egyptian Survey Authority: A Cooperation program with the Dutch Government. ISPRS Proceding, Istanbul 2004.