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QoS Monitoring for ATM-based Networks

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Abstract

Forthcoming applications, especially in the multimedia area, require communication services with guaranteed quality of service (QoS). Due to dynamic changes in the network, it is crucial to monitor continuously the achieved QoS during data transmission. This paper focuses on QoS monitoring of ATM connections in end systems as well as inside the ATM network. QM-SSCS, a service specific convergence sublayer for AAL5 is presented which supports QoS monitoring. Moreover, the ATM Network Monitor ANEMON, an entity for collection of topology and QoS-related information within an ATM network, is described.

Keywords

Quality of Service, Management, Monitoring, ATM Networks, AAL Protocols

1 INTRODUCTION

Service integrated networks such as ATM must be able to provide communication services for a variety of applications with totally different service requirements. Typically, prior to data transfer, applications have to specify their communication requirements in terms of QoS parameters such as throughput, delay, jitter, and reliability. Based on these service requirements, communication resources are reserved and assigned to individual connections in all involved network nodes. However, often it is not sufficient to reserve resources only. Additionally, monitoring of QoS parameters must be applied to ensure that the negotiated QoS parameters are really achieved. A *QoS monitor* computes current values of QoS parameters and is able to detect QoS violations by comparing these values with the negotiated QoS parameters. Based on the results of the QoS

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monitor, resources can be adapted accordingly. Thus, QoS monitoring plays an integral part in a QoS maintenance feedback loop (Aurrecoechea et al. 1995).

A QoS monitor can be applied at different levels of an ATM network where it is able to measure AAL- or ATM-related QoS parameters. Monitoring at AAL layer in end systems can be used to detect violations of application-oriented QoS parameters. Additionally, monitoring at ATM level in end systems is able to determine ATM-related end-to-end QoS parameters, but it is not able to find the reasons of a particular violation. Only monitoring inside an ATM network can identify ATM switches that are responsible for violations detected at the ATM or AAL layer in an end system. However, while QoS monitoring of single connections is typically located in end systems, traditional network monitoring deals with performance characteristics of network nodes and in general does not address QoS of connections.

In order to provide a QoS monitoring for ATM networks, enhancements in ATM end systems as well as in ATM switches are necessary. Monitor entities must be applied in end systems to measure end-to-end QoS parameters. Moreover, ATM switches must be enhanced to provide necessary monitoring information for ATM network monitors in order to measure connection-related QoS parameters within an ATM network. Finally, it is essential to develop management information bases (MIBs) containing QoS related parameters of connections that can be accessed by monitoring and management entities.

This paper presents an approach to QoS monitoring at AAL layer in end systems as well as inside ATM networks. In section 2, special aspects of QoS management in ATM networks are reviewed. QoS and traffic parameters of the traffic contract are discussed in some detail and the current state of connection-related QoS parameters in MIBs is presented. In section 3, an approach to QoS monitoring at AAL layer and protocol enhancements for QoS monitoring are introduced. Section 4 addresses monitoring inside the ATM network. Firstly, so-called *monitoring agents* are presented that provide well defined interfaces to ATM switches. Additionally, *ANEMON*, a network monitor for monitoring connection-related QoS parameters of several ATM switches is described. Finally, section 5 summarizes some of the central issues of this paper and outlines future work.

2 QOS MANAGEMENT IN ATM NETWORKS

ATM networks were designed to support QoS requirements of a variety of forthcoming applications including audio, video, and classical data traffic. At call setup, each application specifies its requirements for the requested ATM connection in a *traffic contract* negotiated between application and network. Typically, the traffic contract includes two parts describing traffic and QoS characteristics (Onvural 1995) by a connection *traffic descriptor* and a so-called *service class* identifying the supported QoS parameters. With this traffic contract, the network guarantees the requested service as long as the application traffic stays within the limits of the traffic descriptor. In this section, the traffic descriptor as well as the service class are described in some detail since they specify the parameters suited for QoS monitoring. Furthermore, an overview over QoS parameters defined in management information bases (MIBs) is given.

2.1 Traffic Description

With a traffic description, an application provides a detailed characterization of its traffic behavior. Particular traffic aspects are specified by several *traffic parameters*. Currently, the following traffic parameters are defined by the ATM Forum (ATM-Forum 1996a): Peak cell rate (PCR), Sustainable cell rate (SCR), Minimum cell rate (MCR), Maximum burst size (MBS), and Cell delay variation tolerance (CDVT). Most of these traffic parameters are application-specified descriptions of the throughput of a connection negotiated between network and application. In contrast, only the parameter CDVT is specified by the network and not negotiated during connection set-up. This parameter is needed by the network in order to determine the maximum number of cells that can arrive back-to-back at the transmission link (Onvural 1995).

Additionally, a classification of traffic parameters is given by several *traffic types* defining allowed combinations of traffic parameters. These traffic types consider the usage of the ATM header CLP field (Cell loss priority) and the tagging mechanism as well as the PCR, SCR, and MBS parameters. The CLP field distinguishes cells with high (CLP = 0) and low (CLP = 1) priority. This bit may be used alternatively by an application or by the network. In the case of applications that do not stay within the agreed traffic contract, the network uses the tagging mechanism in order to allow nonconforming cells to enter the network with CLP = 1. The following traffic types are currently defined:

- atmNoTrafficDescriptor: best effort traffic type
- atmNoClpNoScr: PCR for CLP = 0+1 specified
- atmClpNoTaggingNoScr: PCR for CLP = 0+1 and for CLP = 0 specified
- atmClpTaggingNoScr: PCR for CLP = 0+1 and for CLP = 0 specified, tagging requested
- atmNoClpScr: PCR, SCR, and MBS for CLP = 0+1 specified
- atmClpNoTaggingScr: PCR for CLP = 0+1, SCR and MBS for CLP = 0 specified
- atmClpTaggingScr: PCR for CLP = 0+1, SCR and MBS for CLP = 0 specified, tagging requested

The supported best effort traffic type gives no service guarantees and thus, requires no traffic specification and no negotiation. In contrast, all other traffic types need the specification of PCR for CLP = 0+1, which refers to the aggregated traffic of cells with CLP = 0 and CLP = 1. Additionally, some types require the specification of the SCR and the MBS parameter.

2.2 Service Classes

By selecting one of several service classes for a requested connection, an application is able to choose between different service characteristics. In general, applications have different service requirements and thus, by selecting a suited service class, each application is able to specify the requested service in detail over QoS parameters defined for the selected class. The traffic management specification version 4.0 (ATM-Forum 1996a) currently defines the following five service classes: Constant bit rate (CBR), Real-time variable bit rate (RT-VBR), Non-real-time variable bit rate (NRT-VBR), Available bit rate (ABR), Unspecified bit rate (UBR). In a first step, service classes can be classified by their timing requirements (Garrett 1996). The CBR class is used for real-time applications with tightly constrained delay and jitter requirements, such as uncompressed voice and video. On the opposite, the UBR class is not sensitive to time relations at all. This class supports connectionless data traffic that requires no guarantees form the network. Additionally, a second classification step identifies simple and complex service classes. CBR and UBR are both simple classes, while RT-VBR, NRT-VBR and ABR are complex classes derived from CBR and UBR. RT-VBR is derived from CBR and thus, requires tightly constrained delay and jitter, too, but the source generates traffic that varies over time. NRT-VBR as well as ABR are complex classes derived from UBR. The NRT-VBR is defined for non-real-time applications with bursty traffic characteristics and delay and loss requirements. Finally, the ABR service is especially designed for applications that are able to react to the current network load. Such applications (e.g., TCP) adopt their transfer rate based on feedback signals from the network.

In general, the detailed QoS requirements of applications are specified with a number of QoS parameters. But only subsets of the defined QoS parameters for ATM networks are relevant for each of the described service classes. The following list gives an overview on currently well known QoS parameters for ATM networks (Onvural 1995): Cell error ratio (CER), Severely errored cell block ratio (SE-CBR), Cell loss ratio (CLR), Cell misinsertion rate (CMR), Cell transfer delay (CTD), Mean cell transfer delay (MCTD), Cell delay variation (CDV). Reliability of a connection is described by the first four parameters, the next two characterize delay, and the last one addresses jitter. Up to now, there is no possibility for applications to specify QoS parameters while a new connection is requested. After successful negotiation, the resulting values of the QoS parameters are just indicated from the network.

2.3 QoS Parameters in Management Information Bases

Management information bases (MIBs) are very well suited for accessing management and monitoring information on remote systems. But, only information collected in MIBs can be accessed in this way. For ATM networks, several different MIBs were defined up to now, e.g., ATM-MIB (Ahmed & Tesink 1994), and

ILMI-MIB (ATM-Forum 1996b)). Generally, monitoring information can be classified into information related to negotiated values of the traffic contract and information describing measured values of QoS parameters. For the QoS and traffic parameters at ATM cell level described above (section 2.1 and 2.2), the defined MIBs contain managed objects for some of the negotiated parameters, but for nearly none of the measured values. In ATM-MIB and ILMI-MIB, the traffic contract of an established connection is included by storing the traffic descriptor type and the related traffic parameters (e.g., atmClpNoTaggingScr and the negotiated values of PCR, SCR, and MBS). But, most of the measured values contained in both MIBs are related to physical ATM ports. Thus, they cannot be used for QoS monitoring of ATM connections because their values represent the sum over all ATM connections at one port. For instance, the object ifInOctets for ATM interfaces (Ahmed & Tesink 1994) measures the incoming bytes for one physical ATM port whereas objects monitoring incoming bytes of one particular ATM connection are currently not defined. Thus, information on measured throughput (e.g., PCR and SCR), reliability (e.g., CER and CLR), or time-related QoS parameters (e.g., CTD and CDV) of connections is not available yet.

At the moment, the only MIB information measured for connections is related to the AAL layer. Table aal5VccTable of the ATM-MIB contains three counters on errored AAL5 data units (CRC errors, SAR timeouts, and oversized SDUs). But, this information is available only in end systems and related to AAL data units whereas the traffic and QoS parameters described above are cell-related.

3 AAL LAYER QOS MONITORING

A first step to QoS monitoring of ATM networks is the end-to-end monitoring of ATM connections. The second step is a detailed monitoring within the ATM network which is addressed in section 4. In end systems, the interface to the ATM subsystem is provided by the service access point of the AAL layer. At the moment, the most commonly used AAL type is AAL5 which is implemented on nearly all available ATM adapter cards for end systems. Therefore, the AAL layer QoS monitoring presented in this section is based on *AAL5*. Connection-oriented QoS at the service access point of AAL5 can be described in terms of throughput, delay, jitter, and reliability (Jung 1996). As discussed in section 2.3, QoS parameters for AAL5 layer monitoring should be related to AAL5 data units since the AAL5 layer operates on this data unit size.

In the following, an *autonomous entity for monitoring QoS* in high performance environments is described. This QoS monitor is used for monitoring at the service access point of the AAL5 layer presented in this section. A special MIB defined for AAL layer QoS monitoring is also introduced. Finally, a *service specific convergence sublayer* for AAL5 is presented in order to integrate the required monitoring information into the regular data flow.

3.1 The QoS Monitor

QoS monitoring in end systems is concerned with the collection of several QoS parameters and the detection of QoS violations by comparing the measured QoS parameters with the limits negotiated in the traffic contract. A flexible QoS monitor has been developed and implemented that is able to operate besides alternative protocols under high data rates of networks, such as ATM (Schmidt & Bless 1996). In a second step, this QoS monitor has been placed at the AAL interface monitoring AAL5-related throughput, delay, jitter, and reliability parameters for each established connection. A monitor located at the sender is able to detect whether the application obeys the traffic specification and additionally, a monitor at the receiver is able to detect QoS violations of the ATM network by continuously measuring end-to-end QoS parameters.

The QoS monitor is placed in an autonomous entity that asynchronously communicates with the monitored AAL protocol. Furthermore, the monitor operates event driven, i. e., the AAL protocol collects relevant information, reads the system clock, associates collected monitoring events with a time stamp, and informs the monitor entity. Subsequently, this one computes QoS parameters and checks for QoS violations. Reactions of the monitor can be configured flexibly by a monitoring policy. Possible reactions are periodical reports, reports on demand, immediate reports of QoS violations, or reports of warnings.

Additionally, an SNMP agent extends the QoS monitor in order to integrate the monitoring results into classical SNMP management. For usage of the QoS monitor at the AAL interface, a special MIB has been defined. This *AALQM-MIB (AAL QoS Monitoring MIB)* contains measured values of throughput, delay, jitter, and reliability (e.g., the current, minimum, and maximum value) for each monitored connection. Moreover, the limits of each parameter defined by the application are included.

3.2 A Service Specific Convergence Sublayer for QoS Monitoring

The information required to calculate AAL-related QoS parameters is obtained by additional control information included in each AAL5 data unit. Therefore, a new SSCS (Service Specific Convergence Sublayer) for AAL5 was defined. This *QM-SSCS (QoS Monitoring SSCS)* operates on top of the AAL5 CPCS sublayer and adds a four byte sequence number as well as an eight byte time stamp to each user data unit (Figure 1). Moreover, two fields for padding at the SSCS sublayer are included. With help of this additional information, all monitored QoS parameters in the AALQM-MIB can be computed. The sequence number is used by the receiver to detect the loss of AAL5 CPCS data units in order to calculate the error-related parameters. For computation of time-related parameters such as delay and jitter, the time stamp describes exactly the time the data unit was sent. The required synchronization of the local times at the sender and receiver can be realized by using synchronization protocols like NTP (Network Time Protocol (Mills 1992)). Finally, throughput parameters of the AALQM-MIB can be calculated by using the local time at the receiver and the length field in the AAL5 CPCS trailer containing the size of the CPCS payload.

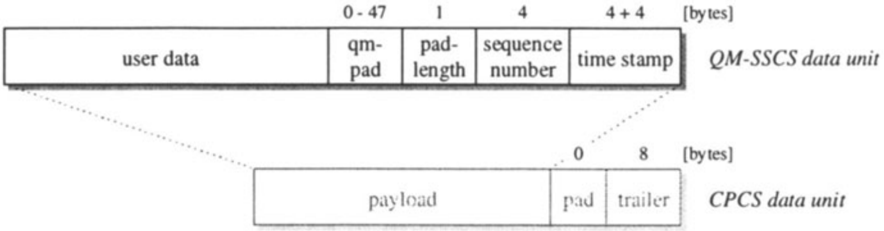

Figure 1: QM-SSCS for AAL5 QoS Monitoring

Additionally, padding is realized by two fields in the QM-SSCS data unit. The field qm-pad is used instead of the CPCS pad in order to align the length of the resulting CPCS data unit to a 48 byte boundary. Thus, using the QM-SSCS, the length of the CPCS pad field is always zero and the sequence number and time stamp are located in fixed positions of the last ATM cell when the CPCS data unit is segmented. SSCS sublayer padding is not necessary for AAL layer QoS monitoring on end systems. However, for monitoring ATM connections on switches, it will be very useful having all monitoring control information in one cell that can be easily identified (ATM header payload type = '1'). Details on the usage of this characteristic can be found in section 4.1. As a result of SSCS layer padding, an additional pad-length field is required for identifying the end of user data. The length field located in CPCS trailer cannot be used any longer since the padding is now located within the CPCS payload.

Implementation of the QM-SSCS is currently done on DEC ALPHA workstations under the operating system Digital UNIX V3.2d. In order to have direct access to the ATM subsystem of ALPHA workstations an ATM API (ATM application programming interface, (Dresler et al. 1997)) has been implemented. This ATM API realizes a service access point for the AAL5 CPCS sublayer. The implemented QM-SSCS integrates all monitoring information into the user data flow and performs the required interaction with the QoS monitor (cf. section 3.1).

4 QOS MONITORING WITHIN ATM NETWORKS

AAL layer monitoring can only provide an end-to-end view on the QoS of connections. In case of detected QoS violations, no detailed statements on their reasons can be made. The switches within the network must be monitored in order to obtain a complete monitoring of ATM networks. This paper proposes an *ATM Network Monitor (ANEMON)* for monitoring switches in an ATM network. As shown in Figure 2, the ANEMON monitor is located on a dedicated monitor station. By communicating with *monitoring agents* of switches, ANEMON collects information on the topology of the ATM network and on QoS parameters of selected connections. In the following, section 4.1 motivates the usage of monitoring agents and section 4.2 describes the ANEMON monitor in detail.

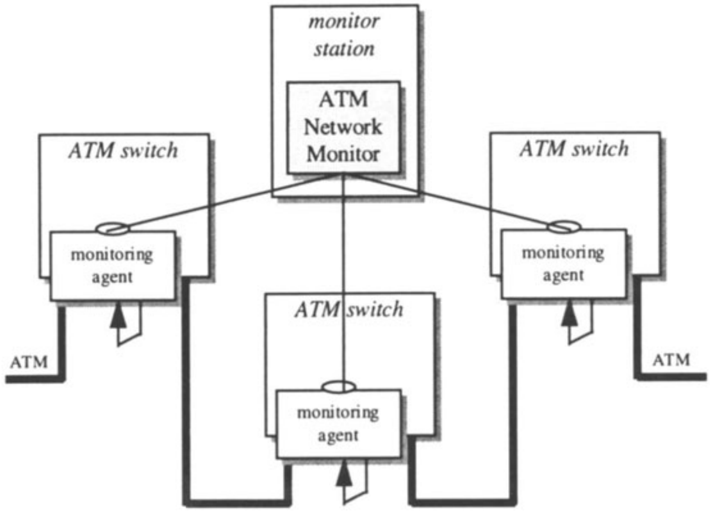

Figure 2: Scenario for the ATM Network Monitor (ANEMON)

4.1 Monitoring Agents for ATM Switches

Each monitoring agent shown in Figure 2 realizes a well defined interface to one switch. At the moment, a proxy agent approach is required for monitoring agents since management protocols (e.g., SNMP, Telnet, etc.) and supported management information (e.g., ATM-MIB (Ahmed & Tesink 1994), and ILMI-MIB (ATM-Forum 1996b)) are in general different for switches from individual vendors. Using a proxy agent acting as management gateway, these differences are hidden and one well defined interface is provided. The proxy agent translates received requests according to the protocol characteristics of the individual switch and forwards them to the switch. Responses of the switch are re-translated and sent to the initiator of the request. In order to build the well defined interface of monitoring agents, *SNMP* was chosen as management protocol because of its great acceptance. The information provided at the SNMP interface of the monitoring agent is defined in a dedicated MIB designed for monitoring purposes (Ritter 1997).

In the future, the presented monitoring agents may be integrated into ATM switches. This leads to a better performance and more possibilities for information retrieval. For QoS monitoring, especially for time-oriented parameters, additional monitoring information such as time stamps has to be integrated into the regular data flow of connections and must be evaluated by each switch. However, ATM switches operate on the very small ATM cells. The integration of monitoring information into each ATM cell is not useful because of the small cell size and will result in a great protocol overhead. Thus, the only way of transporting monitoring information is the integration of dedicated monitoring cells into regular data flow. One possible solution may be the usage of OAM cells (Operation and Maintenance (ITU-T 1993)), but many switches implement a separate data path for OAM cell flows. As a consequence, monitoring results do not reflect the characteristics of individual data connections. A better solution is the integration of monitoring information into some of the regular data cells. For AAL5-based connections, this can be achieved by using the described QM-SSCS with additional SSCS padding as shown in Figure 1. All information useful for QoS monitoring is located in the last ATM cell of a segmented AAL5 data unit. The CPCS trailer contains the size of the AAL5 data unit and the SSCS trailer a sequence number as well as a time stamp. With SSCS padding, all these fields are located in fixed positions of the last ATM cell. Moreover, the last ATM cell of an AAL5 data unit can easily be identified by the payload type field in the cell header since this is the way AAL5 detects the end of its data units. ATM switches have to be extended in order to detect cells with payload type set to „1“ and to deliver a copy of these cells to the monitoring agent on the switch. Over all, this approach enables to perform a powerful QoS monitoring for connections within an ATM network.

Currently, the monitoring agent is implemented as proxy agent being located on a workstation (Ritter 1997). The communication between proxy agent and switch has been optimized for the GIGAswitch/ATM from Digital Equipment Corporation. Two protocols, SNMP as well as Telnet, are used for that communication. The Telnet interface of the monitoring agent is characterized by a very flexible design in order to adapt it to different Telnet interfaces of switches or to changes of the Telnet interface of one particular switch (Wiltfang 1996).

4.2 The ATM Network Monitor

The ATM Network Monitor (ANEMON) represents an entity for monitoring of ATM networks that is designed to provide detailed information on the state of the network and the included components (Wiltfang 1997). From an architectural view, this entity can be classified as management middleware for ATM networks since the service of the ANEMON monitor will be used by management applications. Monitoring information is accumulated from all switches within the ATM network and, after successful evaluation, presented to the applications.

Two different types of information are collected by the ANEMON monitor: information on the *topology of the network* such as configuration and state of switches and second, *QoS parameters of selected ATM connections*. Therefore, the architecture of the ANEMON monitor shown in Figure 3 includes two databases, one for topology information and one for QoS-related information.

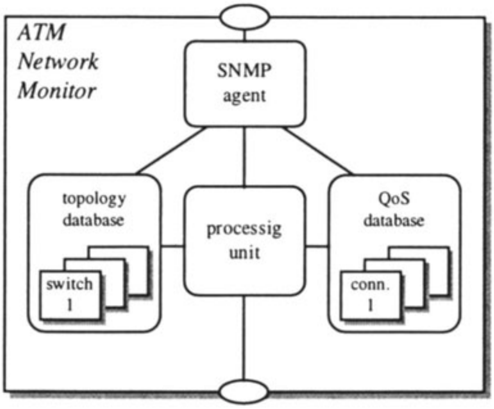

Figure 3: Architecture of the ATM Network Monitor (ANEMON)

The topology database of the ANEMON monitor contains information about the monitored switches. By an initial configuration, each switch has to be registered at the ANEMON monitor. After that, further information such as number and state of ATM ports is obtained by communicating with the switch. For each active ATM port, the ANEMON monitor determines the related ATM port at the other end of the physical link and thus, information on network topology is successively collected. Since the type of information contained in the topology database is almost static, monitoring communication required to collect and update this information is very small. The update interval can be set to a value in the range of several minutes. More dynamic information on state and direction of currently established connections is also stored in the topology database in order to precompute routes of connections within the network. This enables a faster reaction if the ANEMON monitor is requested to monitor QoS parameters of one connection. Generally, the described information in the topology database is necessary in order to obtain the information stored in the second database, the so-called QoS database. Moreover, information stored in the topology database can be used to generate a graphical representation of the recent network state and topology.

Information on QoS-related parameters of selected connections is stored in the QoS database. In order to avoid high network load caused by monitoring traffic, information in the QoS database is only collected on demand. Therefore, the ANEMON monitor has to be requested to monitor QoS parameters of a selected connection in a specified interval. Such a request must identify the connection, the QoS parameters to be monitored, and the update interval for monitoring. For instance, monitoring of transmitted and lost cells can be requested by an application that is located on an end system and has detected a QoS degradation. Because of the dynamic character of QoS parameters, the polling interval for information contained in the QoS database is very small (e.g. seconds). Since a connection must be specified by its connection end point (VPI, VCI) on one end system, the ANEMON monitor needs information contained in the topology database in order to locate the connection within the network and to identify the involved switches.

Furthermore, an SNMP agent and a processing unit are located on the ANEMON monitor. The agent provides access to the information contained in both databases and the processing unit controls all actions within the ANEMON monitor. The implementation of the presented ANEMON monitor is currently done in form of a first prototype.

5 CONCLUSION

This paper presents an approach to QoS monitoring in ATM-based networks. QoS monitoring is applied at two different levels of ATM networks. Firstly, end-to-end QoS monitoring of ATM connections is performed at the AAL layer in end systems. The integration of additional monitoring information into the regular data flow is realized by a QoS Monitoring Service Specific Convergence Sublayer (QM-SSCS) defined for AAL5. By using a powerful QoS monitor (Schmidt & Bless 1996), SSCS monitoring information is evaluated in end systems and directed to the AALQM-MIB. In a second step, QoS monitoring is applied within ATM networks. Only monitoring inside of each involved ATM switch is able to determine the exact reason of a QoS degradation in an ATM network. The presented ATM Network Monitor (ANEMON) was designed to collect information on network topology as well as on QoS parameters of selected connections. QoS monitoring performed by the ANEMON monitor is although supported by the format of the QM-SSCS data unit. For AAL5 connections, this leads to a powerful support of QoS monitoring within ATM networks when a simple enhancement is integrated into ATM switches.

Currently, the implementation of the presented QM-SSCS protocol is done and first test results on behavior and performance will be available soon. Furthermore, a first prototype of the ANEMON monitor is being implemented. This prototype will be able to collect all useful information about the topology of an ATM network and, up to now, some connection-oriented QoS parameters. Connection-oriented parameters are currently restricted by the information being available from ATM switches, especially for the GIGAswitch/ATM. In the future, the concept of evaluating QM-SSCS layer information within ATM switches will be considered in detail in order to achieve a powerful QoS monitoring within ATM networks.

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