

APPLYING INTEGRATED EXPERT SYSTEM IN NETWORK MANAGEMENT

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Abstract: The management of modern telecommunications networks is becoming an increasingly demanding task that is difficult to implement using present traditional methods even assisted by conventional automation techniques. Integration of advanced Artificial Intelligence (AI) technology into existing and future network management system may resolve some of the difficulties. The goal of this research is to develop an integrated expert system for management network applications. The emphasis of this research is to provide a broad view of intelligent systems by capturing the knowledge of human experts and using a modular approach that integrates the knowledge management and network resources specifications. For this purpose, an extension of OSI management framework specifications language has been added and investigated. The advantage of integrating both is that a large problem can be broken down into smaller and manageable sub-problems/modules. Through modification of existing resources or addition of new resources, the integrated expert system can be conveniently expanded in the future to cover the latest research findings and updated standards of network communications.

1 INTRODUCTION

Current communications networks support a large demand of services for which the traditional model of network management is inadequate. The network management has evolved: local systems with autonomous administration, heterogeneous management and integrated management. The traditional expert management uses management knowledge and management information separately. It is necessary to develop new models, which offer more possibilities. We propose a new evolution called Integrated Management Expert Systems.

We propose a technique which integrates the Expert System completely within the Management Information Base (MIB) (Morris, 2003). Integrating both elements is the main purpose of our work. 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 management framework specifications language has been added and investigated in this study. A new property named RULE has also been added, 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 has the power to provide diagnosis of fault network, which can assist civil engineering trainees, inspectorate staff and professional. The NOMOS+ is a prototype implemented through this thesis as a system based on integrated expert rules.

2 NETWORK MANAGEMENT

At the moment there are two main management models: OSI and Internet. Both network management systems operate using client/server architecture. Four fundamental concepts of these models are (Clemm, 2006):

- **Manager or Manager Role:** In the network management model a manager is an 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 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.
- **Network Management Protocols:** Managers and agents require some form of communication to issue

their requests and responses. SNMP is the protocol used to issue requests and receive responses in a management model Internet. CMIP is the protocol used in management model ISO.

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

In the Open System Interconnection (OSI) systems management the information architecture is based on an object-oriented approach and the agent/manager concepts that are of paramount importance.

After this brief introduction to management elements in common to OSI and Internet models, we will approach our research in the integration of knowledge management 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.

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 as classes 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 MODEL OSI

The description of management information has two aspects. First, a Structure of Management Information (SMI) defines the logical constitution of management information and how it is identified and described.

Second, the MIB, which is specified using the SMI, defines the actual objects to be managed. The MIB is a conceptual repository of management information. It is an abstract view of all the objects in the network than can be managed. In OSI, SMI

provides the Guidelines for Definition of Managed Objects (GDMO), for definition objects contained in the MIB (ISO, 1992).

A managed object is the OSI abstract view of a logical or physical system resource to be managed. These special elements provide the necessary operations for the administration, monitoring and control of the telecommunications network. The managed objects are defined according to the International Standardization Organization (ISO) Guidelines for the Definition of Managed Objects (GDMO), which defines how network objects and their behaviour are to be specified, including the syntax and semantics.

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 the TMN (Telecommunication Management Network) architecture (ITU-T, 1996).

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.

4 STANDARD GDMO+

The elements that at the moment form the GDMO standard do not make a reference to the knowledge base of an expert system. To answer these questions, it will be necessary to make changes on the template of the GDMO standard. We present an extension of the standard GDMO, to accommodate the intelligent management requirements.

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

The standard that we propose contains the singular template RULE and its relations to other templates. Two relationships are essential for the inclusion of knowledge in the component definition of the network: Managed Object Class and Package template, Figure 1.

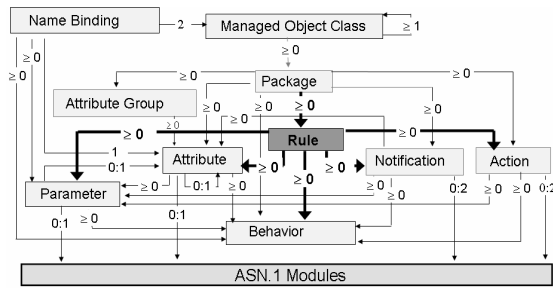


Figure 1: Relations between proposed standard templates.

In the standard we propose, both templates have the new property RULES. Let us study both relationships.

4.1 Managed Object Class Template

This template is used to define the different kinds of objects that exist in the system. The definition of a Managed Object Class is made uniformly in the standard template. This way we ensure that the classes and the management expert rules defined in system A can be easily interpreted in system B.

```
<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]*;]
REGISTERED AS object-identifier;
```

DERIVED FROM plays a very important role, when determining the relations of inheritance which makes it possible to reuse specific characteristics in other classes of managed objects.

This template can also contain packages and conditional packages, including the clauses CHARACTERIZED BY and CONDITIONAL PACKAGES (Hebrawi, 1995).

4.2 Package Template

This template is used to define a package that contains a combination of many characteristics of a managed object class: behaviours, attributes, groups of attributes, operations, notifications and parameters. In addition to the properties indicated above, we suggest the incorporation of a new property called RULES, which contains all the specifications of the knowledge base for the expert system.

```
<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>]*]* ;]
[NOTIFICATIONS
<notification-label> [<parameter-label>]*
[,<notification-label> [<parameter-label>]*]* ;]
[RULES <rule-label> [,<rule-label>]*;]
REGISTERED AS object-identifier;
```

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.

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 need a corresponding associated template.

4.3 Expert Rule Template

Knowledge is represented 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 allows for incremental improvement and fine tuning of the system with virtually no degradation of performance. 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;
```

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 following elements compose a normalized definition of an expert rule.

- <rule-label>: This is the name of the management expert rule and RULE, a key word indicates the type of template.
- BEHAVIOUR: This construct is used to extend the semantics of previously defined templates.

- 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. 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 ISO Registration Tree. The identifier is compulsory.

5 APPLICATION OF GDMO+

To show the viability of our proposal, we proceed to the study and building of a management Expert System, so that the corresponding knowledge base begins to belong to the normalized proprieties information defined by the managed resources. For this we use an expert system developed for the management of a data network belonging to 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 in GDMO+ standard.

We present a rule-based expert system applied to the fault diagnosis in telecommunication system of a power utility. The communications systems employed to implement the integrated intelligent management prototype belongs to the SEVILLANA-ENDESA (CSE) a major Spanish power utility. The current management and control of that network is based on an Expert System called NOMOS developed by the Electronic Technology Department in the University of Seville (Leon, 1999). Our tool understands transceivers and multiplex equipment.

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.

5.1 Related Work

Part of SEVILLANA-ENDESA's long-distance traffic is controlled by a wireless System distributed throughout the CSE network. Expert systems are part of the system dedicated to the management of a power utility's communications system, which we call NOMOS+ (Martin, 2006). It has been employed a Sun Blade 150 Workstation to program the expert system. The resultant expert system has about 200 rules. NOMOS+ is an extension for intelligent decision-making and diagnostic reasoning controlled by its own integrated expert system. NOMOS+ is the first production software written and integrated in GDMO+.

NOMOS+ is implemented in Brightware's ART*Enterprise, an expert system shell. The experience with NOMOS+ is that ART*Enterprise is a useful tool for developing expert systems.

5.2 The System Features

NOMOS+ operations, uses a supervision system called SSC (Communication Supervisory System).

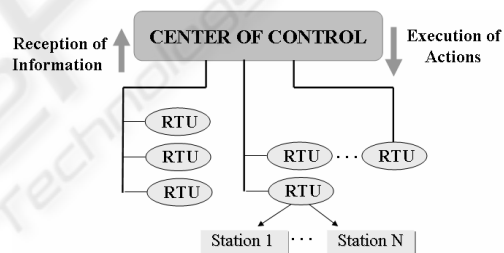


Figure 2: Communication Supervisory System.

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 Centre (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 SSC 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 SSC in order to solve the failures that could appear or to send a technician to repair the stations equipment (Garcia, 2001).

5.3 The System Architecture

Our tool has three major components:

- **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. In our tool we used the ART*Enterprise. By using an existing general purpose tool we were able to build a standard and extensible platform with proven performance and quality.

- **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:** This 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 for managing the system. Also, the user interface components allow administrators to inspect the definitions of management object classes interactively. The user interface allows to modify and to include new expert management rules in the managed objects definition.

5.4 A Management Expert Rule

Next paragraph shows an example of expert rules integration in the GDMO+ proposed standard. This defines a Managed Objects Class: radioTrasnceptorCTR190, which defines 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};
```

```
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};
```

```
linkCTR190 RULE
  PRIORITY 4;
  BEHAVIOUR linkCTR190Behaviour;
  IF (?date ?time1 ?local 7_TX_C2 ?remote ALARM
    (?date ?time2 ?local 7_TX_C2 ?remote ALARM
    & : (<(ABS(? ?time1 ?time2)) 1.00))
  THEN ("Severity:" PRIORITY),
  ("Diagnostic: "Mistake in transmission", ?local),
  ("Recommendation "Revise transceiver");
REGISTERED AS {nm-rule 2};
```

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.

```
...
(31/01 1115.1836 Station1 7_TX_C2 Station4 ALARM)      n
(31/01 1116.2142 Station1 7_TX_C2 Station4 ALARM)      n+1
...
```

After an analysis, the management actions in the expert rules are executed. The connection error returns the following error messages, indicate problems that require corrective action.

The first rule powerErrorCTR190, is in charge of detecting failures in the power supply of the device; the second rule linkCTR190, is devoted to the detection of errors in the data transmission module.

```
FIRE 1: linkCTR190 f-2
Severity 4.
Diagnostic: Mistake in transmission Station4.
Recommendation: Revise transceiver.
1 rules fired.
Run time is 0.074 seconds, 27.0270 Rules/Sec.
```

6 PROTOTYPE VALIDATION

Validation is essential to the decision-making success of NOMOS+ and to its continued use. Validation constitutes an inherent part of the knowledge based expert system development for NOMOS+ and is intrinsically linked to the development cycle (Giarratano, 2005).

To verify the system we feed it with an alarms arbitrary amount. NOMOS+ 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 cases and validation on site, etc. The result of this proof is included in Table 1.

Table1: Prototype Testing Results.

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

From these result we can establish the following conclusions:

- The expert system, with over 200 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.
- As noted above, the NOMOS+ performs satisfactorily with about a 95% rate of success in real cases.
- The speed of the system improves diminishing the number of alarms on which the rest of rules act.

It is noted that the performance of NOMOS+ depends considerably in the facts happened. In the same way the more information is input, chances of diagnosing the likely causes of the problems in the network is increased.

7 CONCLUSIONS

Current networks are very complex and demand ever-increasing levels of quality, making their management a very important aspect to take into account. Network management systems are based on Client/Server architecture, and consist of a Manager (offering user interface for the network administrator), Agents (on managed network devices), a protocol (in between the Manager and the Agents) and a Management Information Base (describing the properties of the managed device). 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 normalizing the expert rules of management within the actual definition of the managed objects. Through the integration of the knowledge within the new extension 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.

To achieve this goal we build a prototype, an expert system integrated is developed as a rule-based expert system which is a computer program using integrated IF-THEN rules.

We conclude pointing out an important aspect of the obtained integration: by using only and exclusively the extended GDMO specification, the administration platform will be able to obtain the management information necessary with respect to the managed objects as well as the expert rules of management that make up the knowledge base of the expert system.

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