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An Intelligent Alternative Approach to the efficient Network Management

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***Abstract*— Due to the increasing complexity and heterogeneity of networks and services, many efforts have been made to develop intelligent techniques for management. Network intelligent management is a key technology for operating large heterogeneous data transmission networks. This paper presents a proposal for an architecture that integrates management object specifications and the knowledge of expert systems. We present a new approach named Integrated Expert Management, for learning objects based on expert management rules and describe the design and implementation of an integrated intelligent management platform based on OSI and Internet management models. The main contributions of our approach is the integration of both expert system and managed models, so we can make use of them to construct more flexible intelligent management network. The prototype SONAP (Software for Network Assistant and Performance) is accuracy-aware since it can control and manage a network. We have tested our system on real data to the fault diagnostic in a telecommunication system of a power utility. The results validate the model and show a significant improvement with respect to the number of rules and the error rate in others systems.**

***Keywords:* Network Management, OSI, Internet, SNMP, CMIP, MIB, Expert Systems.**

I. Introduction

CURRENT communications networks support a large demand of services for which traditional model of network management is inadequate. The network management has evolved from local systems with autonomous administration, to heterogeneous management and integrated management. The traditional expert management uses management knowledge and information separately [1] [2] [3] [4]. It is necessary to develop new models, which offer more possibilities detailed in the next sections. Hence, we propose a new evolution called Integrated Intelligent Management.

We propose a technique which integrates Expert System completely within the MIB (Management Information Base) [5]. The main purpose of our work is integrating both elements. This task is achieved by integrating knowledge base of expert system within the management information used to manage a network. For this purpose, an extension of OSI (Open Systems Interconnection) and Internet management frameworks specifications language has been added and investigated in this study. We also added a new property named RULE, which gathers important aspects of the facts and the knowledge base of the embedded expert system.

By integrating the knowledge base in resources specifications, expert system becomes empowered to provide fault diagnosis for the network, a capability that can assist civil engineering trainees, inspectorate staff and professional. SONAP (Software for Network Assistant and Performance) is a prototype implemented through this proposal as a system based on integrated expert management rules.

In this study we will examine management network, including concepts, approaches and management models. Then, we will face up to problems in OSI and Internet Management Models. Our paper starts with specific applications and works on expert systems in similar fields. We will describe important aspects to normalizing knowledge in order to describe a integrate environment for OSI and Internet network management, respectively. Next section summarizes the performance of SONAP (Simple Object Access Protocol) and the results of the research. We will analyze the practical application of our intelligent integrated system. Finally we outline the conclusion and future works.

II. Network Management

There are several organizations which have developed services, protocols and architectures for network management, figure 1.

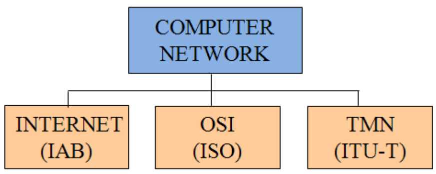

Fig.1. Network management models

The most important organizations are:

- ISO was the first which started, as part of its Open Systems Interconnection (OSI) program [6], the development of architecture for network management.

- Telecommunication Management Network (TMN) developed by the organization called Telecommunication Union (ITU).
- Internet Model by the Internet Engineering Task Force (IEFT).

These organizations have developed client/server architecture, which is a greatly expanded paradigm for communication networks. The main features of the client/server architecture are [7]:

- Manager or Manager Role: In the network management model a manager is a unit that provides information to users, issues requests to devices in a network, receives responses to the requests and receives notifications.

- Agent or Agent Role: An agent is a 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.

- Network Management Protocols: Managers and agents require some form of communication to issue their requests and responses. SNMP (Simple Network Management Protocol) is the protocol used to issue requests and receive responses in a management model Internet. CMIP (Common Management Information Protocol) is the protocol used in management model ISO and TMN.

- Management Information Base (MIB): In addition to being able to pass information back and forth, manager and agent need to agree on and understand what information receive in any exchange. This information changes for each type of agent. The collection of this information is known as management information base. A manager normally contains management information what describes each type of agent which manager is capable of managing. This information typically includes ISO and Internet MIB definitions for managed objects and agents.

A. *Management Information*

This is the information associated with a managed object that is operated on by OSI and Internet Management protocols to control and monitor that object. The management information resides in the MIB which can be seen as a kind of database. The content of this database is not a set of managed objects themselves, but information that is associated with managed objects. The information aspects of systems management model deal with resources that are being managed. These resources are viewed as ‘managed objects’ [8]. The managed object concept is refined in a number or additional standards, which are called Structure of Management Information (SMI) standards.

A managed object is a view of a resource which is subject to management, such as a layer entity, a connection or an item of physical communications equipment. Thus, a managed object is the abstraction of the real resource representing its properties, as seen by management according to its goals. In OSI and TMN systems, management information architecture is based on an object-oriented approach, and the agent/manager concepts are of paramount importance, figure 2.

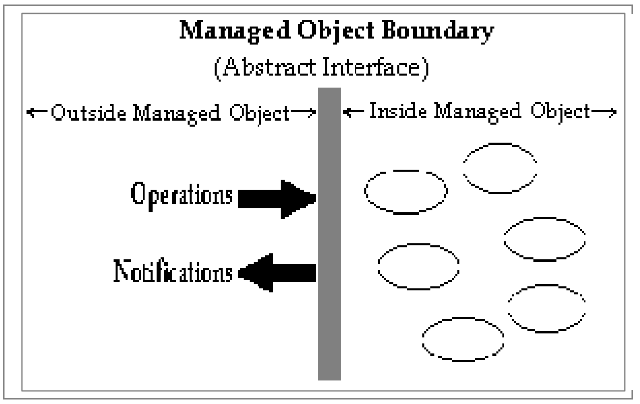

Fig.2. Managed object boundary

Internet management model does not use OOP (Object-Oriented Programming) such as it is used by OSI model. That is the reason for its simplicity. Technically, definitions contain objects, specified with ASN.1 (Abstract Syntax Notation One) macros. ASN.1 is a language for describing structured information, which is widely used in the specification of communication protocols. The language allows arbitrarily complex structures to be built up in a uniform way from simpler components. ASN.1 describes the relevant information and its structure at a high level and need not be unduly concerned with how it is represented while in transit.

Nowadays, we are studying a way to integrate the expert knowledge in the management Internet model. Thus, 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 as classes, where attributes are table columns and every file contains an instance of the class. So, as in OSI, every object has an associated OID (Object Identifier).

III. Problems in OSI and Internet Management Models

An essential part of the definition of an intelligent managed object is the relation between their properties and management knowledge of resource, because this connection is not modeled in a general way. Unfortunately, the knowledge of managed objects is defined using programming languages, which do not give often information about knowledge base of an expert system, increase the possibility of different intelligent implementations that are not compatible. In order to achieve consistent, clear, concise, and unambiguous specifications, a formal methodology has to be used.

OSI and Internet management models are faced with several handicaps to improve integrated intelligent management:

- Management models explain how individual management operations should be performed. However, the current management standards do not specify any sequence in which intelligent operations should be performed to solve specific management problems.

- OSI and Internet management is rather complicated. Both models have introduced several new concepts, which are sometimes difficult to comprehend, making difficult to build intelligent platforms that work with them.

The solution is the inclusion of formal knowledge descriptions in regular RULE-templates, as we will develop in the next sections. The combination of Internet and OSI management demands use of different network management protocols running with different levels of modeling complexity. Also, CMIP requires use of full OSI stack, while SNMP runs with the lower layers of stack. CMIP and SNMP have been designed to scale as network grows, i.e. the ability to perform as “manager” or “agent”.

After this analysis of management elements that are common to OSI an Internet models, we will describe our research about the integration of knowledge management into MIB of OSI and Internet management models. But first, we discuss important aspects on knowledge normalization.

IV. Important Aspects to Normalizing Knowledge

Simple measures which solve all the above mentioned problems are difficult to find. Therefore, this work proposes an alternative approach in which a designer considers a complete set of requirements from the outset. The basic idea about there is no difference between the knowledge design of an expert system and the design of management resources, also implies that it should be possible to model both in terms of a single set of architectural concepts and rules [9].

In order to face the problem that concepts used in current management architectures are not always properly defined, this study proposes the usage of architectural concepts and rules of the Reference Models. As compared to another models, these rules and concepts have been clearly identified and can be applied in a consistent way.

This work demonstrates that it is possible to use in a coherent way concepts and rules defined by Reference Models (OSI and Internet) to model knowledge management. In fact, the model presented can be seen as an extension of OSI and Internet models or a replacement of OSI and Internet management frameworks.

This integrated framework has numerous advantages. Among them:

- The ability to manage knowledge of the expert systems on different network management system, without overloading management applications.

- The flexibility to define new objects that contain all knowledge without notifying the system requirements to interact with these new objects.

- A common set of network management knowledge based on standards.

- A broad top-down view of the integrated multi-vendor network and structured list of network management objects which contain some set of expert rules for the execution.

This structure also provides a wider range of abstraction, in order to facilitate the coexistence of knowledge management models, allowing different levels of modeling complexity and organizing the knowledge management of the managed objects.

V. Integrate Environment for OSI Network Management

This section focuses on the syntax and semantics of the language GDMO (Guidelines for the Definition of Managed Objects) and the extension GDMO+ which is discussed in this paper.

According to OSI Management Information Model, the management view of a managed object is visible at the object boundary. Managed object can be viewed as mediator between network management interface and hardware in every network and is modeled by attributes, actions and notifications. These three elements can usually represent a certain part of the internal state of an element: attributes are managed object characteristics, actions invoke functions which a device can perform, while notifications are spontaneous messages emitted if a specific event occurs.

Similar managed objects are grouped together to form Managed Object Classes, which can inherit their characteristics from other classes and add new features.

In order to allow deployment of equipment from different vendors, OSI framework defines the GDMO language [10]. GDMO has been standardized by ITU (International Telecommunication Union) in ITU-T X.722 and is now widely used to specify interfaces between different components of TMN architecture [11].

This section introduces a framework for the inclusion of formal Knowledge Management descriptions into GDMO specifications. An object-oriented logic programming language is presented, which can be used in conjunction with the framework to specify knowledge management of a managed object.

At this point, the management views are the properties or characteristics of the object.

- Attributes, which are the properties or characteristics of the object.
- Operations, which are performed on the object.
- Behaviour, which is exhibited in response to operations.
- Notifications, which are emitted by the object.

A. *OSI Extension to Integrate the Knowledge Management*

To improve the quality of the descriptions and the resulting implementations, a formal method for specifying knowledge is desirable. Thus formal knowledge descriptions make it easier an engineer to understand the complete information model and to derive a valid, consistent, and compatible implementation from it.

The appearance of managed objects can be formally described using the language GDMO [12], which defines a number of so-called templates that describes a certain aspect of a real device in networks. The elements that exist at the moment form GDMO standard do not make a reference to the knowledge base of an expert system. To solve this uncertainty, it will be necessary to make changes on the template of GDMO standard. Hence, we present an extension of GDMO standard, to accommodate the intelligent management requirements. This paper focuses on a framework and a language for formalizing knowledge management descriptions and combining them with existing GDMO definitions, as depicted in figure 3.

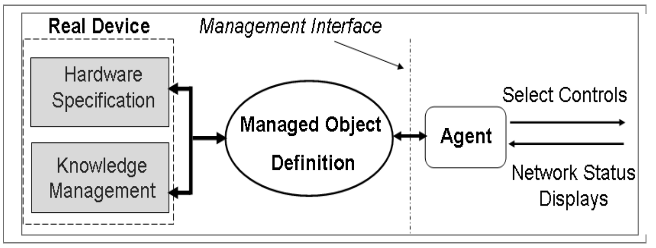

Fig. 3. Integration of knowledge management and resources properties in one single specification.

We describe how to achieve this goal using a new extension called GDMO+. This extension presents a new element called RULE, which defines the knowledge base of the management expert system. This RULE-template groups the knowledge base are supplied by an expert in a specific management dominion. It allows storage of knowledge management in the definition of the resources that form the system which must be managed.

Before considering a concrete language for specifying managed object's knowledge, a methodology for combining formal descriptions with GDMO+ definitions is presented. The methodology is independent of the language used and can be combined with other approaches for formalizing knowledge. It is based on the notion of events and supports the object-oriented features of GDMO+ [13], as shown in figure 4.

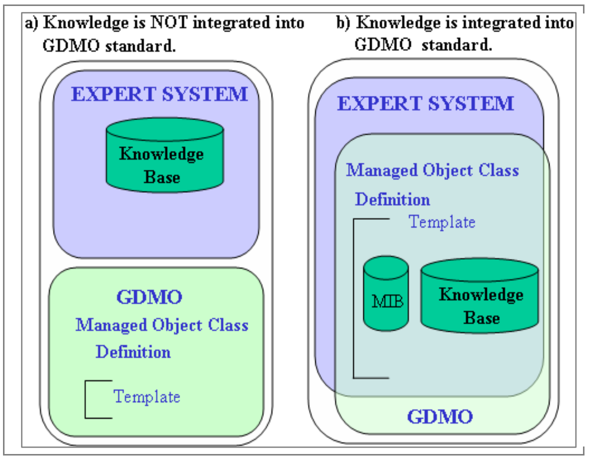

Fig.4. Extension of GDMO+

The knowledge representation is included in the GDMO+ definitions through the combination of knowledge base descriptions and GDMO definitions. Management knowledge is introduced in GDMO+ which defines a number of new templates that contain certain aspects of the expert rules. A rule is an expression such as:

"If the *antecedent* is true for facts in a list of facts, then it can carry out the actions specified in *consequent*".

This template allows the normalized definition of the specifications in 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 [14]. The structure of the RULE template is shown here:

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

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]*]
```

[THEN sentence [, sentence]* ;]
REGISTERED AS object-identifier;

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

After the head, the clause BEHAVIOUR is used to extend the semantics of previously defined templates. It describes the behaviour of the rule. This element is common to other templates of the GDMO standard. Clause PRIORITY represents the priority of the rule, that is, the order in which competing rules will be executed. The key word IF 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. The second key word THEN 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. Finally REGISTERED AS is an object-identifier: A clause identifies the location of the expert rule on the ISO Registration Tree.

VI. INTEGRATE ENVIRONMENT FOR INTERNET NETWORK MANAGEMENT

Internet management can be compared to OSI management model. In fact, Internet management uses many of the concepts that existed in OSI. As a result, the remarks that were made above are, to some extent, also applicable to Internet management [15]. However, as opposed to OSI management, Internet management uses only a small part of management functions for exchange of management information.

Note that objects in Internet and OSI are different. Internet objects are similar to attributes in an OSI managed object, and an Internet object group can be described well as an analogous OSI management object class. In Internet, an object is like a variable found in programming languages; it has a syntax and semantics. Each object can have one or more object instances, each of which, in turn, has one or more values.

An interesting difference between Internet and OSI is the Internet management model takes more pragmatic than OSI. The principal features of their architecture are the following:

- The cost of adding network management to existing systems is minimal.

- All systems connected to the network should be manageable with SNMP. It should be noted that SNMP protocol only defines how management information should be exchanged, it does not define which management information exists. Such information is defined by MIB standards.

- It should be relatively easy to extend the management capabilities of existing systems, by extending the existing MIB’s or adding a new MIB.

Due to these inconveniences, it is questionable whether OSI management will reach the dominant market position that has originally been anticipated. Simple measures that solve all the above mentioned problems are difficult to find. We can used CMIP over TCP/IP (CMOT), which is network management using ISO CMIP to manage IP-based networks. CMOT defines a network management architecture that uses the International Organization for Standardization's (ISO) Common Management Information Services/Common Management Information Protocol (CMIS/CMIP) in the Internet [16]. This architecture provides a means by which control and monitoring information can be exchanged between a manager and a remote network element.

A. Internet Extension to Integrate the Knowledge Management

The MIB-II is the most important and probably best known MIB; it contains all the variables to control the major Internet protocols: IP, ICMP, UDP, TCP, EGP and SNMP. The structure of this MIB is simple; all management variables that belong to the same protocol are grouped together. Within a protocol group there is hardly any additional structure that helps understanding the various variables within that group.

Soon after definition of the MIB-II, other MIBs were defined. Some of these standardized MIB's are FDDI, ATM, X.25, X.500 Directory Monitoring, etc. Next to the standardized MIBs there are also a large number of enterprise specifics MIBs.

The managed objects are defined in the Management Information Base (MIB). These objects must follow a certain set of rules as mentioned in the Structure of Management Information (SMI) such that an object defined by the X group is compatible with the definition of the object by the Y group.

This standard extends that specification by documenting the knowledge management in SMIv2 format. These groups are defined to provide a means of assigning managed object, and a method to know what objects can be managed by implementers of managed agents. We propose the incorporation of an extension of the MIB II named MIB II+. We add a new group named RULES, figure 5.

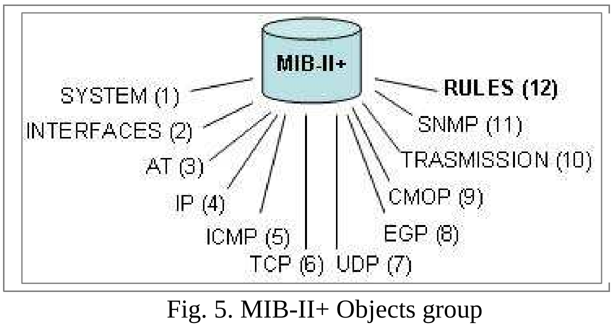

Fig. 5. MIB-II+ Objects group

This group is introduced as a textual convention in this MIB II+ document. Group RULES contains all the aspect related with the expert management.

For two systems to communicate, each one must understand the data sent from the other, using the properly syntax in the application and the presentation layer. This can be achieved by using a language that has the same syntax and semantics.

In the application layer, we use abstract syntax, which states only how data are arranged and what meaning they have. One of the possible abstract syntaxes is ASN.1.

Between the application layer and the presentation layer, a local set of rules can be used to transform data; however the syntax of the data transferred between presentation entities must be understood by each end. This is known as transfer syntax. So, abstract syntax and transfer syntax are negotiated at the beginning, during association time.

One kind of transfer syntax is Basic Encoding Rules, BER. BER state manages how data must be transferred to the other presentation entity. The local syntax can be purely dependent on the local protocols used, in this case SNMP. Figure 6 illustrates the concept of abstract syntax and transfer syntax. We point at ITU-T Recommendations X.208 and X.680 documentation where standardized ways and steps to define data types and data values are described.

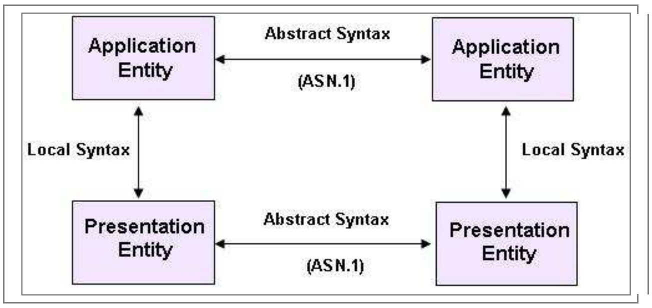

Fig. 6. Abstract Syntax Notation and Basic Encoding Rules

Data types and data values are also referred as types and values, respectively. We broadly classify the ASN.1 built-in types as follows: simple types, structured types, tagged types and subtypes.

To define an expert rule we use the modules definitions. Modules definitions are primarily used for grouping ASN.1 definitions. We introduced in ASN.1 a new concept denominated Expert Rule to definition the new group RULE existing in MIB II+. They also help in using type definitions defined in the other places by making use IMPORT and EXPORT mechanisms. Modules are analogous to functions in C language or subroutines in PASCAL. There are module definitions in the definitions of managed object classes in standards and other documents. The macro used for MIBs definition in SNMP was defined in RFC 1155 draft (Structure of Management Information) and later extended in the RFC 1212 (Concise MIB Definitions). RFC 1155 version is used to define objects in MIB-I. RFC 1212 version including more information and is used to defined objects in MIB-II. Next definition shows OBJEC-TYPE macro in RFC 1212.

These can be enhanced by including formal descriptions. In this case, the specifications formal parts and the knowledge must be distinguishable. An easy solution is the separation by keywords.

VII. Practical Application of the Intelligent Integration

To show the viability of our proposal, we proceed to study and build an expert system, so that the corresponding knowledge base starts to belong to the normalized information proprieties defined by the managed resources. For this, we use an expert system developed for the management of a data network which belongs of an electrical company. The definitions of the employed resources and the expert knowledge base use an unique specification. To define these specifications we will use the syntax and rules investigated above.

We present a rule-based expert system applied to the fault diagnosis in a real telecommunication network, which belongs to the University of Seville. The current management and control of the network is based on SONAP system, which was developed by the Electronic Technology Department of the University of Seville. The knowledge base of this system is integrated in the specifications of the resources, using for that purpose our GDMO+ proposal. These new specifications contain management information of managed resources and include also the set of expert rules that provides the knowledge base of the expert system.

A. *Related Work*

Part of network long-distance traffic is controlled by a wireless system distributed throughout the network. Expert systems are part of the system dedicated to the management of communications system. It has been used a Sun Blade 150 Workstation to program the expert system. The resultant expert system has about 200 rules. SONAP is an extension for intelligent decision-making and diagnostic reasoning controlled by its own integrated expert system. SONAP is the first production software written and integrated.

B. *The System Features*

SONAP operations, uses a supervision system called Control Centre (CC), figure 7.

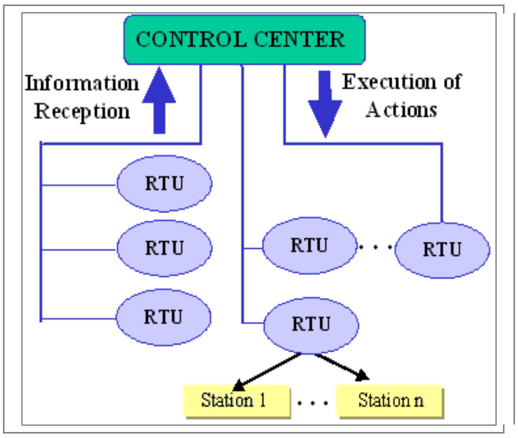

Fig. 7: Control Center system

This system can monitor, in real time, the main parameters of the network, making use of the information supplied by a Supervisory Control And Data Acquisition (SCADA), formed by a Control Centre (CC) 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.

The CC allows the operator to acquire information, alarms or digital and analogical parameters of measure, registered on each RTU. Starting from the supplied information, the operator is able to undertake actions through the CC in order to solve the failures that could appear or to send a technician to repair the stations equipment [17].

C. *The System Architecture*

Our tool has three major components:

- The inference engine: This is the processing unit that solves any faced problems by making logical inferences on the given facts and rules stored in the knowledge base. In our tool we used the ART*Enterprise, an expert system shell. The experience with SONAP is that ART*Enterprise is a useful tool for developing expert systems. ART*Enterprise is an advanced applications development tool, designed for developers offering a variety of advance characteristics: a procedural programming object-oriented language, objects supporting multiple inheritance, encapsulation and polymorphism, etc. Moreover, it is packaged with a GUI builder, version control facilities, and an ability to link to data repositories in most proprietary DBMS formats for developing client-server applications. By using an existing general purpose tool, we were able to build a standard and extensible platform with proven performance and quality. ART*Enterprise offers cross-platform support for most operating systems, i.e., we can develop on one platform and deliver to others.

- The knowledge base: This 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 knowledge base of our system can be extended by adding new higher level rules and facts. To this purpose we can employ user interface.

- The user interface: It controls the inference engine and manages system input and output. The user interface of our tool contains a preprocessor for parsing GDMO+ specification files, a set of input and output handling routines to manage the system. Also, the user interface components allow administrators to inspect the definitions of management object classes interactively. The user interface allows adding new expert management rules in the managed objects definition.

D. *A Management Expert Rule*

Next paragraph shows an example of expert rules integration in the GDMO+ proposed standard. It defines a Managed Objects Class: radioTransceptorCTR190, which comes out the properties corresponding to the radio transceiver devices. This class includes all the specifications corresponding to the resource.

```
radioTrasnceptorCTR190 MANAGED OBJECT CLASS
    DERIVED FROM “rec.X721”:top;
    CHARACTERIZED BY transceptorPackage;
    RULES powerErrorCTR190, linkCTR190
REGISTERED AS {nm-MobjectClass 1};
```

X721 recommendation is applicable to the development of OSI managed object class specifications and provides generic definitions that support OSI systems management functions. DERIVE clause allows use these definitions in standard specifications of object classes, attributes, notifications and action types. The most important properties that we can indicate are the two expert rules that have been associated with the defined class by means of the RULES clause. The two rules are defined by using the RULE template. When there are alarms in the network, the integrated expert system makes a study of the events produced. After an analysis, the management actions in the expert rules are executed. The rule powerErrorCTR190 is in charge of detecting failures in the power supply of the device.

```
powerErrorCTR190 RULE
   PRIORITY 3;
   BEHAVIOUR powerErrorCTR190Behaviour;
   IF (?date ? ?local 7_F_ALIM_2 ?remote ALARM)
   THEN (“Severity:" PRIORITY),
     (“Diagnostic: It damages in the electric feeding
                          of the station” ?local),
      (“Recommendation:
                To revise the electric connection”, ?local);
```

REGISTERED AS {nm-rule 1};

E. Prototype Validation

Validation is essential to the decision-making success of SONAP and its continued use. Validation constitutes an inherent part of the knowledge based expert system development for SONAP, and is intrinsically related to the development cycle [18]. In this section, we compare intelligent agent performance with the traditional managed object one by evaluating the traffic around the management agent and response time in retrieving variables and knowledge management. To verify the system, we feed it with an arbitrary amount of alarms at random. SONAP has been validated with respect to the following aspects: system validation using test cases, validation by studied cases, validation against human experts, validation against tough cases and validation on site. The result of this analysis is included in Table 1.

Alarms Initial Number	Number After Filtration	Filtered Alarms	Fired Rules	Proceeding time	Rules per sec.	Indications to the Operator
100	1	99,00	61	0,321 Sec.	312,2345	3
200	7	96,50	132	1,001 Sec.	298,3345	4
400	21	94,75	321	1,986 Sec.	245,8665	9
600	43	92,83	523	2,456 Sec.	199,4356	13
800	77	90,38	678	7,142 Sec.	123,4546	32

Table1: Prototype testing results

We compared our results with those we had obtained with the traditional system. Note that the response time would vary depending on both the agent and the fault type.

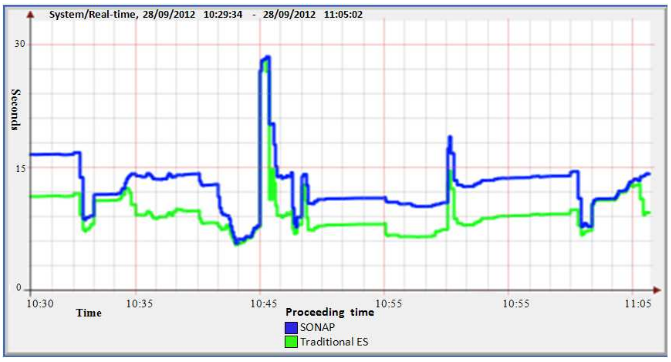

Fig.8. Performance SONAP & traditional Expert System

Figure 8 shows a sample plot of these parameters that was collected as a part of the experiment, which shows that the speed of the SONAP system improves the proceeding time and the average of a traditional expert system.

From these result we can conclude the expert system has produced excellent results which, after extensive field-testing, prove that expert system is capable of filtering 92% of produced alarms with a precision of 97% in locating them, and performs satisfactorily about 91% rate of success in real cases.

VIII. Conclusions

In this paper, we showed possibilities to apply and integrated the artificial intelligence techniques in network management and supervision, using ISO and Internet network management models. We have seen that the current management systems are not able to solve questions brought up in the initial part of this work. Until now, the managed objects are not able to use the knowledge provides by the knowledge base, which collects the management operations and control of a management domain. The managed objects are not able to use the given knowledge by the knowledge base of the expert systems. The point is 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, a new Integrated Management Expert System, an extension of standard GDMO denominated GDMO+ and MIB II+.

A language for formalizing the knowledge base descriptions of the expert systems in OSI and Internet telecommunications management network framework is introduced in this paper. A few questions arises when a language is designed have been discussed. As well, a general framework for the inclusion of formal knowledge management in MIB specifications has been presented. The proposed model is used to specify formally the knowledge from the expert. An expert system has been implemented and used to manage the specifications of the language used by the simulation environment. This demonstrates that expert systems are capable to specify the knowledge of a reasonably sized information model. A large amount of knowledge could be described in a surprisingly short and easy way to understand. The specification of the SONAP information model showed that a large part of the knowledge management was specified in a rather imperative manner.

Our research has demonstrated a useful and interesting modular approach in the development of a knowledge base integrated in expert system, which can be quite powerful in tackling the huge and enormously wide subject on diagnosis of common problems in management network. It is suggested that future work should aim to further development this prototype system, adding more modules based on the framework provided by SONAP. In that sense, more in-depth knowledge and specialized subjects may be captured; in particular, the followings are of great interest: Development of a design module, possibly a large system, to identify specific areas as accounting management, configuration management, performance management and security management.

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