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# Semantic Web Technologies in Support of Service Oriented Architecture Governance

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**Abstract.** As Service Oriented Architecture (SOA) deployments gradually mature they also grow in size and complexity. The number of service providers, services, and service consumers increases, and so do the dependencies among those entities and the various artefacts that describe how services operate, or how they are meant to operate under specific conditions. Appropriate governance over the various phases and activities associated with the service lifecycle is therefore indispensable in order to prevent a SOA deployment from dissolving into an unmanageable infrastructure. The employment of Semantic Web technologies for describing and reasoning about service properties and governance requirements has the potential to greatly enhance the effectiveness and efficiency of SOA Governance solutions by increasing the levels of automation in a wide-range of tasks relating to service lifecycle management. The goal of the proposed research work is to investigate the application of Semantic Web technologies in this context, and propose a concrete theoretical and technological approach for supporting SOA Governance through the realisation of semantically-enhanced registry and repository solutions.

**Keywords:** Service Oriented Architecture (SOA), Web services, Registry and Repository, Semantic Web technologies, SOA Governance

## 1 Introduction

Service-oriented computing is emerging as the dominant paradigm for distributed computing and is changing the way software applications are architected, realised, delivered, and consumed [1]. The term Service-Oriented Architecture (SOA) refers to a software architecture perspective where nodes on a network make computational resources available to other network nodes in the form of services. At a conceptual level, there exist three types of actors within a SOA: service providers, service consumers, and service brokers [2]. The prevailing approach for realising SOA in the software industry today is through Web services technology, primarily due to the way in which Web services naturally implement the SOA philosophy of loose coupling and reusability, and promote interoperability, by leveraging widely accepted XML-based standards such as WSDL, SOAP, and UDDI.

As with any type of software artefact, a service also abides to some form of a lifecycle. Each lifecycle stage is associated with a multitude of service-related activities which are performed by (and may be of interest to) different SOA stakeholders, such as enterprise architects, developers, managers, and others. As SOA deployments gradually mature they also grow in size and complexity [4]. The number of service providers, services, and service consumers increases, and so do the dependencies among these entities. In addition, the number of dependencies among services and the various artefacts that describe how services operate (e.g. interface descriptions, technical documentation), or how services are expected to operate with regard to a specific consumer's requirements (e.g. Service Level Agreements, QoS monitoring logs) also increase at an exponential rate. In the light of these facts, vendors and practitioners started realizing that without appropriate governance over the various phases and activities associated with the service lifecycle a SOA deployment can quickly dissolve into an unmanageable infrastructure [5, 6].

SOA governance is now widely recognised as a precondition for the success and long-term sustainability of a SOA deployment[1], and as a major challenge, from both an organisational and a technological perspective. From an organisational point of view, the challenge lies in establishing an effective and efficient scheme for decision-making with regard to SOA governance and in embedding SOA governance activities within the everyday business processes and working practices of the organisation. From a technological point of view, the challenge lies in providing effective and efficient support for the daily activities of SOA stakeholders, such that SOA governance imperatives (e.g. expressed as policies) can be enforced in a transparent and preferably automated way throughout the service lifecycle. Today's SOA software vendors attempt to address the latter challenge through software tools that integrate service registry and repository functions [7]. However, as will be discussed later in this paper, existing approaches suffer from some inherent limitations that prevent them from reaching full potential in terms of effectiveness and efficiency.

In this paper we explore and try to lay down the initial foundations for investigating the application of Semantic Web technologies in the context of Web service management. The introduction of semantics can assist to overcome some of the aforementioned limitations and advance the state of the art in the area of SOA Governance. In particular, the aim of the proposed research work is to put forward a concrete theoretical and technological approach for supporting SOA Governance through the realisation of semantically-enhanced registry and repository solutions.

The remaining of this paper is organised as follows. Section 2 outlines the characteristics of today's approaches for supporting SOA Governance and points out their limitations. Section 3 discusses the potential benefits that Semantic Web technologies can have in this area. Section 4 sketches the aims and objectives of the proposed research project, and Section 5 summarises the main points from the discussion in this paper.

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[1] According to Gartner Group, through 2010, the lack of working SOA Governance arrangements will be the most-common reason for SOA failure (0.8 probability) [5,6].

# 2 Existing Solutions for SOA Governance and their Limitations

## 2.1 Service Registry & Repository Systems

Service registries are core components within a SOA deployment since they act as service brokers [2]. In an analogy to the way yellow pages are used, service registries allow providers to advertise the availability of their services through some kind of description concerning what a service does and where it can be reached. These descriptions constitute advertisements which allow prospective consumers to discover services matching their requirements. Depending on the registry technology, the format and content of service descriptions can vary significantly. The service description format may be structured (i.e. be machine-readable) or unstructured, and the contained information may range from coarse-grained to rather fine-grained. This also holds for the way in which service consumers describe the characteristics of the services being requested. Together, the format and content of service advertisements and requests determine the extent to which the procedure of matchmaking between the two can be automated in order to increase effectiveness (in terms of matching precision) and efficiency (in terms of the time required for discovery).

Repositories can be complementary to service registries, as they offer the means for managing the variety of metadata and artefacts that may be associated with the services advertised in registries. As noted above, a single service may relate directly or indirectly with numerous artefacts describing its actual or desired characteristics, and these artefacts may concern different phases and activities within the service's lifecycle. Artefacts may be specific to a service (e.g. comprise functional and non-functional specifications, source code, test data, Service-Level Agreements/contracts, logs, etc), but may also comprise policies and business rules with organisation-wide applicability. Notably, each artefact has its own lifecycle from creation to deprecation. This means that a single change in the state of some artefact may cause significant changes to the states of other artefacts, or to the states of services. Artefacts within a repository should therefore be managed and monitored in a way that allows tracking changes, detecting dependencies, and analysing the impact that a change can have in order to take appropriate measures. As with the service descriptions processed by registries, the format and content of the service-related artefacts determine the extent to which the above functions can be automated.

In summary, the typical functions that an integrated registry & repository tool should support include the following:

- Publishing service advertisements and storing service-related artefacts
- Discovering services that are suitable for reuse based on some search criteria
- Creating and managing contracts (SLAs) among providers and consumers
- Creating and managing policies and associating them with services
- Validating services against policies during design-time
- Enforcing compliance of services to policies and contracts at run-time
- Versioning services and artefacts stored in the registry or repository
- Tracking dependencies among services and artefacts and monitoring change

## 2.2 Limitations in Today's State of the Art

Today's commercial solutions for SOA Governance support a great number of functions from those listed above. However, there is an important limitation in the way in which service-related artefacts (such as service descriptions, policies, contracts, etc) are represented within these systems, and this essentially prevents SOA Governance solutions from reaching their full potential in terms of effectiveness and efficiency.

The problem lies in that today's SOA Governance solutions rely on service-related artefacts that are encoded based on standards such as WSDL, WSLA, WS-Agreement, WS-Policy, XACML, and others. XML-based standards like those are machine-readable and thus open up the possibility of increasing the levels of automation in SOA Governance, but also have fundamental limitations.

Firstly, their semantics are inherently implicit, and as a result, the information encoded in specifications that conform to these standards is bound to be ambiguous and subject to alternative interpretations. Consequently, this makes the involvement of users necessary for numerous tasks that could otherwise have been fully automated.

Secondly, service-related artefacts lacking formal rigour and machine-understandable semantics are not amenable to processing and reasoning based on formal-logic, which would allow new facts to be inferred from existing knowledge and decisions to be made upon them, thus promoting automation even further.

Thirdly, the information that is encoded in service-related artefacts must be processed in a product-specific manner [8]. The rules by which the information should be interpreted and conclusions should be drawn are not declaratively defined within the artefacts themselves, but is embedded deep within the business logic and source code of the registry & repository tools, thus preventing agility and interoperability.

# 3 The Potential of Semantic Web Technologies

The lack of machine-understandable semantics within today's Web service specification standards is an inhibitor to providing effective and efficient support for managing the service lifecycle and enforcing SOA Governance requirements. Some even argue that introducing machine-processable semantics in service-related artefacts is indispensable for realising the full potential of SOA [9]. Conversely, we propose that the quality of support that registry and repository tools offer to SOA stakeholders could be significantly enhanced with the incorporation of formal techniques for describing and reasoning about Web service characteristics, through the application of Semantic Web technologies.

Research in this direction, i.e. on combining semantic technologies and Web service technologies, has been mostly taking place under the umbrella term of Semantic Web Services (SWS) [10, 11]. The vision in Semantic Web Services research is to bring formal logic-based semantics into the Web services realm such that the above-mentioned shortcomings of Web services standards can be overcome and service characteristics can be explicated in an unambiguous, computerinterpretable manner that enables automating a broad range of service design-time and run-time activities. By using formal representation schemes to describe Web service characteristics, service-related artefacts can be automatically processed through logic-based inference and reasoning.

Evidently, the degree of automation that can be achieved depends on the expressiveness and overall capabilities of the semantic representation formalism that is adopted for this purpose. Recent years have seen the development of numerous such formalisms for representing service characteristics, termed Semantic Web Service frameworks [12]. The most prominent Semantic Web Service frameworks, also promoted for standardisation through W3C member submissions, have been OWL-S [13], WSMO [14], WSDL-S [15], and most recently the W3C Recommendation of SAWSDL [16] which evolved from the WSDL-S specification.

Research around these frameworks during the past years has mostly focused on the development of methods, techniques and tools for enabling automated Web service discovery [17, 18, 19], composition [20], and execution [21], while the tasks of service selection [22], monitoring [23], testing [24] and management [25] have received less attention. Recently, researchers have also started to focus on the application of semantic technologies for specifying and managing service contracts (Service-Level Agreements) [26] and service policies [27]. Taken as a whole, the research advancements in these areas constitute a body of work that can serve as the foundation for investigating the application of semantic technologies to the overarching aim of semantically-enriched SOA Governance, through the development of semantically-enhanced registry and repository solutions.

## 4 Aims and Objectives of the Proposed Research

The aim of the proposed research work is to investigate the application of semantic technologies in the context of service lifecycle management, and propose a theoretical and technological approach for supporting SOA Governance through the realisation of semantically-enhanced registry and repository solutions.

The objectives to be attained in order to fulfil this aim could be formulated as follows:

- Review the theoretical and technological background to the area, focusing on service oriented computing, semantic technologies, policy and compliance management, and existing systems for SOA Governance.
- Analyse key requirements for supporting semantically-enriched SOA Governance, and define them in the form of a generic scheme that can serve as a reference model.
- Investigate methods, techniques and tools that employ semantic technologies to support service design-time or run-time activities, and can be employed for enabling semantically-enriched service lifecycle management.
- Confirm the viability of the proposed approach through the development of a semantically-enhanced registry and repository system prototype that can be shown to satisfy the investigated requirements.

As illustrated in figure 1, there exist three classes of key technologies to be integrated for the development of the envisaged semantically-enhanced registry and repository system.

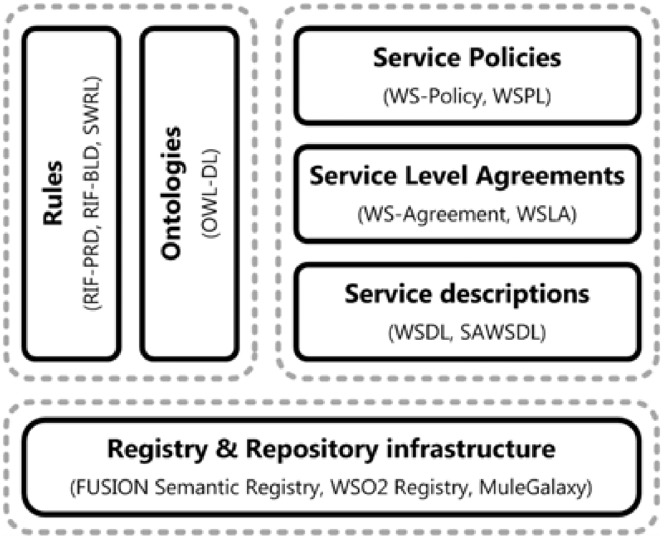


**Fig. 1.** Enabling technologies for the proposed semantic registry and repository system.

*Web Service technology standards:* languages and frameworks for the description of service interfaces, service-level agreements and policies – e.g. Web Service Description Language (WSDL), Semantic Annotations for WSDL (SA-WSDL), Web Services Agreement Specification (WS-Agreement), Web Service Level Agreement Language (WSLA), WS-Policy Framework, Web Service Policy Language (WSPL).

*Semantic Web technology standards:* languages and frameworks for the description of ontologies and rules, including inference rules and production rules – e.g. (Web Ontology Language / Description Logics sublanguage (OWL-DL), Rule Interchange Format Production Rule Dialect (RIF-PRD) and Basic Logic Dialect (RIF-BLD), Semantic Web Rule Language (SWRL).

*Registry and repository infrastructure software:* open source systems and tools for storing service-related artefacts and managing their lifecycle – e.g. the FUSION Semantic Registry[2], Web Service Oxygen Registry[3], or Mule Galaxy Registry[4].

## 5 Conclusions

The introduction of automation in Web service management and the support of SOA Governance activities are currently recognized as major challenges in the domain of SOA, as they are instrumental for the long-term sustainability of a SOA deployment. Software vendors have responded with the development of a variety of SOA Governance offerings based on service registry and repository tools. However, the lack of machine-understandable semantics in service-related artefacts (service

[2] http://www.seerc.org/fusion/semanticregistry
[3] http://wso2.org/projects/governance-registry
[4] http://www.mulesource.org/display/galaxy/home

descriptions, policies, contracts, etc) imposes rather restrictive limits to the effectiveness and efficiency such solutions can ultimately achieve.

The incorporation of formal techniques for describing and reasoning about Web service characteristics, based on Semantic Web technologies, can result in significant enhancements in this solution space, can have a positive impact for the industry, and can contribute to the advancement of the state of the art in related academic research areas. Despite its encouraging potential this research topic remains largely unexplored, since the industry has only recently started realising the importance of SOA Governance and since the potential benefits that Semantic Web technologies can bring towards this goal have not yet been fully demonstrated by the Semantic Web Services research community and other related academic communities.

On these grounds, we propose to investigate the application of Semantic Web technologies in the context of Web service management, and to work towards the formulation of a concrete theoretical and technological approach for supporting SOA Governance through the realisation of semantically-enhanced registry and repository solutions.

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