MODELLING FOR QUALITY OF SERVICES IN DISTRIBUTED GEOPROCESSING

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ABSTRACT

Geographic information (GI) services are increasingly the state of the art in geoprocessing, promising novel geospatial solutions, products and services. Dynamic chaining of GI services however, presents exciting quality of service (QoS) challenges. Consequently, sustainable use of GI services demands careful consideration of the diverse user requirements and the complexities of dynamic service chaining in view of the QoS limitations of the Internet. An initial and necessary step towards provision of QoS guarantees in Internet GIS is QoS-aware service chaining, where services are discovered and composed on the basis of their non-functional quality characteristics. The paper presents an architecture for QoS-aware service chaining and defines an extensible QoS model for GI services. Further, to facilitate the successful evolution of GI enterprise into effective service providing nodes on the GI service infrastructure, an integration framework for GI enterprises presented. While the provision of hard QoS guarantees on the Internet remains elusive, QoS-aware service chaining will greatly improve the quality experienced by Internet GI applications and users.

1 INTRODUCTION

The thrust of GIS research in recent years has centered on web-based geographic information (GI) services. GI services are modular components of geospatial computing applications which are self-contained, self-describing and can be published, located and invoked across a network to access and process geospatial data from a variety of sources (Doyle and Reed, 2001). Built to open interfaces, the services can be discovered and chained at run-time to deliver functionality of value to a user . Consequently, GI services enable cross-system and cross-organisation interoperability, promising a whole range of novel applications as they emerge as the state of the art in geoprocessing.

Services that are dynamically chained present a new model for delivering geospatial solutions, products and services to diverse communities of users. Chaining of services is achieved via one or combinations of the following three architectural patterns; user defined (transparent) chaining, workflow-managed (translucent) chaining, or aggregate services (opaque chaining) (ISO/TC211, 2002). The major difference between the architectural patterns is the level of control the user has over the chaining process. On the one extreme, in transparent chaining, the user defines and controls the order and execution of the services. On the other extreme, in opaque chaining, the user has little or no control on the chaining and execution of services. Clearly, the different patterns are meant for different types of users - transparent chaining is for highly skilled users whereas opaque chaining is for naive users. Translucent chaining falls between these extremes.

Existing implementations of GI services are rather simple and static, with limited capability for dynamic chaining. In a bid to address the above limitations, current GI industry efforts are focussed on migrating GI service specifications to comply with general XML-based web service standards of SOAP, WSDL, and UDDI (OGC, 2003). Services based on the new specifications can be discovered dynamically and chained using established standards like BPEL4WS (Andrews et al., 2003).

It is anticipated that as the technology becomes mundane, GI services will proliferate. Similarly, the number of users of these services will explode. Furthermore, ubiquitous GI services will enable exciting but quality of service (QoS) sensitive applications like mobile and wireless location-based services. Meanwhile, services will get increasingly integrated in mission critical business processes. As a result, quality of service (QoS) emerges as a critical concern and a major factor of competition.

QoS is a prerequisite to an effective infrastructure for GI services, and by extension, a dynamic and sustainable GI market. Providing QoS guarantees on the Web remains a big challenge because of the best-effort service model of the Internet, limitations of the messaging and transport protocols, and heterogeneity of the underlying distributed resource platform (Spreitzer and Janssen, 2000, Wang, 2001, Mani and Nagarajan, 2003). The large volume and high compute-intensity characteristics of spatial data further accentuate the QoS problem.

Sustainable exploitation of GI services therefore demands careful consideration of diverse use requirements and QoS related constraints on the complex process of dynamic service chaining and the unique character of spatial data in view of the limitations of Web computing. Moreover, users will have different QoS requirements which the composed service chain should meet.

Typically, a service chain comprises disparate services that are discovered and orchestrated at run-time. Individual services have distinct non-functional quality characteristics like performance, cost, reliability, etc. Furthermore, the number and availability of services will vary over time, as new services become available and others are retired. A first step towards providing QoS guarantees in service chains will thus be to enforce QoS-aware discovery and composition of services, whereby services are selected from

a community to participate in a business processes based on their non-functional quality attributes. 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.

Further, a sustainable QoS-aware service infrastructure is predicated on dynamic and collaborative GI marketplaces in which agile and effective GI enterprises are service nodes. How existing enterprises will evolve to be effective partners in the service infrastructure still remains very much an open issue.

The paper defines an architecture for QoS-aware discovery and composition of GI services and an extensible QoS model for GI services. The quality model defines key non-functional quality characteristics of GI services and service chains. The paper further defines an enterprise integration framework for GI enterprises towards a dynamic GI market based on the geographic information service infrastructure. The framework identifies the fundamental building blocks for designing, developing and operating highly integrated GI enterprises as effective service nodes on the service infrastructure.

2 THE GI SERVICE INFRASTRUCTURE

Over recent years, the GI service infrastructure has emerged (Alameh, 2001, Radwan and Morales, 2002) presenting an evolutionary framework for delivering geospatial solutions, products and services that meet constantly changing user requirements . It extends the capabilities of the GDI with services enabling delivery of value-added information products beyond raw spatial data.

The GI service infrastructure is made up of disparate nodes that collaborate to deliver complex services via the Web, the nodes being enterprises with business goals. Through business-to-business (B2B) standards like Rosettanet, EDI and BPEL4WS, the nodes can dynamically discover each other, negotiate innovative business propositions, and collaboratively execute common business processes to address a market opportunity and meet strategic mission. The service infrastructure therefore sets the foundation for GI e-commerce and business integration.

3 QOS-AWARE SERVICE CHAINING

Quality of service (QoS) is widely used in various disciplines with equally diverse meanings. Table 1 presents some definitions from literature. More abstract definitions like *'quality is what the customer says it is'* or *'quality is customer satisfaction'* are not uncommon. The common theme in all these definitions however, is the abstract notion of user satisfaction, which clearly has many perspectives.

In this paper we focus on both qualitative and quantitative measures of quality of service and section 4 defines

(Franken, 1996)	User perceived performance
(ITU-T, 1994)	The collective effect of service performances which determine the degree of satisfaction of the user of a service
(P806-GI, 1999)	The degree of conformance of the service delivered to a user by a provider with an agreement between them
(ITU/ISO, 1995)	A set of quality requirements on the collective behavior of one or more objects and may be specified in a contract or measured and reported after an event
(Wang, 2001)	QoS is the ability to provide resource assurance and service differentiation
(ISO, 2000)	Quality is the totality of the characteristics of a product (or service) that bear on its ability to satisfy stated or implied needs

Table 1: Some definitions of QoS

some them. The required QoS at any time will thus be constraints on any of the measures or specified combinations of these measures. It suffices to note that the list in section 4 in not in any way exhaustive.

The notion of quality presented in this paper departs from classical spatial data quality. This is because while high quality spatial data is necessary, its not sufficient for QoS in a web services environment. QoS comprises systemic and business process quality criteria like performance, cost, reliability etc., over and above spatial data quality.
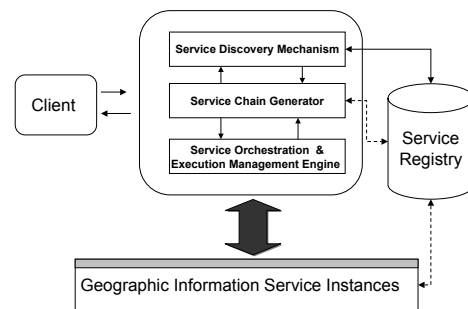

Figure 1: Architecture for QoS-Aware Service Chaining

The concept os QoS-aware service discovery and composition is particularly relevant to translucent and opaque chaining (ISO/TC211, 2002) where naive users are at play. In an operational environment, users need only to specify the services they need and corresponding QoS requirements and should not be bothered with the complex issues of defining the service chain, discovering the suitable services, orchestrating them and monitoring their execution to ensure achievement of QoS targets. These issues should be transparent to the user.

The architecture of Figure 1, presents the functions needed for QoS-aware service chaining. The key componets are; the *service discovery mechanism*, the *service chain generator* and the *service orchestration and execution management engine*. Typically, the client specifies a request for services with QoS constraints. The Qos requirements are end-to-end, save for exceptional cases where business policy dictates otherwise (like when services from certain nodes are not allowed), hence they apply to the service chain as a whole and not the service instances per se. Based on the request specifications , the *service chain generator* determines the type of services necessary, the sequence of execution, and QoS-related constraints for each. The *service discovery mechanism* queries the registry to find services that meet specified requirements, which are then orchestrated and managed by the *service orchestration and execution management engine* to ensure delivery of the service as requested. Once defined, the service chain can be re-used as a single service in a more elaborate business process. Its notable that the services that are discovered and choreographed are those that optimise the QoS of the entire chain.

4 QOS MODEL FOR GI SERVICE

In defining a QoS model for GI services, important non-functional quality characteristics are identified that play a role in enhancing user experience or necessary for proper operation of Internet GIS applications. For each characteristic the definition includes its semantics and a method of estimating its value.

1. Performance: Performance is about the timing aspects of a service. User perceived service performance refers to the time duration in seconds between the instant a request for an operation is submitted and the duration a response is made available. It comprises two components:

   - Transmission delay T_{delay}, the time it takes to relay the request from client to the geo-service and to relay the generated response back to the client and is a function of the volume of data being relayed, the bandwidth, propagation distance or number of network hops. Estimates of T_{delay} can be obtained from time series of ping measurements to the service over different times of the day and a profile can then be generated indicating the latency over time.

   - Processing delay, P_{delay}, which is the duration between the instant a request is received for service and the instant when a response is generated.

   Therefore
   $$Performance\ [R] = T_{delay} + P_{delay}$$

   and in the geo-service node, processing delay is the average response time for executing the specified operation and includes anytime spent waiting for resources

W_{time} and the time spent on servicing the request S_{time} therefore $P_{delay}=W_{time}+S_{time}$. A service publishes its performance or provides a means of acquiring the information.

2. Cost: Cost refers to the price charged for executing an operation at a particular site. Several charging schemes may be used include a flat rate cost price, charging depending on time spent in providing the service, amount of information or data processed, etc. Providers publish cost information or provide a means for acquiring it.

3. Reliability: This is the probability that the service will execute correctly and adhere to specified service level agreements for the duration its required. Reliability can be provider specified. However better estimates can be obtained from observations on the service as

   $$Reliability\ [r] = \frac{1}{N} \sum_{i=1}^{N} r_i$$

4. Availability: This is the fraction of time the GI service is accessible to provide service over some fixed period time i.e.
   $$Availability\ [A] = \frac{t}{T}$$

   where t is the time the service is accessible and T is the fixed time period. A service may publish its availability or provide a means of obtaining it. It can also be estimated from observations on the service.

5. Security: Security refers to the requirement that the service supports certain security protocols and mechanisms e.g. registration, authentication, secure transactions etc.

6. Reputation/Trustworthiness: This is a measure of the reliability of the service as perceived by the user. It depends on the users experience with the use of the service and is independent of published QoS of the service. Reputation is an estimate of the quality of experience (QoE), and a rank can be assigned, say [1,10] or some other convenient interval.

7. Interactivity support: This quality measure is valid for portrayal services that generate graphical displays of spatial data or geographically referenced information. Interactivity refers to the extent the user can interact with the graphical output through querying features, pan, zoom in, zoom out, etc.

8. Location: This is not a quality measure of the service perse but refers to the geographic region to which the data accessed by the service refers. This characteristic is therefore only valid to data access services, and will aid distinction of GI services depending on geographical region its data covers. A bounding box or some other convenient means of describing the spatial extent may be applied but this need be agreed upon by the negotiating entities.

9. Health of the GI service: This is the transient status of the service at the time of discovery and composition is executed.

QoS-aware discovery, composition and orchestration of a GI service chain is necessary to build quality into the GI business process where the process is made up of disparate services operating under different policies and with varying non-functional quality characteristics. With quality as an important competitive factor, providers will apply various strategies to enhance the quality and performance of their services. Several strategies exist in literature, see for example (Zeng et al., 2003, Shan et al., 2002, Menasce and Almeida, 2000).

Further, while QoS-aware chaining of GI services does not provide absolute guarantees on quality of services, its a first and necessary step in that direction. Once an appropriate service chain has been composed, a fitting service model can then be sought, where possible. Nonetheless, the provision of absolute QoS guarantees demands a guaranteed service model in the Internet core and similar guarantees from the GI service providers.

5 INTEGRATING THE GI ENTERPRISE

GI providers have faced volatile markets in recent years precipitated by technology advances, changing user needs, increasing competition, abundance of data in distributed databases and entrepreneurial government policies (Groot, 2001, Kure and Amer, 1992). As a result many strategies have emerged to address market volatility over the years. Modern methods of operations management found great appeal in GI processing to enhance efficiency of business processes and improve performance (Radwan et al., 2001). As a result, business process re-engineering, total quality management and continuous process improvement have all gained popularity in the design, operation and management of GI workflows (Cerco, 2000), with changes in legal and institutional frameworks allowing for new business models and cost recovery measures.

In an increasingly competitive and global GI marketplace agility and collaboration become guiding principles. There has been growing effort towards collaboration in the GI marketplace over the years with outsourcing being the most established (OS, 1996, Groot, 2001, Cerco, 2000). With the advent of the Web, the geospatial data infrastructure (GDI) emerged to make large volumes of spatial data held in disparate, globally distributed systems, more broadly accessible and sharable through the Web (Nerbert, 2000, Groot and McLaughlin, 2000). Since its inception in the 1980s, many GDI initiatives exist, making distributed spatial data resources accessible to growing to users (Masser, 1999).

The notion geographic information services infrastructure takes the GDI a level higher to enable on-line access and processing of spatial data. The GI service infrastructure concept presumes that enterprises will embrace and exploit
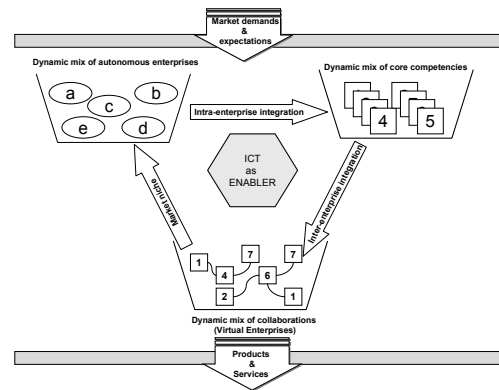

Figure 2: Virtual enterprize cycle

the technology to deliver services and achieve competitive advantage. As the technology matures, the challenge is on GI enterprises to evolve and leverage the technology to be competitive and relevant in an increasingly volatile and global marketplace.

Experiences from the manufacturing and service sectors show that integration is a basic prerequisite for the agile enterprise. Williams and Li (1998) define enterprise integration as the coordinated operation of all elements of the enterprise working together towards optimal fulfilment of the enterprise mission. Integration is necessary for flexible structures and business processes (Vernadat, 1996), which allow the enterprise to rapidly reconfigure and enter collaborations with other enterprises in common value networks.

Within the enterprise, integration breaks down the rigid walls of hierarchical management structures through free but controlled flow of information resulting in decentralised decision making and evolution of core competencies.

At the inter-enterprise level, developments are centered on the virtual enterprise (VE). The VE is a temporary alliance of autonomous enterprises collaborating in a common product cycle and sharing resources, skills and costs to address a business opportunity while meeting corporate strategy (Franke, 2002). In a virtual enterprise, disparate enterprises coalesce to share core competencies and satisfy a market need, while presenting themselves in the market as one entity.

Figure 2 shows the evolution cycle of a virtual enterprise. The figure indicates that integration allows enterprises to develop core competencies by leveraging ICT. To satisfy a market opportunity, enterprises dynamically discover each other, negotiate innovative business propositions and collaborate in common value chains, in which each party participates with its core competencies, to deliver the required product or service. If the opportunity persists, the collaboration can yield a new enterprise. The VE presents an ideal model for designing, developing and operating highly integrated GI enterprises.

Several standard methodologies and reference architectures exist for enterprise integration. Basically, they outline the enterprise development process, its phases and the main

concerns for each phase of the process. Common standards include generalised enterprise reference architecture and methodology, GERAM (IFIP-IFAC, 1998), Purdue enterprise reference architecture, PERA (Williams and Li, 1998), computer integrated manufacturing open systems architecture, (CIMOSA), and Grai Integrated Methodology (Grai-GIM). Similarly, standards for B2B integration are increasingly available e.g. EDI, RosettaNet, BPEL4WS etc.

As standards for business process integration get increasingly available and the technology for open geoprocessing becomes mundane, the potential for GI providers to evolve into responsive and competitive partners in the geographic services infrastructure explodes. Nonetheless, GI enterprises need a sound strategic policy on the role of IT in the enterprise. This policy is necessary if the enterprise is to effectively leverage ICT and create a dynamic fit between its internal structure and the products and services it offers in the marketplace.
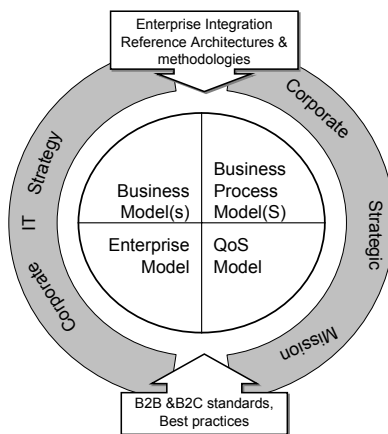

Figure 3: The enterprise integration framework

Figure 3 is a framework for enterprise integration in which the reference architectures and methodologies and business process integration standards play a role. The framework comprises:

- A strategic mission that spells the role and purpose of the enterprise.

- A corporate IT strategy that defines the place and purpose of IT in the organisation.

- Enterprise model, which is a computational model of the structure, activities, processes, and resources that make up the enterprise and is necessary to support analysis and operation of the enterprise especially in volatile environments where the effects of changes to processes need to be quickly estimated. It's very useful for evaluating 'what if' scenarios.

- Business models defining strategic product-service offerings of the enterprise and its position in the market place. Basically, these define what the enterprise does, for whom and how it raises revenue from its activities.

- Business process models that capture the networks of value-adding activities necessary to realise the product-service offerings. They are computational models for reasoning about the business process.

- Quality models that capture important performance and quality measures across the enterprise, with appropriate measures and ways of estimating them. They also define how to address transient performance or quality problems.

- The enterprise integration reference architectures and methodologies, business process integration standards, bench marks and best practices that provide valuable guidelines and methods for developing and operating efficient and responsive GI enterprises through intra- and inter-enterprise integration.

6 CONCLUSION

GI services are fast emerging as the state of the art in geoprocessing and present exciting QoS challenges. Provision of hard QoS guarantees on the Internet remains elusive, and QoS-aware chaining of GI services is an important and necessary step towards QoS guarantees in Internet geoprocessing, and will greatly enhance the quality perceived by the user or Internet GI application. An architecture for QoS-aware service chaining is presented, which is particulary relevant to opaque service chaining, where naive users are at play. An extensible QoS model is also defined, in which QoS requirements are a set of constraints on any specified measures or their combinations.

In the increasingly competitive and global GI markets, competitive enterprises will be highly agile and responsive. GI services, and the emergent services infrastructure, offers an innovative technology for collaborative geoprocessing. However, for the technology to deliver robust benefits to the GI community, GI providers, many being traditional mapping and cadastral agencies managing the a large proportion of the worlds' geospatial resources from decades of activity, need to evolve into effective partners in the marketplace. The enterprise integration framework presented in the paper identifies the fundamental building blocks in designing, developing and operating highly integrated GI enterprise as an effective service providing node in the GI service infrastructure.

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