Distributed Management: Implementation issues

Rui Pedro Lopes, José Luís Oliveira

***Abstract*-- Management processes have to react on time to the new challenges put by a crescent movement of the computing world to the Internet paradigm. The enormous base of legacy knowledge and legacy systems leads the SNMP management framework to a necessary choice in nowadays management scenarios. However, even with the recent SNMPv3, its services correspond roughly to low-level operations for setting or retrieving network equipment parameters. The IETF Distributed Management working group have been producing normalization documents that intent to apply to the enrichment of SNMP semantics, especially in what concerns the processing of management information.**
This paper will present the recent outcome of this WG and will discuss an implementation project that aims to apply mobile agent technology in these scenarios.

***Index terms*-- Distributed management, SNMP, Disman.**

I. Introduction

For several years the network management buzzword was mostly associated with SNMP. Guided by the simplicity and the shorter inference principles soon has conquer the attention of a market with a big appetite for this solutions. However, its evolution has suffered from several drawbacks and has open space for other approaches.
The straight path that was maintained by SNMPv3 working group, which last results were published as draft standards by the IETF, may have provide a new breath into the SNMP management framework. SNMPv3 tries to eliminate previous versions weaknesses by the inclusion of some new features. Among these are the security support and a flexible architecture that allows the redefinition of current modules or the introduction of new parts inside the framework. Each SNMP configuration is classified as a "SNMP Entity" composed by several interacting modules: Dispatcher, Message Processing, Security, Access Control and Application module. The combination of these modules allows providing different SNMP roles (i.e. an agent, proxy or manager) [1].
The Application(s) use services from the SNMPv3 engine to send and receive messages, authenticate, encrypt and control the access to managed objects [2].

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The Dispatcher subsystem coordinates the communication between SNMPv3 engine subsystems and differentiates modules belonging to the same subsystem. Based on the PDU information, it determines which application should be invoked and coordinates the respective transport mappings.
In a working scenario, before transmitting the message, the dispatcher checks the selected protocol version and type (Fig. 1). Following this information, the adequate message processor is invocated which itself relies on the next subsystem (security) to pack the message.

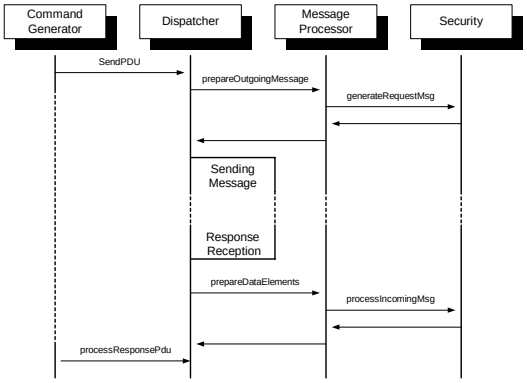


Fig. 1. Commands flow inside an SNMP Entity.

The SNMP framework is a centralized approach, i.e. a NMS uses distributed agents to collect management information. This data is retrieved on demand by the NMS to be processed.
This approach has some drawbacks, in particular due to the lack of extensibility and scalability of the model on very large networks. This constraint results from the inability of a centralized manager to handle huge amounts of management information and also because centralized polling across geographically distributed sites is infeasible and expensive [3]. Moreover, system updates usually entail the modification of several agents or of the management station itself. In addition, there are occasions where it is necessary to cope with situations where the management station is not accessible. The classic management architectures are not well suited for low-bandwidth or disconnected operation.
Several authors have addressed these problems along the past years [4][5][6] resulting in ad-hoc and partial solutions typically based on management distribution and delegation.

Inside the IETF, the Distributed Management (Disman) WG was chartered to define an architecture where a main manager can delegate control above several distributed management stations thus improving scalability through distribution and allowing “off-line” operations.

II. DISMAN

Management distribution allows reducing the processing load on traditional centralized management station (NMS) by delegation tasks upon several Distributed Managers (DM) or upon more powerful agents. A DM is an SNMP entity that receives requests from another manager and executes those requests by performing management operations on agents or other managers.
Since the management entities are split over the network and collaborate between themselves by assignment, a hierarchy of several “islands” is created increasing the robustness and fault tolerance of the overall management system. Although if the access to the central manager is not possible, each DM may handle locally critical situations.
The IETF Disman framework is based on distributed applications and services. This kind of application performs some management function, often by monitoring and controlling managed elements. The distributed management services can perform functions or store information once for all applications on the local system thus making a set of applications more efficient. Each service is provided by a specific MIB interface.
Currently there are being proposed several MIB to address different but complementary issues of management operations distribution [7]:

- Event MIB
- Notification Log MIB
- Remote Operations MIB
- Schedule MIB
- Script MIB
- Expression MIB

The Event MIB is the successor of the SNMPv2 Manager-to-Manager MIB. It provides the ability to monitor MIB objects either locally or remotely and takes an action when a trigger condition occurs.
The Notification Log MIB is intended mainly for notifications providers but may be also used by consumers. It defines a mechanism to cope with notifications lost by recording each notification data.
The Remote Operations MIBs group (ping, traceroute, lookup) enables the correspondent network-checking operation to be performed at a remote location. It provides a standard way to perform remote tests, to issue periodical sets of operations, and to generate notifications with test results.
The Schedule MIB provides the definitions to perform the scheduling of actions periodically or at specific times and dates. The actions are modeled by SNMP set operations on local MIB variables (restricted to INTEGER type). More complex actions can be realized by triggering a management script, which is responsible for performing complex state transitions.
The Script MIB module allows the delegation of management functions over distributed managers. Management functions are defined as management scripts written in a language supported by the managers. It may be a scripting language (such as TCL) or native code, if the remote site is able to execute this code. The module does not make any further assumptions on the language. The distributed manager may be decomposed in two blocks: the SNMP entity, which implements this MIB, and the runtime system, capable of executing the scripts. The Script MIB sees the runtime system as the managed resource, which is controlled by the MIB. The runtime system can be defined as an SNMP application, according to the SNMPv3 architecture.
The Expression MIB was planned to move to the agent side part of the management information processing typically performed by managers. In other words, it supports externally defined computation expressions over existing MIB objects. The Expression MIB allows providing the Event MIB with custom-defined objects. The result of an expression can trigger an event, resulting in an SNMP notification. Without the Expression MIB such monitoring is limited to the objects in predefined MIBs.
There are several reasons for a manager to apply some kind of expression on management information. Aggregation of data can be done in simple statistical tasks, such as the percentage of inbound discarded packets that contained errors (1), or in expressions with a higher degree of complexity.

$$100 \times \frac{\text{ifInErrors}}{\text{ifInDiscards} + \text{ifInErrors} + \text{ifInUnknownProtos}} \quad (1)$$

The work presented here is mostly based on an implementation of Expression MIB proposal.

III. EXPRESSION MIB OVERVIEW

The Expression MIB is currently an internet-draft (11th) of the Distributed Management working group, within the Operations and Management Area of the IETF. The MIB is divided in three main groups [8]:

- `expResource` – this group is related to resource control, with particular incidence on sampling parameters since this operation can have some impact on system resources.
- `expDefine` – is organized in three tables which gather information about the expression definition and about the errors occurred while evaluating it:
  a) `expExpressionTable`, defines the expression string, the result type as well as the sampling period.
  b) `expErrorTable` maintains a table of errors’ registers gathering information such as: the last time an error occurred on evaluating the expression, the operation in which it occurred, the error type.
  c) `expObjectTable` controls each element characteristics inside the expression. The expression

string may contain variables and each variable may have different sampling types and be or not wild-carded.

- `expValue` – this group has a single table which instantiates the evaluation objects. It is by querying this table that the result from the expression is known.

A. *Sampling and Wildcards*

The Expression MIB supports three types of sampling:

1. *absolute* – the objects are sampled just before calculating the result.
2. *delta* – the difference from one sample to the next. It is necessary to maintain the last sample. Creates a constant overhead whether or not anyone is looking at the results, so not very suitable for severely limited environments.
3. *changed* – boolean indicating whether or not the object changed its value since the last sample.

In addition to sampling, the MIB also defines wildcarding, allowing the usage of a single expression over multiple instances of the same MIB object. While regular objects are resolved by a SNMP Get operation, wild-carded objects are controlled through the GetNext operation. Users are familiar with wildcarding for referencing multiple files (such as "cp foo.* /tmp"). On this MIB, wild-carded objects are attributes. If there is more than one wildcard variable on an expression they all must have the same OID termination (semantics) to maintain coherence on the result.
For example, the expression (2) has two variables each corresponding to a wild-carded OID, ($1= "1.3.6.1.32.1.4" and $2= "1.3.6.1.50.2.7.1.321").

```
100*$1/$2                                    (2)
```

The object values are retrieved by GetNext operations thus retrieving the instance INDEX. If the result from GetNext $1 is "1.3.6.1.32.1.4.1.2.3", the INDEX part is "1.2.3". So $2 will be "1.3.6.1.50.2.7.1.321.1.2.3".
An OID can be specified (`expExpressionPrefix`) in order to help retrieve the INDEX. In this example it can be captured in each of the two OIDs since both follow a MIB definition where it is possible to look at the INDEX clause.

B. *Subsets*

According to the conformant statements the implementation of the Expression MIB can leave out several parts.

1. *No wildcards* - significantly reduces complexity. Suitable for expressions made up of individual MIB objects but not suitable for expressions applied across large tables.
2. *No Deltas* - reduces state that must be kept and the burden of ongoing processing unnecessary sampling threads. Suitable for applications that do not require expressions or events on counters.
3. *One object expressions* - reduces the complexity of parsing expressions, retrieving multiple objects per expression and doing expression evaluation. This is the slightest implementation of the Expression MIB that supports the threshold of the Event MIB.

C. *Expression Definition*

The key aspects in defining expressions are *parameters*, *results* and *operators*.
We can define an expression as:

"*result = parameter operator parameter*"

where "parameter = constant | variable | function | result".
The Expression MIB allows several operators with C-like significance, such as:

```
( ) + - * / % & | << >>  ! && ||
== != > >= < <=
```

and a set functions, such as the presented in Table 2.

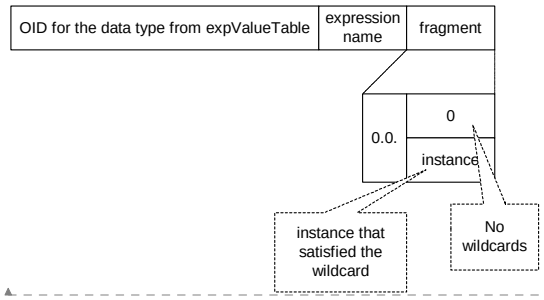
Table 2 – Functions.

Function	# Param.	Parameter type
counter32	1	integer
counter64	1	integer
arraySection	3	array, integer, integer
stringBegins	2	octetString, octetString
stringEnds	2	octetString, octetString
stringContains	2	octetString, octetString
oidBegins	2	oid, oid
OidEnds	2	oid, oid
oidContains	2	oid, oid
Average	1	integer
Maximum	1	integer
Minimum	1	integer
Sum	1	integerObject* (wildcard)
Exists	1	anyTypeObject

Comment [rp1]: Nao percebi o que queria dizer com isto…

D. *Expression Values*

An expression is executed through a row on the `expValueTable`. Each row has only one column, formatted according to the result type of the expression. The value is accessed by an OID containing the OID for the data type, the expression name and a fragment (Fig. 2).



Field Code Changed

Fig. 2. Value identification OID.

The expression name has the form of *x*."owner".*y*."name" converted to dot separated integers. The integer *x* is the length of the owner and *y* is the length of the string which identifies this expression to the particular owner. Each word character is converted to integer and separated from the other integers by a dot.

The fragment starts with “0.0.” and ends with a zero, if there is no wildcard or, otherwise, with the instance that satisfied the wildcard.

IV. Expression MIB Implementation Issues

The implementation of the Expression MIB can be divided in two sections (Fig. 3):

1. The communication module, responsible for receiving and sending SNMP commands.
2. The agent, responsible for the SNMP agent behavior.

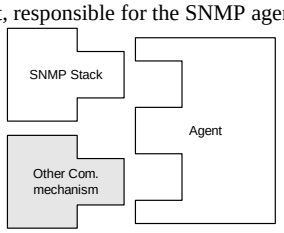


Fig. 3. Agent modules: communication and agent.

With a well-established interface between the communication mechanism and the SNMP engine it is possible to switch modules maintaining the agent. This feature is useful if we want, in runtime, to use SNMP or other communication method, for example, to check CORBA or RMI performance, or to add mobility to the agent [9].

A. Agent Structure

Considering the SNMP operations and the tree-like organization of objects in the agent, some decisions can be made to help on the agent architecture planning. Management operations have information about “which” object and “what” to do with it. In “which”, it is possible to point precisely the object (the case of *get* and *set*) and to define a walking procedure (*get-next* and *get-bulk*). In “what”, the operations are retrieval (*get*, *get-next* and *get-bulk*) and restore (*set*).

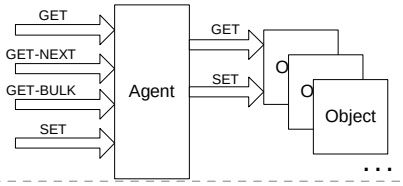


Fig. 4 – SNMP operations on Agents.

Adapting these concepts to an O-O language, the “which” is modeled by a container class (`Agent`) and the “what” are methods to call on contained objects (`Object`) (Fig. 4).

B. Expression MIB Objects

The user defines an expression by setting some objects on the expExpressionTable and on the expObjectTable.

C. Expression Parser

To evaluate an expression it is necessary to recognize the expression components (operators, functions, constants and variables), i.e. the lexicon, and the grammar (the expression organization). There are, available as public domain software, lexical and grammar analysis tools, which generate code such as C [10] or Java [11]. As this implementation is Java based, the chosen tools were JLex, a lexical compiler, and JavaCup, a grammar compiler [12]. Both compilers generate source code based on specification files. These routines are then compiled (into Java .class files) and included in the Expression MIB agent.
The lexical analyzer starts reading the stream of characters and tries to matches the sequences identifying tokens. The tokens information is forward to the grammar, which groups tokens into meaningful sequences and invokes action routines to act upon them. In this particular case, it must recognize a complete expression and evaluate the result.

D. Value objects

How do the previous sections fit in the Expression MIB implementation? To better answer this question, it is necessary to realize how the Expression MIB works (Fig. 5).
When started, the agent waits for input. When receiving a SET message it inspects to which table it is destined. After populating the appropriate table, it confirms if both the `expExpressionEntryStatus` and all the related `expObjectEntryStatus` are set to ‘active’. If so, it creates an entry on `expValueTable`, after checking for syntax errors.

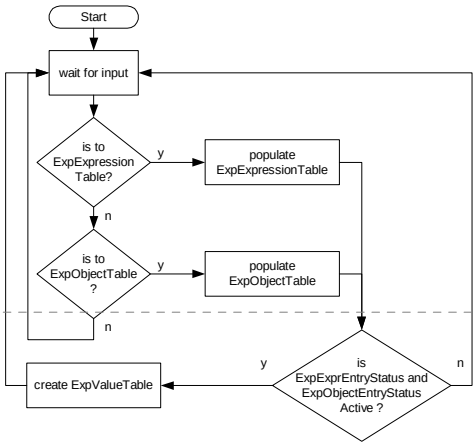


Fig. 5. Expression definition.

This object is then responsible for calculating the expression. If the expression has some sort of delta sampling, it launches a thread to periodically calculate the expression and store the result. If the expression is ‘absolute’, meaning that there are no periodic sampling

involved, the expression is calculated only when the `expValueTable` is queried.
The process of calculating the expression is, on the whole, the most complex part, particularly when wildcarding is used. For this purpose, the agent:

1. Retrieves the expression string (`expExpression`).
2. Creates a parser object (based on the code generated by JLex and JavaCup).
3. Checks to see if the expression is wild-carded (`expExpressionPrefix`).
4. Builds a list of objects (variables) that the expression contains.
5. Retrieves the value of each object (`expObjectTable`).
6. Calculates the expression value and stores it in the appropriate `expValueTable` instance.

E. Problems and Solutions

The Expression MIB specification is well written and shows some examples to ease clarifying the agent operation. It is easy to implement the `expExpressionTable` and the `expErrorTable` although the `expObjectTable` has some aspects that require further explanation. For example, the wildcarding aspect is somehow very scattered on the document. The objects `expObjectDiscontinuityID` and `expObjectDiscontinuityIDWildcard` are overlooked, so it may be difficult to understand its role. It would help the implementers if the `expObjectConditional` objects where a little bit more explained in the document, as they are essential for condition checks.
Other problems may arise when moving processing to the agent, in particular if it is running on restricted environments in terms of memory or CPU.
To study the impact of adding a parser to an agent we have performed some preliminary load tests. In these tests we were mainly concerned with the overload of delta sampling by comparing this situation to the situation of 'absolute' value.
We measured the agent used memory for 0, 1, 20 and 100 expressions with one (Fig. 6) and three (Fig. 7) variables both for absolute and delta sampling.
For reference, we measured the minimum memory spaced required by the JVM and found that it uses 3780 Kbytes. The Expression MIB agent with no objects (0 expressions) uses an additional 2104 Kbytes.
We used a Linux box (kernel 2.2.14, glibc-2.1.1) with the Blackdown (www.blackdown.org) port of the JDK1.2.2 – Classic VM (build Linux_JDK_1.2.2_RC4, native threads, sunwjit).

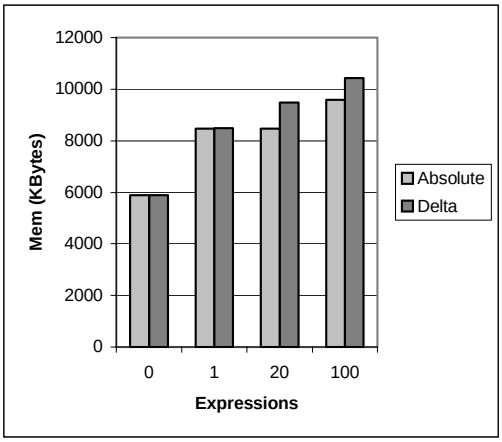


Fig. 6 – Memory load for one variable expression.

We can see that, as expected, the number of expressions is proportional to the used memory. Moreover, the difference between delta and absolute expressions is considerable (near 25% for 20 one variable expressions and 18% for 100 one variable expressions).

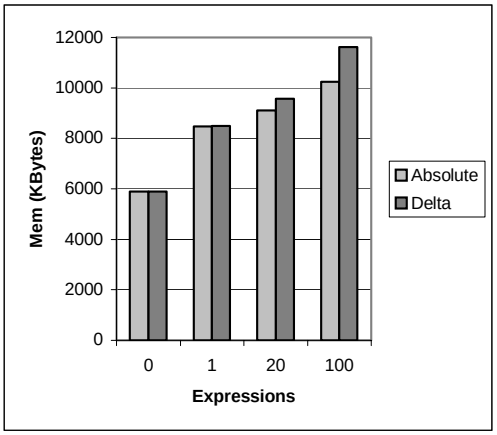


Fig. 7 – Memory load for three variables expression.

The memory requirements increase with the number of expressions and with the number of variables per expression.
For CPU utilization we also did some tests by changing the sampling interval (for absolute sampling the CPU is used only when a get message is received on a value object). For 100 expressions with evaluated every five seconds the processor (Intel Pentium II 333MHz) was near 100% load. For 20 expressions evaluated every ten seconds it as near 10%.
For the pointed values, the memory requirements are somewhat excessive for restrictive environments. The JVM we used (Java 2 Platform Standard Edition) is not targeted to such kind of platforms and we did not try a more adequate virtual machine, such as the Java 2 Micro Edition. In terms of CPU usage, it is very dependent of the sampling

period and may be considered acceptable if the interval between samples is sufficiently long.

V. Future Approaches

For further improving the Disman framework and, in particular, Expression MIB implementations, we are working on two different approaches: using mobile agents in distribution and the definition of SNMP Macros.

A. Mobile Agents in Distribution

The Disman framework aims at distributing the management power among agents (also called Distributed Managers) to cope with network scale problems and offline operation.
The framework, as seen above, describes a way to define expressions on values sampled from the local host (it is possible to sample values from another hosts but it is necessary to define the Script MIB and the appropriate scripts, which further increases the platform resource requirements and complexity). Moreover, the framework does not define any load balancing mechanism to cope with eventually limited platform resources.
On such scenario there are several advantages of using mobile agents. By mobile agents we consider software entities, which can exhibit mobility by actively changing their execution environment, transferring themselves during execution [13]. There are, at the moment, several mobile agents platforms, relying on interpreted code or on the Java Virtual Machine [14][15][16].
In fact, they can [17]

- save significant bandwidth by moving locally to the resources they need;
- carry the code to manage remote resources and do not need the remote availability of a specific server;
- perform load balancing;
- correlate information from several agents.

The mobility support in Distributed Managers allows them to adapt to a changing environment and simplifies tasks such as agent and tasks distribution.
Fig. 8 presents two situations of Distributed Managers with mobile characteristics. In the first situation (one) the DM choose to clone to a different management domain because the instantaneous load increased. Situation two presents an approach where the communication with the upper management station is interrupted. As an example, the DM may have detected a problem in the platform where it was installed and choose to migrate to a different location to continue its operation without assistance from the management station. When the station gets back on-line it may migrate to the original host and continue its operation. Other situation where this move may occur is when the interaction between the DM and some agent delivers high volumes of traffic. In this case, instead of generating traffic across several links the DM can move near the agent and interact with it locally. The DM can dynamically infer about these condition in order to adapt to the best network position and the best host to perform.

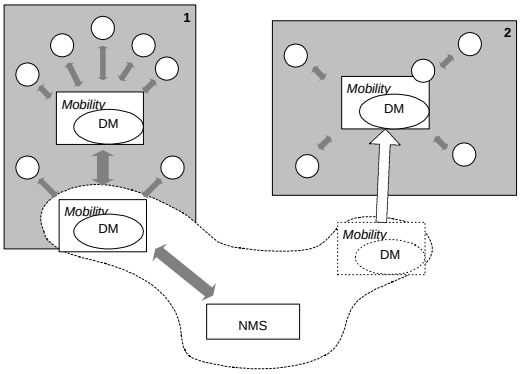


Fig. 8 – Mobile Disman Architecture.

In addition, the migratory nature allows the Expression MIB to sample values from any host in the itinerary without the need for further complexity.
From the usability point of view, the user (manager) may define DMs in the topmost Management Station and set its behaviour. After creating the desired DM he can define an itinerary to be followed or some kind of distribution policy. It must be considered that the SNMP framework does not expect the agents to move, so it is necessary to maintain knowledge of the current location of the agents. This fact also helps managing the DMs. The join of the two entities implies the introduction of SNMP services inside an Agent System (the host kernel for agents).

B. SNMP Macros

The SNMP framework and, in particular, the Expression MIB, requires creating or changing several objects values for the definition of a single expression (typically 10 to 15 objects). This situation is similar to Assembly programming, where many instructions are necessary to define a single, higher-level operation.
Obviously, this fact causes difficulties to the user when interacting with the Network Management System. It is important to have a tool to ease the burden caused, particularly, by repetitive tasks. The first step in this direction goes through creating Macros – a series of commands and instructions that can be grouped together as a single command to accomplish a task automatically.
SNMP commands are used to retrieve, create and/or change data on the agents. Each command requires an identifier (the OID) and, in the case of creating or changing a parameter, its value. By gathering all the information about an operation (OIDs, values, types) according to some format it is possible to define what we call SNMP Macros. We define a Macro as a tree structure, possibly having objects from several MIBs, each MIB having several TABLES and/or several VALUES (Fig. 9). We use XML to define these tags.

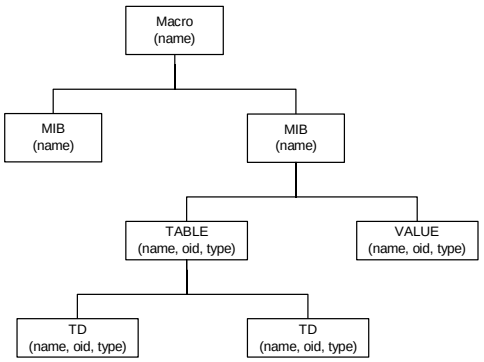


Fig. 9 – Macro structure.

On a practical scenario, the user interacts with a graphical user interface to create a set of Macro templates suitable for the desired operations (Fig. 10). These Macros can then be stored for future use.

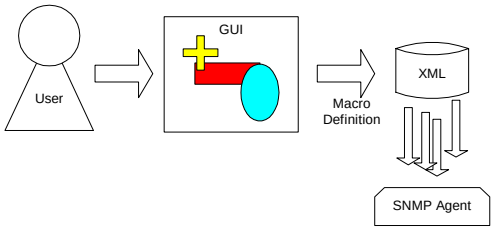


Fig. 10 – SNMP Macro definition.

When executing the Macro, the system reads the XML tree and performs the defined operations.

VI. Conclusion

The management of enterprise networks, i.e., to monitor and to act on network components, is a task that involves commonly the use of heavy and complex applications. This difficulty is further enlarged in situations where network scale or connection characteristics inhibit the full use of the SNMP framework.

The Disman framework, proposed by the IETF, addresses these problems by distributing some of the management application responsibility to the agents (Distributed Managers).

This paper has presented an implementation of the Disman Expression MIB and suggests its association with mobility support, permitting the Distributed Manager to adapt to a changing management environment. Furthermore, it allows increasing management efficiency by reducing management traffic, providing a better use of network resources and enhancing flexibility. We also suggest SNMP Macro definition to relieve the user from the burden caused by repetitive tasks.

The mobility characteristic raises several new issues in Disman DMs. At the moment we are mainly concerned with the performance of the DM in terms of load balancing and network efficiency. The next step to be performed is to associate the Expression MIB implementation with mobility characteristics and get historical data from network nodes to perform a study aiming at extracting "when to move" information. An adequate sensing mechanism and correct decision mechanisms may increase the management system overall efficiency.

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