Automated End-to-end Management in ATM Networks

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Abstract

ATM network management and ATM traffic control are usually separated : traffic controls are performed automatically by the set of real time algorithms while management tasks are inherently slow and may often involve a human manager. However, network management and traffic control operations interact each other (e.g., the two basic traffic control functions, CAC and UPC, are necessary to guarantee the desired broadband network performance. Therefore, an automated management is being increasingly demanded. This paper presents an approach for ATM management automation based on a domain-based structuring of the management activity and the application of a uniform and recursive management model. The approach is applied to VCC and VPC manangement emphasizing a real-tome management of an ATM switch which is the basic network element of B-ISDN.

1 Introduction

Asynchronous Transfer Mode (ATM) has been adopted by CCITT (ITU now) as the transport and switching technique for the Broadband Integrated Services Digital Network (B-ISDN). One reason industry has turned its attention to the management of ATM-based Broadband networks is to ensure that operations impacts and needs are identified and addressed early in the BISDN development process. Without the appropriate tools to anticipate, detect, and overcome failures, congestion and periods of degraded performance that may occur within BISDN, the viability of this broadband network will be jeopardy.

Usually, ATM network management and ATM traffic control are separated. Indeed, traffic controls are performed automatically by the set of real time algorithms (with response time of the order of microseconds) while management tasks are inherently slow and may often involve (if automated network management tools are not provided) a human manager [1]. However, network management and traffic control operations interact each other. Indeed, the two basic traffic control functions (CAC and UPC) are necessary to guarantee the desired broadband network performance [2], [3]. Therefore, an automated management is being increasingly demanded [4].

This paper addresses management automation by refining a uniform and recursive management model and its application to end-to-end ATM connections. It is structured in two main parts. In the first one, we introduce our domain based architecture for organizing management systems and our uniform model for the management activity. The model allows for recursive and generic structuring we consider as the basis for management automation. In the second part, we apply our concepts to structure the management of an ATM-based network highlighting VCC (Virtual Channel Connection) and VPC (Virtual Path Connection) management structuring. As an example, an automated plan activation process for an ATM switch management is presented.

2 Our Approach

2.1 Management System Structuring

Management quality comes through good organization. Therefore, we have defined a management architecture as a guideline for building and organizing management systems [5], [6]. Two structuring principles underlie the realization of our architecture. The first is the use of domains as a mean for grouping resources determined by management need (e.g., a domain applying a specific management policy).

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The dependency between the emerging domains reflects both hierarchical interactions (e.g., control of resources, authority delegation to subordinate managers [7]) as well as peer-to-peer interactions (e.g., negotiations between peer managers to prevent/resolve management conflicts). The second structuring principle is to separate management policies from the resources and activities being managed. This separation allows, on one hand, to provide managers with an abstract and uniform view of the managed resources hiding these last heterogeneity and, on the other hand, to implement a uniform and generic model for the management activity.

According to these structuring principles and as depicted by figure 1, our domain is composed by a managed part (the set of resources to be managed) and managing part (the domain manager and the abstract representations of the managed resources). The whole management system is then logically constructed in a hierarchical domain structure where low level domains provide their services to those of the upper layers. The management activity can be applied recursively through the levels of the hierarchy.

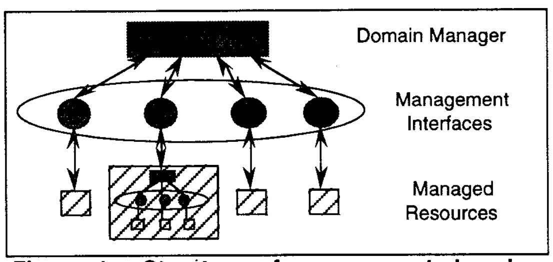

Figure 1 : Structure of management domains

Defining and applying such a uniform and recursive management model is the key step towards management automation which constitutes the ultimate aim of this work. However, the semantics of management are not yet adequately understood. Besides a very coarse model describing management as the activity of gathering information and exerting control, the complex task of management is usually built into management applications. Such an approach hinders integration and open cooperation.

2.2 Management Activity Modelling

We define three kinds of management information ([8]) : goals, policies and plans. The manager model starts with high level goals (e.g. as input from a superior authority) and ends up with management plans stating exactly what is to be done (control actions) on the occurrence of certain situations (observed state). The manager reports about its management to its superiors particularly when it fail to achieve the goals. Management policies are introduced as intermediaries between (abstract) management goals and (executable) management plans. They are general statements about how management goals will be achieved, and are used to ease decision making .

The activity of the manager consists then of three distinct phases (see figure 2):

- making management policies from management goals;
- deriving management plans from management policies;
- executing management plans.

These phases are executed according to two modes of operation of the manager :

- *proactive management* stimulated by arrival of goals from higher level managers and,
- *reactive management* on events detection or arrival of notifications from managed resources and/or lower level managers.

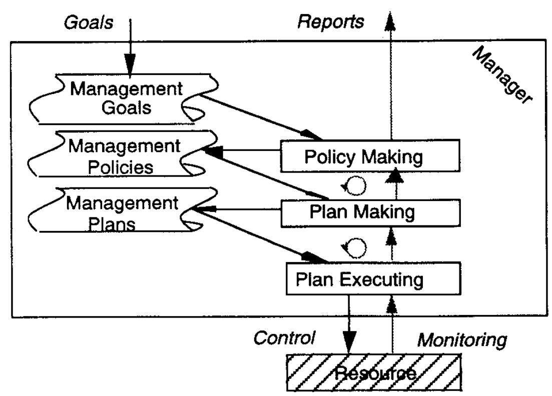

Figure 2 : Management process within the manager

Adhering to this model enables the dynamic change of goals, policies and plans which are currently very often hard-coded into management applications.

In order to provide an automated management activity, it is necessary to be able to dynamically specify high level management policies and to turn them automatically into low level control commands to be executed on managed resources. The complexity of the tasks of making and interpreting (informal) management policies make difficult such automation. Very few works have explored the problem of specifying management policies. The more significant ones are those held by Moffet & al. [9], but their policies are restricted to access rights [10].

3 ATM-Based Network Management

3.1 Domain-based structuring

In an ATM network, due to the large number of VP connections and VC connections that may be configured it is not practical to *manage* every one of them, although they will be systematically *controlled*. VCCs and VPCs that have relatively long or permanent holding times are mainly those that are candidate for management and are those for which domains are created. These last are encapsulated in the highest level ATM domain responsible of all end-to-end connections management. Each VCC domain is responsible of an end-to-end connection management and thus of the corresponding lower level connections (VPCs). Therefore, a domain is created for each VPC involved in the VCC connection. The management entities of a VPC domain are distributed among ATM switches which leads us to consider each VPC domain as a set of ATM switch domains. The management of each switch at the frontier between two VPC (i.e. where new VC numbers are assigned [11], [12], cf. figure 3) is shared by these VPC domains. This domain organization is illustrated by figure 4.

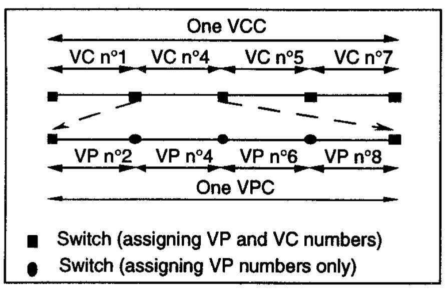

Figure 3 : ATM end-to-end connection

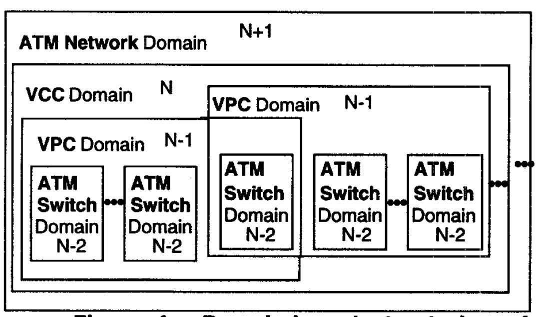

Figure 4 : Domain-based structuring of an ATM Network

Every ATM Switch which is the basic network element of B-ISDN is composed of ports. Every port supports many connections. A port identifies a virtual path (VP), a connection identifies a virtual channel (VC). Note that a VP is a generic term for a bundle of virtual channel links while a VC is a generic term used to describe a unidirectional communication capability for the transport of ATM cells. These three management domain levels, namely Switch, Port, and Connection do not share the same management functionalities, i.e. the management is performed differently on each of these domains (see figure 5).

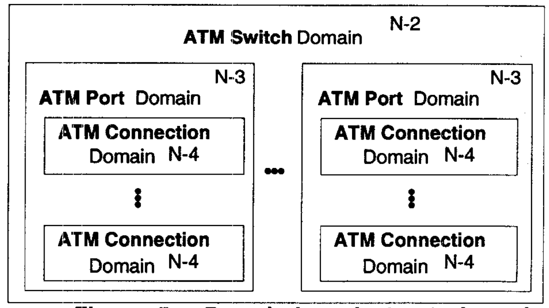

Figure 5 : Domain-based structuring of an ATM Switch

In the following subsection, we present, as an example, the switch domain manager. Due to its position in the management hierarchy, the switch manager receives its management goals from higher level managers (VCCs through VPCs) and delegates management subtasks to lower level managers (namely VP and thus VC managers).

3.2 Switch Domain Manager

In the scope of our ATM-based network management demonstrator, we have designed managers in such a way that only a limited and well defined set of goals can be specified, from which a set of policies can be determined automatically and then turned into a plan of actions by applying *Policy Predicates* to a predetermined set of plans in the form of *Plan Template*.

A plan template consists of a tree of action sequences with state and policy decisions at each branch. Policy predicates are represented as explicit calculations to determine a policy decision.

The first step to apply the previous approach consists of determining the manager ingredients that are:

- Goals,
- State attributes, i.e. status of the managed resources in this domain,
- Policy attributes such as thresholds and management options, and,
- Actions.

For the purpose of ATM end-to-end connections performance management, we have defined 3 high level management goals :

- Goal G1 : Loss rate for data flow is limited to p% of transmitted cells on VCC n°i with priority P1.
- Goal G2 : Transit delay for voice and video flows is limited to T for VCC n°i with priority P2.
- Goal G3 : Control and management delay is limited to p% by unit of time; beyond this limit, all actions with priority less than P3 are forbidden.

Among the more significant state attributes to ATM performance management, there are [13, 14]:

- Cell Loss Ratio (S-CLR) ,
- Cell Misinsertion Rate (S-CMRe) ,
- Cell Misinsertion Ratio (S-CMRo),
- Cell Error Ratio (S-CER),
- Cell Block Error Ratio (S-CBER),
- Severely Errored Cell Block Ratio (S-SECBR),
- Cell Transfer Delay (S-CTD) ,
- Mean OAM CTD (S-MOC),
- OAM Cell Delay Variation (S-OCDV).

We add the following ones :

- S-avai : a boolean reflecting the availability of the switch;
- VP-i-avai : a set of booleans reflecting the availability or not of each VP managed in the switch;

The policy attributes that are relevant to cell loss and transit delay are :

- S-CLR-max : maximum cell loss rate accepted for the traffic;
- VLB : use Virtual leaky bucket algorithm option;
- Discard : discard (or not) cells with CLP bit set to 1 option;
- EBCI : use explicit backward congestion indicator option;

Now, from these policy and state attributes and in conjunction with the set of goals, we can decide the composition of policies. Two policy predicates can be defined for the switch manager:

- Policy predicate P1 :

```
if S-CLR > S-CLR-max
then if   [ S-CLR > S-CLR-max *1.01
           & P(Loss rate) < P(Ctrl delay) ]
        then desactivate VP     (-->"no")
        else activate virtual leaky bucket
                          (-->"yes")
else do nothing
```

- Policy predicate P2 :

```
if  [ P(EBCI)> P(Loss rate)
     & S-CLR < S-CLR-max ]
then  discard cells with CLP set to 1
              (-->"yes")
    else send OAM cells with EBCI
          mechanism          (-->"no")
```

We have identified which control actions may be performed by a switch manager. These are (but not limited to) :

- A0/A1 : save (respectively ignore) message;
- A2/A3 : set to true (resp. to false) VP-i-avai;
- A4/A5 : execute (resp. stop) virtual leaky bucket;
- A6/A7 : discard (resp. stop discarding) cells with CLP bit set to 1;
- A8/A9 : set to true (resp. to false) VLB attribute;
- A10/A11 : set to true (resp. to false) Discard attribute;
- A12 : send OAM cells with EBCI mechanism;
- A12 : send OAM cells with EFCI mechanism;
- A14/A15 : set to true (resp. to false) S-avai;

The second step consists of setting up a plan activation process. A plan is a set of actions to be activated when certain situations occur. A situation is determined by the values of the previous attributes. Typically, a plan activation process is handled as follows:

- Incoming messages (e.g. event notification);
- Update of state attributes;
- Check against policy attributes;
- Invocation of action(s), i.e. the corresponding plan.

According to this, we obtain for the switch manager, the reactive plan template shown in figure 5, where :

- N1 : notification indicating to the switch manager the values of certain VP-state attributes (e.g. CLR, ...);
- N2 : notification from the switch manager asking the VPC domain manager a connection reconfiguration;
- N3 : notification from the switch manager to the VCC domain (through the VPC domain) concerning bandwidth renegociation;
- S-G1 : this sub-goal is sent by the switch manager (to the VP domain manager) to put the VP out of service.

According to this plan activation process, the switch domain kernel receives a notification (N1) from its VP sub-domain which indicates the values of certain parameters such as the cell loss rate attribute (CLR). Within the OAM cells, a parameter reflects the state of the switch with respect to the management activity. If the switch is active, it checks the EBCI (Explicit Backward Control Indicator) mechanism. If this last is unavailable, policy prediacte (P1) is computed.

Two cases are then possible : - the VP is put out of service if the cell loss rate is not acceptable and a reconfiguration of the connection request is sent to the superior VPC domain; - if the result of predicate P1 is positive, the VLB (Virtual Leaky Bucket) is activated and the superior VC domain is asked for bandwidth renegociation. If the EBCI mechanism was available at the level of the switch, policy predicate (P2) is computed. If a positive result is obtained, next arriving cells marked with bit CLP (i.e., CLP = 1) are discarded; otherwise, all switches down to the source of the cells are notified.

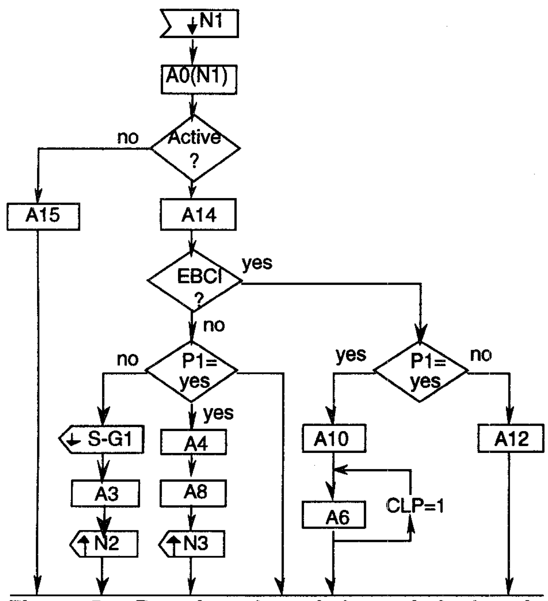

Figure 5 : Reactive plan of the switch domain manager

4 Conclusion

In this paper, we have proposed a hierarchical management structure for ATM end-to-end connections highlighting the increasing demand for a comletely automated management support tools. In order to respond to this requirement, we have introduced a uniform management model and refined it recursively through the levels of the management hierarchy. The model is based on a formal specification of management policies from high level abstract goals and on an automated plan derivation and execution process.

In this paper, emphasis lies on the switch domain manager, this being a basic network element in B-ISDN. In particular, we have presented a reactive plan for automated performance management at the level of the switch domain. This plan is more adapted to the transport of data which is sensitive to cell loss. For voice and video transport which are highly dependent on transit delays, proactive management will be more helpful due to its ability to anticipate problems that may occur in the network and, particularly, periods of performance degradation. Proactive plans for ATM switch management, the corresponding policy predicates together with the overall end-to-end view of ATM management are under development and will be presented in a subsequent paper.

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