Fault Identification and Prevention for PVC Management in ATM Networks

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Fault Identification and Prevention for PVC Management in ATM Networks

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Abstract

In order to meet the need of network management for emerging large complex heterogeneous communication networks, a distributed proactive self-adjusting management (DPSAM) framework was developed. The framework facilitates the incorporation of artificial intelligence and distributed computing technologies in building advanced natwork management systems. PMS, a PVC (Permanet virtual Circuit) management system for ATM networks, is developed based on DPSAM framework. PMS provides a scalable, end-to-end path management solution required for today's ATM network and service management It aims to assist network operators to perform PVC operations with simplified procedures and automatic optimum route selection. It also provides effective decision-making support for PVC fault identification and prevention. In this paper, PVC fault identification and prevention along with an overview of the DPSAM framework and PMS will be presented.

1 Introduction

In order to alleviate some of the shortcomings in the traditional network management systems, which are characterised as highly-centralised, reactive, and operator-based, a distributed proactive self-adjusting management (DPSAM) framework was developed at the National Research Council of Canada. The framework is designed for building network management systems that are capable of performing self-corrective and proactive preventive actions. It incorporates artificial intelligence (AI), web-centric, and distributed network computing technologies to deal with the challenges in the management of the emerging heterogeneous communication networks, especially ATM networks. In the management of ATM communication networks that have recently increased dramatically in size and complexity, the PVC (Permanent Virtual Circuit) management [8][9] is considered as one of the most important tasks. This task includes various PVC operations such as path creation, path upgrade, path deletion, PVC fault identification, PVC fault correction, PVC fault prevention, and PVC QoS guarantee. To assist the operator to perform this management task, we developed PMS, a PVC management system for ATM networks [1], by incorporating DPSAM framework. PMS is an ATM network management tool for service providers and enterprise network operators to effectively manage network resource, to provide good quality service, to improve network performance, and to reduce downtime loss. It provides a scalable, end-to-end path management solution required for today's ATM network and service management. During the research and development of PMS, we have focused on two main issues: PVC operation support with automatic optimum route selection, and decision-making support for PVC fault identification and prevention. In this paper, we mainly present the PVC fault identification and prevention. The PVC operation support will be presented in detail in another paper. The main contributions of this paper are:

(1) The developed DPSAM framework is effective and feasible for building intelligent network management system;
(2) The developed PMS, supports network operators on:
   - *End-to-end path management with automatic optimum route selection,*
   - *Simplified PVC operation with user-specified requirements,*
   - *Effective decision-making for PVC fault identification and correction,*
   - *Proactive decision-making for PVC fault prediction and prevention.*

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(3) The implemented knowledge bases for PVC fault identification and prevention are significant and effective for guaranteeing PVC service quality.

This paper is organised as follows: Section 2 is an overview of the developed DPSAM framework and PMS; Section 3 describes the fault identification procedure; Section 4 is about fault prevention; Section 5 is on an experiment environment; and the final section concludes the paper.

2 DPSAM and PMS Overview

2.1 DPSAM Framework

DPSAM framework is designed for building intelligent network management systems, which are able to perform self-corrective and proactive preventive actions. Our strategy is to apply the needed artificial intelligence technologies such as machine learning and knowledge-based reasoning and network computing technologies such as CORBA to network management area. The central idea in the DPSAM framework is that the system continually monitors and analyses the network data and predicts changes in terms of historic and current states. If the management system anticipates that a fault will occur in the near future, it takes proactive actions; in case that a fault has already occurred, it takes reactive actions. The main features of such a management system can be summarised as follows:

- *Proactive*: the network management system is capable of predicting problems and avoiding them before they occur;
- *Self-adjusting*: the network management system is able to correct certain faults or malfunctions automatically; and
- *Distributed*: the network management tasks are distributed and agents can be located in different locations or platforms or network devices.

As shown in Figure 1, the DPSAM framework has two working models: decision-making support model and automatic management model for developers to implement network management systems for different requirements. The core components in the DPSAM framework are network state monitoring, fault identification, proactive actions and reactive actions, fault prediction, fault prevention, and automatic fault corrective and preventive actions. These software components are either embedded objects or independent agents that could be distributed over the network with the support of CORBA middle-ware. What we need to point out here is that the DPSAM framework can be applied not only to communication networks but also other applications such as diagnostic and maintenance of complex equipment.

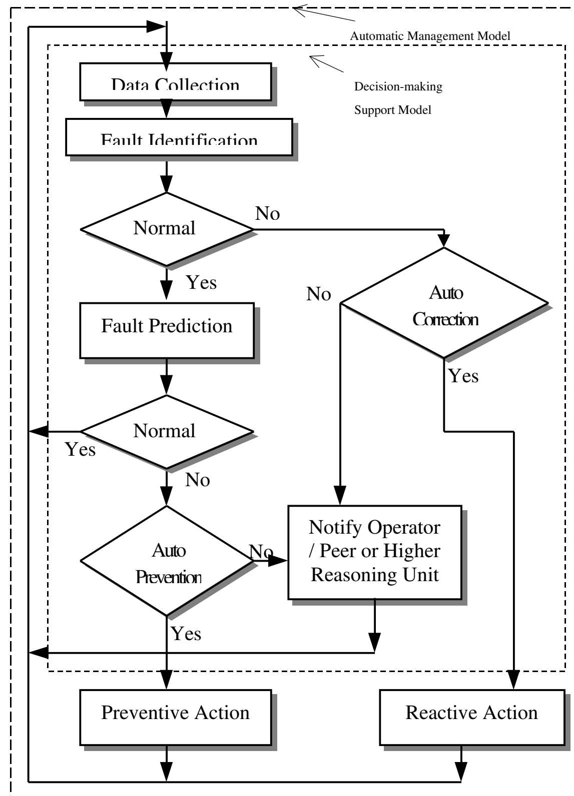

Fig.1 A Basic DPSAM Unit

2.2 PMS Overview

Based on the DPSAM framework, we developed PMS, a PVC management system for ATM networks. PMS is developed with AI, CORBA, and Web-based technologies. The developing environment is Jess4.0, JDK1.1.6, OrbixWeb3.1, Apach1.3.0 Web-server for Solaris platforms, and Microsoft Peer Web-server for NT platforms. PMS provides a scalable, end-to-end path management solution required for today's ATM network and service management. It offers a simple mechanism for setting up Permanent Virtual Path Connections (PVPC) and Permanent Virtual Channel Connections (PVCC) with a point-and-click user interface. The PVC can be established automatically or manually according to user-specified requirement and QoS parameters such as throughput and delay. PMS also monitors and maintains the managed PVCs by performing real-time traffic data analysis, fundamental alarm correlation, and incident association. When PMS detects some problems or foresees some future anomalies, it will perform the necessary correction or prevention automatically whenever feasible. On the situations that automatic actions are not possible, PMS will notify network operator with detailed information such as the nature of the problems, the location where they occur, the reasons why they happen, and the procedures to correct or prevent them.

PMS is developed based on a CORBA-based and three-tiered architecture. Such architecture accommodates existing management protocol standards such as SNMPv1, SNMPv2, and CMIP, and uses CORBA as the underlying distributed middleware. The key characteristic of a three-tiered architecture is the separation of distributed computing environment into three layers: presentation, functionality, and data components. This is needed for building flexible, scalable, reusable, maintainable application. CORBA was chosen as the distributed middleware because it is a stable standard with mature products available. The Object Request Broker (ORB) provides a way to invoke methods on remote objects without necessarily knowing the location of those objects, or even their exact functionality. Thus, CORBA clients can manage distributed devices without explicit knowledge of the composition, size,

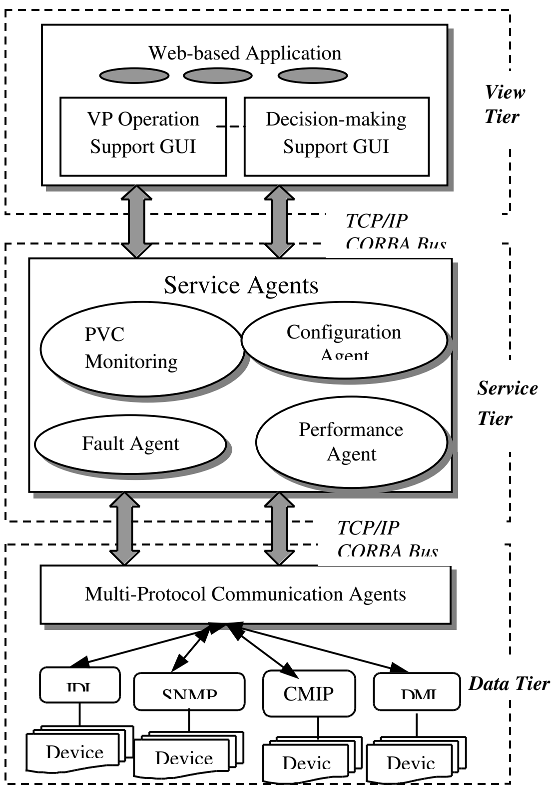

Fig.2 A CORBA-Based Three-Tiered Architecture

or topology of the network. As shown in Figure 2, the top tier is the view layer; the middle tier is the service layer; the bottom tier is the data layer. For the PMS prototyping system, these three tiers are implemented as follows.

View Tier. This tier is made up of user interface applications that provide various kinds of applications by invoking the methods of the objects in the middle tier which may be located in different locations and platforms over the network. PMS View Tier provides web-based user graphical interface for operator to access and control ATM networks from remote locations by using Java-enable browser. These downloadable applications include

- PVC operation support user interface;
- network representation and network element view user interface;
- PVC status user interface;
- user interface of decision-making support for PVC fault management; and
- interactive user interface for knowledge base update.

Some examples of PMS graphical user interfaces are shown as Figure 3.

Service Tier. It contains the service agents. The main service agents are configuration agent, fault agent, performance agent and PVC monitoring agent. They perform the PVC monitoring, operation, and management tasks that include fundamental functionality recommended by the OSI and TMN. They provide the service to the requests from View Tier applications. These agents could be distributed on different locations and different platforms, because they are designed to support CORBA IDL communication. The software components of DPSAM framework are embedded in these agents to perform the following PVC operations and management tasks:

- simplified PVC operations with automatic optimum path selection;
- fault identification and correction;
- fault prediction and prevention; and
- automatic fault correction and prevention.

Data Tier. This tier is usually made up of objects that interact with database management systems. Because PMS is developed to be able to manage ATM networks that contain multi-vendor equipment [10], this tier is made up of multi-protocol communication agents, which comprise different protocol objects such as SNMP, CMIP and DMI. Multi-protocol communication agents perform all the interacting operations with device agents and cope with the requests from service agents. In our implementation, these agents also perform a protocol-proxy task. They serve to service agents via CORBA IDL interface and map IDL requests to different protocol data objects. From the viewpoint of device, they map different protocol data objects to IDL data objects and deliver them to service agents. In terms of existing protocol device agents, they perform the role of the proxy agents to the device agents such as SNMP, CMIP, and DMI. The details how to map the data between different protocol will be reported in a different paper.

always exists when a progressive bandwidth sharing strategy is used. Its effects and handling methods in switches are different depending on different vendor equipment used in the network. It is assumed that congestion is a traffic problem and may be resolved by renegotiating for demanding a lesser PVC QoS request. If renegotiations are impossible and congestion persists, we need to rebuild or re-route the

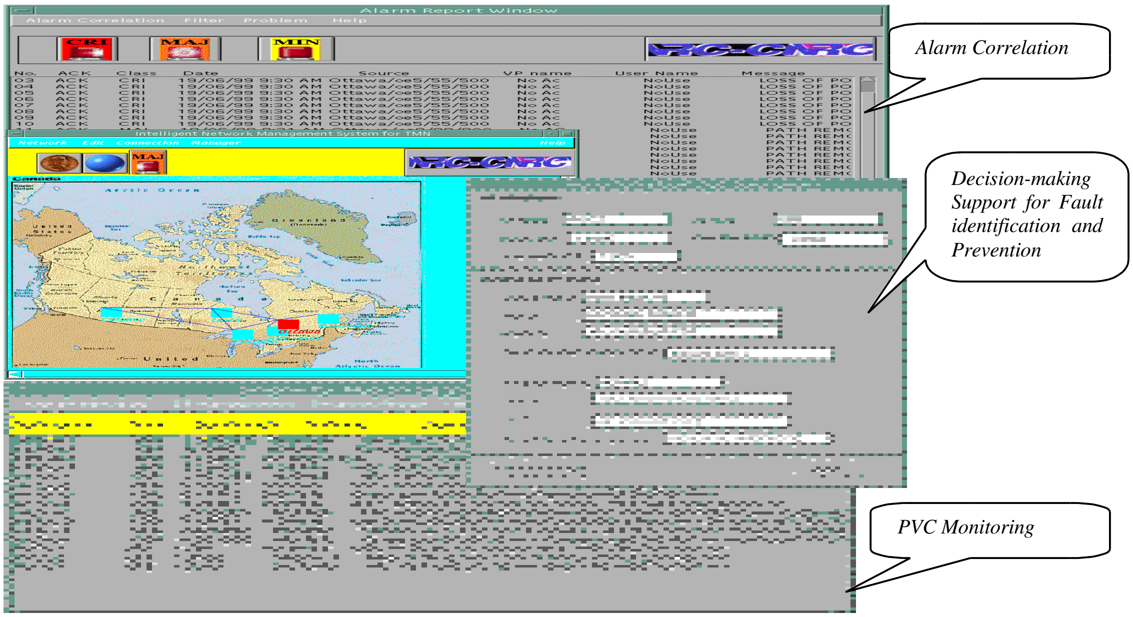

Fig.3 Examples of PMS Graphical User Interfaces

3 Fault Identification

3.1 PVC Fault Classification

According to PVC characteristics and the requirement of the PVC QoS, it is possible to classify PVC faults into four categories:

- Path Hardware Break (PHB);
- Path Software Break (PSB);
- Path Congestion(PC); and
- Path Overload (PO).

PHB represents the category of faults caused by hardware failures such as damaged transmission media, broken device, and power down. For example, when an OC3 card in a switch is broken, all the PVCs connected to this card will be treated as having PHB problems. PSB represents the collection of faults caused by software problems in switching system or errors in operation. PC and PO are used to reflect the PVC performance in PVC management. Congestion affected PVCs. Path overload mainly reflects the path traffic capability. It is caused by subscriber's traffic load and bandwidth usage. At the beginning of a PVC application, the subscriber might have anticipated a small traffic load and applied for a small bandwidth. With subsequent increase of traffic load, the PVC becomes overloaded. We assume that the overload may be avoided by renegotiating existing PVC QoS parameters. Overload is different from congestion. Congestion is caused by network traffic, or path routing, while overload is caused by subscriber's traffic load.

To represent the symptoms for these problems, we introduce the concept of "*incident*" and "*incident set*". *Incident*, denoted as *Ix,* is an object (or message) representing the symptom of a problem. An *incident set* consists of a set of incidents (I_1, I_2, I_3 … I_n). Corresponding to the path problems defined above, we define one incident set for each problem. These incident sets are noted as follows:

IS_{phb}♐ $(I_{phb1}, I_{phb2}, I_{phb3} \ldots\ldots, I_{phbi})$;
IS_{psb}♐ $(I_{psb1}, I_{psb2}, I_{psb3} \ldots\ldots, I_{psbj})$;
IS_{pc}♐ $(I_{pc1}, I_{pc2}, I_{pc3} \ldots\ldots, I_{pcm})$;
IS_{po}♐ $(I_{po1}, I_{po2}, I_{po3} \ldots\ldots, I_{pon})$.

Whenever there exists an incident, an incident set will be opened for the corresponding problem. It means that the path problem has happened if its incident set was opened. Otherwise, we say that the PVC problem is fixed or cleared when its incident set is closed. The defined incident object contains the following main attributions:

- *time stamp;*
- *severity;*
- *location;*
- *current status;*
- *reason;*
- *recommended reactive action for fixing current problems;*
- *predicted future status; and*
- *recommended proactive action for preventing future problems.*

These attributions reflect the key information in fault management: *Who, What, Where, When, Why, How and Future*. "*Who*" and "*Where*" indicate which switch or which group equipment has problem for the monitored PVC. Location answers these two questions. "*What*" means what kind of problem in the monitored PVC; current status is used to answer this question. "*When*" stands for the time when problem happened; time stamp can be used to answer this question. "*Why*" is to state the reason of the problem; the reason is responsible for this question. "*How*" is the action to fix PVC problem; the recommended reactive action is designed to handle this problem; "*Future"* means what will happen in the near future for the monitored PVC, the predicted future status is provided to handle this question. The task of PVC fault identification and prediction is to determine these attributions in formulating incidents.

3.2 Fault Identification

The procedures normally used by network operators to identify and correct a path problem in ATM network can be summarised as follows

- collecting necessary data such as alarms and traffic data for the monitored PVC from all network elements;
- detecting problems in terms of their knowledge of network elements, experiences, network topology and current network status;
- isolating the problem further by using other supporting means like loop test, echo test and backup analysis; and
- correcting the problem by taking a reactive action.

Because there are a great volume of alarms generated from the network elements and many of these may have derived from the same problem, it is hard for an operator to identify network problems. In addition, it is very common for an infrequent operator to make diagnostic errors in complex situation. To assist network operators to manage network and reduce the human error and misunderstanding in the process of fault identification, the knowledge-based approach is considered as one of the most effective approaches [2][5][6][7]. There have been numerous achievements in applying knowledge-based approach to alarm correlation. However, these knowledge-based alarm correlation systems can only reduce the amount of alarms, it cannot detect the problem from the viewpoint of PVC management requirement, and it also cannot help operator to make decision for PVC fault identification and prediction. Therefore, the operator still needs to make decision for PVC fault correction and prevention by himself. To assist the operators to effectively manage the PVC, we developed a knowledge-based system to identify the PVC problems and make decision for fault correction. This knowledge-based system is implemented by using Jess4.0. The knowledge base consists of DPSAM knowledge, PMS system knowledge, Generic PVC management knowledge, and vendor's ATM specification knowledge. As shown in Figure 4, knowledge-based fault identification comprises four main inference procedures: data collection, fault detection, fault isolation, and fault correction. They are described as follows.

3.2.1 Data Collection

Fault is a disorder occurring in the hardware or software of the managed ATM switches, or a problem caused by network traffic density and path routing. Alarm events are external manifestations of the happened faults. Alarm events are defined by ATM vendors and generated by ATM equipment in network, and they are observable to network operators. In the PMS, alarm events are important data that must be collected. Alarm events are very useful for detecting PHB and PSH problems. In order to effectively detect the problem of the path congestion and path overload, it is also necessary to collect traffic data for the monitored PVCs. Another reason why we need traffic data is that alarm events might be lost and not real time because they are sent to management system via notification. Consequently, we collect the alarm events from all the managed ATM switches and the traffic data for the monitored PVCs.

3.2.2 Fault Detection

The task of fault detection is to find out the symptoms of PVC problems from the collected alarm events and traffic data. According to the definition of the incident, the fault detection is to generate the incidents by using fundamental alarm correlation and traffic data analysis; then to associate the incidents and open an incident set for the PVC problems. In this section, we discuss alarm correlation, traffic data analysis, and incident association.

3.2.2.1 Alarm Correlation

In the network management area, alarm correlation is often used to aid the operator to diagnose the network fault by reducing the amount of alarms. In PMS, besides reducing the amount of alarm events, the fundamental alarm correlation is used to generate the meaningful incidents for incident association. The fundamental mechanisms of alarm correlation [3][4] mainly contain

[A,A,…,A] ➔ *A*	compression,
[A, B, p(A)< p(B)] ➔∅	suppression,
[nxA] ➔ *B*	count,
[A,A⊂B] ➔ *B*	generalisation,
T[A, B…] ➔ *C*	temporal relation,
[A, B, … , ∧∨¬] ➔ *C*	Boolean pattern.

3.2.2.2 Traffic Data Analysis

The task of traffic data analysis is to analyse the collected traffic data and to generate the incidents for happened problems if traffic data imply that the problem exists. Usually, traffic data analysis is used to detect the congestion and overload problems by monitoring *used bandwidth* of the managed PVC. The used bandwidth is obtained from the collected traffic data, which are "passing-in cells", "passing-out cells", "discarded cells", and "OAM cells". For example, when a PVC is being monitored, if its used bandwidth at given time gets close to or greater than the pre-determined upper-threshold of its bandwidth utilisation, a new incident will be formulated. Its attributions will be assigned: the time stamp is the given time; the location will be assigned to one of group equipment name or number, VPI and VCI; the current status will be set to "path congestion problem"; the severity will be assigned to "MAJOR". This opened incident will be used in the incident association.

3.2.2.3 Incident Association

The task of incident association is to open an incident set for the corresponding PVC problems in terms of the generated incidents from alarm correlation and traffic data analysis. To this end, the system needs to classify and group the incidents obtained from alarm correlation and traffic analysis into different incident sets and maps the incident set to the monitored PVC.

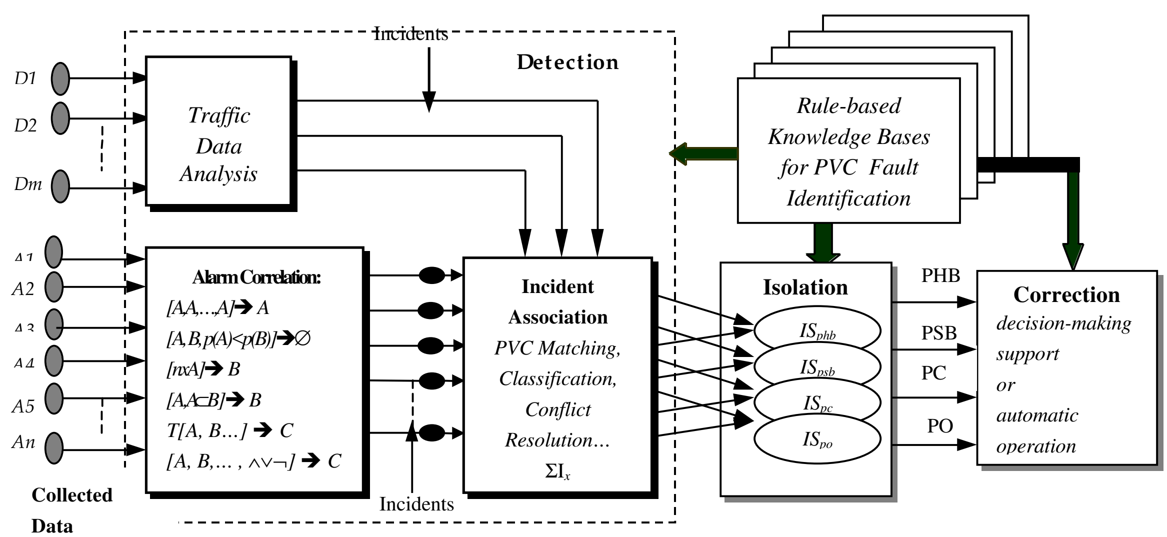

Fig.4 PVC Fault Identification and Correction

3.2.3 Fault Isolation

Once an incident set is opened in fault detection, we need to further confirm the problem. The task of fault isolation is to isolate the problem when the opened incident set contains several incidents. To confirm a problem, we could use other supporting means such as loop test. The assumption is that the monitored PVC can only have one problem at any given time. In this step, the reason and location will be also determined.

3.2.4 Fault Correction

The fault correction is to determine an effective reactive action for the identified problem. This task is done with a policy-based fault correction strategy. When the problem can't be corrected automatically, or the decision-making support model of the DPSAM is used, it will give the decision-making supporting information to assist the operators.

4 Fault Prevention

In order to prevent the fault and provide the proactive PVC management support, it is necessary to predict the future status for the managed PVCs. Considering that ATM network has complexity, wide-scale, dynamic network configuration, we adopt a Neural Network (NN) approach to predict the future status according to historical data and current status. To reflect the dynamic change of ATM network, the PVC configuration data are included in the neural network training input parameters. In this study, the training of the designed neural network was done in off-line environment. In on-line path monitoring, the NN component is used to predict the future status for the monitored path. According to the predicted status, the fault detection is used to detect the future problems.

5 Experiment

To test the prototyping system and evaluate the effectiveness of the DPSAM framework, especially decision-making support for fault identification and prevention, we built an ATM network simulator and a real ATM network as an experiment environment. The prototyping system is connected to the ATM network simulator and the real ATM networks through TCP/IP network. The communication protocol between PMS and ATM network simulator is CORBA IDL, and between PMS and the real ATM network is SNMP. The ATM network simulator will generate raw alarm events and raw traffic data in terms of X.721 standard

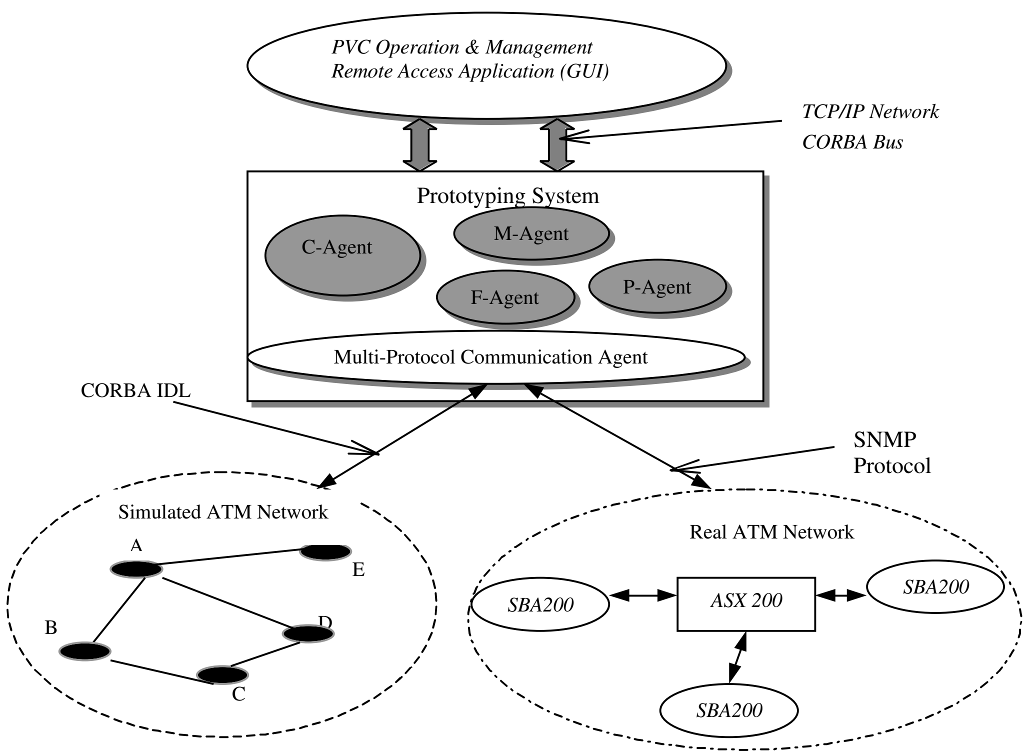

Fig. 5 An Experiment Environment

and vendor's specifications. The alarm events are generated according to simulated network problems. The traffic data are generated in terms of QoS parameters of the managed PVCs and the simulated network problems. As shown in Figure 5, the real ATM network is set up with a Fore System ASX200 switch and SBA200 ATM adapters. Several PVCs are set up between two Sun Workstations through ATM switch ASX200 and SBA 200 ATM adapters. By using such environment, it is not hard to test the effectiveness of decision-making support for fault identification and prevention.

6 Conclusions

In this study, based on the developed DPSAM framework, we have prototyped PMS, a web-based PVC management system for ATM networks, by using AI, CORBA, and web-based technologies. This PMS can provide effective support to network operators on:

- End-to-end path management with automatic route selection;
- Simplified PVC operation with user-specified requirements;
- Decision-making for fault identification and correction; and
- Proactive decision-making for fault prediction and prevention.

The presented knowledge-based fault identification and prevention for PVC management are necessary for PVC QoS guarantee and service management. As to our future work, we need to enhance the knowledge base and its management. We will also focus on the policy-based automatic fault correction and prevention.

7 Literature

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