# Towards Semantic Web Services-based Network Configuration Management

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***Abstract*—As the Internet continue to grow, the tasks of configuration management for IP network devices are becoming more and more difficult. Over the past few years, much effort has been given to improve the deficiency of SNMP in configuration management scope, only few have succeeded to be standardized, the famous one of which is Netconf developed by the IETF. Even the Netconf is still far from its aim to implement the automation of the network configuration. These days, Semantic Web services have become a promising technology and it seems that it may be used in configuration management scope. This paper first analyzes the Netconf approach and a promising Semantic Web services-based approach to configuration management for IP network devices is then introduced in the paper. To realize Semantic Web services-based configuration management, this paper provides the application of OWL-S, a semantic markup for Web services.**

***Index Terms*—Configuration management, Netconf, OWL-S, Semantic Web services.**

## I. Introduction

The rapid pace of Internet evolution is currently witnessing the emergence of diverse network devices. Currently, IP networks, which are composed of these network devices, are becoming larger and more complex. Efficient management techniques are needed to manage these networks. Since its introduction in the late 1980s, the Simple Network Management Protocol (SNMP) has been the most widely used approach for network management on the Internet. However, SNMP has been used mostly in monitoring for fault and performance, but was hardly used for configuration management, since the SNMP management framework has some weaknesses related to configuration management in managing large networks.

Today, it seems that eXtensible Markup Language (XML) technologies, such as XML Schema, XML Path Language (XPath), eXtensible Stylesheet Language (XSL), Simple Object Access Protocol (SOAP), and Web Services Description Language (WSDL), are a promising solution to overcome the shortcomings of SNMP. These days, the Network Configuration (Netconf) Working Group (WG) [1] of the Internet Engineering Task Force (IETF) is in process for standardization of configuration management for network management using XML technologies.

However, current standardization efforts of Netconf WG are only focus on the definition of a set of operations, without sequencing them, providing essential information as they depend on each concrete resource, and specifying the way to perform that configuration. Since Semantic Web services has become a promising technology, it seems that it may be used in configuration management scope. The main goal of this paper is then to introduce the Semantic Web services-based approach to configuration management for IP network devices, and provide the application of OWL-S to realize Semantic Web services-based configuration management.

The organization of the paper is as follows. Semantic Web services are introduced in Section II in order to demonstrate its potential in the field of configuration management for IP network devices. Then OWL-S, a semantic markup for Web services, is introduced in Section III. By means of OWL-S, a feasible method is provided in Section IV to realize Semantic Web services-based configuration management. We conclude our work in Section V.

## II. The Potential of Semantic Web services in Configuration Management

### A. Semantic Web services background

As an integration of Web and XML, Web services has emerged as one of the promising technologies in management, for they can provide a distributed management capability for monitoring the services of applications on the Internet or intranet using standard XML protocols and formats. In order to better use Web services in network management, WSDL and SOAP over HTTP, provides the capability for the standardizations of management information definition and access. The word “services” in Web services refers to a Service-Oriented Architecture (SOA). The Web services-based SOA, combined with related technologies, is depicted in Fig. 1.

Nowadays, Semantic Web and Ontology (the main component in Semantic Web) has been another promising technology, which can be used in the field of network management. As Tim Berners-Lee has presented, the Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation [2]. The Semantic Web architecture put forward

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by Tim Berners-Lee in the academe is depicted in Fig. 2. Ontology plays an important role in Semantic Web, for it is much more powerful than XML and RDF in expressing semantics.

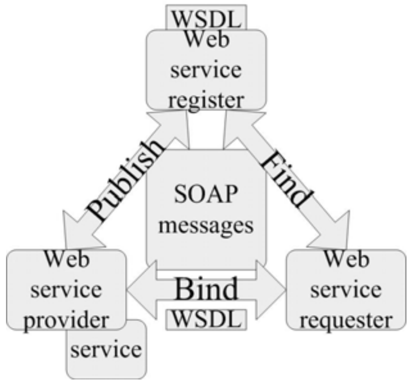


Figure 1. The Web services-based SOA

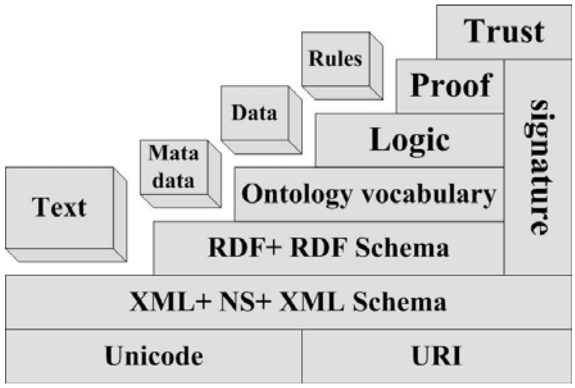


Figure 2. Semantic Web architecture

Semantic Web services, as a new research paradigm, is generally defined as the augmentation of Web Service descriptions through Semantic Web annotations, to facilitate the higher automation of service discovery, composition, invocation, and monitoring in an open, unregulated, and often chaotic environment (that is, the Web) [3]. The Semantic Web services vision is to describe Web services' capabilities and content in an unambiguous, computer-interpretable language so as to improve the quality and robustness of existing tasks. Semantic Web services will also enable a broad range of new automation tasks that humans previously performed, including automated composition, interoperation, execution monitoring, and recovery [4].

Briefly speaking, Semantic Web services can greatly enhance the semantics that Web services are provided, thus implement the automation of Web service discovery, composition, invocation and monitoring.

### *B. Configuration management using Semantic Web services*

Although Netconf WG aims in automation of network configuration, it just focuses on the definition of a set of operations, without providing a way to automate the configuration, such as sequencing operations, giving essential information, specifying the way to perform that configuration. In order to automate the network configuration, each specific configuration is treated as a Web service. Since Semantic Web services can greatly enhance the semantics that Web services are provided, automation of the configuration can then be implemented.

In fact, Semantic Web services represent an important step toward a new vision of Web services with the application of Semantic Web, in terms of utilizing, managing, and creating semantic markup languages for services. Thus in order to easily use Semantic Web services for configuration management, an appropriate markup language is in great demand to standardize the definitions of management information and operations.

WSDL only provides a mechanism to describe a Web service in a modular manner. This means that a WSDL document can just be used in the case that the services are not automated. But considering the semantic manners added into the Web services, we need a markup language particularly for Semantic Web services. In this case, OWL-S, an application of OWL, in particular, has evolved into a semantic markup language for Web services. OWL-S complements WSDL descriptions by supporting a richer semantics, including logical constraints between the input and output parameters of service. Moreover, WSDL documents can specify data types using XML Schema, whereas OWL-S uses OWL classes, which provides a better semantics [5].

## III. OWL-S: A Semantic Markup for Web Services

OWL-S [6] is an ontology developed in the Semantic Web scope, aiming at the automatic discovery, invocation, composition and interoperation of Web services. The four tasks, which the OWL-S is expected to be able to do, are shown as follows.

- Automatic Web services discovery.
- Automatic Web services invocation.
- Automatic Web services composition and interoperation.
- Automatic Web services execution monitoring,

Note that, versions of OWL-S developed so far have not ventured into the area of the fourth task. However, this task can be very useful for management of these Web services, where a user could know the state of a request.

The ontology of services in OWL-S is depicted in Fig. 3.

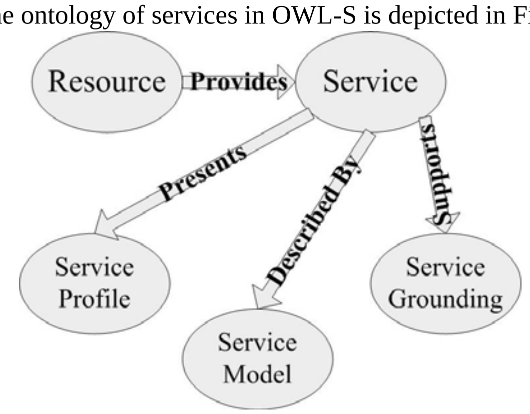


Figure 3. The ontology of services in the OWL-S

The ontology shown in Fig. 3 is composed of several classes, the main one of which is the Service class. In order to construct the ontology of services, it is needed to provide three essential types of knowledge about a service:

•The *ServiceProfile* class provides the information needed to discover a service, such as what the service require of the user(s), or other agents, and provide for them. Thus, the Service "presents" a *ServiceProfile*.

•The *ServiceModel* class tells about how the service works and details the semantic content of each request, in other words, how to use the service. Thus, the Service is "describedby" a *ServiceModel*.

• The *ServiceGrounding* class details how an agent can access the service and defines a mapping with a WSDL document of the service. Thus, the Service "supports" a *ServiceGrounding*.

## IV. Applying OWL-S to Semantic Web Services-based Configuration Management

### *A. A generic configuration service*

As stated in Section II, Semantic Web services are a promising technology in configuration management. Since OWL-S, the semantic markup for Web services, can be used to describe how to perform a specific configuration for a network device, it may be useful in Semantic Web services-based configuration management.

Now that OWL-S, the ontology for Web services, has been presented in Section III, a generic configuration service can then be applied to management for IP network devices at the Semantic Web services level. In essence, OWL-S is an upper ontology within the OWL-based framework of the Semantic Web, for describing Web services [6]. Thus then we can specify a generic ontology for configuration service, in the same way of which each network device can define its own configuration service. Considering the influence of Netconf WG, this generic ontology for configuration service will be based on current Netconf efforts.

As shown in Fig. 3, there are three classes to construct the Service class: the *ServiceProfile* class, the *ServiceProcess* class, and the *ServiceGrounding* class. Using these four classes, we can define four main instances for the generic configuration service, which is depicted in Fig. 4.

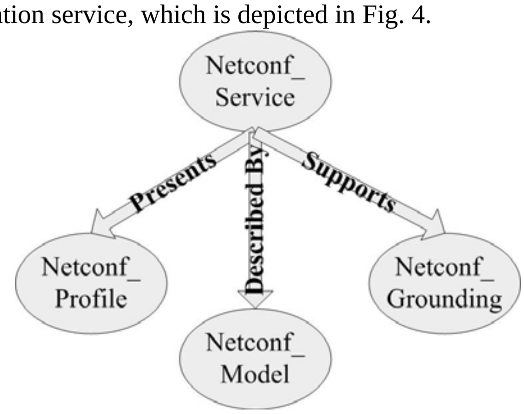


Figure 4. Four main instances of OWL-S classes for the generic configuration service

### *B. Standardization for configuration information and operations*

Configuration information exchanged between managers and managed network devices by means of Web services can now directly be instances of ontology classes, since OWL-S specify data types using OWL classes in order to provide a better semantics. Thus the configuration information can be defined in OWL, allowing a complete integration with OWL-S.

Configuration operations based on Netconf can be defined as **AtomicProcess** instances. The reason is that, the atomic processes are directly invocable, have no subprocesses, and execute in a single step.

The base definitions of those configuration operations are as follows:

- <get-config>: Netconf_Getconfig
- <edit-config>: Netconf_Editconfig
- <copy-config>: Netconf_Copyconfig
- <delete-config>: Netconf_Deleteconfig
- <hello>: Netconf_Hello
- <kill-session>: Netconf_Killsession
- <lock>: Netconf_Lock
- <unlock>: Netconf_Unlock
- <getall>: Netconf_Getall

Additional operations, which provide more functionality to supplement the base operations, are defined as follows:

- <commit>: Netconf_Commit
- <discard-changes>: Netconf_Dischargechange
- <validate>: Netconf_Validate

Each of these processes has its own input and output parameters. As stated before, the configuration information can be used as the parameters of these configuration operations, which can be define as OWL class.

### *C. Automation of the configuration service*

The definition of processes includes a set of preconditions and effects that can be expressed as formal logic rules, in order to model the behavior of the processes. The main processes are composite ones, which specify the behavior that the client can perform by sending and receiving a set of messages using control constructs (sequence, split, join, choice, if-then-else, iterate, repeat-while, repeat-until).

A specific configuration service needs a composite process, which can be decomposable into several atomic processes. Then the Netconf_Model can be composed of the set of atomic processes defined above. Those selected atomic processes for a specific configuration service represent a series of configuration operations, performing according to a pre-defined control flow using one or more control constructs, such as sequence and if-then-else. Thus in this way, automation of the configuration service become possible recur to the control flow of the Netconf_Model.

## V. Conclusion

In summary, this paper aims at analyzing the XML-based Netconf approach to improve the deficiency of SNMP in configuration management scope, introducing a promising Semantic Web services-based approach to configuration management for IP network devices, and providing the application of OWL-S to realize Semantic Web services-based configuration management.

Since Semantic Web services-based approach is a new trend in configuration management scope, the work about the application of OWL-S to Semantic Web services-based configuration management for IP network devices is part of ongoing research. We strongly encourage interested parties to react and comment on the discussed issues.

## REFERENCES

[1] IETF, "Network Configuration (Netconf)", http://www.itef.org/html.charters/netconf-charter.html.

[2] T. Berners-Lee et al., "The Semantic Web", *Scientific American*, vol. 284, May 2001, pp. 34-43.

[3] T. Payne and O. Lassila, "Semantic Web Services", *IEEE Intelligent Systems*, vol. 19, July-August 2004, pp. 14-15.

[4] S. A. Mcllraith et al., "Bringing Semantics to Web Services", *IEEE Intelligent Systems*, vol. 18, January-February 2003, pp. 90-91.

[5] J. E. López de Vergara et al., "Application of OWL-S to define management interfaces based on Web Services", Proceedings of the 8th IFIP/IEEE International Conference on Management of Multimedia Networks and Services (MMNS 2005), October 2005, pp. 24-26.

[6] W3C, "OWL--Web Ontology Language Overview", W3C Recommendation, February 2004.