Quality of Service in a Global SDI

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SUMMARY

During the last years, a lot of effort was put into paving the path for interoperable geographic information (GI) web services that should overcome the disadvatages and infexibilities of monolithic GI systems. International standardization organizations like ISO or the Open Geospatial Consortium are working on specifications for self-describing GI web services that can be published, located, and invoked across a distributed computing platform, generally, the web. Dynamic cross-system and cross-organizational web service discovery and chaining at runtime allow the user to benefit from geographic data and geoprocessing functionalities that reside at different physical locations . Though a lot of technological obstacles still remain unsolved, GI web services will soon emerge to the state of the art technology in distributed geocomputing. The day the web service technology will become commonplace, GI web services will proliferate and according to Mani and Nagarajan, quality of service will become a significant factor in distinguishing the success of service providers. This paper deals with chosen issues of quality of service with regard to interoperable GI web services. Taking a rather distant point of view, the paper aims at presenting the results of a quality of service experiment that has been conducted at the University of Muenster during the GDI North-Rhine Westphalia joint project 2004. It shall broaden the view upon quality of service aspects within a global SDI.

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1. SPATIAL DATA INFRASTRUCTURES

Spatial Data Infrastructures (SDIs) help to share digital geographic data across institutional, regional, or national borders. Data providing GI web services as well as data processing GI web services work seamlessly together to expose the behavior of an integrated system. The composability of these services to build service chains allows for establishing new products that are tailored to the needs of distinct application domains, eventually opening up new markets. Recent experiences witness that once an error occurring at a certain node within a SDI is likely to propagate through the distributed systems and may have impact on other GI web services. The failure of core services, like data providing services that usually constitute the backend of any GI web service chain, may have affects on the entire service chain if no failover mechanisms exist. Though other services might be replaced dynamically by integrating new service instances into the chain, e.g. Web Map Services which take over image rendering and just need a set of data with some rendering constraints, dynamic service chain recomposition is still a difficult task to execute.

Let's do a simple math example. Say we have a GI web service chain where a Web Map Service has to render the data streamed from two Web Feature Services. Additionally, let this Web Map Service also request another map for some distinct Web Map Service. If these three data sources do not share a common spatial reference system, we will have to make use of a coordinate transformation service to do the necessary processing. Our example consists of a small number of five distinct GI web services. Let each of these five services have the availability of 95 percent. If we chain them together we will easily recognize that the availability of the entire service chain will not exceed 77. This means that every fourth try to invoke the chain is about to fail.

The Institute for Geoinformatics at the University of Muenster has performed an investigation on quality of service aspects within a regional SDI – the so called GDI North-Rhine Westphalia (GDI NRW). This regional SDI now proceeds from its prototypical status to the operational status. Indeed, GDI NRW is a regional SDI, but the results of the investigation are of great value for any kind of SDI: local, regional, national, or international.

2. QUALITY OF SERVICE

Encyclopædia Britannica and Brockhaus provide a twofold view of quality (Latin *qualitas*). First, the word quality is used as a synonym of property or characteristic of something. In this sense, quality would cover anything that may be ascribed to a GI web service for the purpose of describing it (e.g. metadata elements defined in ISO 19119 and ISO 19115). Second, the word quality is in parlance where merit, grade or value is in question. In this sense, two GI web services would differ in quality if the merits of one service outclass those of another one. Quality here can be understood to cover measurable quality of a service (e.g. performance benchmark expressed in quantitative terms) and perceived quality of that service (e.g. idiosyncratic judgment of suitability to fulfill a particular requirement).

In general, quality of service (QoS) concerns a set of qualities related to the individual behavior of a web service or to the collective behavior of a service chain. From the service requestor's perspective, an end-to-end QoS could refer to a desired value of something or a threshold that should be exceeded or not exceeded. As far as the geographic information domain is concerned, in their book Peng & Tsou (2003) provide an introductory chapter on QoS in relation to GI web services. Their main focus is on performance (measured in terms of response time or throughput of a GI web service) and reliability (measured in terms of availability of a GI web service).

Following Mani and Nagarajan, quality of service (QoS) will become a significant factor in distinguishing reliable services from faulty ones as the widespread proliferation of web services continues. In this context, the management of QoS metrics directly impacts the success of organizations participating in e-commerce (Cardoso, Sheth et al. 2004). This is true for any application domain independently of any domain specific characteristics, as recent research has shown (Franken 1996; Menascé 2002; Ludwig 2003; Onchega 2004).

What is QoS, or better, what distinguishes the quality of different web services? Communication between arbitrary nodes within the internet mainly bases on the TCP/IP reference model. The Internet Protocol (IP) uses a package based transport that divides any continuous data stream into individual packages that are forwarded from one node to the other without any guarantee of completeness or order of the packages received. The quality of service defines or guarantees or certain ratio of IP transfer delay (real, mean, and variation), packet error and packet loss, and the spurious packet rate. All of those parameters address external transport characteristics, i.e. independent of the content that is transported from the source to the target. On the transport layer of the OSI layer model, the term *quality of service* is used to provide a measure by which the quality of package transport and delivery can be qualified. The definition is rather narrow compared to what applies to the higher levels of the OSI layer model, where we have to broaden the term to permit a wider possible area of applicability.

Following the definition given by IBM (IBM 2000; IBM 2001), Web Services are self-contained, modular applications that can be described, published, located, and invoked over a network, generally, the Web. The web service stack is – in most cases – using the underlying IP for packet transport. Though external characteristics still play an important role, we have to broaden the term QoS to investigate the content based quality characteristics additionally. A solid framework how QoS can be characterized, how QoS requirements can be specified, and how QoS can be managed is provided by the ISO Standard 13236 which defines an abstract Quality of Service Framework. It serves as a common vocabulary to service providers and services users rather than being a collection of placing requirements on either side. ISO 13236 understands the term service in such a general sense and is flexible enough to be used as a solid base for the investigation of QoS aspects of standardized Web Services.

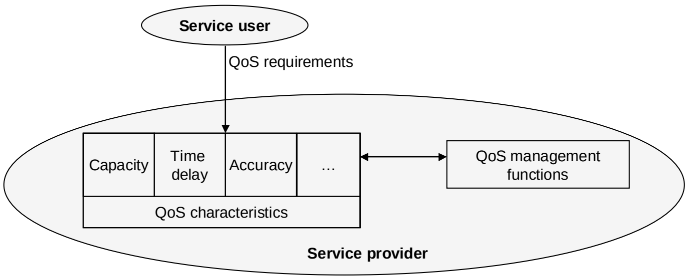

Figure 1: Relationships between QoS concepts (ISO/IEC 1998)

Service users have specific requirements on a variety of QoS characteristics (see figure 1) that identify a quantifiable entity each. QoS management functions refer to all mechanisms that allow the monitoring, controlling, and administration of QoS parameters. Those functions are only available to the service provider. If we address QoS characteristics, we have to differentiate two different perspectives: The first adheres to the user who has no knowledge about the internal structures of a web services. All QoS parameters are either based on pure performance aspects or adhere to distinctive features that are described in the service specification. We call this the external perspective. The second perspective – called internal – is the one of the service provider that has knowledge about the internal structures of the service and therefore can set up a much more detailed QoS framework. In this article, we will skip that second perspective and concentrate on the first one.

The external QoS perspective can be further differentiated. We have to distinguish content and non-content related characteristics. Non-content related quality of service parameters either provide measures for quality issues that are only based on performance issues like availability, reliability, response time or even security aspects or costs etc., or adhere to functional aspects, e.g. accuracy or completeness. The latter describe how the service instance works in regard to the specification. Content related characteristics represent a portfolio of aspects that are all dependent on the response model that is provided by the service. Being very specific for each service type, content related characteristics often depend on subjective demands by the user.

3. SERVICE MONITOR EXPERIMENT

OGC Web Service interface specifications define a mandatory getCapabilities operation for each service type that is intended for self description. The result models of the different service types shows a common structure; it follows the instructions of the OGC Web Services Common Specification (Whiteside 2004). Therefore, among the non-functional and non-content related QoS characteristics, a broad range of QoS parameters can be tested.

Functional aspects are the primary target of the CITE (Compliance & Interoperability Testing & Evaluation) initiative. CITE is an ongoing initiative of the Open Geospatial Consortium that is building tests for OGC specifications. Service instances are tested concerning compliance with the OGC specifications. CITE does not provide a tool to measure QoS parameters other than the functional ones. Those tests are of major interest to the service provider who wants to ensure that his service instance is compliant to the OGC. On the other side, users mainly assume compliance and are more interested in aspects like availability and response times or supported optional features. Currently, the publish-find-bind paradigma does not support any QoS information. Screening a web cataloge for suitable services, it is more than frustrating if most of the listed service instances do not respond. For that reason, we created a tool we called Service Monitor. The Service Monitor is a web service itself that allows the user to register GI web service instances that have to be continuously monitored. Users could be humans or other web services (see figure 2).

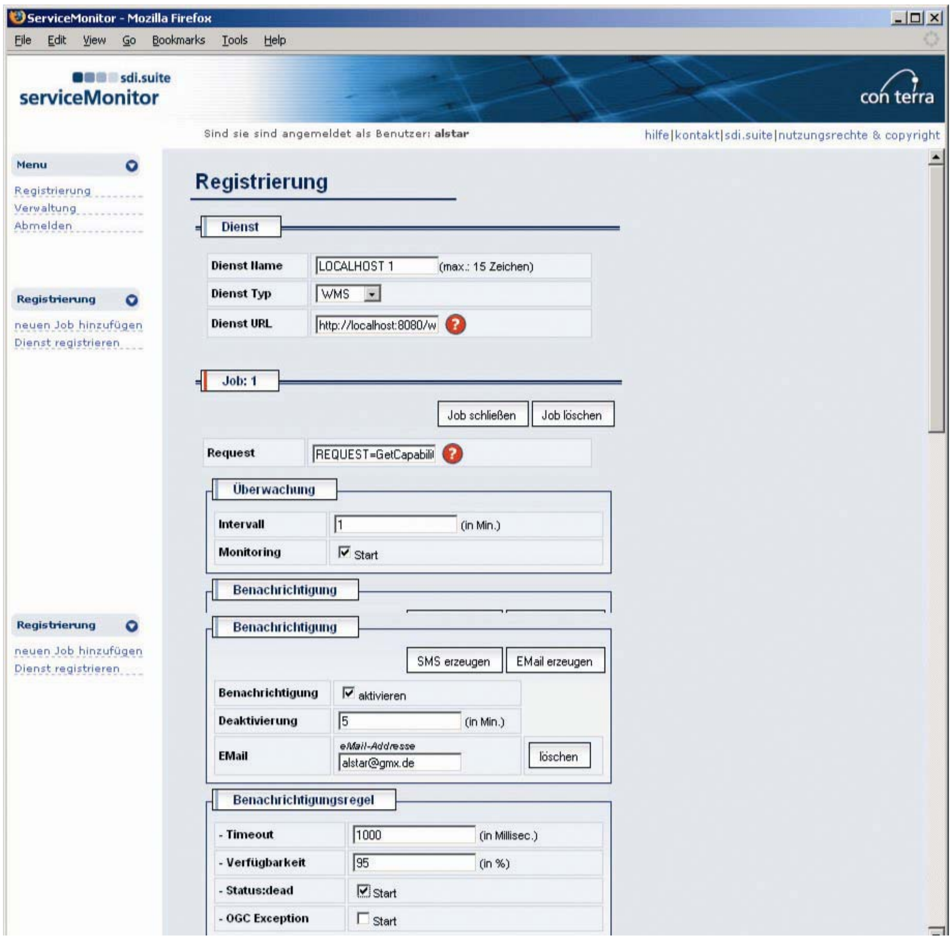

Figure 2: Web Service Monitor registration page (in German)

For example, the Service Monitor functionality is intensively used by catalog services to provide information about the availability of listed services (see figure 3). The Service Monitor generates detailed reports on a broad range of QoS aspects.

Based on the ISO QoS Framework, we differentiate two different kinds of users which may benefit from the employment of a Service Monitor. On the one side, the service requestor may be interested in the current and past service availability. This becomes even more important where a GI web service is an integral part of a web service chain. On the other side, the service provider is interested in providing good appropriate performance to the user.

The Service Monitor provides different interfaces for both user types. The service provider is enabled to register the GI web services that should be monitored and gets detailed reports on the non-content QoS characteristics. It is also possible to register thresholds and to receive notifications in case the service is running on low performance. Though this is interesting information to the user as well, the only information the user is able to get is the information about the service availability. For those reasons, the Service Monitor can be easily integrated into an OGC Web Catalog Service. Figure 3 illustrates this scenario. The current availability of a web service is indicated using a traffic lights metaphor.

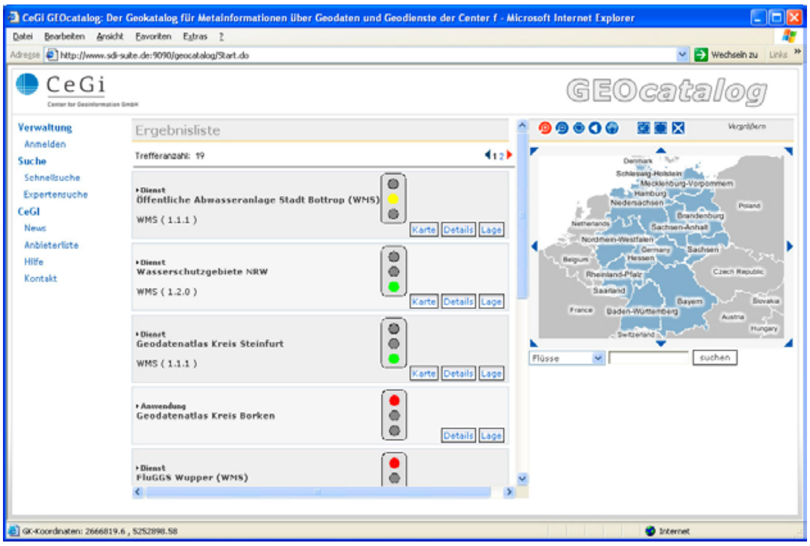

Figure 3: Catalog client result page with service monitor information added

4. CONCLUSION AND OUTLOOK

In the paper at hand we discussed shortly a Quality of Service framework that is needed to measure and eventually improve the quality of Spatial Data Infrastructures. We did not show detailed results of the multiple test runs for political reasons, but summarize the results to the statement that Spatial Data Infrastructures seem to be stable enough to enter the operational phase now.

Although this paper mainly addresses QoS parameter of distinct standardized web services, web service chains provide even more complex scenarios that have to be addressed in the future. Recent publications (Cardoso, Sheth et al. 2004) mainly address non-content QoS parameters and put the burden of controling QoS to the workflow engine. The standardization process for service chaining within spatial data infrasturctures is still at its very beginning. Only, it has shown that the level of acceptance of the upcoming SDI very much depend on the availability and performance of the web services involved. Therefore, it is important to integrate QoS issues into the current service chaining discussions. One of the biggest remaining problems is sticking to the HTTP POST and GET operations rather than moving onwards to SOAP based communication. Much more information about the Quality of a specific service or an underlying service chain could be provided by using SOAP without infringement of current specifications.

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BIOGRAPHICAL NOTES

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