An Intelligent Approach to an Efficient Internet Network Management

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***Abstract*— Telecommunications networks are continuously growing in scale and complexity, and the amount of information and services provided more day to day. The management of the resulting networks gets additional important and time-critical. More advanced tools are needed to support this activity. In this paper we describe the design and implementation of a management platform using Artificial Intelligent reasoning technique. This paper explores intelligent agent architecture to make the argument for an intelligent solution as opposed to traditional methods. We propose a new paradigm where the intelligent network management is integrated into the conceptual repository of management information. This study focuses on an intelligent framework and a language for formalizing knowledge management descriptions and combining them with existing Internet management model. Based on the present proposal and Internet management model, we describe the design and implementation of an integrated intelligent management platform named ALATUS. We have tested our system on real data to the fault diagnostic in a university wireless network. The results of a validation show a significant improvement with respect to the number of rules and the error rate in other traditional systems.**

Keywords-SNMP; MIB; IAs; Management Network.

I. INTRODUCTION

Due to the increasing complexity and heterogeneity of networks and services, many efforts have been made to develop intelligent techniques for management. Current communications networks support a large demand of services, which the traditional model of network management is inadequate. Classic management architectures are not well suited for low-bandwidth or disconnected operation. Traditional management frameworks such us OSI (Open System Interconnection) and SNMP (Simple Network Management Protocol) are capital approaches where a manager uses distributed agents to collect management information. But these strategies have drawbacks, in particular due to the lack of extensibility and scalability on very large networks. This restriction is coming from the inability of a centralized manager to handle huge amounts of management information across geographically distributed sites, which is also expensive in resources. A key technology for operating large heterogeneous data transmission is network intelligent management [1].

Several authors have addressed these problems along the past years [2][3][4][5][6] resulting in ad-hoc and partial solutions typically based on management distribution and intelligent delegation. There is no full scale of integration of IA (Intelligent Agent) applied to SNMP network management architectures. The main contribution of this paper lies in the proposal for a framework that integrates management object specifications and the knowledge of expert systems. This study draws on the theory, experimentation and findings of the SNMP management model and the integration management knowledge to obtain an efficient network control. The goals are to improve insight and understanding of network management, and present an alternative distributed management network model. This architecture is based on the idea that a main manager can delegate the control to several IAs agents thus improving scalability and efficiency of a management network through intelligence distribution and intelligent management actions. In order to develop it a language to formalize the knowledge base description in Internet management model is discussed.

The scope of this work covers why IAs are very well suited to meet the network management requirements and how an intelligent-agent-based system can be applied to achieve intelligent network management. The study addresses problems that traditional network management poses and makes the argument for the solution based on IAs agents to these problem areas. Section II examines Internet management network model, including concepts and major approaches. Section III presents capabilities required for an efficient network management and current shortcomings of SNMP model. Section IV gives the formulation of proposal and a schema of the various stages in the system development. Section V presents a conceptual, high-level intelligent agent named ALATUS and summarizes the performance of the research. Finally we outline the conclusion and future works.

II. INTERNET MANAGEMENT NETWORK OVERVIEW

According to ISO (International Organization for Standardization), the network management model defines a conceptual architecture for managing all communication entities within a network. There are several organizations which have developed services, protocols and architectures for network management. The most important organizations are: ISO, which was the first one and started as part of its OSI program [7], Telecommunication Management Network (TMN), developed by International Telecommunication Union (ITU), and Internet Model by the Internet Engineering Task Force (IEFT), figure 1.

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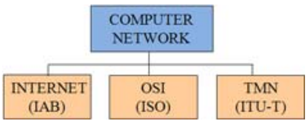

Figure 1. Management Models.

A main concept in management networks is the managed object, which is an abstract view of a logical or physical resource which must be controlled. The managed objects provide necessary operations for the running, monitoring and control of the telecommunications network. These operations are realized through the use the Common Management Information Protocol (CMIP) to OSI model and SNMP in the Internet model. SNMP is one of the widely accepted protocols to manage and monitor network elements and operates in the application layer in Internet protocol suite, commonly known as TCP/IP (Transmission Control Protocol/Internet Protocol) suite [8].

The SNMP framework is based on the principle of minimally simple agents and complex managers. The managed object provides an abstract view of a real resource, and the agent provides a management view of their underlying logical and physical resources, such as transport connections to the managing applications. For a right running, the management processes involved will take on one of two possible roles, figure 2.

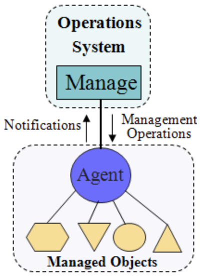

Figure 2. Manafe/Agent roles.

In SNMP uses, one manager has the task of monitoring or managing a group of hosts on a computer network, so it is responsible for network management processes. An agent performs the management operations on the managed objects according to the request of the manager, and reports notifications that managed objects produce.

A. *Information Management Repository*

SNMP objects represent single, atomic data elements that may be read or written in order to effect the operation of the associated resource. This set of managed object classes and instances under the control of an agent is known as Management Information Base (MIB), an abstraction of network resources, properties and states for the purpose of management. SNMP information modeling principles are collectively referred to as the Structure of Management Information (SMI) and are specified in (RFC1155) for SNMPv1 and in (RFC1902) for SNMPv2. The MIB is written in Abstract Syntax Notation 1 (ASN.1), a standard syntax for data types and values, which is maintained by ISO [9]. ASN.1 is a language for describing structured information, which is widely used in the specification of communication protocols. 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.

The manager and agent use the MIB with a relatively small set of commands to exchange information. When an SNMP device sends a trap, each data object in the message is identified with a number string called an Object Identifier (OID). A SNMP manager knows the value of an object/characteristic, such as the state of an alarm point, the system name, or the element uptime. All these information will assemble in a GET packet that includes the OID for each object/characteristic of interest.

The MIB is organized in a tree structure with individual variables, such as point status or description, being represented like leaves on the branches. The MIB is an ASCII text file that describes SNMP network elements as a list of data objects. It is like a dictionary of the SNMP language where every object, related to an SNMP message, must be listed in the MIB. The first step towards development of an agent is to define its MIB. The steps involved in developing the MIB file are [10]:

- Data identification: To identify data or objects which need to be managed using IA methods, laying them out in the form of scalar or tabular objects. In that way, all knowledge associated to a specific managed resource is categorized.

- Data definition: Construct ASN.1 MIB definitions for the IA. In this study, we define different ASN.1 types of knowledge related to the network resources. For this purpose, we have used an editor tool. Editors can help in MIB design hiding the unimportant details of the MIB syntax rules, clauses etc.

In our work a framework for the inclusion of formal Knowledge Management descriptions into MIB specifications has been proposed. 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.

III. Intelligent Management Agents

IA technology has the capability to distribute intelligence throughout network and perform intelligent management functions dynamically. This provides efficiency and flexibility, and cuts down on bandwidth constriction and overloading on a single central control. An important goal is convergence on solutions despite of incomplete or inconsistent knowledge or data. IAs can seek to cooperate to solve problems using task and domain-level protocols actively and dynamically. IAs learn the normal behaviour of each measurement variable and add intelligent knowledge to the management network resources. IA is based on three essential properties: autonomy or self-government independence; communication, which is the ability to speak with a peer; and cooperation in order to create a

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collaborative environment to work together.

So as to improve the quality of the IA description and the resulting implementations, a formal method for specifying knowledge is desirable. Due to IA is based on management knowledge, formal knowledge descriptions helps to make easier for an engineer to understand the complete information model and to derive a valid, consistent and compatible implementation. In the next section knowledge management using ASN.1 notation is modelled. It defines the formal specification of managed object types and the associated access mechanisms [11].

An IA is essentially a self-contained software program module that is programmed to carry out specific actions on behalf of a human user or another software entity in a certain software environment. Every SNMP IA maintains an information database which describes the managed device parameters and the knowledge base where all relevant information used with management purposes (data, rules, cases, and relationships) is stored. IA can perform actions such as to collect management information about its local environment, store and retrieve management information as it is defined in the MIB, execute specified tasks or collaborate with other agents. These actions are conducted in an autonomous way that requires little or no human intervention, figure 3.

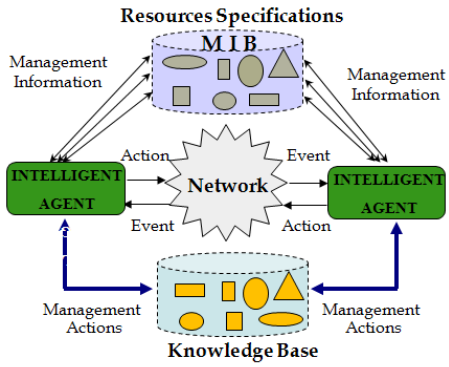

Figure 3. SNMP Intelligent Agents.

In our proposal IAs are the administrative systems and have the task of monitoring or managing a group of devices on a network. Each IA executes, at all times, a software component called an agent which reports management actions via SNMP to the managed objects. This component software is supplied with the right MIB file. The SNMP IA can correctly interpret alarm data from any device that supports SNMP and executes the corresponding management actions.

IV. INTERNET MANAGEMENT MODEL EXTENSION

Although SNMP SMI identifies how resources are represented and named within the MIB, there is no mechanism provided by SNMP to enable agents to operate with management knowledge. In this section, we face the problem of specifying knowledge transfer and how to describe this knowledge in the abstract syntax notation in order to show rules to create the MIB, to improve insight, and understanding of network management. The structure of SMI, an SNMP standard, defines the structure of the MIB information and the allowable data types. The philosophy behind SMI is to encourage simplicity and extensibility within the MIB. When we are planning monitoring SNMP resources, it is necessary to be able to read MIBs so that we can get a realistic idea of what management capabilities we have available. Just looking at the physical components of a device will not tell us what kind of events and knowledge we can get from it. So the MIB is the guide to the real capabilities of an SNMP device. It is usual that a manufacturer adds a new component or functionality to a device without describe it in the MIB. In fact, nowadays, a lot of devices have sketchy MIBs that do not fully support all their functions. However, the object description in the MIB is a capital point in order to combine all their properties and management actions.

Whit the purpose of achieving an SNMP IA the knowledge base and the MIB have been joined, figure 4.

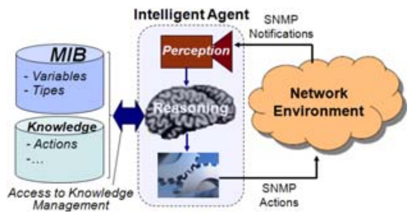

Figure 4. Intelligent Agent Architecture.

SNMP SMI defines a specification for describe the properties of new object types, while ASN.1 is used to specify the object syntaxes and the tabular structure. ASN.1 is specifically designed for communication between dissimilar agents, thus it is the same for every system and it can be used for describing almost anything. In this work we have used ASN.1 notation to extend the SNMP model by integrating the knowledge base in the MIB. Once a term is defined in ASN.1, it can be used as a building block to make other terms. ASN.1 defines each term as a sequence of components, some of which may be sequences themselves. ASN.1 provides basic types like boolean, null, integer, real, etc., and type constructors that can be used to define new types: CHOICE, SEQUENCE, SET, and SEQUENCE OF and SET OF. We take advantage of ASN.1 flexibility and extensibility to apply a top-down approach to our problem.

First we consider the problem as a whole to describe the most general data types and second we concentrate on more specific types which are referenced in general data types, in order to show a set of rules, which allows intelligent actions. There are different knowledge representation techniques to structure knowledge. In our study, we are going to represent the knowledge management in production rules or simply

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rules. Rules specify actions for the inference engine with the purpose of taking them when the premise or conditions in the rule are true. Rules are expressed as "IF-THEN" statements, which are relatively simple, very powerful and a natural way to represent expert knowledge [12]. A major feature of a rule-based system is its modularity and modifiability that allow an incremental improvement and fine tuning of the system with virtually no degradation of performance. The next definition shows the new elements of the knowledge type using ASN.1 notation.

```
Know_Rule ::= SEQUENCE {
    priority     INTEGER,
    condition ConditionType,
    action       ActionType    }
```

The priority of the element is defined using the primitive element "integer". However condition and action elements are defined as new types named "ConditionType" and "ActionType" respectively. We can do this because these types are defined in another sequence like so:

```
ConditionType ::= SEQUENCE {
    variable  OCTET STRING,
    operator OperatorType,
    value       INTEGER            }

 OpertatorType ::=SET { equal                     [1] INTEGER,
                        not equal                 [2] INTEGER,
                        less than                 [3] INTEGER,
                        …           }
```

When a type is defined, a name to reference it in another type assignment should be given to it.

```
ActionsType ::= SEQUENCE     {
    executemode        Modetype,
    command  OCTET STRING,
    arguments OCTET STRING   }

Modetype ::=SET { user         [1] INTEGER,
                  privileged  [2] INTEGER,
                  global       [3] INTEGER,
                  interface    [4] INTEGER     }
```

In ASN.1, the concept of information object class is used to represent formally properties uncovered by the notions of type and value in particular [13]. An information object class is a group of things sharing common characteristics. We have used object class to interpret the semantic links between types and values in a management action definition.

```
ACTION ::= CLASS {
            &code INTEGER UNIQUE,
            &Argument-type,
            &Return-result-type }
```

The class has three parts: an identification code to specify the function which must be executed by the remote application: an argument with a value that conforms to the ASN.1 type of the argument; and the IA, which receives a value that conforms to the result type if the function execution was successful, otherwise one specified error message. The block WITH SYNTAX defines a more user-friendly syntax to denote the objects of this class.

```
WITH SYNTAX {ACTION CODE &code
    TAKES AN ARGUMENT OF TYPE &Argument-type
     AND RETURNS A VALUE OF TYPE &Return-result-type}
```

The following definition is an example of expert rules integration in the SNMP IA proposed standard. It defines an IA named *accessPoint* corresponding to a real device in the network. *AccessPoint* IA contains all the specifications and knowledge corresponding to the device. These units offer the convenience of multiple functions such as establishing radio channels, controlling signals, monitoring stations, monitoring alarm conditions, controlling logic to activate operations in response to commands received over said communications network, and so on.

```
accessPoint IA-OBTECT-TYPE                    -- Object
            SYNTAX  SEQUENCE OF accessPointEntry
            ACCESS  not-accessible
            STATUS  currrent
            DESCRIPTION  "Access point Slot Table"
::= { accessPointsSatus 2}

accessPointEntry IA-OBJECT-TYPE             -- Instance
            SYNTAX  AccessPointEntry,
            ACCESS  not-accessible
            STATUS  currrent
            DESCRIPTION "An entry in accessPoint"
        INDEX {accessPointNbr, … }
::= { accessPoint 1 }

AccessPointEntry :=SEQUENCE{  -- SEQUENCE statement
     accessPointNbr              Unsigned32, -- index 1
     accessPointStatus            INTEGER,
      …
    accessPointLinkDown   LinkDown_Rule   -- index 4}
```

The expert rule used in the SNMP IA specification is *accessPoinLinkDown*. This expert rule is used to capture and detect anomalies or defects of operations produced in the access point device and suggest the necessary measures for solving the problem. When a mistake occurs, the rule goes to the agenda system. This rule is fired when the conditions are right: "The physical link on one of the switch (controller) ports is down". The rule provides recommendations on how to solve the failures.

```
Link_Down_Action ACTION ::= CLASS {CODE 12,
    ARGUMENT  Port "{0}" is down on Switch "{1}."
     RETURN "Troubleshoot physical network connectivity to the
affected port"}
```

Using this methodology, we can define all the knowledge management in a specific domain network and add these new types in a MB module. The module will constitute the complete knowledge specification of the management network.

V. Development Environment

Whit the purpose of improving insight and understanding of network management, we have developed a system named ALATUS based on SNMP IAs. The following system exemplifies how network topology information, resources properties and management information may be used to develop dynamically an intelligent diagnostic when errors occur.

We have studied an example of alarm detection and incident resolution concerning a private wireless network of the University of Seville. It provides wireless access using this technology in all of its departments where ReInUS (Radio network of University of Seville) facilitates access to connection. ReInUS allows the University community to connect to its network using WiFi technology: libraries, classrooms, departments, leisure rooms, open spaces, etc. Today, the University of Seville has 1200 wireless access points distributed in five campus. Every access point provides different capabilities to maximize wireless LAN performance, security, reliability and scalability.

ALATUS system works together with the access points providing real-time monitoring, management functions and supporting simultaneous data forwarding. The intelligent alarm management system will not just report that there is a problem, but the location of the problem, provide instructions for corrective action and correct the situation automatically. Fault identification involves testing the hypothetical faulty components and repair by taking intelligent actions. Advanced features just described can make the difference between a minor incident and a higher downtime. In ALATUS system, an IA agent works collecting information from the resources, in order to detect the network anomalies that typically precede a fault. It creates knowledge, about the network node, stored in MIB, which saves the management knowledge and a set of variables related to that node in particular, figure 5.

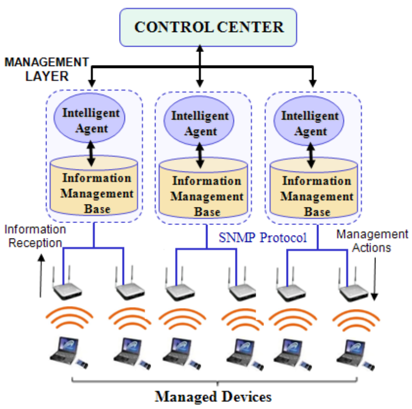

Figure 5. Wireless Network Architecture

The runtime system is defined as an SNMP application, according to the SNMPv3 architecture. The system has two major components [14]:

- Graphic Unser Interface (GUI): In our system, we have implemented a GUI written in Java running on a server who controls the whole embedded system. It is a set of I/O handling routines for managing the system and allows the management of the system by the user. To access the interface only requires a Web browser such as Explorer o Mozilla. The GUI controls the inference engine and manages system input and output.
- Inference engine. The distributed IA may be decomposed in two blocks: the SNMP entity, which implements the MIB, and the runtime system, capable of executing the scripts. Inference engine sees the runtime system as a set of distributed IAs. IAs emphasize autonomy and learning with the purpose of performing management tasks in the managed resources. In order to distribute intelligence in the network, ALATUS has been developed according to rule-based expert systems technique. This knowledge representation technique has played an important role in modern intelligent systems and their applications in strategic goal like setting, planning, design, scheduling, fault monitoring, diagnosis and so on. Conventional rule-based expert systems use human expert knowledge to solve real-world problems that normally would require human intelligence [15]. The management operations are modeled as scripts written in an intelligent language like CLIPS (C Language Integrated Production System) and associated with the MIB variables of a specific resource. CLIPS is a public domain software tool which provides a complete environment to build rules and/or objects based on expert systems.

A. *System Validation*

Validation constitutes an inherent part of the knowledge based expert system development and is intrinsically linked to the development cycle. ALATUS has been validated with respect to the following aspects: system validation using test cases, validation on site and validation against human experts. To verify the system, we have feed it with arbitrary amount of real alarms at random for more than one year. We have analyzed the evolution of the incidents from April 2011 to July 2012. We can appreciate a negative trend in the number of incidents resolved and how ALATUS system improves this negative trend with its implementation since October 2011. The result of this analysis is included on Table 1.

TABLE I. Prototype Testing Anaksyis

	Apr.11	**Jul.11**	**Oct.11**	**Jan.12**	**Apr.12**	**Jul.12**
Initial Events	458	543	745	879	907	947
Resolv. Incidents	358	426	558	681	700	786
Warning to Oper.	311	346	498	305	201	101

Overall, figure 6 reflects an increase of total events, which causes a higher number of incidents in the university wireless network. But as time progresses, we also observe an increase of solve alarms and less alarms to operator.

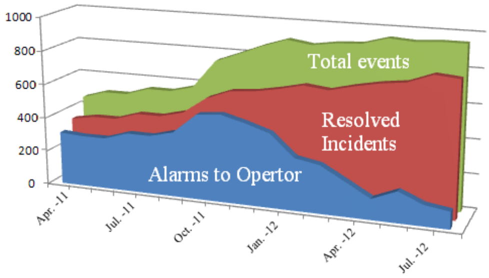

Figure 6. Prototype results

From these result, it can be said that ALATUS system reduces the need for additional dedicated monitoring software, thereby the cost and complexity of WLAN I reduced. This solution has produced excellent results which, after extensive field-testing, has proved to be able to filter 95% of produced alarms with a precision of 93% in locating, with about a 96% rate of success.

VI. Conclusion and Future Works

In this study, we have proposed that IA technologies are a future leading solution to face the current management network problems. We have seen that actual management systems are not able to solve questions explained in the initial parts of this paper. Until now, the managed objects are not able to use the information that the base of knowledge collects from management operations. The necessary requirements of area analysed must undertake those aspects.

This paper introduces an original contribution to include management knowledge coming from the network devices themselves into the specifications of the MIB. To formalize the main proposal of this work, a language to describe the knowledge base descriptions in Internet management network has been introduced. A number of questions raised from the design of a language have been discussed, and a general framework for the inclusion of formal knowledge management in SMI has also been introduced.

This research has showed an useful and interesting modular approach in the development of a knowledge based integrated expert system which can be quite powerful in tackling the huge and wide subject on diagnosis of common problems in management network. An integrated knowledge process is developed to guarantee the whole engineering procedure which uses expert rules as knowledge representation technique. This demonstrated that ALATUS is capable to specify the knowledge of a reasonably sized information model.

In our work, where knowledge is brought onto networks based on Internet model, can be reviewed like a first step toward automated management by using intelligent agents on SNMP. One guideline of our future work is to improve the agent's performance. We are also studying deeply how to incorporate the previous knowledge available at a network node. In that sense, we plan to get further investigating the feasibility and limitations of other knowledge representation techniques such as semantic networks, Bayesian networks and ontology engineering. In addition to the fault detection functional area, currently we are also studying possibilities of expanding the scope of our successful tool to other functional areas such as accounting, configuration, performance and security management.

References

[1] N. Agoulmine, "Autonomic network management principles: from concepts to applications", Burlington, Academic Press/Elsevier, 2011
[2] Z. Wang, Y. Wang & G. Shao, "Research and Design of Network Servers Monitoring System Based on SNMP", First International Workshop on Education Technology and Computer Science, 2009
[3] C. Zhu, L. Shu, T. Hara, L. Wang, S. Nishio & L.T. Yang, "A survey on communication and data management issues in mobile sensor networks", Wireless Communications and Mobile Computing, Wirel. Commun. Mob. Comput., John Wiley & Sons, Ltd, 2011
[4] A. Martín, C. León, J. Luque & I. Monedero, "A framework for development of integrated intelligent knowledge for management of telecommunication networks", Expert Systems with Applications, Volume 39, Issue 10, Pages 9264-9274, 2012.
[5] S. Yang, Y. Chang, "An active and intelligent network management system with ontology-based and multi-agent techniques", Expert Systems with Applications, Volume 38, Issue 8, 2011.
[6] H. Xu & Debao Xiao, "A Common Ontology-Based Intelligent Configuration Management Model for IP Network Devices", First International Conference on Innovative Computing, Information and Control - Volume I (ICICIC'06), 2006
[7] J. Ding, "Advances in network management", Boca Raton: CRC Press, 2010
[8] D. Nikolaou & T. Wolf, "Architecture of network systems", Burlington, Morgan Kaufmann, 2011
[9] J. Larmouth, "ASN.1 complete," San Francisco, Cal. Morgan Kaufmann, 2000
[10] L. Walsh, "SNMP MIB Handbook: essential guide to MIB development, use and diagnosis" Stanwood, WA : Wyndham, 2008
[11] A. Pedai, I Astrov, "Multi-Rate Expert Systems in Supply Chain Simulation for Telecommunication Industry," Wireless Communications, Networking and Mobile Computing, 2008. WiCOM '08. 4th International Conference on , 2008
[12] J. Liebowitz, "Knowledge management handbook, collaboration and social networking" Boca Raton, Fla. : CRC Press, 2012
[13] S. D. J. McArthur, S. M. Strachan, and G. Jahn, "The design of a multiagent transformer condition monitoring system," IEEE Trans. Power Syst., vol. 19, no. 4, pp. 1845–1852, Nov. 2004.
[14] S. Sahin, M.R. Tolun, Y. Baykal, "Expert System for Access Telecommunication Networks," Computer Science and Information Engineering, 2009 WRI World Congress on , vol.4, no., 2009
[15] A. Lezhenko, S. Kuznetsov, I Kuznetsov, "Techniques and Methods for "Smart" Processing of Information Flows in Applications of Information and Telecommunication Technologies: The Use of Expert Systems for Data Mining," Cyberworlds (CW), 2011 International Conference on , vol., no., pp.168-172, 4-6 Oct. 2011

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