# Standard-Based Integration of W3C and GeoSpatial Services: Quality Challenges

Michela Bertolotto[1], Pasquale Di Giovanni[1,2], Monica Sebillo[2], and Giuliana Vitiello[2]

[1] School of Computer Science and Informatics
Belfield, Dublin 4, Ireland
michela.bertolotto@ucd.ie
[2] Department of Management and Information Technology (DISTRA)
Via Giovanni Paolo II, 132-84084 Fisciano, SA, Italy
{pdigiovanni,msebillo,gvitiello}@unisa.it

**Abstract.** In recent years, Service Oriented Computing (SOC) has become one of the leading approaches for the design and implementation of distributed solutions. The key concepts are the notion of service and the possibility to seamlessly combine several modules to offer more sophisticated functionality. Such features were soon recognized by both W3C and OGC as relevant for their purposes, although their standards are incompatible and the seamless communication and exchange of information between these types of services are not directly achievable. The current most accepted solution to address this matter is represented by the development of a wrapper that manages technical issues that arise during the translation of requests and responses between them. However, the design of such a software module presents challenges in terms of infrastructure design and Quality of Service. In this paper we describe some issues to be faced when developing a service wrapper aimed at integrating existing geospatial services into a W3C service-based infrastructure.

## 1 Introduction

The Service Oriented Computing (SOC) paradigm has emerged as one of the leading approaches for designing and implementing distributed applications. The key idea behind this approach is the concept of service, an autonomous software module that, combined with other services, can be used to create complex solutions.

A service exposes its functionality through its public interface whose methods can be invoked by any software system without the need, for the service client, to know any detail about the service internal structure and business logic. However, since services and their clients can be developed by different entities, the first issues to address involve describing the public interface and providing a framework for data exchange in a wide accepted way and in a technology neutral manner.

In this context, the World Wide Web Consortium (W3C) has defined a series of universally accepted standards based on the use of the Extensible Markup Language (XML) in order to guarantee their independence from a specific platform or technology. The two most important W3C standards are the Web Services Description Language (WSDL) for the description of the service interface and the SOAP

S. Casteleyn, G. Rossi, and M. Winckler (Eds.): ICWE 2014, LNCS 8541, pp. 460–469, 2014.

protocol for the exchange of messages [3], [13]. The flexibility and pervasiveness guaranteed by the W3C infrastructure has promoted during time the development of a growing number of service based solutions in many diverse fields [4].

The service-based approach has also become one of the preferred ways to discover, access, and manage geographic information. The ability to offer traditional Geographic Information Systems (GIS) capabilities in a distributed manner has been recognized by the geographic community as a valuable opportunity to provide new ways to use geospatial information and increase its distribution. However, despite the wide acceptance of the W3C proposals as a means to promote interoperability and platform independence, the GIS community has developed, over time, its own set of standards for the fulfilment of geospatial data oriented services. In particular, the proposals of the Open Geospatial Consortium (OGC), which represents the reference organization for "the development of international standards for geospatial interoperability" (http://www.opengeospatial.org/), have become the *de facto* standard for developing distributed geographic applications.

Unfortunately, although both W3C and OGC standards are based on XML for data exchange and HTTP as the transport protocol, some design choices make them totally incompatible. Nevertheless, a better integration between these two worlds could be of interest for both communities. In fact, the former could access and process the wide amount of geospatial data currently available only by invoking OGC services, while the latter could benefit both from additional standards, such as those for access management and security, and from the huge amount of supporting infrastructures for W3C services. Such awareness is stimulating a radical revision of such standards to remove their intrinsic incompatibilities.

The currently most accepted solution to this aim is represented by the development of a software wrapper, usually a service itself, that "translates" the requests and responses messages from the W3C services format to a format suitable for the OGC services and vice-versa, while keeping the structure of the original services unchanged [2], [5], [15]. However, the concrete development of a wrapper does not represent the only issue to solve since, independently of the actual set of adopted standards, every service-oriented solution cannot disregard fundamental non-functional requirements, such as the quality of the provided information, its security, the service response time. In fact, taking into account essential Quality of Service (QoS) aspects is of utmost importance to guarantee a satisfactory computation and make the SOC paradigm a feasible option for the development of complex distributed solutions.

In this paper we discuss our research in the area of geospatial service-oriented architectures. We analyze the challenges involved in the integration and reuse of heterogeneous services with focus on QoS aspects, and propose recommendations for the development of a viable solution that takes such aspects into account.

The remainder of this paper is organized as follows. In Section 2 we provide an overview of the two main W3C standards and compare them with the OGC proposals. In Section 3 we briefly describe the most important QoS attributes that directly impact on the development of service-based solutions, and discuss the QoS issues that affect the development of distributed solutions for geospatial data. In Section 4, we describe the main challenges that arise during the design of a wrapper addressed to the W3C-OGC services dialogue. Some conclusions are drawn in Section 5.

## 2 W3C and OGC Standards for Service Based Development

The functionality of a service is exposed through its public interface and the communication between a service and its clients is based on various messages exchange patterns. However, the actual definition of the public interface and the structure of messages are strongly related to the particular set of standards adopted. In this section we provide an overview of the main characteristics of the two major W3C standards, namely WSDL and the SOAP protocol, and compare them with the three principal OGC proposals, namely the Web Map Service (WMS), the Web Feature Service (WFS) and the Web Coverage Service (WCS) standards.

WSDL [3] is an XML based language for describing W3C services. A WSDL document separates the abstract aspects of a service description from more concrete ones, such as the binding to a certain network protocol. The typical structure of a WSDL document is made up of seven elements, namely Types, Message, Operation, Port Type, Binding, Port and Service. In particular, the former four are meant to statically define the public interface of a Web service, while the latter three are used to bind the interface to a concrete network protocol. A direct drawback of such design choices is that, in a W3C-oriented environment, the structure of the message payload has to be completely specified at design time [22].

SOAP is "a lightweight protocol for exchange of information in a decentralized, distributed environment" [13]. Three basic components characterize a typical SOAP-based message: an Envelope, a Header and a Body. The Envelope can be seen as the container of the message itself. The optional Header field can be used to carry additional information useful to guarantee some properties, such as security and reliability of exchanged messages. The Body element encompasses the real payload of the exchanged message.

When compared to the W3C choices, the design philosophy of the OGC standards is quite different, and the main dissimilarities between them concern the different approach for the public interface design, and the binding type and the binding time of operations. Two further clear differences are the basic role of the Geography Markup Language (GML) [21] and the fact that each type of OGC service is based on a separate standard explicitly designed to deal with a specific kind of data. Moreover, they also specify the functionality offered by the service interface along with the possibly needed additional data structures. A direct consequence of this choice is that, with OGC services, the actual structure of the message payload can be known only at run time, differently from what occurs in W3C environments.

As for the service specification, the most widespread and commonly used are WMS, WFS and WCS. A WMS allows clients to request georeferenced map images from one or more geospatial databases. WFS allows for accessing and manipulating geographic features. Finally, the WCS defines an interface for the exchange of geospatial information representing phenomena that can vary in space and time, known as coverages. The only functionality that is common to these three types of services is GetCapabilities, it allows a geospatial service to expose its capabilities to clients.

## 3 QoS Issues in Geospatial Web Services

The increasing adoption of the OGC proposals as a concrete means to access and make use of geospatial data in a distributed and vendor independent manner, has shifted the attention from data and information supply to information quality and implementation of services themselves. Thus, also for OGC services, the assessment of the most common QoS attributes is becoming fundamental to distinguish between reliable and non-reliable services. Generally speaking, QoS within the SOC paradigm represents an important and widely discussed topic, due to its basic role in various key aspects. The scientific and industrial communities have defined several main QoS categories and various attributes for each of them that contribute to the fulfillment of the desired QoS property. Moreover, a W3C working group [19] has identified a set of basic QoS requirements that have to be taken into account during the development of a Web service, namely Performance, Reliability, Scalability, Capacity, Robustness, Exception Handling, Accuracy, Integrity, Accessibility, Availability, Interoperability and Security. A complete analysis of these can be found in [20], while approaches to express and describe QoS characteristics and metrics can be found in [18].

As for the quality of geospatial Web services, basic assumptions about QoS attributes still hold. However, their evaluation must be performed according to both the specific characteristics of geospatial data and the way it is handled by OGC-compliant solutions. In addition, another relevant aspect that must be taken into account is represented by the technical differences among the various software implementations of the OGC standards and the related supporting infrastructure.

From a high level perspective, the process of obtaining knowledge from geospatial information can be viewed as a three step process, namely querying the data, assembling the retrieved subset and finally performing the effective computation [25]. The first issue along this sequence of operations is represented by the specific characteristics of geospatial data that usually is voluminous and heterogeneous, distributed among different data silos and can suffer from access restrictions due to institutional policies [11]. Such characteristics have, of course, a significant impact on the actual quality of the final information offered by geospatial services to third party users. In fact, as clearly discussed in [12], due to the common practice of combining data from multiple sources, geospatial datasets are inclined to contain errors since the various providers can make, for example, different assumptions about data structure. As defined in [12], the most important quality components for geospatial data are lineage, completeness, logical consistency, attribute accuracy and positional accuracy.

The aforementioned quality attributes are useful to assess also the quality of metadata that, due to its importance in this context, must be accurately evaluated. Indeed, a poor quality metadata determines the lack of information quality and can lead final users to formulate wrong assumptions about the received dataset.

The ISO19113 standard, instead, identifies five criteria for geospatial data quality, namely positional accuracy, temporal accuracy, logical accuracy, thematic accuracy, and completeness [17]. Finally, a recent factor that influences the quality of geospatial data is represented by the creation of user-generated geospatial content and Web 2.0. How to efficiently assess the quality of such a type of data is still an open research question. An example of filtering and composition of Web 2.0 sources can be found in [1].

As for the quality factors that mainly impact on the actual development of geospatial services dealing with significant amount of data, a first important discussion can be found in [10]. This document shows how, from a general point of view, the quality attributes proposed by W3C and mentioned in the previous section can be applied to geospatial services, except for the scalability requirement. In [9] some more specific directives and obligations for implemented services are mentioned. In particular, the three fundamental QoS criteria to respect are:

- performance: the time for sending the initial response to a discovery service request shall be maximum 3 seconds in normal situations. Normal situations represent out of peak load periods, i.e., 90 % of the time;
- capacity: the minimum number of simultaneous requests served by a discovery service according to the performance quality of service shall be 30 per second;
- availability: the probability of a network service to be available shall be 99% of the time.

In [24] the common issues impacting on the overall QoS and concerning current proposals and implementations of OGC standards are discussed. The authors divide those issues into three levels, namely standard definition, software implementation of the standard, and software application. Among the various problems, the following are functional to the goal of the present discussion: the lack of a standardized authorization/authentication mechanism, the misuse of the standardized HTTP error codes, the version proliferation, the discrimination between mandatory and optional features, and the high level of autonomy offered by the various standard specifications.

A concrete example of QoS issues in a real software solution can be found in [26]. In the development of their prototype for real time geospatial data sharing over the Web, authors notice how the adoption of OGC standards is useful to solve problems at the syntactic level, while several issues may arise at the semantic level. System reliability represents the second important problem that is particularly accentuated when OGC services are provided by different entities. Security is another major concern. Finally, performance bottlenecks due to the transfer of redundant XML data over the network and the high cost of the parsing XML messages have a serious impact on the effective use of the proposed solution.

In [11] several OGC-compliant services implementations are tested. The results related to relevant performance parameters, show how, due to the GML verbose nature, a consistent number of bottlenecks may arise when there is the need to transfer large amount of geospatial data. Moreover, different software solutions vary in the way OGC specifications are implemented. Two direct consequences may arise from such dissimilarities, namely the reduced quality that can be perceived by final users and critical interoperability problems.

# 4 A Wrapper-Based Solution

In order to face effects deriving from technical and semantic differences between W3C and OGC services the currently most accepted solution is represented by a software wrapper that manages most of the technical topics that arise during the translation of requests and responses [15]. However, such a translation cannot be automated due to several issues that need to be carefully taken into account during the wrapper design to make this solution a feasible option. First of all, a wrapper is usually a service itself, then it requires a typical supporting infrastructure of service-based solutions, while its design might be influenced by the specific needs of the application under development. Indeed, two symmetrical types of wrapper can be developed, either adapting the interface of an OGC service to the technical requirements of a W3C-based infrastructure or vice-versa. Existing W3C services providing geospatial information that could be useful in an OGC-based Spatial Data Infrastructure (SDI) constitute an example of the latter case. The second cause of difficulties is represented by the number of services whose functionality has to be exposed by the intended wrapper. In fact, although the simplest solution concerns a one-to-one mapping, i.e., a wrapper adapts the interface and functionality of a single W3C / OGC service, it is also possible for it to gather functionality of different services. A typical example is constituted by a W3C service that offers, in a single WSDL document, the methods to access the data layers of either two WFSs or a WFS and a WMS. Finally, a further issue concerns the need to properly structure the WSDL document in order to distinguish among the various OGC services since the public interface and signatures of the implemented methods are rigorously standardized by the Consortium.

In the following, we discuss some challenges about the design of a one-to-one wrapper by describing a concrete example of an OGC to W3C mapping, Moreover, some basic QoS parameters are investigated that are affected when offering geospatial data coming from other OGC services and exploited through W3C standards.

As a concrete example where an OGC-to-W3C wrapper can actually promote and support a better information exchange between different entities, we illustrate its usage in the context of a research activity aimed at helping Sri Lankan farmers improve their productivity by providing them with customized and up-to-date information, such as the current selling prices of a product. Such an activity constitutes a pilot study for the Social Life Networks for the Middle of the Pyramid (SLN4MoP) project, an international collaborative research program that aims at providing real-time information to meet the daily needs of people living in developing countries [23].

The proposed system is based on a client-server architecture, although some technological constraints and the elicited needs of the involved stakeholders deeply influenced its overall design. As for the client tier, a common trait in many developing countries is the wide spread of mobile devices compared to the diffusion of traditional PCs. Such a factor led us to propose a mobile solution for the actual application with which the farmers interact. Detailed information about the implications and design challenges of our choice can be found in [6,7].

As for the back-end, the blueprint of the architecture has been organized by exploiting the principles of the SOC paradigm, which better comply with the *in progress* nature of SLN4MoP project, that is, providing its functionality as set of interacting services helped us to easily satisfy several fundamental design goals and QoS parameters. In particular, we needed both a reliable and flexible infrastructure, where new software modules can be added and can communicate with the existing ones without affecting the original design and behavior, and a reduced complexity during the access to heterogeneous and distributed data sources hiding, at the same time, the underlying different storage formats.

As for the QoS aspects, since the business processes are now decomposed into a series of interacting services, the availability, interoperability and performance parameters are of utmost importance for an efficient usage of this system. However, while availability strongly depends on the failure ratio of the underlying supporting components, interoperability and performance deserve further considerations.

To support our discussion, we consider the following real scenario. A governmental officer needs to visualize on a map the position of all local markets of a given district along with the selling prices of certain crops. The required operation corresponds to a combination of two atomic functions, namely the provision of various data units for the composition of a map, and a list of scalar values. The former is a typical functionality offered by an OGC service, the latter can be provided by a W3C service. In order to derive the expected result, it is necessary to invoke an advanced service capable to split and direct the atomic requests towards components in charge of performing them, and then combine responses deriving from them as a unique output. This capability represents a fundamental feature of the SOC paradigm: the services composition, namely the ability to compose services to obtain complex results.

One of the most common types of composition is service orchestration where the messages exchanged among services and the execution order of their interactions, is coordinated by a central controller. In order to effectively make the orchestration possible, all the involved services need to share the same Interface Description Language (IDL) and the same framework for the messages exchange. Then, the interoperability in the context of services orchestration represents a key requirement, but, as shown in our scenario, protocols based on different rules for the definition of the public interface and the message exchange system, make services orchestration not directly achievable.

The solution we have proposed is based on a wrapper addressed to a syntactic translation from OGC to W3C, which exploits existing orchestration middleware and the well-established services orchestration in W3C environments. In particular, the task performed by the proposed wrapper consists in the translation of SOAP-based messages into OGC-compliant requests and vice-versa. Such a task can be partitioned into four main steps:

1. the wrapper receives, from a W3C service a SOAP message containing a request for a specific geospatial dataset;
2. the wrapper translates the SOAP-based request into a format suitable for the underlying OGC service, and sends the query;
3. the OGC service returns the desired information;
4. the wrapper translates the received response into a SOAP-compliant format and sends it back to the requesting client.

However, a wrapper-based solution presents an important drawback, namely a serious impact on the overall composition performance. Such an aspect, in the context of our project, cannot be underestimated and requires further investigation.

Besides traditional aspects (such as, the quality of the underlying network that contributes to the achievement of a satisfactory performance level), a relevant factor for performances is represented by the specific characteristics of geospatial information (described in Section 3). As compared to the size of traditional SOAP messages, the size of geospatial data is usually several orders of magnitude larger. Since in the wrapper-based solution such data has to be packaged in the Body element of a SOAP message, it is clear that encoding, decoding and transmission of SOAP messages represent new significant issues. Such a problem has a direct impact on measurable values (like response time or throughput) directly related to the Quality of Experience of final users. Moreover, it might also influence the behavior of other aspects of the entire Service Oriented Architecture (SOA) to which the wrapper belongs, such as the transaction management protocols and the above described services orchestration. In particular, in a traditional orchestration the execution of an operation may depend on the output of a previous computation, and data complexity. The above described scenario deals with high volumes of data and long running operations, then the considerable amount of waiting time needed to process or simply transfer SOAP-encoded geographic data may cause a throughput reduction. In the worst case, a time-out error may occur that causes the entire workflow blocking. An asynchronous strategy based on appropriate SOAP message patterns (e.g., Fire and Forget) [8] represents a possible solution for all wrapper-based and time-consuming tasks.

Another aspect that adversely affects the performance and effectiveness of a wrapper is related to the supplementary delay caused by the need to query remote OGC sources. Information caching represents a feasible solution to reduce this inconvenience and improve performance and overall scalability. Some considerations about the design choices of OGC services support this option. In particular, most of OGC services are basically read-only services whose queries "access groups of features rather than individual features" [16]. Of course, traditional cache invalidation mechanisms (on demand, time limited, etc.) can be used to force the wrapper to invoke the original data source and refresh the local cache. Examples of cacheable items are the Capabilities document returned by the invocation of the GetCapabilities function, and the GML Schemas returned by the DescribeFeatureType function of a WFS.

A further service property to be taken into account when designing a wrapper, concerns its level of flexibility and reusability (a desirable property in the SOC paradigm). Such parameters are related to the granularity of a service, namely its size. In [14], the authors classify service granularity into three different categories: functionality granularity, data granularity and business value granularity. In a wrapper-based solution for service orchestration, data granularity represents the unique parameter that can be investigated during the design. Some optimizations can be done, however such parameters depend on the implementation and specific choices made for the original OGC service. A detailed discussion about this topic can be found in [16].

## 5 Conclusions

The goal of the research we are conducting is to define an infrastructure for the provision of heterogeneous Web services within a geographic information system. In particular, the focus of our current efforts is on the orchestration of traditional and geospatial services. The solution we have proposed is based on a wrapper that integrates W3C and OGC services in a seamlessly manner. In this paper we have discussed the QoS parameters that should be properly considered in this context. We have emphasized that, besides parameters that the literature suggests to take into account when dealing with these two standards separately, it is necessary to include some criteria that exclusively derive from the growing complexity of the integrated solution, such as supplementary delay and throughput reduction. Indeed, a wrapper-based solution implies a notable impact on the service performances and effectiveness, and then it is essential to handle those QoS parameters during the design phase in order to perform the best choices, independently from the technology used in the subsequent implementation step. In the future, we plan to complete the infrastructure proposed for SLN4MoP, and stress it by testing its performances against a large amount of data.

## References

1. Barbagallo, D., Cappiello, C., Francalanci, C., Matera, M., Picozzi, M.: Informing observers: quality-driven filtering and composition of web 2.0 sources. In: EDBT/ICDT Workshops, pp. 1–8 (2012)
2. Bertolotto, M., Di Giovanni, P., Sebillo, M., Tortora, G., Vitiello, G.: The Information Technology in Support of Everyday Activities: Challenges and Opportunities of the Service Oriented Computing. Mondo Digitale (2014)
3. Christensen, E., Curbera, F., Meredith, G., Weerawarana, S.: Web Services Description Language (WSDL) 1.1. World Wide Web Consortium (2001), http://www.w3.org/TR/wsdl
4. Costagliola, G., Casella, G., Ferrucci, F., Polese, G., Scanniello, G.: A SCORM Thin Client Architecture for e-learning Systems Based on Web Services. Int. J. of Distance Education Technologies. 5(1), 19–36 (2007)
5. Di Giovanni, P., Bertolotto, M., Vitiello, G., Sebillo, M.: Web Services Composition and Geographic Information. In: Pourabbas, E. (ed.) Geographical Information Systems: Trends and Technologies, pp. 104–141. CRC Press (to appear, 2014)
6. Di Giovanni, P., Romano, M., Sebillo, M., Tortora, G., Vitiello, G., Ginige, T., De Silva, L., Goonethilaka, J., Wikramanayake, G., Ginige, A.: User Centered Scenario Based Approach for Developing Mobile Interfaces for Social Life Networks. In: First International Workshop on Usability and Accessibility Focused Requirements Engineering (UsARE 2012), pp. 18–24. IEEE (2012)
7. Di Giovanni, P., Romano, M., Sebillo, M., Tortora, G., Vitiello, G., Ginige, T., De Silva, L., Goonethilaka, J., Wikramanayake, G., Ginige, A.: Building Social Life Networks Through Mobile Interfaces: The Case Study of Sri Lanka Farmers. In: Spagnoletti, P. (ed.) Organizational Change and Information Systems. LNISO, vol. 2, pp. 399–408. Springer, Heidelberg (2013)
8. Erl, T.: Service-oriented architecture: concepts, technology, and design. Prentice Hall, PTR (2005)

9. European Commission: Commission Regulation 1088/2010 amending Regulation (EC) No 976/2009 as regards download services and transformation services (2010), http:seur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:02009R0976-20101228:EN:NOT
10. European Commission: INSPIRE Network Services Performance Guidelines (2007)
11. Giuliani, G., Dubois, A., Lacroix, P.: Testing OGC Web Feature and Coverage Service performance: Towards efficient delivery of geospatial data. J. of Spatial Information Science. 7, 1–23 (2013)
12. Goodchild, M.F., Clarke, K.C.: Data Quality in Massive Data Sets. In: Abello, J., Pardalos, P., Resende, M.G.C. (eds.) Handbook of Massive Data Sets, pp. 643–659. Kluwer Academic Publishers, The Netherlands (2002)
13. Gudgin, M., Hadley, M., Moreau, J.J., Nielsen, H.F.: SOAP Version 1.2. World Wide Web Consortium (2001), http://www.w3.org/TR/2001/WD-soap12-20010709/
14. Haesen, R., Snoeck, M., Lemahieu, W., Poelmans, S.: On the Definition of Service Granularity and Its Architectural Impact. In: Bellahsène, Z., Léonard, M. (eds.) CAiSE 2008. LNCS, vol. 5074, pp. 375–389. Springer, Heidelberg (2008)
15. Ioup, E., Lin, B., Sample, J., Shaw, K., Rabemanantsoa, A., Reimbold, J.: Geospatial Web Services: Bridging the Gap between OGC and Web Services. In: Sample, J.T., Shaw, K., Tu, S., Abdelguerfi, M. (eds.) Geospatial Services and Applications for the Internet, pp. 73–93. Springer, New York (2008)
16. Ioup, E., Sample, J.: Managing Granularity in Design and Implementation of Geospatial Web Services. In: Zhao, P., Di, L. (eds.) Geospatial Web Services: Advances in Information Interoperability, pp. 18–35. IGI Global, New York (2011)
17. ISO 19113: Geographic information - Quality principles. International Organization for Standardization (2002)
18. Kritikos, K., Pernici, B., Plebani, P., Cappiello, C., Comuzzi, M., Benrernou, S., Brandic, I., Kertész, A., Parkin, M., Carro, M.: A Survey on Service Quality Description. ACM Computing Surveys 46(1), Article 1 (2013)
19. Lee, K.G., Jeon, J.H., Lee, W.S., Jeong, S.-H., Park, S.-W.: QoS for Web Services: Requirements and Possible Approaches. World Wide Web Consortium (2003)
20. O'Brien, L., Bass, L., Merson, P.F.: Quality Attributes and Service-Oriented Architectures. Software Engineering Institute (2005)
21. Portele, C.: OpenGIS Geography Markup Language (GML) Encoding Standard. Open Geospatial Consortium Inc. (2007), http://www.opengeospatial.org/standards/gml
22. Schäffer, B.: OWS 5 SOAP/WSDL Common Engineering Report. Open Geospatial Consortium Inc. (2008), http://www.opengeospatial.org/standards/dp
23. Sebillo, M., Tortora, G., Vitiello, G., Di Giovanni, P., Romano, M.: A Framework for Community-Oriented Mobile Interaction Design in Emerging Regions. In: Kurosu, M. (ed.) Human-Computer Interaction, HCII 2013, Part III. LNCS, vol. 8006, pp. 342–351. Springer, Heidelberg (2013)
24. Vanmeulebrouk, B., Bulens, J., Krause, A., de Groot, H.: OGC standards in daily practice: gaps and difficulties found in their use. In: GSDI11 World Conference (2009)
25. Wei, Y., Santhana-Vannan, S.-K., Cook, R.B.: Discover, Visualize, and Deliver Geospatial Data through OGC Standards-based WebGIS System. In: 17th International Conference on Geoinformatics, pp. 1–6. IEEE (2009)
26. Zhang, C., Li, W.: The Roles of Web Feature and Web Map Services in Real-time Geospatial Data Sharing for Time-critical Applications. Cartography and Geographic Information Science 32(4), 269–283 (2005)