An Ontology-based Approach to Improve SNMP Support for Autonomic Management

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Abstract—**The SNMP protocol remains a broadly adopted technology in the Internet management framework and its MIB was proposed to guarantee interoperation. In order to enable the management of new equipment, the human manager must compile the correlated MIB file (MIB description) and choose the right objects to manage an implicit knowledge. This paper presents an ontology-based approach and a Semantic SNMP extension, to improve the framework's autonomic support.**

Keywords—Internet Management; SNMP; MIB; Autonomic Management; Ontology.

I. Introduction

For more than two decades, SNMP (Simple Network Management Protocol) has been the core technology in the Internet management framework. Simple architecture, well defined data type representation, and large adoption, have made SNMP the *de facto* standard in telecommunications industry.

Aiming to reduce human operation in massive distributed modern systems, Autonomic Management has emerged as an important paradigm for network management [1]. Flexibility, adaptation, self-capabilities, intelligence, and machine-to-machine interaction are common requisites for Autonomic Management Systems. This paradigm intends to take decisions at run time, based on messages exchanging and knowledge processing. Consequently, interoperability arises as main concern since information is central in management systems.

In 2001, Berners-Lee *et al.* [2] proposed to handle the interoperability problem in an open and heterogeneous computing environment, the Web, by regarding terms' semantics, thus creating the Semantic Web. Ontologies are proposed in [2] as "*a way to discover common meanings*". Semantic interoperability is a research vector for autonomic management, since networks and its services continue to grow in number of components and complexity, as well as the global data interchange demand.

SNMP, even in its current version (v3), does not have adequate support for autonomic management. In order to have an effective interaction, agent and manager applications shall previously (at development time) agree about the management information meanings/semantics. Even when representing similar information, different managed objects (different Object Identifiers) do not have an explicit association.

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This paper presents an ontology-based approach and an SNMP lightweight extension, to improve the framework's semantic support and to enhance SNMP's manager autonomic applications. These approach aims to improve the Internet framework flexibility and machine-readability, keeping it simple and able to still operate in conventional scenarios. The lightweight SNMP extension here proposed is called Semantic SNMP.

II. SNMP Data Structuring and Semantic Gap

As a standard, SNMP must have a well-defined syntax. However, when considering its semantics, it can be concluded that the lack of formalization facilitates the occurrence of undesired communication effects. The MIB is a structure for data storage and is frequently used in network equipment to help management via SNMP. SMI describes primitive types (e.g.: integer, gauge, etc.), defined types (e.g.: NetworkAddress, Counter, etc.) and object identifier (OID), but does not describes the managed information meaning or context (semantics). To avoid interpretation problems, MIB designers try to organize the management data in a way that human managers can understand it. This is done basically by grouping related objects in a tree structure and by a textual description of each MIB field. MIB structure and objects grouping can, however, induce different interpretations than that initially proposed by the original designers. Textual description (description field) also can lead to miscomprehension due to the notorious ambiguities of natural languages.

The network interfaces management can be used to illustrate a semantic gap in a SNMP MIB. Interface is a well-known concept in SNMP MIB and there is a dedicated table for it in MIB-II (interfaces group). In optical equipment, for instance, interfaces have specific management information. In this case, part of the information will be at MIB-II and a more specific part appears at a specific MIB, for example, the OPT-

IF-MIB (RCF 3591). To correctly use these two MIBs (e.g., in an integration or interoperation scenario), a human has to manually map the concepts and integrate information between them during the manager application development time. The mapping activity is, as previously discussed, error-prone because of the lack of formal semantics of the network (management) concepts. Manual mapping of management information can be hard, even for small MIBs, if he or she has to compare each OID and DESCRIPTION and find the best matches.

Furthermore, the experience of Network Management Research Group of the Internet Research Task Force in the development of SMIng [4] commented about the problems related to definition of management data models, which remains a significant effort. Problems also arise because of the increasing number of deployed management protocols, generating duplications and inconsistencies.

III. A Brief Review On Ontologies In Autonomic Network Management

Ontology came up in Philosophy meaning a systematic explanation of the being. In computing, ontologies are used to provide a large number of resources for intelligent systems as well as for knowledge representation and reasoning [7].

A. Ontology Definition

As stated in [8], an important point that should be emphasized is the difference in the senses of the term used by the information systems community, on one side, and artificial intelligence and semantic web communities on the other. For the former, the term ontology has been used as a system of categories, independent of language. Ontologies, in this sense, are called in this paper *Conceptual Model Ontologies*. In contrast, for the latter and for most areas of computer science, the term ontology is used as a concrete engineering artifact, designed for a specific purpose, and represented in a specific language [8]. Ontologies artifacts in this sense are here called *Lightweight Ontologies, Computational Ontologies* or simply *Ontologies.*

There are many potential applications to *Ontologies*. According to [7], Fikes has divided the main areas of application of ontologies into: (a) **collaboration**, providing a “skeleton” of unified knowledge; (b) **interoperability**, allowing the information integration from different sources; (c) **education**, being a source of reference; and (d) **modeling**, representing important reusable blocks.

The most known paradigm for ontology implementation is the classical paradigm, used for the Semantic Web. The goal of semantic web research is to allow the vast range of web-accessible information and services to be more effectively exploited by humans and machines. To facilitate this process, the Resource Description Framework (RDF) and the Web Ontology Language (OWL) have been developed as W3C (World Wide Web Consortium) standard formats for data and knowledge representation, sharing and integration. A key idea behind the semantic web is to address this problem by giving machine accessible semantics to annotations, transforming them into **semantic annotations** [9].

B. Ontology and Semantics in Network Management

The lack of a formal semantics in network management models was presented by Vergara *et al.* in [10] and [11]. According to them, different management models (SNMP, CMIP, CIM/WBEM and Corba) could be correlated. In their work, a heuristic (human driven) mapping process was used to establish a semantic equivalence between these models. As a result, Vergara *et al.* presented a network management meta-model. The term Ontology, with the meaning of taxonomy and of a common information model, has been used in the network management context since then. Interoperability has become an issue in the network management, as pointed in [12].

Autonomic Management and Self-management researches have taken ontology first as information taxonomy [13], then as a data representation standard [14] and later as an endogenous interoperability solution [12]. Thus, interoperability is reached only inside the proposed solution, i.e., interoperability just exists if the communicating parts implement the proposed framework or model. Even so, ontology as an interoperability tool is frequently used as an approach to improve autonomy and self-features of network management solutions [15]. Interoperability between different autonomic solutions (exogenous interoperability) remains an open subject.

In some cases, Internet management framework (SNMP, Netconf, etc.) ontologies have been used as a lightweight reference model [11] without consistent formalization. Considering autonomy, only few contributions aims to improve the Internet management framework. The most relevant of them is the use of Action Semantics inside the SMI objects' *Description Field* in a MIB File (*.mib), providing a semantic description of interaction between management entities (agents, manager and proxy) [16].

C. The Search for a Network Ontology

To face the challenge of exogenous interoperability, some domain ontology for computer networking and network management must be proposed, debated and adopted as reference by the related community. There are a vast number of ontology proposals for different fields in telecommunications. Although some of these network *ontologies* are under standardization organizations, like the Semantic Sensor Network (SSN) Ontology [17] – W3C, and the Infrastructure and Network Description Language (INDL) [18] – Open Grid Forum, most of the *ontologies* are isolated proposals. These ontologies' types range from computational ontologies to conceptual model ontologies. Even with all community's interest, there is no consensus about an integrated ontology reference model for networks. Also, according to [9], integrating different *ontologies* may prove to be at least as hard as integrating the resources that they describe.

D. The Strategies Behind the Improvement of SNMP Support for Autonomic Management

The MIB II can be considered as a minimal implicit ontology for SNMP entities. Thus, the first strategy is to identify the concepts stated into the basic Internet management MIB (MIB-II, RFC 1213). Four main concepts are identified:

- **Node** (System) – representing the device in focus or some part of it;
- **Interface** - representing connectivity capabilities in any context;
- **Service** – representing a generic Node service capability (see RFC 1213's topic 1.3.6.1.2.1.1.7 – sysServices - description);
- **Layer** - representing the hierarchy order, protocol, technology or context of a service (see RFC 1213's topic 1.3.6.1.2.1.1.7 – sysServices - description).

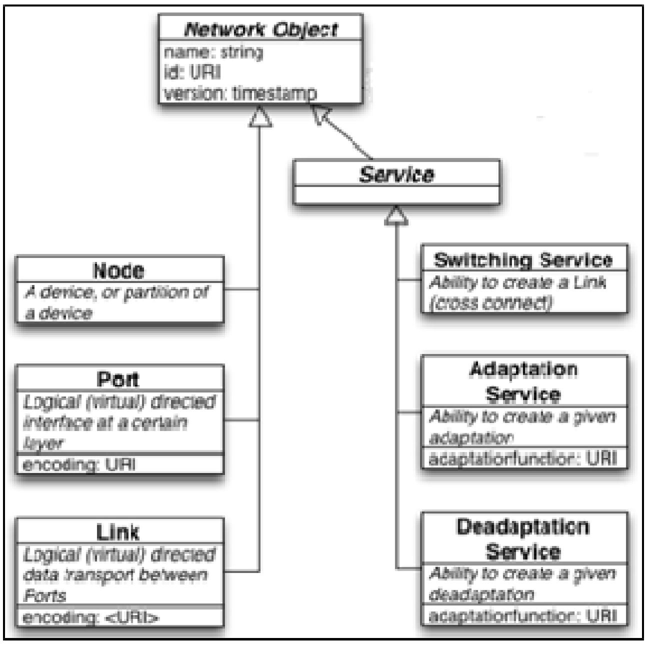

Figure 1 - INDL Schema Fragment [20]

Observing other MIBs (e.g. EthernetLike MIB, RMON MIB, ATM MIB, etc.), it can be also noticed that almost all of them are strongly associated with one or more of those three first concepts. A larger number of MIBs were developed to represent services (e.g. SIP MIB, APS MIB, ALARM MIB, etc.) and a service needs a context information. Layer is the concept that gives some organizational perspective to service, associating it with some technology, protocol or scope.

The INDL provides a lightweight ontology containing the same first three main concepts, as showed in Figure 1 (INDL Schema). The INDL's concepts Node (nml:node) and Service (sss:service) have the same meaning of the key concepts found in management MIB-II, the INDL's concept Port (nml:port) has a very close meaning of Interface (disregarding directionality). However, INDL doesn't represent the Layer concept. Thus, layer concept can be added as an INDL extension. This paper uses Layer and INDL's concepts: Node, Service and Port as a basic ontology to give to MIB objects a first level of meaning (semantics).

The second strategy is to observe the attributes of a MIB object and the convention of management MIB-II object names. This paper's proposal uses the access keyword to infer if an object is a configuration item (ACCESS read-write) or a monitoring item (ACCESS read-only). The words Table and TableEntry are used to identify tables and tables' rows, respectively. The ifIndex is used as primary key of other tables containing complementary Interface information. Other possibilities in this direction were not explored at this moment.

The third strategy is to connect a MIB Object to a specific concept in an external ontology. This strategy can improve the SNMP MIB semantic support, creating pointers to any alternative, complementary, or more detailed external ontology. This strategy can handle problem of synonyms (concepts with different names, but same meaning) and allows the correlation of one MIB object with diverse concepts in different ontologies.

IV. The Semantic SNMP Extension For Autonomic Support

The Semantic SNMP extension consists of **three key points**: **(i)** an extension of the MIB-II with a new table for semantic mapping of SMI tree branches; **(ii)** the inclusion of semantic notation into the Description field in the MIB file to link management objects to its external formal semantics – a reference ontology; and **(iii)** to store ontologies and MIB files in the Internet where they can be organized and retrieved.

A. SNMP MIB Extension

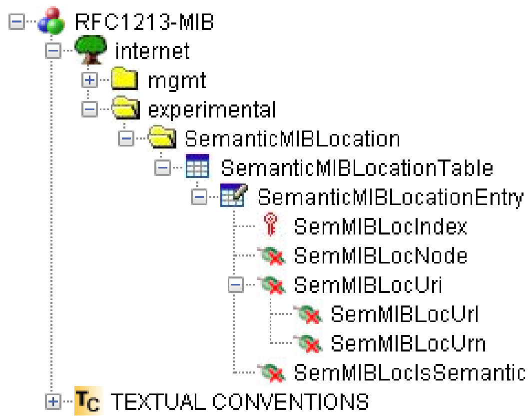

Figure 2 - Propose for MIB File Location table

This first key point proposes a new table to store information about MIB files for specific managed objects in private or experimental branches of the SMI structure. Each entry in this table contains the correlation among the initial OID of a certain branch (e.g.: .1.3.6.1.2.1.2), the Uniform Resource Identifier (URI = URL + URN) (e.g.: "http://www.ietf.org/rfc/rfc1213.mib") of its correspondent MIB file, and a Boolean flag indicating if this MIB file has semantic information inside. This last field is part of the second key point of the Semantic SNMP extension.

In addition, each entry has a unique index. Figure 2 shows a MIB Files Location table and in a preliminary implementation.

A non-autonomic SNMP manager application is not going to be affected by this change. However, an autonomic manager application can retrieve the location of additional MIB files to verify if they have semantic information about its managed objects.

B. *Semantic Notation on Description Field of MIB File*

The Semantic MIB file adds information that correlates the ontology (which can be formalized, for example, in OWL) and the original MIB objects. Thus, to add a semantic reference obeying the SMI syntax, we propose a semantic tag in the DESCRIPTION field of the object declaration. This semantic tag is identified by <@SEMANTIC NETWORK_LAYER = "layer_name"> token, where "layer_name" defines the network layer (for any technology or hierarchical system). Bellow it, the tag <CONCEPT> and </CONCEPT> points to the concept (URL of ontology file) that defines the meaning of MIB object. The attribute definition, <DEF=x>, where x = [1..n], can be used repeatedly, expressing synonyms or alternative concept location.

The following SMI object definition fragment presents the insertion of the semantic annotation (tags) as an example.

```
ifNumber OBJECT-TYPE
SYNTAX  INTEGER
ACCESS  read-only
STATUS  mandatory
DESCRIPTION  "The number of network interfaces
(regardless of their current state) present on this
system.
<@SEMANTIC NETWORK_LAYER = "OSI_link_Layer">
<CONCEPT> <DEF=1>
http://www.example.com/indl_base.owl#Port
</DEF>
<DEF=2>
http://www.ietf.org/rfc/rfc1213.owl#Interface
</DEF>
/CONCEPT>
</@SEMANTIC>  "
::= { interfaces 1 }
```

Once all objects are semantically described, the Semantic SNMP Manager can organize, correlate and process MIB objects under the same meaning. Different objects - with same formal meaning - can be processed in the same way.

V. CONCLUSION AND FUTURE WORKS

Aiming to address the problem of semantic lack in Internet Management Framework, the Semantic SNMP extension consists of three key points: (a) an extension of the MIB-II with a new table for semantic mapping of SMI tree branches; (b) the inclusion of semantic notation into the Description field in the MIB file to link managed objects to its external formal semantics – represented by an INDL based ontology; and (c) to store ontologies and MIB files in the Internet where they can be organized and retrieved.

As a future work, intelligent applications capable of collect the annotated semantic information in MIB Description Files can be developed and compared with traditional autonomic SNMP applications. This proposal could be extended to other management protocols, like the Netconf.

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