# A Classification Framework for Network and Service Management Models

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***Abstract*—Today's network and service management models are extremely heterogeneous in their characteristics. The constant evolution in this research field has lead to a steady development of models with new paradigms in their method of working. Even with this constant evolution, it is important for network managers to understand what are the models that better suit their requirements. In this article, a new up-to-date classification framework capable of characterizing today's most important network management models is presented. The seven different properties that compose this framework allow a broad coverage of the management models main functionalities. This enables a quick and useful comparison between the several model options in the network management area.**

## I. Introduction

Research of architectures which allow the successful management of information system networks began in the late eighties [1] [2]. Since that time, several new technologies have sprouted from a wide variety of research communities. This proliferation of heterogeneous technologies has considerably increased the complexity in the definition and classification of the various projects that constitute the network management study field.

To solve these problems, in 1999 Martin-Flatin *et al.* [3] presented a taxonomy which classified the paradigms that were available at that time, based on four different criteria: the granularity at which the delegation process takes place; the semantic richness of the information model; the degree of automation of management tasks; and the degree of specification necessary to achieve a management objective. Due to its age, this taxonomy cannot cope with the newly developed network management models where new paradigms have been developed that do not fit in any of the proposed categories. Several new investigation topics, like web services or ontology based management systems, which have been researched in recent years, need to be included in a more up to date taxonomy, with criteria that correctly reflect their specific characteristics. This fact originates the need to investigate an updated framework which is capable of classifying the various network management models used on our days.

This paper performs the following contributions: *(i)* create a new, up-to-date, network management model taxonomy with criteria that enables the accurate characterization of distinct properties present in today's network management models and *(ii)* classify the various models surveyed with the developed taxonomy.

The work performed should enable network operators and network management researchers to determine the main characteristics present in each model and to perform reliable comparison among them. This study also aims to serve as a tool which provides a quick and reliable form to discover the model that is more suitable for satisfying a combination of network requirements.

Section number two presents a list of studies which relate to the developed work. Section three the proposed classification framework, along with detailed explanation of its seven properties, is presented. Section number four joins the previous two sections by instantiating all network management models listed in the second section with the proposed classification framework. Finally the last section, number five, discusses the results achieved and draws the final conclusions.

## II. Related Work

There are multiple surveys describing the various characteristics of researched network management models. These articles provide an extremely rich and complete description of each of the models, detailing the various design options, their algorithms and their functionalities.

Pavlou [4] studies the evolution of management models which have been developed over the last twenty years. Each model is given a detailed description and there is a relevant attention to the historical perspective of the area, where the appearance of new models is derived from the disadvantages present in previous ones.

A list of network management technologies, with their properties, strengths and weaknesses is presented in [5]. This study main focus centers on analysing the models from the perspective of a network operator, paying special attention to their requirements.

Martin Flatin *et al.* [3] is an article which provides a common taxonomy for characterizing all network management models using a common set of properties. This taxonomy is incrementally built and presents the reader with four different criteria. Different management models are then compared using this taxonomy and their main characteristics are listed.

## III. Proposed Classification Framework

This section of the article presents a framework model which has the purpose of classifying the various paradigms

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existing in the network management area. This study should serve as a guide for participants of the systems and network management community, allowing the quick reference of the main characteristics of various network management models.

The proposed classification framework is composed of seven axis, each one characterizing an important aspect of the studied network model:

- Interoperability - Quantifies if the model supports interactions with nodes using different management models.
- Information Model Semantic - Classifies the abstraction degree of management rules that is permitted by the information model.
- Distribution - Indicates the concentration of network management functions on a subset of nodes.
- Automation - Defines the level of interaction performed between the human operators and the network application in order to configure and run the platform.
- Delegation Granularity - This measure represents the granularity dimension by which management functions can be delegated.
- Scalability - Specifies what is the network dimension in terms of number of nodes, that the model can support.
- Task Specification - Indicates the level of semantic abstraction present in the definition of tasks when management responsibilities are delegated between two nodes.

It is important to notice that these criteria are not independent; for example the delegation granularity is highly correlated with the degree of automation. This will be possible to observe on section IV. Another characteristic present in these criteria is that they can assume continuous values or discrete values. Continuous values are used when two different values can be compared with a greater than function, for example a model $A$ is more scalable than model $B$. Discrete values are used when no greatness function can be made between the different values that a property can assume, for example model $A$ is Centralized, and model $B$ is Hierarchical Distributed.

The following sub-sections detail each one of the presented criteria with a description and with the values they can possess.

### *A. Interoperability*

One of the main objectives desired in a network management system is the ability to interact seamlessly with multiple vendors equipment. As empirical knowledge proves, it is highly unlikely that a single network management model will be present in all nodes which need to be managed. The interoperability axis classifies the network management model systems according to their ability to exchange information and management commands with nodes that use other technologies. The two levels for this classification assume continuous values between them:

- No Model Interoperability - The network model does not natively support the possibility to interact with nodes whose management model is different between them.
- Model Interoperable - The network model provides the possibility for nodes with different models to interact with each other.

### *B. Information Model Semantic*

Network management paradigms that use information models which are semantically richer allow the creation of entities with more abstractive expressiveness. This feature enables the specification of management tasks to be performed more quickly and in an language more similar to the goals desired by the network operator. Three level of information models can be defined [3]:

- Managed Objects - Low level abstractions where the communication model imposes the format for the information model.
- Computational Objects - High level abstractions where the information model is independent of the communication protocol. There is a programmatic interface that divides the invoker from the operations supported by the invoked object.
- Goals - The information model supports the abstract concept of goals which represent the objectives that network should accomplish. These goals are sent from managers to agents and it is up to the agent to work out the sequence of actions needed to achieve these goals.

### *C. Distribution*

The level of distribution that characterizes a network management model is defined as the concentration of management functions on a restricted number of nodes of the system. This is a important characteristic for managing bigger networks where it is impossible for a single node to interact with all devices. Another important feature provided by a high level of distribution is the improved reliability of the network management system, since an error on one device performing a managing role only affects a subset of the network. The distribution classification is divided into three discrete levels:

- Centralized - All management functions are present on a single network node.
- Distributed Hierarchical - Management functions are distributed between various nodes grouped in layers. Each node can only exchange management functions with a node present on an adjacent layer.
- Distributed Cooperative - The various management functions are performed between any group of nodes and all nodes can potentially perform any management role.

### *D. Automation*

By classifying the various models by their degree of automation we define the level of interaction that human operators need to perform with the system in order to manage the network. A high level of automation reflects on lower response times because the number of abnormal events which were not explicitly defined in the system configuration and require human intervention is lower.

In terms of automation two levels, which possess continuous values between them, are defined:

- Regular Human Intervention - Whenever an abnormal event occurs in the network, in order to correct the problem, human intervention is necessary to send management functions.
- Strategic Control by Operators - Human intervention is only necessary on setting and modifying goals. The management system most discover the correct sequence of steps to accomplish these goals.

### *E. Delegation Granularity*

When delegation occurs between nodes, the coverage dimension of managed entities which participate in the management task can differ according to the network management model. It can vary from a small group of nodes present in a single domain, to all nodes that are necessary to perform a complex management task. In this axis, three different types of delegation granularities can exist:

- No Delegation - No delegation occurs between different manager nodes.
- Delegation by Domain - In this type of delegation the node which delegates knows, by some static information, what are the nodes to whom it can delegate. This group of nodes is normally called management domain.
- Delegation by Task - In a delegation by task model, the delegating node dynamically discovers other nodes that can perform the desired task. These delegation routes are not static as it is possible to discover what are the better nodes to delegate a task responsibility.

### *F. Scalability*

The term scalability refers to the number of different nodes that one instance of the network model can manage. This quantity dimension affects directly who is the target audience for that network model.

We have divided scalability in two levels which assume continuous values in the interval between them:

- Less Scalabe - At this level, the described model can only manage a few nodes.
- More Scalable - This level represents a global system where the communication infrastructure contains a high number of nodes, possibly including several network administration domains.

### *G. Task Specification*

When one node delegates management functions to another, the specification of the function to accomplish a specified task varies according to the network management model. This means that messages transferred between the nodes can range from explicitly commands that perform actions to macro management tasks where only the objectives that are intended to be achieved are indicated.

In terms of task specification two levels are proposed:

- Micro Specification - Management functions are exclusively composed of limited functions like the primitive Get and Set commands over managed objects and those are executed directly.
- Macro specification - It is possible to issue management commands in an high level abstract level, where the specific properties of the managed object can be abstracted.

## IV. Classification of the Network Management Models

This section presents an instantiation of the proposed network management classification framework. In order to allow a clearer comparison of the characteristics associated with each model, the model classification was divided into three different stages, each one correlating related properties.

Figure number 1 classifies the surveyed network management models according to three axis: Delegation Granularity, Task Specification and Information Model Semantic. Due to the differences existing between SNMP version one and later versions, this network management paradigm was divided into two different models. Semantic mapping ontology model [6] [7] was intentionally omitted from the drawing as its properties are a direct consequence of the properties present in the models that it uses as base. By analysing figure 1, it is possible to observe that four major groups are present: network management models where no delegation is possible (just SNMP v1), delegation by domain with managed objects semantics, delegation by domain with computational object semantics, and finally delegation by task with goals semantics. Web services network management model can be classified into two different delegation granularities, by domain or by task, depending on the implementation of the model.

Figure number 2 compares the scalability of the management model with its distribution level. Through the analysis of the figure it is possible to observe that most solutions reside on a cluster with an hierarchical distribution and a

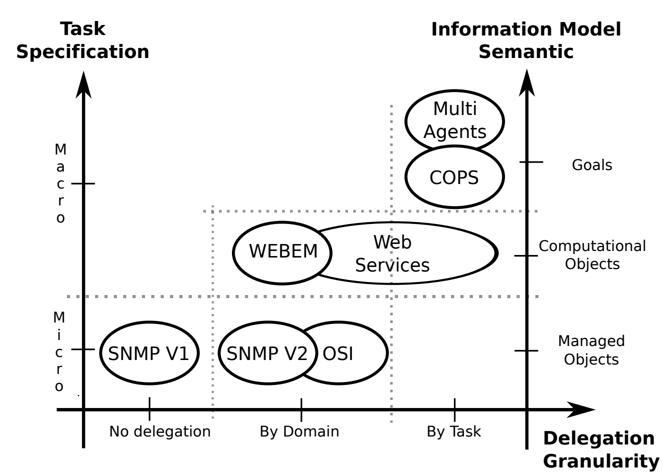


Fig. 1. Comparing models by Delegation Granularity, Task Specification and Information Model Semantics

medium scalability capability. In order to achieve high levels that can cope with Internet size number of nodes, a cooperative distributed option is the only paradigm which presently copes with this goal. It is important to notice that the scalability axis is composed of continuous values and that semantic ontology network management model is omitted for the same reasons present at figure 1.

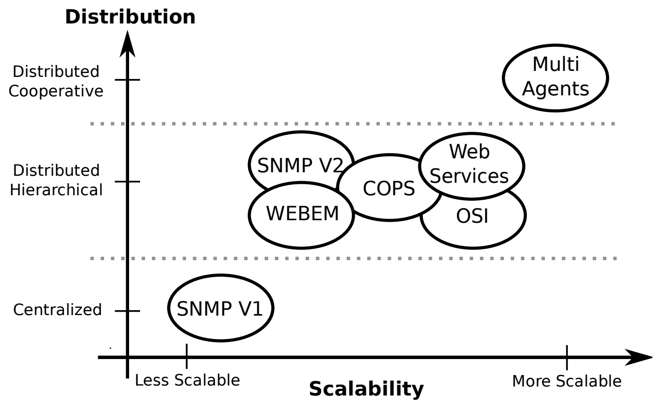


Fig. 2. Comparing models by scalability and their distribution level

Finally, figure number 3 presents a relation between the interoperability of the network management model and its automation properties. Notice that both axis's values are continuous and so their relative position is important and that presently only one model can actually provide a high level of interoperability.

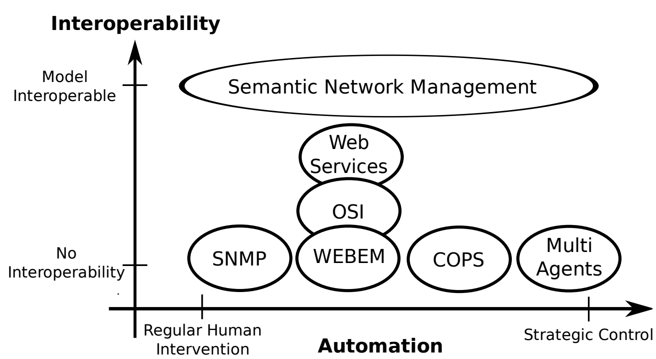


Fig. 3. Comparing models by interoperability and automation properties

As it is possible to see through the analysis of the three figures in which the properties of various network management models are listed, no model is capable of fulfilling all requirements. Each property present in the framework can impact other properties. When a network manager user chooses a model with a property it is important for him to understand the impact that this decision will have on the remaining properties.

## V. Conclusions

With the objective of better understanding the various models that compose today's network management research field and to address the lack of classification frameworks that include most recent technologies, this article proposes a new classification framework that characterizes the best known network management paradigms according to seven different properties.

We have started, in section 1, by presenting the motivations that lead to the development of this work. It was described that today's network management models use heterogeneous paradigms for their functioning, and that is becoming extremely hard to quickly and reliably compare the various properties present in these models.

The following section explained the developed classification framework through which the defined criteria allowed the characterization and comparison of the properties present in each model. The seven proposed criteria provide a broad taxonomy that covers most aspects present in today's best known network management models. Each one of the criteria had its possible values defined and explained in order to reduce the possibility of ambiguities when applying the framework.

Finally, the last section instantiated the framework with the most well known non-proprietary network management models. With the help of this taxonomy it is now possible for network operators and network management researchers to determine the main characteristics present in each model and to perform comparisons between them. This is a tool which allows the easier discovery of the model that is more suitable for the specificities of some particular situation, as it continues to not exists one single solution that fits all needs.

This article has also showed that some properties, for example a high degree of scalability, can be highly dependent on other properties, like the distribution type of the model. It is therefore important that network managers understand what are the characteristics of each model before choosing to manage their network using a specific technology.

In the future, it is the authors intention to maintain the framework updated to support new network management models as they are researched and published.

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