

CGDI IN ACTION: EXPLORING QUALITY OF SERVICE

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ABSTRACT:

The national GeoConnections program has funded many projects for sharing geospatial information in its priority policy areas – public health, public safety and security, environment and sustainable development, and matters of importance to aboriginal communities – resulting in many geospatial Web Services in the Canadian Geospatial Data Infrastructure (CGDI). To build user confidence in using geospatial Web Services in the CGDI for their decision making, knowing the quality of these services is important.

In this paper, the authors discuss the results of a GeoConnections-funded project in exploring the Quality of Service (QoS) metrics and applying them to test services in the CGDI. Essential QoS metrics, including availability, reliability, time latency, response speed, performance testing, and load testing, were determined. All these QoS metrics can be dynamically monitored by machines through simulating service requests at certain time intervals. The selection of candidate services for testing were from GeoConnections projects and from services discovered in the GeoConnections Discovery Portal, with the balanced representation from different levels of government and the private sector, communities of interest, and geographic regions. Based on the designed QoS metrics, tests were carried out for these candidate services. The availability and reliability were evaluated using the Federal Geographic Data Committee (FGDC) Service Status Checker. Other QoS metrics – time latency, response speed, performance testing, and load testing – were measured using Proxy Sniffer™. In conclusion, this study proposed and implemented QoS measurement for services in the CGDI. The visibility of service quality will support users in choosing and employing geospatial Web Services in the CGDI for their day-to-day planning and decision making.

1. INTRODUCTION

In Canada, the GeoConnections program, which is led by Natural Resources Canada, strives to build the Canadian Geospatial Data Infrastructure (CGDI) to support online decision making by sharing geospatial information. The development of the CGDI can reduce the cost in geospatial data collection and enable the integration of various data for decision making, offering benefits to end-users, developers, and providers. Besides advocating national standards for geospatial information sharing, GeoConnections further enhances the interoperability of CGDI by endorsing many international standards from International Organization for Standardization (ISO) and Open Geospatial Consortium (OGC), such as Web Map Service, Web Feature Service, and Web Processing Service (GeoConnections, 2010a). Since 2005, GeoConnections has collaborated and supported more than 160 projects with governmental agencies, private companies, and non-profit organizations to aid decision makers (GeoConnections, 2010b). Four areas have been given priority in the CGDI development: public safety, public health, aboriginal community, and environment and sustainable development (GeoConnections, 2010c).

Spatial Data Infrastructure (SDI) is generally characterized as a hierarchy of agencies or organizations ranging from those with the most detailed data (large scale) to organizations with less

detailed data (small scale). Each of these levels or layers can form an SDI, enabling users above and below to access data and services. For each SDI layer or level, there are nodes that provide geospatial data and services that support the infrastructure. For certain applications, it is often needed to move from less detailed data to more detailed data in certain areas. For example, various datasets are often accessed when a user zooms into an area for a more detailed view of the area in a situational awareness application. This requires access to data at various levels of the CGDI hierarchy. Each of these nodes must be operational continuously and adhere to the strict SDI interoperability standards in order for the infrastructure to provide the highest level of service quality possible.

Meanwhile, there is an increasing user need for good service quality in the consumption of services in SDIs. The limitation in service quality is a barrier for the low usage of geospatial Web Services by GIS users (Box and Rajabifard, 2009). The fast development of CGDI has demonstrated successful stories of applying geospatial technology in various fields, and many geospatial Web Services have been implemented and registered in the CGDI. It would be beneficial to make the quality of service information visible to stakeholders, which will ensure that consumers can get their data when requested and providers deliver a suitable quality of service. One current trend in the software development is to build applications from independent services, and service quality therefore is a crucial factor in the

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selection and composition of these services for applications (Marzolla and Mirandola, 2010). Utilizing the service quality information, stakeholder can trust to build their applications based on geospatial Web Services that meet their requirements.

This project, advancing CGDI in Action, is developed from a desire to create a project that would increase the visibility and utilization of the CGDI as an operational asset for users. It was determined that the promotion of the CGDI as an asset that can be used by a wide variety of users would require supporting information about the types of services already available for use and their quality. This project was developed to identify the Quality of Service (QoS) of geospatial Web Services and implement tools that can report on quality of these services.

This paper is organized as follows. Section 2 discusses the term of service quality and the QoS in (geospatial) Web Service context. Section 3 describes the methodology for service evaluation in this project, including service selection, QoS exploration, and tool identification. Section 4 presents the implementation details and discusses the test results. Section 5 concludes this paper.

2. SERVICE QUALITY

Service quality is concerned with the activities that occur in the user consumption of a service from a service provider. Parasuraman et al. (1988) defined service quality as the discrepancy of the users' perceptions and expectations of a service. This service quality evaluation is from the user's perspective and depends on subjective attitudes of users. ISO (1986) defined service quality as the totality of characteristics of a service on its ability to satisfy stated or implied needs. This definition is more objective, with the requirements to qualify and quantify the characteristics of services and needs. To evaluate service quality, QoS metrics needs to be determined for differentiating service quality from different services.

The rapid development of the Internet leads to the deployment of new types of services, such as Web Services and geospatial Web Services. Web Services use standard protocols to support machine to machine interaction. The important characteristics of Web Services are standard-based, self-describing, self-contained, modular, and accessible over the Web (Tsalgatidou and Pilioura, 2002). Geospatial Web Services uses the Web Service technologies to provide the access of geospatial data or functions over the Web. Service quality consideration has been brought to evaluate these new services. The QoS for (geospatial) Web Services generally considers the functional and non-functional characteristics from the objective perspective (Mani and Nagarajan, 2002; Peng and Tsou, 2003; Onchaga, 2006; Subbiah et al., 2007). Functional characteristics of (geospatial) Web Services are related to the data/information provided from services and non-functional characteristics are related to service interaction process. QoS metrics such as data accuracy, completeness, resolution, time, and integrity can be used to measure functional characteristics. On the other hand, the following QoS metrics can be used to evaluate non-functional characteristics: time latency, availability, reliability, throughput, cost, security, reputation, location, conformance to standards, and stability. Evaluating functional characteristics usually needs human involvement, while some non-functional characteristics could be measured automatically by using machines to simulate the interaction with geospatial Web Services.

3. METHODOLOGY

3.1 Service selection

To come up with a list of geospatial Web Services for evaluation, the search process started with a subset of GeoConnections projects from 2005 to the 2009. These projects were considered as potential use cases, which cover a wide range of applications such as water and air monitoring, emergency management, and land use planning. In compiling potential geospatial Web Services, information such as sector (i.e., public health, aboriginal, public safety, environment, systems), project description, project partners, jurisdiction, and completion date was pulled together into a document to come up with a short list of project resulting in geospatial Web Services. The most popular services implemented in these projects were the Web Map Service (WMS). As the number of other types of services such as Web Feature Service (WFS) and Web Coverage Service (WCS) were still limited in the CGDI, we focused on the service quality measurement of WMS in this project.

The selection of candidate services was designed to include balanced representation from different levels (national, provincial, local, and enterprise) of government and the private sector, communities of interest, and geographic regions. Based on these high-level criteria, nineteen possible projects were included in the short list. However, upon extensive follow-up investigations, it was determined that only three such sources from this short list were viable candidates for ongoing monitoring. The WMS from other projects may either under development and not ready for viewing, internal-facing and only accessible from inside an organization's intranet, or no longer being supported due to lack of continuing funds or departure of internal champions.

The selection process was broadened to search viable WMS from the GeoConnections Discovery Portal in 2009. The portal was valuable in discovering a select number of national, provincial, local, and enterprise "anchor nodes" offering Web Services, and effort was made to identify and add other sustaining nodes that would serve as appropriate services. The services had been monitored to ensure they actually worked and served meaningful data.

Twelve candidate services were finally selected as representative services at the national, provincial, local, and enterprise levels, with three nodes in each level. The candidate service providers include Natural Resources Canada, Indian and Northern Affairs Canada, Agriculture Canada, GeoBC, NS Department of Natural Resources, Land Information Ontario, Regional Municipality of York, Halifax Regional Municipality, Prince Albert Grand Council, ESRI Canada, Bird Studies Canada, and Eastern Ontario Model Forest. All candidate service providers have been contacted and confirmed their participation in this project. These candidate services will be tested over the course of this project to build a core set of nodes that will serve to assess and promote the CGDI in Action.

3.2 Quality of Service metrics

Considering the generality and particularity of geospatial Web Services with other Web Services, we tried to determine essential QoS metrics of geospatial Web Services that could be monitored automatically by machines. All the determined QoS metrics in this project belong to non-functional characteristics

of services, including availability, reliability, time latency, response speed, performance testing, and load testing.

- Availability - indicating whether a service is up for immediate use.
- Reliability - measuring the percentage of successful service responses. Non-successful service responses include incorrect and overtime responses.
- Time latency – estimating the time lag between sending a request and receiving the corresponding response, including the network time and server time of requests.
- Response speed - determining the relation between response data size and time latency.
- Performance testing - evaluating service performance (time latency, response speed) under a specified number of well-defined simultaneous requests.
- Load testing - evaluating service performance in terms of time latency, response speed, and failure rate under the condition of simulating an increasing number of simultaneous requests.

All these QoS metrics can be dynamically monitored by machines through simulating service requests at certain time intervals. With the designed QoS metrics, service consumers can set their expectations and service providers can make plans on their service configuration.

3.3 Tool identification

A German company Con terra has released its product sdi.suite serviceMonitor, which supports constant monitoring and reporting on registered geospatial Web Services, including WMS, ArcIMS services, and ArcGIS server services, and enables automatic email or text message notification when the service criteria are not met (Con terra, 2010). The Service Status Checker (SSC) is another tool for monitoring service health, which was designed by the U.S. Federal Geographic Data Committee (FGDC) to test geospatial Web Services such as WMS, WFS, ArcIMS services, and Z39.50 (FGDC, 2010). The SSC offers both real time testing (accepts XML requests, performs tests, and immediately returns test results in XML) and archive testing (performs daily batch tests on registered services and stores test results in a database). Both tools can monitor WMS status, and arrangements have been worked out for short-term secure and confidential usage of the FGDC SSC on this project.

Through an analysis of SSC and the proposed QoS metrics, FGDC SSC was chosen to test the availability and reliability metrics. The response time provided by SSC was not completely satisfactory, because SSC used the entire world range to request maps from geospatial Web Services in testing. Other proposed QoS metrics – time latency, response speed, performance testing, and load testing metrics – were decided to be evaluated using Web load testing tools. After investigating a number of different options for Web load testing, the Proxy Sniffer™ and Gaia were selected to test time latency, response speed, performance testing, and load testing metrics. They are comparatively easier to set up for executing the WMS load testing tasks. Proxy Sniffer™ is a Web load testing tool which is able to run performance tests by simulating virtual users against Web applications (Engineering Office David Fischer GmbH, 2010). Gaia is a freely available tool that is able to access common, standards-based geospatial Web Services like WMS, WFS, and WCS (The Carbon Project, 2010). Load test

scripts for simulating real user requests (e.g., bounding box and scale parameters) could be developed by exploring the maps from WMS using tools (e.g., zoom in, zoom out, and pan in the toolbar) in Gaia with its proxy destination to Proxy Sniffer™.

4. IMPLEMENTATION AND DISCUSSIONS

With the determined candidate services, testing/monitoring operations started from October 2009. The availability and reliability tests were planned to carry out hourly during the testing period. The load testing was planned to be performed at a longer interval (e.g., quarterly), because its results would not change significantly unless new investment has been done to the services.

4.1 Availability and reliability testing

Although SSC archive testing provides valuable information in an easy-to-use format for daily monitoring of a service, SSC users can only gain access to historical test results for a limited time frame. In this project, more granular results over longer periods of time are required for analysis. Therefore, an automated routine was developed to make use of the SSC's live testing facilities to obtain more detailed testing results than the default tests on archive testing. A routine was created to test on an hourly basis. The overall testing process of availability and reliability testing is described in Figure 1. The testing server sends a live testing request with parameters such as type and URL to FGDC SSC. SSC immediately tests the performance of the corresponding WMS by sending GetCapabilities and GetMap requests and returns an XML document describing the test results. The test results are recorded to a comma separated file on an ftp server for download. Based on the comma separated result file, the availability and reliability scores can be summarized daily, weekly, or monthly.

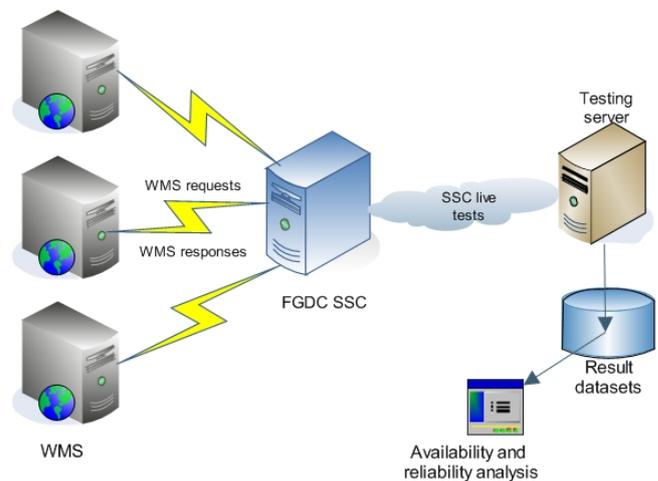


Figure 1. Availability and reliability testing

The WMS GetCapabilities test results from FGDC SSC were used to evaluate service availability. If a service is up, correct responses should be received from GetCapabilities requests. However, errors will occur if the service is down. The availability score of a service is equal to the service up-time divided by the summation of service up-time and down-time. The availability tests were carried out hourly every day, and the scheduled down-time of these nodes for system maintenance has not been considered in calculating the availability score. Most candidate services achieved 90% monthly availability

during the testing, and more than half of them reached 99% monthly availability in the official test period.

Similarly, the WMS GetMap test results from FGDC SCC were used to evaluate service availability. Reliability represents the degree of a service being capable of maintaining its service quality. The number of failures over a period of time is a measure of reliability of a Web Service. The failure could be the cases such as internal server error, request timeout expired, network connection aborted by server, and wrong content size. The reliability score of a service is equal to the number of successful responses divided by the number of requests. Most services had the reliability score more than 99% during the test, which implies all components for the services are quite stable in handling requests when the services are on.

4.2 Load testing

WMS usually provides a list of data layers, and the performance from each data layer varies. To relieve the workload, two or three representative layers (point, line, polygon, or image) were selected from each service for load testing in this project. The process of load testing is shown in Figure 2. Firstly, test scripts need to be developed for testing the selected data layers from candidate services. To simulate real user requests in the test scripts, the exploration of data layers should be within the supported scale as some data layers from WMS have scale range restriction in visualization. By setting Proxy Sniffer™ as the proxy for Gaia, Proxy Sniffer™ will record the test scripts when the data layers from WMS are explored in the Gaia viewer. Then, load testing can be executed by using the developed test scripts with different parameters such as the number of concurrent users and the load test duration. Load testing should be completed during the low usage of services to get a full representation of the service performance without other users accessing the service. After that, the test results from load testing can be analyzed to evaluate the performance of WMS. Load testing can estimate the maximum/average/minimum time latency and average response speed at a certain number of concurrent users. It can also evaluate how the average time latency, average response speed, and failure rate of a service are affected by the number of concurrent users.

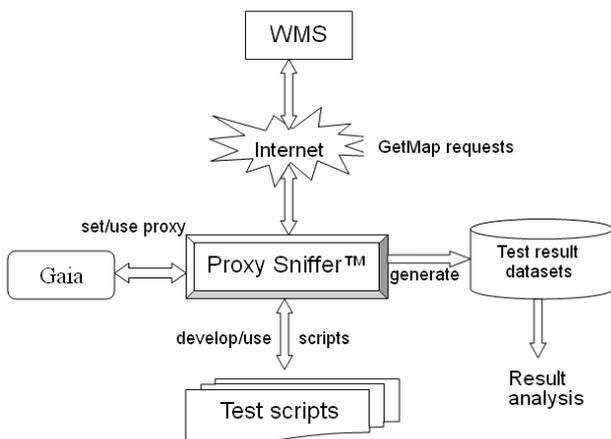


Figure 2. Load testing process

Load testing in this project was carried out at off-office hours in order to make user simulation testing more accurate and not disturb normal daily operations at the node. The load testing

simulated a number of concurrent user requests (e.g., 1, 5, 10, 15, 20) to evaluate the average time latency, maximum time latency, minimum time latency, average response speed, and failure rate. All user requests are based on the recorded test scripts, which represents the real user requests. In the load testing, this project uses more rigorous tests in which the user's think time is not included. So, it is more demanding to the services, as every concurrent user carries out the loop of sending a request, waiting for a response, and receiving the response.

The results of service quality in the load testing can be described by graphs. For example, Figure 3 and Figure 4 show the average time latency and failure rate graphs respectively of three typical data layers from a candidate service. The response time from this service is acceptable, and the failure rate is low. In general, no failure happened to all candidate services where simultaneous users were fewer than 10. Most candidate services can respond within 2 seconds (1 user) and 5 seconds (10 concurrent users).

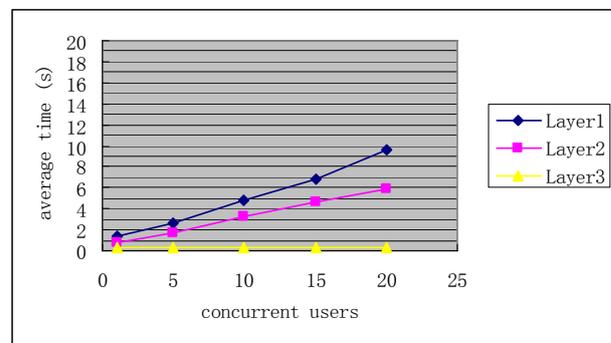


Figure 3. Average time latency graph in load testing

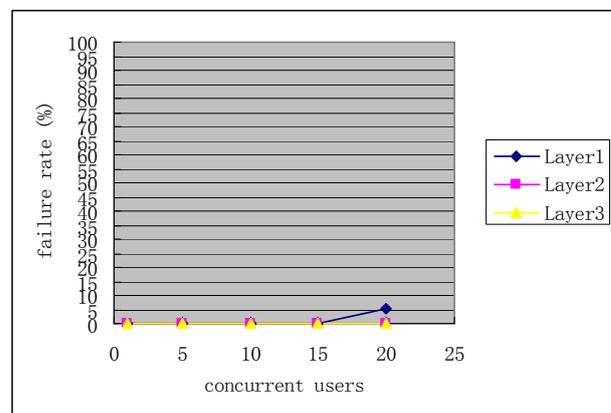


Figure 4. Failure rate graph in load testing

4.3 Discussions

In fact, the capacity in load testing of the selected candidate service would be more powerful than the results shown in the graphs. Concurrent users usually have their think time, which will significantly influence service quality evaluation. For example, extending think times from 2 seconds to 10 seconds could possibly allow the service to handle 5 times as many users (MSDN, 2010). However, the simulation of the user's think time is a challenge in measuring geospatial Web Service quality testing. Moreover, because the same test scripts will

continue to be performed by all concurrent users in the load testing, a service can show good performance if it has appropriate cache mechanism. The selection of representative layer and the comprehensive of test scripts will also affect the load test results. In addition, network connection is also a factor worth consideration in measuring service quality, as the service requests and service responses need to be transferred through the network. The network conditions in both the service provider and service consumer sides are important to achieve better value in QoS metrics such as the response time and response speed.

5. CONCLUSION

This project aims to increase the utilization of the CGDI as an operational asset for end-users through improving QoS and promotion of selected CGDI enabled services. QoS metrics have been determined on the evaluation of geospatial Web Service quality, and tools have been identified and used to test candidate WMS services. The tools and methodologies identified in this project can be used to test other WMS services in the CGDI. Similar approaches could be applied to other types of geospatial Web Services, such as WFS and WCS. Additional QoS metrics such as conformance to standards, service transaction number, exchanged information amount, and data update frequency can be further considered for more comprehensive quality evaluation of geospatial Web Services.

The reaction to service quality issues from the participating service operators is positive. This project has provided participating organizations valuable information on their service quality. The visibility of service quality makes it possible for service providers to determine whether their service quality levels need to be improved. The visibility of the service quality will support end users and developers in choosing and employing geospatial Web Services in the CGDI for their day-to-day planning and decision making.

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