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Integration of Knowledge Management in the MIB for the Network Management

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1. Introduction

In a heterogeneous and distributed context, the management of telecommunication networks and services is becoming increasingly important in operator and service provider environments. This management cannot be performed without the contribution of intelligent management functions, which ensure the most important management operations of provisioning, assurance and billing. More advanced tools are needed to support this activity. It is necessary to develop new models, which offer more possibilities.

To resolve this difficulty in this chapter we study the integration of advanced artificial intelligence technology into existing network management models. We describe the design and implementation of a management platform using Artificial Intelligent reasoning technique.

This study focuses on an intelligent framework and a language for formalizing knowledge management descriptions and combining them with existing OSI management model. In this chapter we present a methodology to specify intelligent agents, based on management OSI model.

We propose a new paradigm where the intelligent network management is integrated into the conceptual repository of management information. In modern network elements management information is increasingly stored in a distributed manner locally with the network elements into Management Information Base (MIB) databases. These databases contain all relevant configuration data and the dynamic state data (measurements and alarms) in a standardized format. We study a technique which integrates the knowledge base of expert system within the MIB used to manage a network.

A new property named RULE has been added in the MIB, which gathers important aspects of the facts and the knowledge base of the embedded expert system. By integrating the knowledge base in resources specifications, system has the power to provide diagnosis of fault network, which can assist engineering trainees, inspectorate staff and professional. Furthermore this paper outlines the development of an expert system prototype based in our propose GDMO+ standard and describes the most important facets, advantages and drawbacks that were found after prototyping our proposal.

This paper is organized as follows. In the section immediately below, we describe the evolution of network management and the role of network management functions. We will examine the management network, including the concepts, major approaches, and management models. It starts with specific applications and work on expert systems in similar fields. We propose a new Intelligent Integrated Management Model and an extension of standard called Extended GDMO or simply GDMO+, for the incorporation of the management expert rules. Next will examined the design and development of a prototype. From there, we present the concept the formulation of the system design proposal and also an outline of the various stages in the system development cycle. Next section summarizes the performance of the system and the results of the research. Finally we outline the conclusion and future works.

2. Management network overview

The purpose of network management is the assignment and control of proper network resources, both hardware and software, to address service performance needs and the network's objectives. With the ever-increasing size and complexity of underlying networks and services, it has become impossible to carry out these functions without the support of automated tools (Zuidweg, 2002). As the size of communication networks keeps on growing, with more subscribers, faster connections and competing and cooperating technologies and the divergence of computers, data communications and telecommunications, the management of the resulting networks gets more important and time-critical. Telecommunication and services are in the process of revolutionary yet evolutionary changes due to transformation of the regulatory environment that in turn has given rise to rapid improvements in the underlying application, networking, computing, and transmission technologies.

There are two dominant network management models, which have been used to administration and control the most of existing networks: TMN and SNMP. Both network management systems operate using client/server architecture. SNMP standards are defined in a series of documents, called request for comments or RFCs proposed by the Internet Engineering Task Force (IETF) and Telecommunications Management Network TMN is introduced by the ITU-T (the former CCITT). Of these two TMN is gaining popularity for large complex networks.

In private network environment, SNMP enjoys near-universal support. In the public environment, however, a more heterogeneous mix of de facto telecommunications industry standards has prevailed, with a move toward TMN support. Moreover TMN was the first who started, as part of its Open Systems Interconnection (OSI) program, the development of the architecture for network management. The OSI management environment consists of tools and services need to control and supervise the management networks.

2.1 OSI network management model

The OSI network management model is a starting point for understanding network management. There are three basic components comprising the elements of the management architecture to support a successful implementation of the OSI Network Management Model, figure 1:

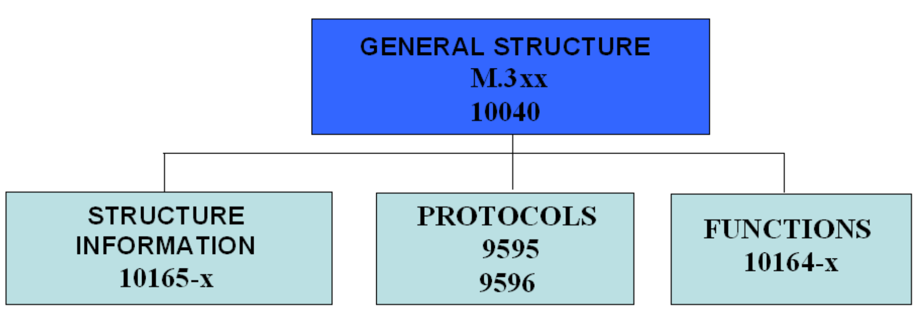

Fig. 1. Overview of OSI Network Management Model.

- An information component involved with five major functional areas: fault, configuration, accounting, performance, and security management in network management which facilitate rapid and consistent progress within each category's individual areas (International Organization for Standardization [ISO], 1993).
- A communication component which focuses upon how the information is exchanged between the managed systems (International Telecommunication Union [ITU-T], 1992).
- A functional component involved with the various activities performed in support of network management (International Telecommunication Union [ITU-T], 1996).

According to the International Organization for Standardization (ISO), the OSI network management model defines a conceptual model for managing all communication entities within a network. This main concept is the managed object, which is an abstract view of a logical o physical resource to be managed in the network (Hebrawi, 1995). Managed objects provide the necessary operations for the administration, monitoring and control of the telecommunications network. These operations are realized through the use the Common Management Information Protocol (CMIP) (International Telecommunication Union [ITU-T], 1997). This is a network management protocol built on the OSI communication model. The related Common Management Information Services (CMIS) (International Organization for Standardization [ISO], 1998) defines services for accessing information about network objects or devices, controlling them, and receiving status reports from them. For a specific management system, the management process involved will take on one of two possible roles, Figure 2:

- A Manager or Manager Role is an element that provides information to users, issues requests to devices in a network, receives responses to the requests and receives notifications. These notifications are unsolicited information from devices in the network concerning the status of the devices.
- Agent or Agent Role is an unit that is part of a device in the network that monitors and maintains status about that device. It can act and respond to requests from a manager and can provide unsolicited information (or notifications) to a manager.

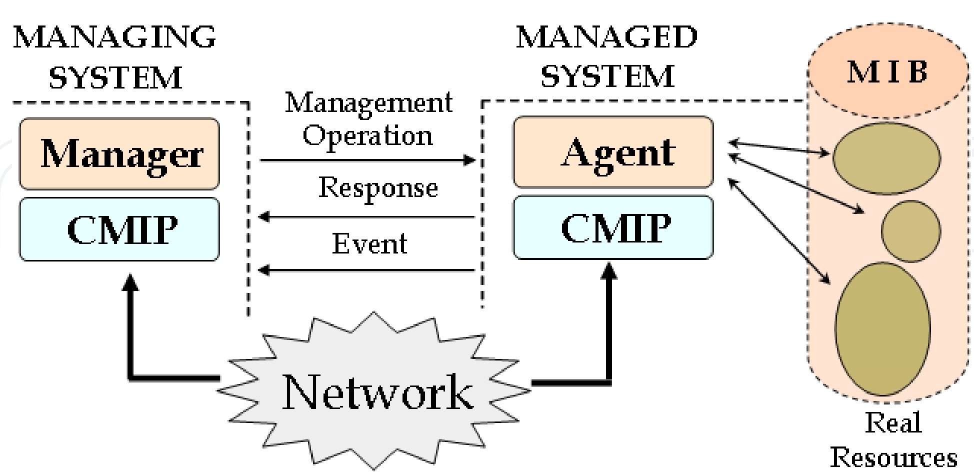

Fig. 2. OSI manager/agent architecture

These managed objects are defined according the ISO Guidelines for Definition of Managed Objects (GDMO). GDMO language uses the object orient programming and defines how network objects and their behaviour are to be specified, including the syntax and semantics.

This standard has been standardized by ITU-T in ITU-T X.722 and is now widely used to specify interfaces between different components of the TMN architecture. GDMO properties values types are described using the abstract syntax notation one (ASN.1) (Morris, 2003). ASN.1 describes an abstract syntax for data types and values.

Nowadays there are different domains of application of the expert systems in topics related with the network management. OSI classifies the systems management activities into five functional areas. We can categorize the expert systems used in network management within these five groups. Some expert system examples are Max & Opti, ANSWER, Trouble Locator, and CRITTER in fault diagnosis area, ESS-ES, ECXpert, and APRI in accounting management area, ACE, XCON, SMCS, and EXSim in configuration management area, TASA, NETTRA, and Scout in performance management area, NIDES, P-BEST, and NIDX in security management area. In this context the expert system that we have built, would be included in the area of work of the fault management (Liao, 2005; Negnevitsky, 2002; Yaguo & Zhengjia, 2009).

After this brief introduction to management elements, we will approach our research in the integration of knowledge management of expert system into MIB in the OSI management model. We are studying the way to integrate the expert knowledge in the management Internet model. Internet management model doesn't use the Object Oriented Programming such as it is used by the OSI model. This is one of the reasons for the Internet model simplicity. The definitions contain objects, specified with ASN.1 macros. In internet model the resources specifications can only be groups of scalar variables and cells tables in spite of not being an Object Oriented Programming model. We can use the tables of the Internet model as classes of the OSI model, where the attributes are the table columns and every file contains an instance of the class. The same as in OSI every object has an OID associated identifier.

3. Management knowledge definition

After describing a number of important aspects which have to be considered when designing a language for behaviour descriptions, this section focuses on the syntax and semantics of the language GDMO which is discussed in this paper. Practical experience with GDMO shows that, from an intelligent point of view, the quality of GDMO specifications is not satisfactory. The managed object specifications are incomplete to define the management knowledge of a specific resource. As consequence a new element is necessary.

To solve the current problem to undertake an intelligent integrated management we offer an original contribution to include expert rules in the specifications of the network features. To answer these questions, it will be necessary to make changes on the template of the GDMO standard. To formalize the main proposal of the paper, we analyze necessary requirements area to undertake the related aspects with the knowledge integration in the managed objects. We present an extension of the standard GDMO, to accommodate the intelligent management requirements, figure 3.

GDMO is organized into templates, which are standard formats used in the definition of a particular aspect of the object. A complete object definition is a combination of interrelated templates. There are nine of these templates: class of managed objects, package, attribute, group of attributes, action, notification, parameter, connection of name and behaviour (Morris, 2003), figure 4.

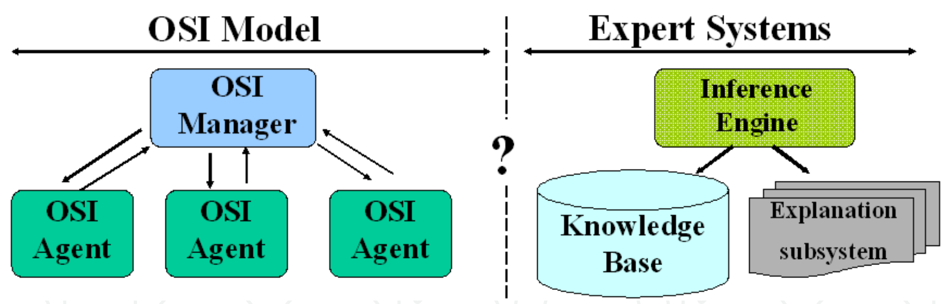

Fig. 3. Independence of Objects and Expert Management

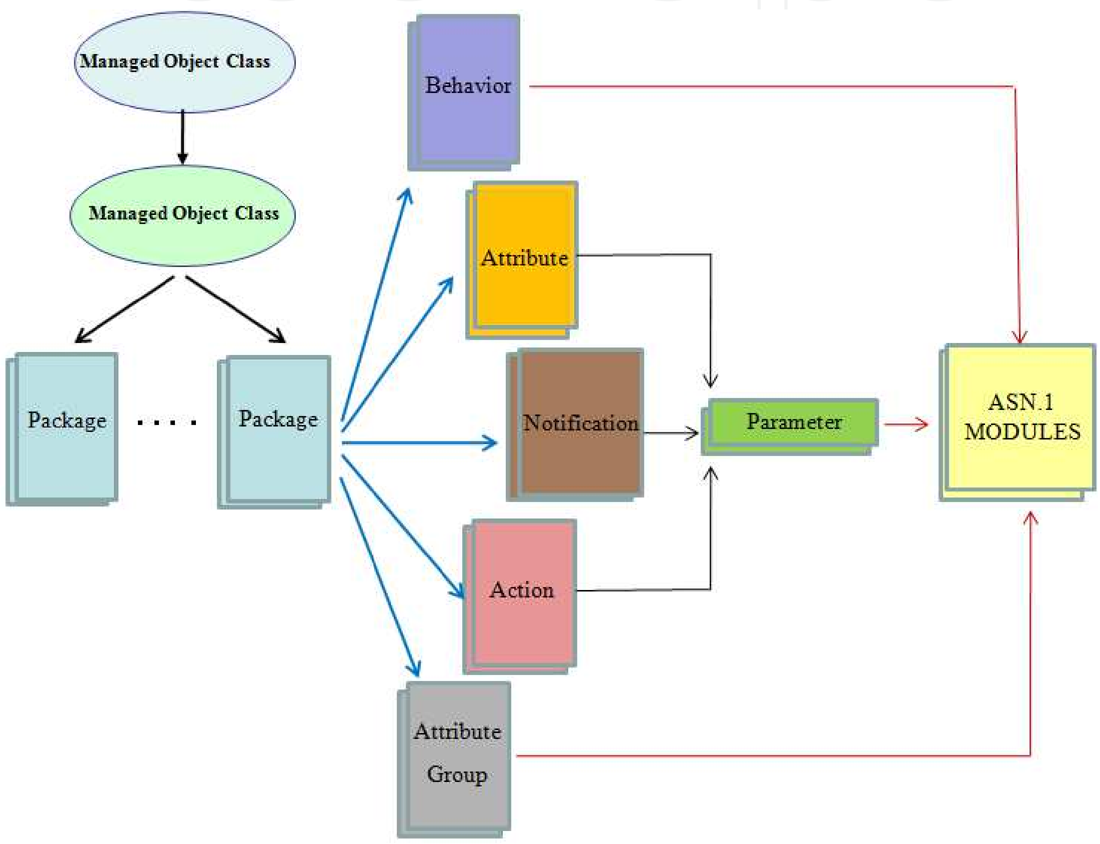

Fig. 4. Independence of Objects and Expert Management

The elements that at the moment form the GDMO standard do not make a reference to the knowledge base of an expert system. Until now the managed objects are not able to use the knowledge that the base of knowledge provides which collects the management operations and control of a management domain. We observe the need to define new structures for those cases in which it is necessary to express the knowledge. To solve this problem we suggest a refinement of the package template. We propose to extend the Guidelines for Definition of Managed Objects with the following goals: facilitate the normalization and integration of the knowledge base of expert system into resources specifications.

These goals will allow to developers specify the storage location and the update method of intelligent managed and provide a way to specify complex managed. Thus the description of certain aspects of managed object knowledge, e.g. the definition of expert rules, can be supported. We proposed adding a new property in GDMO standard named "rule". This

attribute will define all the aspect about the management knowledge in a specific managed object class. The set of managed object classes and instances under the control of an agent is knows as it's a MIB, an abstraction of network resources properties and states for the purpose or management. The MIB, which is specified using the Structure Management Information (SMI) defines the actual objects to be managed (Clemm, 2006).
Two relationships are essential for the inclusion of knowledge in the component definition of the network: Managed Object Class and Package. GDMO includes the basic template MANAGED OBJECT CLASS, which is always implemented and GDMO also defines an optional template named PACKAGE, which defines a combination of properties for later inclusion in a managed object class template.

4. Management information and knowledge management structure

Management information models are abstractions of the network resources. They define the structures and contents of management information that the management functions act upon. A management information model provides a common characterization of the network resources, enables multiple management functions to interact with each other, and supports different management functions (Huang, 2008). Management information is exchanged among management systems where management functions are implemented (Goleniewski & Jarrett), 2006).
Attaining interoperability of network management systems and a common view of managed resources in a managed network environment requires that information models comply with standard models. The management functions currently exchange management information by means of techniques defined in ITU-T X.700.
These recommendations incorporate the important object-oriented and manager/agent paradigms for information modelling. The object-oriented approach for information exchange allows for grouping of data and the executable operations to be fully encapsulated into an object and object properties to be extended through "inheritance." The data can be manipulated only via the access operations provided in the object. The guidelines for the definition of managed objects, ITU-T Recommendation X.722 allow for a common data structure for managed objects in the managed and managing systems. Managed objects include their names, attributes, operations that can be performed on attributes, notifications that objects can emit, and behaviour descriptions of the objects.
The definition of a managed object class is made uniformly in the standard template, eliminating the confusion that may result when different persons define objects of different forms. This template is used to define the different kinds of objects that exist in the system. Classes describe what information and services they provide each manage object and GDMO defines format for this information (Kuo et al., 2005). This way we ensure that the classes and the management expert rules defined in system A can be easily interpreted in system B. Managed object class structure is show here:

```
<class-label> MANAGED OBJECT CLASS
    [DERIVED FROM  <class-label>   [,<class-label>]*;]
    [CHARACTERIZED BY <package-label> [,<package-label]*;]
    [CONDITIONAL PACKAGES                                        (1)
        <package-label>  PRESENT IF condition;
       ,<package-label>] PRESENT IF condition]*;]
REGISTERED AS object-identifier;
```

DERIVED FROM clause specifies the superclass or superclasses from which this managed object is derived (inherited). This plays a very important role, when determining the relations of inheritance which makes it possible to reutilize specific characteristics in other classes of managed objects. In addition, a great advantage is the reusability of the object classes and therefore of the expert rules which are defined. By using this clause, any attribute, operation, notification, and behaviour exposed by managed objects, as well as inheritance and containment relationships among managed objects and managed object classes, can be defined, figure 5.

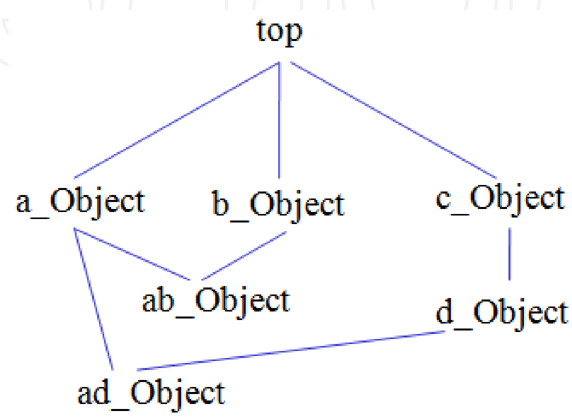

Fig. 5. Inheritance between classes

Packages included in the object class definition are identified by the CHARACTERIZED BY and CONDITIONAL PACKAGES clauses. The CHARACTERIZED BY clause identifies the package or packages that are always present when the managed object is included in the system. The CONDITIONAL PACKAGES clause is used to identify those packages that may or may not be included each time the managed object of this class is instantiated. Finally, the REGISTERED AS clause identifies the location of the managed object class on the OSI registration tree (Stallings, 2000).

4.1 Package template

The PACKAGE template is used to specify the characteristics that represent a consistent set of specifications about a network resource. One purpose of the package is to provide a set of re-useable definitions that can be used in several managed object class specifications. All the properties that we define in the package will be included later in the Managed Object Class Template, where the package is incorporated. A same package can be referenced by more than one class of managed objects. For each managed objects class, the following information is defined:

1. Attributes: are the types of data supported by the class (managed object).
2. Operations: are the actions supported by the class.
3. The behaviour of the managed object.
4. Notifications: are the types of unsolicited information a managed object can send to a manager.

The current template package in GDMO standard is adapted and we add a new feature. In addition to the properties indicated above, we suggest the incorporation of a new property called RULES and its associated template called "RULE", which contains all the specifications of the knowledge base for the expert system, figure 6.

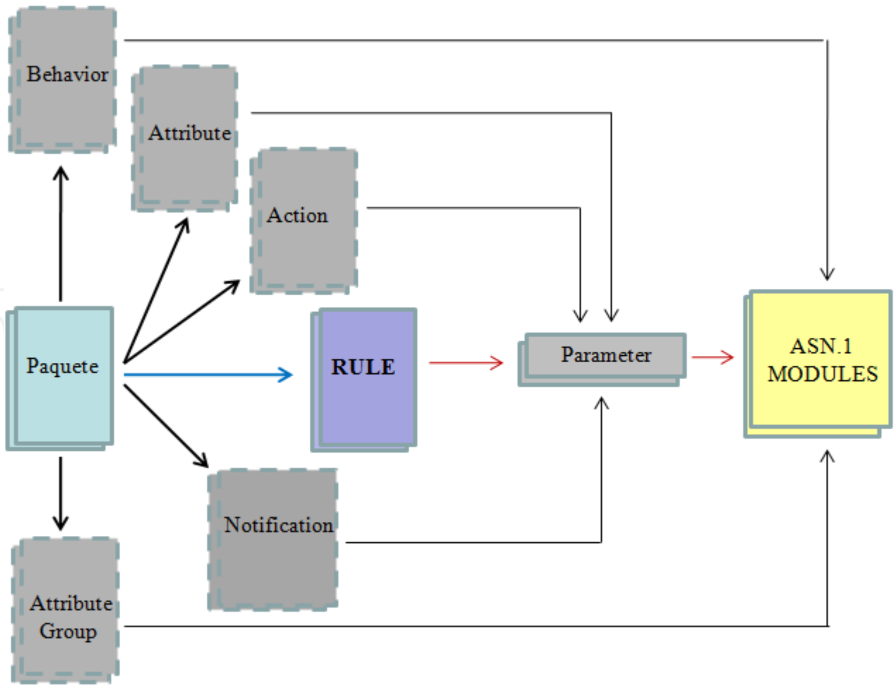

Fig. 6. New rule template.

Next definition shows the elements of a package template, in which it is possible to observe the new property RULES.

<package-label> PACKAGE
[BEHAVIOUR <behaviour-label> [,<behaviour-label>]*;]
[ATTRIBUTES <attribute-label> propertylist [,<parameter-label>]*
,<attribute-label> propertylist [,<parameter-label>]*]*;]
[ACTIONS <action-label> [<parameter-label>]*
[<action-label> [<parameter-label>]*]* ; (2)
[NOTIFICATIONS <notification-label> [<parameter-label>]*
[<notification-label> [<parameter-label>]*]* ;]
[RULES <rule-label> [,<rule-label>]*;]
REGISTERED AS object-identifier;

The property RULES allows a treatment similar to the other properties, including the possibility of inheritance of rules between classes. Like the rest of the other properties defined in a package, the property RULES needs a corresponding associated template.

4.2 Expert rule template

There are a number of different knowledge representation techniques for structuring knowledge in an expert system. The three most widely used techniques are expert rules, semantic nets and frames (Brachman & Levesque, 2004). For this study we use expert rules. We represented the knowledge in production rules or simply rules. Rules are expressed as IF-THEN statements which are relatively simple, very powerful as well as very natural to represent expert knowledge. A major feature of a rule-based system is its modularity and modifiability which allow for incremental improvement and fine tuning of the system with virtually no degradation of performance.

In our study case the template RULE permits the normalized definition of the specifications of the expert rule to which it is related. This template allows a particular managed object class to have properties that provide a normalized knowledge of a management dominion. The structure of the RULE template is shown here:

```
<rule-label> RULE
        [PRIORITY        <priority> ;]
        [BEHAVIOUR <behaviour-label> [,<behaviour-label>]*;]
        [IF occurred-event-pattern [,occurred-event-pattern]*]          (3)
        [THEN      sentence [, sentence]* ;]
REGISTERED AS object-identifier;
```

The first element in a template definition is headed. It consists of two sections:
- <rule-label>: This is the name of the management expert rule. Rule definitions must have a unique characterizing name.
- RULE: A key word indicates the type of template, in our case a definition template and the specifications for the management expert rule.

After the head, the following elements compose a normalized definition of an expert rule.
- BEHAVIOUR: This construct is used to extend the semantics of previously defined templates. It describes the behaviour of the rule. This element is common to the others templates of the GDMO standard.
- PRIORITY: This represents the priority of the rule, that is, the order in which competing rules will be executed.
- IF: It contains all the events that must be true to activate a rule. Those events must be defined in the Notification template. The occurrence of these events is necessary for the activation of the rule and the execution of their associated actions. We can add a logical condition that will be applied on the events occurred or their parameters.
- THEN: This gives details of the operations performed when the rule is executed. Those operations must be previously defined in the Action template. These are actions and diagnoses that the management platform makes as an answer to network events occurred.
- REGISTERED AS is an object-identifier: A clause identifies the location of the expert rule on the OSI registration tree. The identifier is compulsory.

5. Fault management application using GDMO+ specifications

In order to evaluate the fault management capabilities of the integrate management solution proposed we have simulated an application that monitors an environment to collect fault event data (Baker et al., 2008). As said before we have considered a private network. We suppose this network as being heterogeneous and hierarchical. The intelligent sensor nodes only disseminate data when the network is being monitored and an error occurs in a resource (Premchand et al., 2008), figure 7.

The use of integrate knowledge in agents can help the system administrator in using the maximum capabilities of the intelligent network management platform without having to use other specification language to customize the application (Akinyokun & Imianvan, 2006).

Our system has the following components: an inference engine, a knowledge base, and a user interface, figure 8.

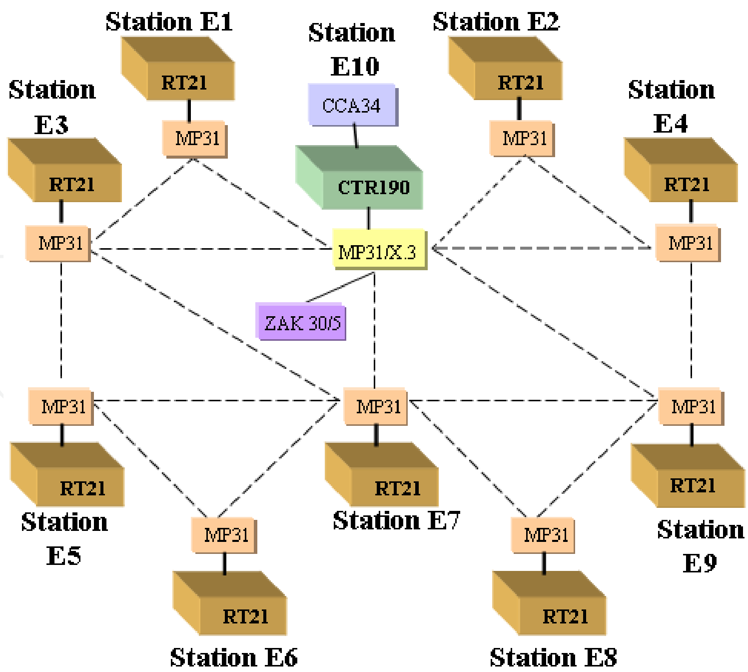

Fig. 7. Power Company Network

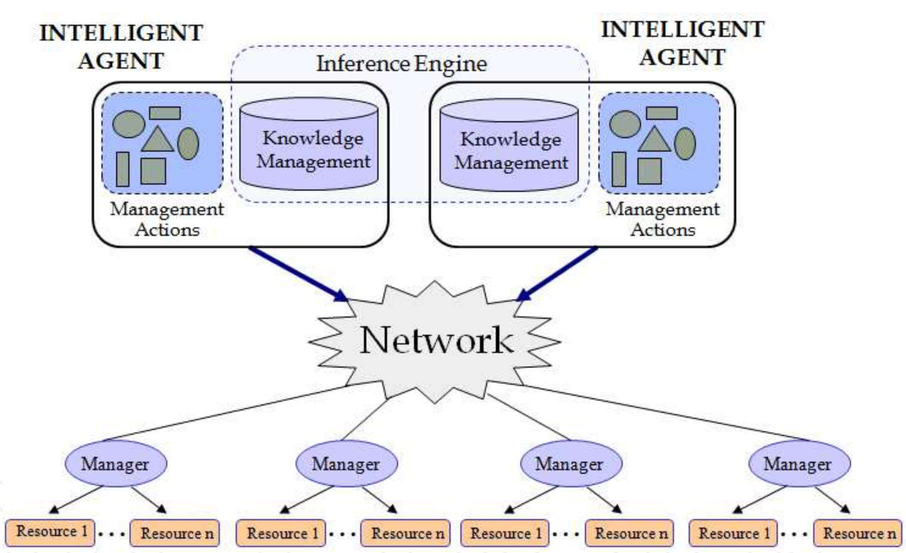

Fig. 8. Architecture System

- The inference engine: This is the processing unit that solves any given problems by making logical inferences on the given facts and rules stored in the knowledge base. It defines the managed objects and the expert rules belonging to the Expert System that manages this network (Waiman et al., 2005). Our system is implemented in Brightware's ART*Enterprise, an expert system shell. ART*Enterprise is a set of programming paradigms and tools that are focused on the development of efficient, flexible, and commercially deployable knowledge-based systems. Expert system shells simplify developer interactions by eliminating the developer's concern with operating system requirements. Its use can therefore reduce the design and implementation time of a program considerably. By using an existing general purpose tool we were able to build a standard and extensible platform with proven performance and quality. The experience with our prototype is that ART Enterprise is a useful tool for developing expert systems.

- The knowledge base: The core of the system, this is a collection of facts and if-then production rules that represent stored knowledge about the problem domain (Power & Bahri, 2005). The knowledge base of our system is a collection of expert rules and facts expressed in the ARTScript programming language ART*Enterprise. The knowledge base contains both static and dynamic information and knowledge about different network resources and common failures. The resultant expert system has about 600 rules and it has been employed Workstation to program the expert system. This initial knowledge has been acquired from the experts in the management domain. The knowledge base of our system can be extended by adding new higher level rules and facts.
- The user interface controls the inference engine and manages system input and output. It is a set of I/O handling routines for managing the system. This includes tools for browsing the inheritance architecture classes generated by both GDMO and ASN.1 compilers. Moreover our system includes facilities to browse the GDMO classes using a Web browser such as Explorer o Mozilla (Hui et al., 2005).

6. Control centre

Detection mechanisms are implemented real-time in our prototype and have been embedded with the network elements, network protocols and devices. System operations, uses a supervision system called CSS (Communication Supervisory System) (Lei et al., 2009). This system can monitor, in real time, the network's main parameters, making use of the information supplied by a Supervisory Control and Data Acquisition (SCADA), formed by a Control Center (placed on the main CSE building), and Remote Terminal Units (RTUs) installed into different stations. The use of a SCADA system is due to the management limitations of network communication equipment. Fault identification involves testing the hypothetical faulty components. Repair is achieved by taking intelligent corrective actions.
The CSS allows the operator to acquire information, alarms or digital and analogical parameters of measure, registered on each RTU (Doukas et al, 2007). Starting from the supplied information, the operator is able to undertake actions through the CSS in order to solve the failures that could appear or to send a technician to repair the stations equipment.
The management system in normal operation generates different notifications and alarms. An alarm is an event generated asynchronously whenever the value of some quality indicator crosses a predefined threshold (either positively or negatively) (Maggiora et al., 2000). Those alarms are caused when an incident occurs. These events are accompanied by parameters that show different aspects of the events (León et al., 1999).

```
...
(31/01 1100.200 stat1 7_TX_C2 stat2 Alarm)                    1
(31/01 1103.106 stat1 7_TX_C2 stat2 Alarm_Disappears)         2
(31/01 1122.168 stat1 CTR190/7_RX stat2 Alarm)                3
(31/01 1134.169 Mux3 EXT_FONIA MAD Alarm_Disappears)          4
(31/01 1134.122 stat4 CCA34C_C1C2 stat3 LOCAL_CHANEL_2)       5
(01/02 1034.135 Transc_1 SPU1_BER_1 BER Alarm)                6
(01/02 1034.146 Transc_1 SPU1_BER_1 BER Alarm_Disappears)     7
...
```

Each alarm contains information about circumstances that caused the incident. The working memory is where all knowledge is contained each item of knowledge is called a Fact. In a previous relation, taking as an example the third fact, the following information is obtained:

- Date alarm: 31/01.
- Time: 1122.168.
- Alarm kind: CTR190/7_RX. (This case means "Reception error")
- Implied equipments:
  • Origin: stat1, "station1".
  • Destiny: stat2, "station2".

These events or notifications used, they are previously defined using the corresponding notification template and are including in the same class of managed objects in which the expert rule acts. When a connection error occurs the device returns the following error messages.

F1 (31/01 1100.200 stat4 7_TX_C2 stat2 ALARM)
F2 (31/01 1103.168 stat4 7_TX_C2 stat2 ALARM)

These alarms indicate problems that require corrective actions. The management system analyzes and checks the rules that match these conditions. If the antecedent of some rule is satisfied, this rule is ready to fire and is placed in system the agenda. When a rule is ready to fire it means that since the antecedent is satisfied, the consequent can be executed. The executed management expert rule in this case is transmissionError. The results generated by the management system are show following:

FIRE 1: transmissionError f-2
Severity 4
Diagnostic: It damages in the modulate transmission between station4 and station2.
Recommendation "Revision transceiver
1 rules fired.
Run time is 0.074 seconds, 27.0270 Rules/Sec.

7. Final prototype verification

The purpose is to achieve a functionally correct prototype. Validation constitutes an inherent part of the knowledge based expert system development and is intrinsically linked to the development cycle. Validation is essential to the decision-making success of the system and to its continued use. An expert system not validated sufficiently may make poor decisions. Validation certainly gives confidence in the system which affects the value of the prototype.

Validation concerns have the following objectives:

- to ascertain what the system knows, does not know, or knows incorrectly.
- to ascertain the level of decision expertise of the system.
- to determine whether the system is adequately theory based.
- to analyze the reliability of system.

To verify the system we feed it with an alarms arbitrary amount. As described our system has been validated with respect to the following aspects: system validation using test cases, validation by case studies, validation against human experts, validation against tough case and validation on site, etc. The result of this proof are including in Table 1.

Alarms Initial Number	Number After Filtration	Filtered Alarms	Fired Rules	Proceeding time	Rules/Sec.	Indications to the Operator
100	1	99	51	0,118 Sec.	432,2034	1
200	10	95	102	0,412 Sec.	247,5728	6
300	31	89,6	155	1,250 Sec.	124,0000	20
400	31	92,25	201	1,438 Sec.	139,7775	16
500	32	93,6	254	2,975 Sec.	85,3782	19
600	38	93,66	293	5,249 Sec.	55,8202	16
700	44	93,71	346	17,982 Sec.	19,2415	18
800	55	93,125	394	26,938 Sec.	14,6262	23

Table 1. Prototype Testing Results

From these result we can establish the fallowing conclusions:

- Filtration process effectiveness is very high: almost 90% of the whole. This has the advantage of a decreasing percentage in the amount of indications presented to the operator.
- The speed of the system improves diminishing the number of alarms on which the rest of rules act.

The expert system, with over 600 operation rules, has produced excellent results which, after extensive field-testing, proved to be capable of filtering 90% of produced alarms with a precision of 95% in locating them, Figure 9.

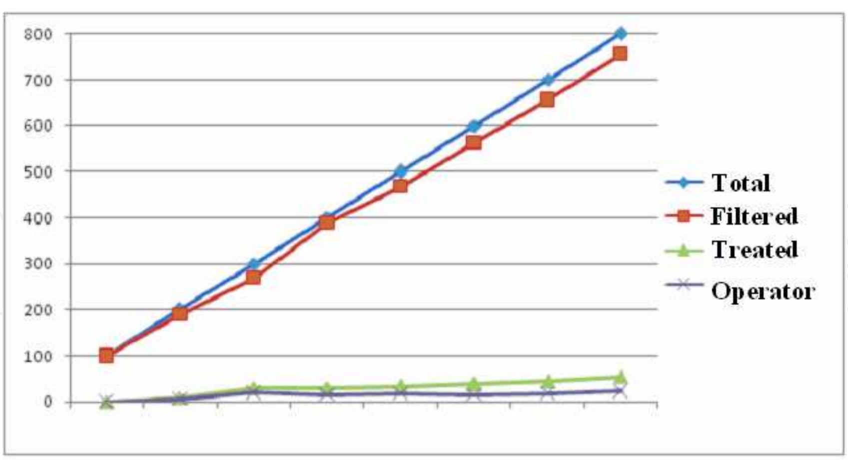

Fig. 9. Filtration Process Effectiveness

As noted above, the system performs satisfactorily with about a 95% rate of success in real cases. The confidence values provided were also found to be in reasonable relative order. It is also noted that the performance of the system depends considerably in the facts happened. The more information is input, the better the chance of diagnosing the likely causes of the problems in the network.

8. Conclusion

Current networks are very complex and demand ever-increasing levels of quality, making their management a very important aspect to take into account. The traditional model of network administration has certain deficiencies that we have tried to overcome by using a model of intelligent integrated management. To improve the techniques of expert management in a communications network, we propose the possibility of integrating and normalising the expert rules of management within the actual definition of the managed objects. Intelligent managed objects characteristics are autonomy, reactivity, pro-activeness, mobility and learning.
In this chapter we showed possibilities to apply and integrated the artificial intelligence techniques in network management and supervision, using OSI. We showed possibilities to apply and integrated the artificial intelligence techniques in network management and supervision, using ISO network management standard.
Unfortunately, the knowledge management is defined in using different intelligent techniques. This results in knowledge specifications which are often ambiguous, increasing the possibility of different implementations not being interoperable. To achieve consistent, clear, concise, and unambiguous specifications, a formal methodology has to be utilized. This paper introduces a framework for the inclusion of formal knowledge descriptions into GDMO specifications. An object-oriented logic programming language is presented, which can be used in conjunction with the framework to specify the management knowledge of managed objects.
We have supplied an original contribution to include expert rules in the specifications of the network elements; for this purpose we have proposed a new standard called Extension of GDMO standard or simply GDMO+. Through the integration of the knowledge within the new extension of the GDMO standard, we can simultaneously define the management information and knowledge. Thus, the management platform is more easily integrated and allows a better adaptation for the network management. Moreover we have built a prototype and experiments have been carried out in order to test the efficiency of our proposal. This demonstrated that GDMO+ is capable of specifying the knowledge of a reasonably sized information model. A large amount of the management knowledge could be described in a surprisingly short and easy to understand manner.
It is suggested that future work should aim to further development of this prototype system by adding more modules based on the framework provided by the system so that more in-depth knowledge and specialized subjects may be captured; in particular the following are of great interest: Development of a design module, possibly a large system, for identifying specific areas like accounting management, configuration management, performance management and security management. Moreover use of external programs and graphics interface to enhance the functions of the system will be desirable. Finally study the possibility of using another method of knowledge representation and reasoning different to the rules: Semantic nets, neuronal nets, frameworks, etc.

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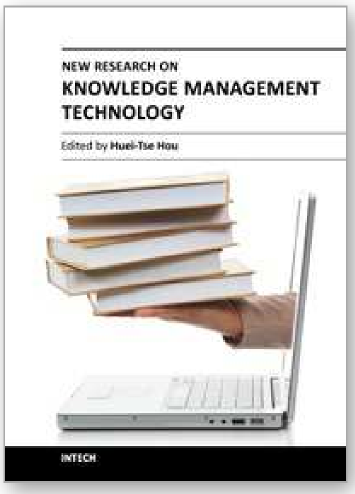

New Research on Knowledge Management Technology
Edited by Dr. Huei Tse Hou

ISBN 978-953-51-0074-4
Hard cover, 228 pages
Publisher InTech
Published online 24, February, 2012
Published in print edition February, 2012

Due to the development of mobile and Web 2.0 technology, knowledge transfer, storage and retrieval have become much more rapid. In recent years, there have been more and more new and interesting findings in the research field of knowledge management. This book aims to introduce readers to the recent research topics, it is titled "New Research on Knowledge Management Technology" and includes 13 chapters. In this book, new KM technologies and systems are proposed, the applications and potential of all KM technologies are explored and discussed. It is expected that this book provides relevant information about new research trends in comprehensive and novel knowledge management studies, and that it serves as an important resource for researchers, teachers and students, and for the development of practices in the knowledge management field.