Designing an Integrated Enterprise Model to support Partnerships in the Geo-Information Industry

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Abstract

Continuous pressure on government budgets, rapid changes in business opportunities and quick technological improvements make today's geo-information market very dynamic. This forces organisations, such as National Mapping Agencies (NMA) and GIS companies, to change the way they generate services and to adopt new working strategies. In this transition, organisations have realised that satisfying user with varieties of geo-information services, in large volumes and in near real-time mode, goes beyond the capacity of 'single' organisations. Therefore, these organisations are seeking for mechanisms that enable them to work together in a more collaborative way. These collaborations can be better realised making use of modern business strategies such as the Virtual Enterprise.

The Virtual Enterprise idea is very appealing to organisations working in a very dynamic and fast-growing market. In a Virtual Enterprise (VE), individual (small as well as large) organisations or part-there-of work as a collaborative network to deliver specialised products or services on the basis of common business understanding. Such enterprises are called "Virtual" because of their temporary nature, based on seizing business opportunities and exploiting the strengths offered by the information and Communication technology. A VE combines distributed functions provided by the participating organisations to deliver services, and it is structured and managed in such way that it is seen by third parties as one single enterprise.

Within this context, the Geographic Data Infrastructure (GDI) is viewed as integrated entity linking data providers and user communities on the bases of the common goal of data sharing. Such an entity can be enhanced such that it is possible to share in addition to data, business goals, strategies, processes, operations, value-added products, etc. enabling the development of geo-virtual enterprises. In this environment any participant organization can extend its share to the ever-growing information market, by simply providing access to its geo-services and consequently becoming a tool that can be used in the generation of different 'complex' services. In this setting, the GDI will become a collaborative working environment, linking autonomous nodes that cooperate in order to achieve business goals and to deliver services to their end users.

The development of such an enterprise requires the design of an integration platform that enables interoperability and inter-working of functional entities within heterogeneous environment. The geo-information industry can benefit from the various models and tools that have been developed in other industries for integrated enterprise modeling, as well as the vast development made by OGC to develop standard, interoperable, access interfaces, to facilitate access to GIS services over the Internet (Web Services, Internet GIS).

1 The new geo-information production organisations

1.1 Challenges

Digital geo-information technology was initially introduced in many NMAs around the world, in the late 1960s, mainly to support data acquisition and to replace lengthy and rigid cartographic operations. Experience in these organisations, however, indicates that return on revenue on the heavy investment made is still below expectations. This is because these organisations still follow their traditional way of doing business. This traditional way of working was designed when government funds were secure and the mapping market was relatively stable, unfortunately, that is no longer the case. At present, these organisations have to work differently and should pay attention to the following considerations:

- Reduced government funds and the need to generate revenue to support its existence;
- A fast growing GIS-market and the emerge of a new generation of geo-information users;
- User's dissatisfaction due to lengthy base-mapping programs;
- The user's need for new products that substitute the conventional base maps;
- New competitors encouraged by cheap technology and easy access to raw data, and with the flexibility to adapt to changing requirements;
- The continuous development in information technology and its impact on the geo-information industry.

1.2 Improvement Actions

In many countries, NMAs are under the pressure to revise their mission and become competitive and self funded, without violating their national mandate. This requires these organisations to deliver services to the customer's specifications. That is, to provide data and other tailored products in time, at affordable costs and with the required quality. It is also important for NMAs to play a role in developing the necessary infrastructure to facilitate access to their goods, such as data, processes, etc. [6].

Improvement projects should in any case benefit from modern business concepts applied in other industries. These concepts include, a.o., Business Process Redesign (BPR), Workflow Management (WFM), Total Quality Management (TQM), Enterprise Resource Management (ERM), Just-In-Time (JIT) Services. These concepts should guide the organisational shift towards a better marketing strategy and an optimum use of technology to achieve business goals [18].

Geo-information providers, NMAs in particular, need to redefine their working strategies and embrace modern business practices in their production processes to meet diverse customer demands, and at the same time obeying their national mandates. These should lead organisations to focus on their core competencies, and outsourcing and collaboration with others organisations in areas, which are not their strengths. Examples of collaboration strategies can be found in Ordnance Survey (Partner Initiative), the National Imagery and Mapping Agency NIMA (Partnership Division) and the U.S. Geological Survey USGS (National Map project) [19] to mention some.

2 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 organizacin 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, 12].

3 Impact on GIS market: going beyond the traditional boundaries of NMAs

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, which we considered in our research activities at ITC for further elaboration. These consequences are, among others:

1. Downsizing: organisations focus on their main competences, and make use of ready-made services from other providers, for those tasks, which are not their strength (outsourcing, collaboration with other organisations).
2. 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.
3. A different view of GDI: In the early days, GDI was meant to provide a mechanism, with technical and institutional arrangements, to access data hosted in distributed, mostly heterogeneous databases. 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 (see Section 4).

4. Interoperable, distributed GIS functionality: GIS systems have been in existence since the 1970s, as stand-alone applications, independently developed by organisations in response to their specific needs. As a result, numerous incompatible data formats and spatial conceptions emerged; it became difficult to share and reuse this data across departments and disciplines which is associated with high reproduction costs. 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 [12, 14].
5. 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 [11, 16, 17].

New research perspective

We therefore focus our research towards the 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. 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.

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, organisation 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.

4 From GDI to GSI

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.

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. We call it the Geo-information Service Infrastructure or GSI for short (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 [12, 6, 13].

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.

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

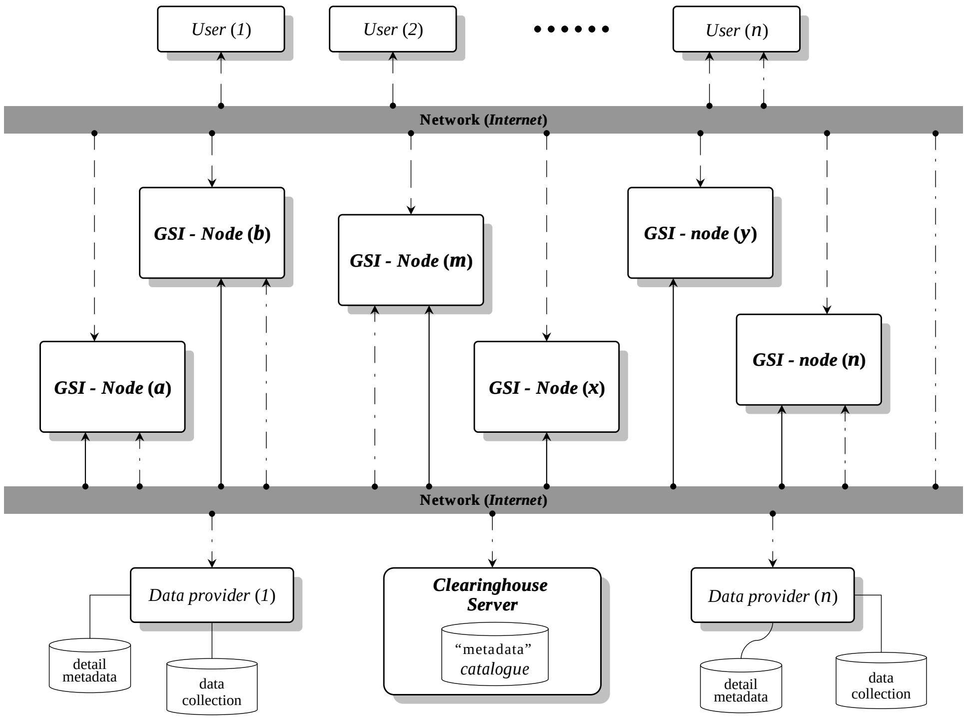

Figure 1: The GSI system concept

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.

5 Modeling the GSI as a VE

5.1 Integrated Enterprise Modeling

Looking at the GSI as a VE facilitates its development and maintenance as it can be seen as an enterprise entity to be analysed, modeled and executed with concepts from enterprise modeling 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 organisation's business and operational levels. The model plays a vital role in enterprise integration and managing virtual enterprises. It represent 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. Several reference models and standards that are providing frameworks for specifying open, flexible and distributed systems with various internal interactions such as goals, processes, information, resources, rules, etc., as well as external interactions with their, mostly changing, environment (Integrated Enterprise Modeling Approaches by ISO reference Model, CIMOSA, PERA, etc.). These models define a set of abstractions (viewpoints) of an enterprise with the associate viewpoint languages defining the concepts of each viewpoint [3, 9, 16].

Open distributed processing (ODP) describes systems that support heterogeneous distributed processing both within and between organisations through the use of common interconnection model. The ISO RM-ODP model describes an architecture of distributed system in abstract way give a framework of concepts, structures, rules and functions (i.e. describes the components without prescribing an implement), also to support several capabilities to be integrated, such as distribution, interoperability, the portability, etc. Five standard viewpoints (abstractions, building blocks) are defined, addressing different aspects of the system and enable the 'separation of concerns. It allows large and complex specification of an ODP system to be separated into manageable pieces, each focus on the issues relevant to different members of the development team. These five 'viewpoints' are:

- Enterprise Viewpoint: concerned with business activities and rules
- Information Viewpoint: describes information objects that are handled throughout the 'value chain' in the enterprise, starting from the data acquisition up to the finished products
- Computational viewpoint: describes the system as a set of interacting objects that provide services
- Engineering Viewpoint: exposes the distributed nature of the system, describes how a system assigns functions and information to various components (tiers) along network and provides standard definitions to describe engineering constraints.,
- Technology Viewpoint: describes the physical structure of the hardware/software components that build the system.

Each viewpoint is an abstraction that specifies the whole system from its perspective, but not independent from other viewpoints. The dependencies expressed by a set of general concepts and relations that ensure the consistency of the system.

Each viewpoint is supported by a viewpoint language (a formal description to provide rigourous system description and analysis of the model properties).

5.2 Modeling a GSI

Accordingly, the enterprise model for GDI will consist of various models (each can be broken into more detailed sub-models); some are described below:

- Enterprise Viewpoint: it is concern with the context of a service architecture (the overall environment in which the system operates). It focuses on the purpose for the existence of the enterprise in terms of value and products that it can be delivered, scope and policies for that system, in accordance with user requirements ('Business Model'). In particular, the roles and activities that exist, the objects processed, the interaction between the system and its environment, the organisational requirements and structure, areas of responsibilities and decision levels ('Organisation Model'). This view also concerns with the cost-oriented analytical view of the enterprise to evaluate the cost-effectiveness of the various parts of the enterprise, the pricing structure, etc. ('Economic Models'). Functional, behavioural and structural rules, constraining some aspects of the business such as processes and resources, have to be identified and documented. They also include the rules enforced by law and regulations, e.g. Information Policy, Standards, etc. ('Legislation Model').
- Information viewpoint: It focuses on the information required by an applications (information flows, information structures, constraints, processing rules, etc.) through the use of conceptual schema describing objects and relationships, the semantics of information and information processes, ('Information Models'). This also includes the definition of metadata: data set metadata (used by data providers to characterise their geographic data, to facilitate data discovery, retrieval and reuse), service metadata (a capability document describing the service, its functionalities and its provider). It also concerns with the provision of feature catalogue describing feature types, and product specifications (describing an information community, its mapping to dataset: the application, spatial schema, metadata, quality information, reference system, etc.) includes (Metadata Standards). These descriptors will be applicable to every data set in the 'value' chain for the geo-information within an enterprise or an information community, starting with

extracted datasets from various data sources, the intermediate value-add geospatial-based products along the way and the datasets included in the finished products [4, 11, 16].

- Computational viewpoint: It specifies the functionality of an ODP application (conceptual design of the distributed applications in a distributed-transparent manner (i.e. independently of the computers and the network infrastructure). It captures components (the functional decomposition of the system into a set of services (functionality provided by an entity) that accessed through interfaces (set of operations that characterise the behaviour of an entity). Processes are modeled 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:
  - 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 geo-referencing, 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)

  An overall consistency amongst these 'local' models throughout the entire VE must be enforced, following existing integrated modeling approaches, such as:
  - Master Model-Based Integration, where only one reference model (generic model) is developed and from which all other models are derived.
  - Unification-based integration, where models are based on a common semantic reference (which is a semantic unification mechanism, based on ontologies) and the supporting standards.

5.3 Consistency and views

During the development process of a system such as the GSI, the task of the designer is to understand the needs of users and stakeholders and construct a description of the system. This description captures the fundamental decisions that the architecture exhibits to satisfy those needs. This description generally consist of one or more views, where a view is a specialised description of the system relative to a particular set of concerns.

Rather than having a single representation that conveys everything there is to say about a system, views address a subset of concerns of the whole system. This subset of concerns can be defined based on any achievable objective. A subset of concerns may address a class of stakeholders (e.g., administrators, thus an administrative view or control view) or a specific characteristic of the system (e.g., a performance view). A view is therefore characterised as follows [8]: the *purpose* defines the concerns the view addresses; the *scope* defines the boundaries of what is in the view and what is not; and the *elements* which defines the elements that comprise the view and the relations among them. One important principle of a view is its wholeness, a view fully describe a system with respect to is associated set of concerns.

Despite the large number of views that one can imagine, experience has told designers that a fairly small set of recurring concerns, such as those pertaining to system structure, behaviour, etc. are the most common. This does not suggest that this set of views is closed or even finite: new technology and new paradigms change our way of looking at systems, enabling the appearance of new views.

Views are first created as a complete semi-independent entities, because their purpose differ, but then they have to be composed or integrated to embody the overall architecture of the system. This integrated view construction requires that views are related at the element level. This is achieved by defining a set of primitives upon which describe or create a view. Such primitives are part of a metamodel that defines the semantics and syntax used to create views. A view is then created out of three primitive architectural elements: components, constraints and connections. Consistency among views is then achieved by modeling the relations between the elements of the various views.

6 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 fulfill a client demand. The GSI broker

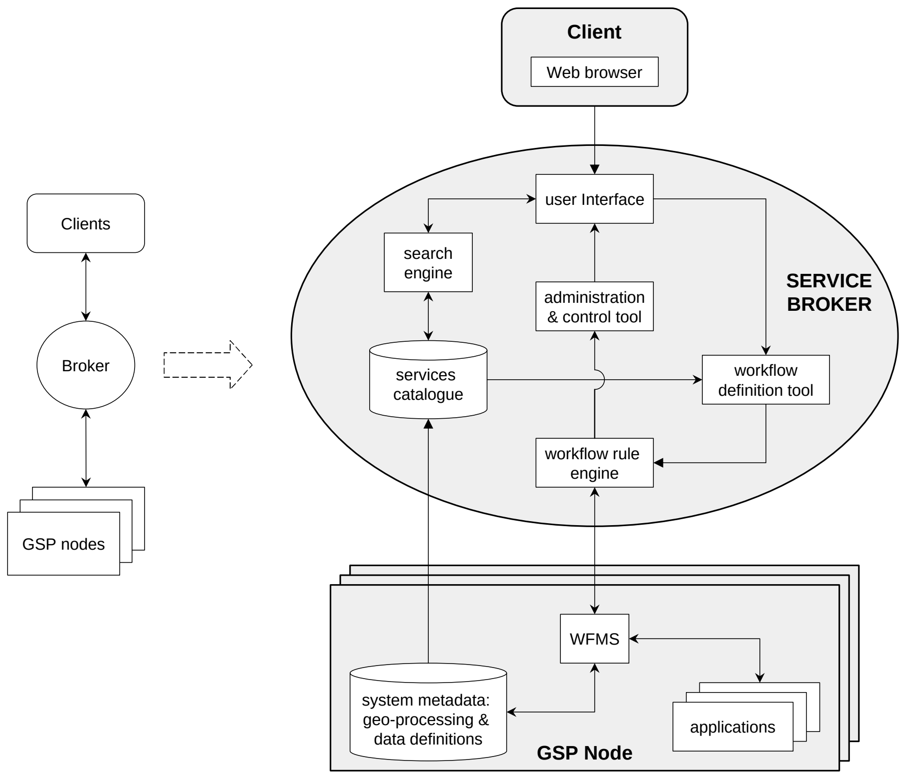

Figure 2: The GSI system concept

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, 12, 10].

Following the OCG service taxonomy categories (Table 1) [15], the broker will support the workflow with additional capabilities for control and management that can be placed into the System Management OGC categories [16]. The main components of the GSI architecture are the user (client), the broker and the GSI

Table 1: OGC service taxonomy

Service Categories
Human Interaction
Information Management
Workflow
Processing
Communication
System Management

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.

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 will be 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.

The GSP node executes the part of the service required.

7 Quality of Services

In is increasingly evident that distributed infrastructures will be the mainstay of future geographical information markets. However emerging infrastructures need to provide users with levels of performance, availability and reliability comparable to centralized environments if they are to gain widespread acceptance. Furthermore one can expect these requirements to become increasingly critical as users increase their reliance on distributed systems for mission critical operations. Consequently, future geographical information markets can only be predicated on robust infrastructures that provide guarantees on performance, availability, reliability and other important quality characteristics.

This necessitates a broader concept of quality that takes into account the dynamic aspects of distributed access, processing and dissemination of geographical information, in addition to spatial data quality. Further, it becomes evident that methods that have for long been employed by traditional GI providers in centralized environments to define, implement and manage quality of service have limited application in the open environments. Performance, availability and reliability have attracted growing attention in the research community especially with the advent of the Internet. The concept of quality of service (QoS) has been various applied in distributed systems to capture the notion of the performance perceived by an end-user of a system [5]. In geographical service infrastructures QoS may be viewed as the level of performance guaranteed over the distributed infrastructure. Given that components in emerging infrastructures will expose their quality attributes i.e. performance, cost, availability, reliability, conformance to standards etc. via open interfaces, users will have the possibility to discover and chain services depending on criteria of interest potentially making end-to-end quality of service compossable, predictable, and specifiable.

As the technology matures and distributed geoprocessing becomes pervasive, the greatest challenge becomes providing QoS guarantees over an increasingly complex Internet environment - a challenge that is accentuated by the unique character of spatial data. The quest to provide and support QoS in open environments motivates current initiatives to investigate emerging infrastructures from a performance perspective and develop frameworks for defining, implementing and managing QoS in open geoprocessing environments.

8 Concluding remarks

Geo-information 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. 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.

The operational model of such enterprise is based on the concept of unbundling functionalities in the current stand-alone production systems in the participating organisations to be delivered over the Internet, as independently developed, yet interoperable autonomous services. Such services are essentially processes that run on web services, in addition to other commercially ready-to-use web map services, offering fundamental mapping and GIS functions. Under this model, these services can be combined and chained in order to construct customised solutions and products.

Organisations willing to participate in virtual enterprises need to align their processes according to standards defined to the particular domain, as a high degree of integration and exchange of information takes place.

The realisation of such an enterprise is heavily supported by ICT tools for the integration and communication of processes and information. Furthermore, collaboration, management and integration tools like workflow management system, enterprise resource planning and project planning, all are requirements to manage information, processes and control-flows across the boundaries of the participating organisations. The evolution of

Web Mapping Services and the OGC development of standards to achieve interoperability of GIS services play a key role in making such an enterprise feasible.

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 catalogs in the market.

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 support 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] Y. Bishr, W. Kuhn, and M. Radwan. *Interoperating Geographic Information Systems*, chapter Probing the semantic content of information communities – a first step toward semantic interoperability, pages 211–221. Kluwer Academic Publishers, 1999.

[5] L. Franken. *Quality of Service Management: A Model-Bases Approach*. PhD thesis, Centre for Telematics and Information Technology, Twente University, Enschede, The Netherlands, 1996.

[6] Richard Groot and John McLaughlin. *Geospatial Data Infrastructure: Concepts, cases and good practice*. Oxford University Press, New York, United States of America, 2000.

[7] 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.

[8] IEEE Computer Society. IEEE Recommended practice for architectural description of software-intensive systems. Technical report, The Institute of Electrical and Electronics Engineers, Inc., September 2000.

[9] ISO/IEC. 10746-2: Information Technology − Open Distributed Processing − Reference Model: Foundations. Draft International Standard, International Organization for Standardization, Genève, Switzerland, September 1996.

[10] 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.

[11] C. Kottman. *Interoperating geographic Information Systems*, chapter The OpenGIS Consurtium and progress Toward Interoperability in GIS. Kluwer Academic Publishers, 1999.

[12] Alvarez C. Luisa Liliana. Geoinformation virtual enterprises design and process management. Master's thesis, International Institute for Geo-Information Science and Earth Observation ITC, Enschede, The Netherlands, March 2003.

[13] Javier Morales, Luís Ferreira Pires, and Marten van Sinderen. Model driven geo-information systems development. In *Proceedings of the Sixth International Enterprise Distributed Object Computing Conference EDOC 2002*, pages 155–166, Lausanne, Switzerland, September 2002. IEEE Computer Society.

[14] Javier Morales and Mostafa 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.

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

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

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

[18] Mostafa Radwan, Richard Onchaga, and Javier Morales. A structural approach to the management and optimization of geoinformation processes. Official publication no. 41, European Organization for Experimental Photogrammetric Research (OEEPE), Frankfurt, Germany, 2001.

[19] U.S. Geological Survey and U.S. Department of Interior. *The National Map: Topographic Mapping for the* 21^{st} *Century*. Technical report, Office of the Associate Director for Geography, U.S. Geological Survey, Reston, Va., United States of America, November 2001. Cooperative Topographic Mapping Program.