

Service Level Management in ATM Networks

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Abstract

Contractual relation between customers and telecommunications service providers are becoming increasingly complex, due largely to changes in the marketplace and growth in the number and complexity of services on offer. In order to guarantee a certain quality of offered service and in response to customer needs, some mechanisms of service level management must be applied. The service level management in telecommunication networks is made by a agreement, established during the service subscription, which is used by customers and service providers to control the service level. This paper introduces a service level management system, which can be applied to different telecommunication systems. Initially, an architecture for service level management is presented, including many aspects, from the creation of the service level contract, up to monitoring the service level. Moreover, it is presented a complete service level management system for ATM Networks, including contractual management and information gathering.

Keywords

Quality of Service(QoS), Network Management, Service Level Agreement(SLA), ATM.

1 Introduction

The competition progressively introduced into service provision market and the growth in the number and complexity of services on offer is providing more and more choices to telecommunication customers and are encouraging them to become increasingly discerning in terms of the quality of service guarantees. Service providers are realizing the need to differentiate their products by adding value to their services, and also by providing special consideration to customer needs. For these reasons, the contracts between service providers and customers of telecommunication services should contain elements allowing a clear definition regarding the service levels, protecting the interests of both. One mechanism to supply this is the Service Level Agreement (SLA) Management System, which allows the customer to verify if the offered quality of service(QoS)[1][2] in according to the agreed values.

The term service level agreement (SLA), used in this document, refers to the service contract between providers of telecommunications service and their customers. The SLA is a document that defines service characteristics for the regular contract accomplishment. The SLA should contain a

number of objectives and measurable parameters, which the service provider guarantees to their customers.

An SLA management system supplies information on how the contracted service has been supplied in a certain period, monitoring if the service on offer is in accordance with it. Typically, SLAs include statements about the system or service availability, the time to identify malfunctions, the time to repair, the provisioning time and other quality of service targets. Therefore, the SLA Management System has as its main objective, to determine how the SLA is being executed, providing a proof to the customer that the service provider is meeting its commitments. Another important objective of SLA, concerns the service understanding, by providing a standard approach to service level evaluation among multiple organizations.

Many operational benefits can be achieved with an SLA[3] management system: validation of offered QoS, the ability to refund values for non execution of the objectives established in SLA, the identification of points in the infrastructure where capacity needs to be improved, a global vision of service deployment, and automated QoS report. The benefits specific to the customers are the possibility to compare the QoS levels among several suppliers, the reception of consistent performance data, and QoS control and trends. The main benefit to service providers is the improvement of their customer satisfaction, although other operational benefits can be perceived too, for example, the automatic generation of performance reports, the structured service level information processing, and the provision of automatic service level management tools.

This work describes an SLA Management System for the telecommunications infrastructure, conceived and implemented to be independent of platform, protocols, service type and topology. Its main feature is the annotation of thresholds and rules to automate service management actions, according to the service type. It is also discussed how the necessary performance information could be collect and processed, allowing the validation of the defined rules. We also, introduce the definition of SLA contracts and all its components, and the definition of rules and actions that should be taken based on the collect data. Finally, a model for SLA in ATM networks is discussed.

2 Management of Service Level Agreements

The relationships between service providers and customers became complex, hindering the understanding of the terms that characterize the quality of a telecommunication service for their customers. Based on these ideas, members of TeleManagement Forum (TMF)[9] created a recommendation to be used as base for telecommunication services negotiation in terms of Service Level Agreement.

2.1 Service Level Agreement

A service level agreement is a formal negotiation between a provider and a customer of a telecommunications service. It is defined with a common group of terms for service description (i.e. priorities, responsibilities, thresholds, QoS[6] values and other parameters). An SLA contains many aspects of the relationship between customer and service provider, describing the expected service performance.

SLAs are used by service providers to supply the customers with a contractual service level warranty, and it can be based on complex performance measures, to assure that the service level is being respected. Typically, the service provider accomplishes the service level measures and

informs the customer, or it allows the customer to obtain the information through some automatic access method. Examples of involved elements in SLA negotiation are presented in the Figure 1.

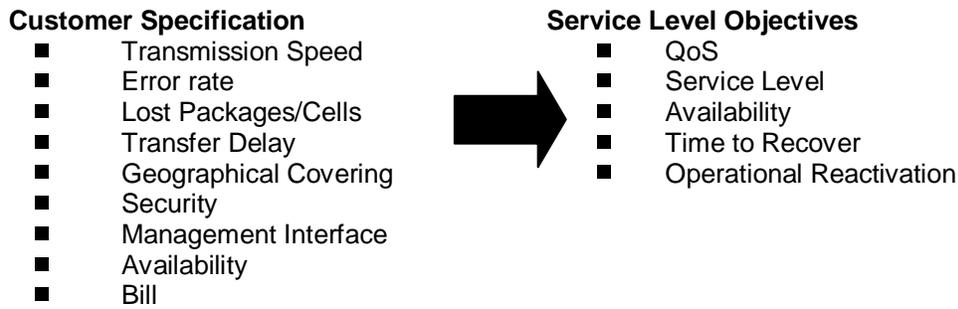


Figure 1 Negotiation between Service Provider and Customer

A SLA should contain a number of objectives, defined by means of measurable parameters, that the service provider commits to provide to their customers. These parameters may be reported in order to allow the verification by customer that the rules established in the contract are being observed. Typical SLAs include statements about:

- system or service availability;
- time to identify the cause of a customer malfunction;
- time to repair a malfunction;
- provisioning time; and
- quality of service measures.

2.2 Quality of Service Description

The QoS parameters that are governed by an SLA supply a general vision of how the service is actually offered. The QoS measures given to the customer are composed by a group of measures classified as operational measures and other classified as platform specific measures. The operational measures are related with the service provider performance and with its ability in the identification of operational problems, correction of faults and provisioning times. The service specific measures take into account a group of platform specific QoS parameters, which are specific of the network technology used to provide the service. Examples of parameters that can be used for the quality of service description are presented in Figure 2.

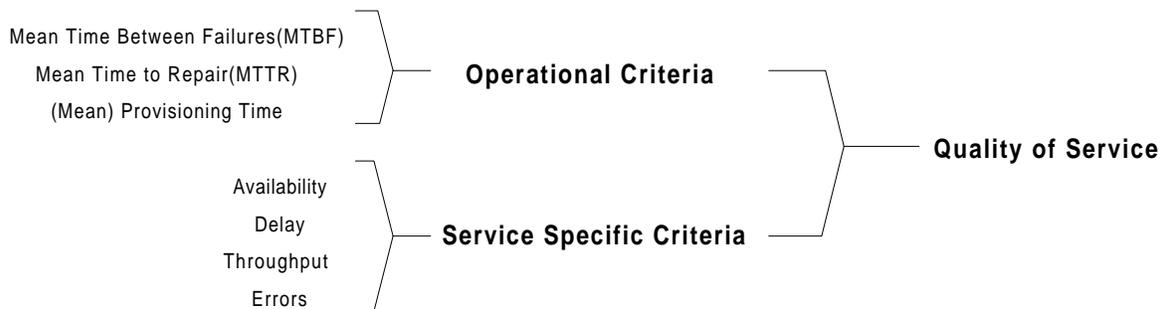


Figure 2 Approaches for Quality of Service Description[8]

2.3 Service Availability

Through a research among its associates, TMF tried to identify the most important parameters for QoS composition. The research results showed that service availability (SA) is the parameter that customers are more interested in. The TMF[8] established a service availability description and calculation pattern for the understanding convergence around the meaning of these parameters. There exist other availability definitions different from that proposed by TMF, but none of them is capable to describe service availability in a clear way and without interpretation mistakes. With the calculation models for service availability definition, the TMF is trying to establish a practical and common notation that can be used for SLA verification.

The service availability definition proposed by TMF is expressed as a percentage, and indicates the time during which the contracted service at the respective service access points (SAPs) is operational. Operational means that the customer has the ability to use the service as specified in the SLA. Any event that reaches the service at the SAP, causing some service degradation, is defined as an outage, and the time interval in which the service was affected is defined as outage interval. The basic definitions for service availability (SA%) and service unavailability (UA%) are showed in Equation 1.

$$SA\% = 100\% - UA\%$$
$$UA\% = \frac{\sum Outage\ Interval}{Activity\ Time} \times 100\%$$

Equation 1 Service availability and unavailability definition

3 Service Level Model for ATM Networks

ATM Networks were projected to support the traffic and QoS[6] needs of a great variety of new applications, including audio, video and data. The service level model construction for ATM networks is necessary to represent the ATM services in terms of traffic and quality of service. This model should supply the service representation in terms of a SLA. A typical model should contain measures that characterize the operational capacity of service provider and measures that characterize the service.

The service provider presents a series of characteristics related with its operational capacity, for example, provisioning time, mean time between failures and time to repair. These measures are capable to supply a picture of quality levels offered to customers. The measures referring to the service provider operational criteria should include:

- total number of SAP outage intervals;
- time to Restore for a specific SAP,
- exceeding Committed Time-to-Restore;
- mean Time to Restore for a specific SAP/SAP Group;
- mean Time Between Failure for a specific SAP/SAP Group; and
- service Availability.

The operational criteria should can be negotiated between the provider and the customer. The measures related with the ATM service are those that characterize the its specific behavior, with

respect to traffic, and according to the service category. In the following items the specific measures related with ATM quality of service will be discussed.

3.1 Quality of Service in ATM Networks

The quality of service in ATM networks is represented by a group of parameters that characterize the traffic type, and by a group of parameters that represent the traffic needs in terms of QoS needs[6][4]. The types of ATM services are organized in service categories, defined with base in the flow information type, cell loss sensibility and cells delivery time variations. The ATM service categories defined by ATM Forum in the Traffic Management Specification[10] are:

- **CBR** *Constant Bit Rate*
- **Rt-VBR** *Real-Time Variable Bit Rate*
- **Nrt-VBR** *Non-Real-Time Variable Bit Rate*
- **UBR** *Unspecified Bit Rate*
- **ABR** *Available Bit Rate*

These service categories are divided in two groups[8]: with support to Real-Time applications or without support to Real-Time. For the traffic with Real-Time constraints there are two categories: Constant Bit Rate (CBR) and the Real-Time Variable Bit Rate (rt-VBR). There are three categories for applications that do not need Real-Time support: Available Bit Rate (ABR), Unspecified Bit Rate (UBR) and the Non-Real-Time Variable Bit Rate (nrt-VBR). Each category has parameters that identify the traffic produced by the user and the quality of service.

The CBR category is used by time-Real applications that need to transmit a fixed amount of information with a small delay variation, as for example voice and video applications, without compression. The UBR traffic is the opposite of CBR, not supplying any cell transmission rate or cell delivery times warranty. It is used to support connectionless services. The rt-VBR category is destined to applications that need to transmit a variable information amount, but have a small tolerance to cell delivery time variations. The nrt-VBR category is used by applications whose traffic is characterized by bursts periods which do not present requirements concerning cell loss and cell delivery times. The last service category, is destined to applications that operate according to the “network load” and which do not present any need for transmission guaranties concerning cell loss or cell propagation times.

Application needs are defined through QoS parameters for each service category. The following parameters list defines the information used to describe QoS in ATM[10] networks. The connection availability is characterized by the following parameters: Cell Error Ratio (CER), Severely Errored Cell Block Ratio (SECBR), Cell Loss Ratio (CLR) and Cell Misinsertion Ratio (CMR). The cell delivery time and the cell delay variation are characterized by Cell Transfer Delay (CTD) and Maximum Cell Transfer Delay (MCTD). The delivery delay introduced by the transmission support is characterized by Cell Delay Variation (CDV).

Traffic parameters are those used to define the traffic behavior in ATM connections. For this moment, there are five traffic parameters defined by the ATM Forum[10]: Peak Cell Rate (PCR), Sustainable Cell Rate (SCR), Minimum Cell Rate (MCR), Cell Delay Variation Tolerance (CDVT) and Maximum Burst Size (MBS). These parameters are defined according to the needs for transmission capacities, traffic type and cells delivery time. The only parameter above that is not

defined by the user it CDVT. The network defines this parameter to assure that the cells are being generated in appropriate intervals. PCR establishes the maximum rate in which the customer can emit cells in an ATM connection. MCR establishes the minimum cell transmission rate that the network should always made available for an ABR application. SCR is used to characterize a burst source, establishing the maxim cell transmission rate during a burst. MBS establishes the maximum cell burst duration i.e., the maximum number of cells that can be transmitted during a burst.

3.2 Service Availability of ATM Permanent Virtual Connections

The main parameter that clients are interested in is the service availability (SA). The ATM services are provided in a connection based mode, where a permanent or switched virtual connection (PVC or SVC) must be established before any data be transferred. In the service setup phase the user and the network negotiate a traffic contract describing the traffic characteristics and the required QoS. By using the connection admission control (CAC) mechanisms, the network will verify if sufficient resources are available for the operation the new connection. If there are no sufficient resources, the connection request will be refused. After the setup phase, the service provider must take care of the traffic to continuously offer sufficient resource to assure the QoS. This is performed by monitoring the network and controlling its utilization.

ATM networks were designed to support any kind of communication service, which makes their management very complex. These facilities and the capacity to integrate voice, data and multimedia flow, make the ATM technology suitable to build the future multi-service network, but also make them sensible to service level reduction and network outages.

Many different king of events can cause ATM service outage, for example: physical media errors, congestion, inadequate network project, and inadequate traffic management policy. We have identified some ATM related events that influence SVC and PVC availability. They are corresponds to performance or fault parameters that can be monitored, and are used to determine if the connection is operational or not in a specific moment.

One second where a fault has occurred can be classified on one of there categories: SES_{ATM} (Severely Errored Second), ES_{ATM} (Errored Second), and US_{ATM} (Unavailable Second). SES_{ATM} occurs when the connection is not operational during a second. ES_{ATM} occurs when the connection is partially affected during a second. US_{ATM} happens after the occurrence of ten consecutive SES_{ATM} , meaning the service has entered in the unavailable state, that is, the network is unable to support the connection. The events and their corresponding effects in the ATM service availability (AS) are presented in Table 1.

Event	Service Availability
CLR > error objective	SES_{ATM}
SECBR > error objective	SES_{ATM}
CMR > error objective	SES_{ATM} or ES_{ATM}
CER > error objective	SES_{ATM} or ES_{ATM}
AIS	SES_{ATM}
neanCTD > delay objective	SES_{ATM} or ES_{ATM}
meanRTD > delay objective	SES_{ATM} or ES_{ATM}
More than 10 consecutive SES_{ATM}	US_{ATM}

Table 1 Event and their effects over the SA

The two main network parameters that affect the service level are CLR and SECBR, and when their value cross the defined threshold, the corresponding second is marked as SES_{ATM} . When CMR and CER cross the defined threshold, the corresponding second can be marked as SES_{ATM} or ES_{ATM} , depending on the service provider criterion. In optical networks CMR is expected to be very low and CER too. The influence of these parameters is felt mainly in real-time services.

When a loss of signal or a physical media error that affects the connections happens, an alarm indication signal (AIS) is generated. This fault is reported to each affected connection and the current second is marked as SES_{ATM} . The cell transfer related events are important in real-time services that are very sensible to the cell delay variations. To calculate meanCTD it is necessary clock synchronization between transmitter and receiver, and when this is not possible the alternative Round Trip Delay (RTD) can be used. The seconds are marked as SES_{ATM} or ES_{ATM} , depending on the nature of the supported service. Finally, the connection enters the unavailable state after ten consecutive SES_{ATM} . When this happens, those seconds are included in the total US_{ATM} .

The service availability formula of ATM PVC is defined according to these parameters and is presented in the Equation 2.

$$SA\%_{ATM_PVC} = \left[1 - \frac{\sum_0^n US_{ATM} + \sum_0^m SES_{ATM} + \sum_0^k ES_{ATM}}{Total\ of\ Seconds} \right] \times 100$$

Equation 2 ATM-PVC Availability Calculation Formula

The SA formula is valid to the ATM services that offer guarantees in terms of traffic and QoS, that is CBR and VBR. The other two ATM service categories (UBR and ABR) offer best effort services, and the formula do not apply. The SA formula should permit the calculation of service level in each monitored ATM connection. The parameters are calculated within the SLA driver, that collects ATM traffic and QoS parameters, and sums up the US_{ATM} , SES_{ATM} and ES_{ATM} .

3.3 SLA for ATM Networks

The ATM service subscription phase involves the negotiation between customer and service provider of the aspects concerning in service installment, when a service level agreement is established. Several QoS aspects are defined in SLAs for ATM networks[2]: type of traffic, transmission rates, mean time between failures, threshold values, and others. The contract should be established in common agreement among the parts and will be valid during all the service lifetime. A model for SLA definition is presented in the Figure 3.

The SLA Management System can be used to define the SLA in the following way:

- First, service provider staff and the customer define the parameters. A service engineer and/or a telecom engineer may be involved in this step, for describing the appropriate parameters, thresholds and values.

- A service can be defined according to a service hierarchy. For example, in Figure 4, we are defining the ATM rt-VBR service that inherits from the operational service. Both the inherited criteria and specific criteria are shown in the window below.
- Then, for each criterion it must be defined the thresholds and rules (see Figure 5).

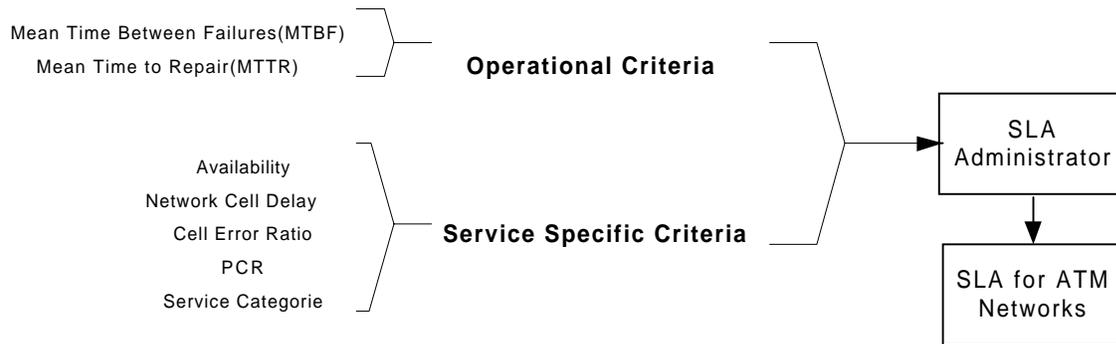


Figure 3 SLA for ATM Services

Figure 4 shows an example for the definition of an ATM rt-VBR service. Starting from the name that identifies the service and from its description, we made the definition of the operational criteria and service specific criteria, that will be applied to this service type. The criteria can be applied, added or removed. In the example of Figure 4 we can see two operational criteria (MTBF and MTTR) and four ATM rt-VBR service specific criteria (CLR, SECBR, AS and meanCTD).

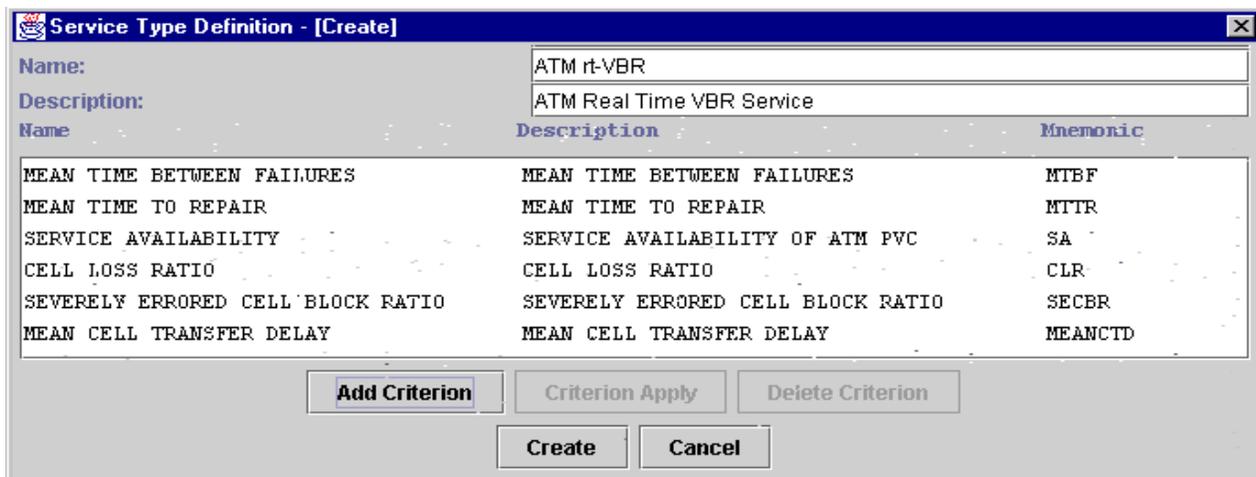


Figure 4 Example of ATM VBR service definition

An example of ATM rt-VBR service profile definition is showed in Figure 5. In this example, we can see the definition of a service profile, including the involved thresholds and rules: after selecting a service type from the list of the five predefined ATM services types, we can supply the threshold values for each criterion (in this example, MTBF, MTTR, CLR, SECBR and SA). The service type and profile definition is performed within the SLA Administrator Module and it will be used as the basis for SLA management, for the ATM rt-VBR contracted service. The important parameters for service operation are added or removed starting from a list of the possible parameters for the service type. The parameter thresholds and monitoring rules must be defined after the parameter is added to the list. After being defined, the parameters are collected by the

Driver, passed to the Server for the evaluation of rules and thresholds, and finally, delivered to the customer by the Monitor.

Service Profile Definition - [Create]

Service Type: ATM rt-VBR

Name: VIDEO CONFERENCE WITH COMPRESSION

Description: VIDEO CONFERENCE PROFILE

Criterion Name	Mnemonic	Threshold	
MEAN TIME BETWEEN FAILURES	MTBF	72	HOURS
MEAN TIME TO REPAIR	MTTR	6	HOURS
SERVICE AVAILABILITY	SA	99.6	%
CELL LOSS RATIO	CLR	0.0009	%
SEVERELY ERRORED CELL BLOCK RATIO	SECBR	0.03125	%

Rules

AVAILABILITY WARNING

Add Edit Remove

Create Cancel

Figure 5 Example of ATM rt-VBR service profile definition

4 Architecture for SLA Management

The SLA Management System periodically monitors the telecommunications network, to verify if the offered service levels are in agreement with the SLA. It monitors the occurrence of any violation of these quality requirements and reports such information for customers and service provider. Management actions are dispatched automatically, in order to avoid contractual violations, and in the case of contractual violations, corrective actions can be taken, for example, automatic interaction with billing system to perform invoice refund or discount in future services.

For accomplishing its tasks it should periodically verify the requirements to attain the SLA objectives:

- to inspect the service level, i.e. to monitor continually the offered services to verify if they are in agreement with the SLA;
- to collect service performance data and to calculate QoS criteria based on them;
- to match QoS criteria against thresholds;
- to trigger the management actions according to predefined rules;
- to organize service performance data on a comprehensive performance reports;
- to deliver performance reports in reliable and secure way.

The SLA management system described in this paper presents two important characteristics: the independence of platform and operating system and an open architecture, allowing it to be easily integrated to other systems, for example, performance data collection and billing systems. The architecture defines four modules showed in the Figure 6: Drivers, Administrator, Server and Monitor.

The quality of service (QoS)[6] information are collected by Driver modules, that are responsible by communication with performance monitoring systems. The Driver collects performance information, building the interface between the system and the network. It should exist a different Driver for each supporting network technology (e.g. an ATM driver, a SDH driver, a Frame Relay driver and so on). The Administrator module allows the definition of all necessary service level information for SLA creation and maintenance. This module handles information for customers, service providers, service elements, service types, SLAs and service performance reporting schedule. The Server module accomplishes on-line, management tasks on the objects that compose an SLA, including the reception of performance data from the collector module, validation of contractual rules, the triggering of management actions, consolidation of performance data, automatic generation of performance reports and dispatching of reports for customers and service provider. The QoS[5] information is supplied to the customer by the Monitor module. It delivers to customers the consolidated performance reports according to the schedules.

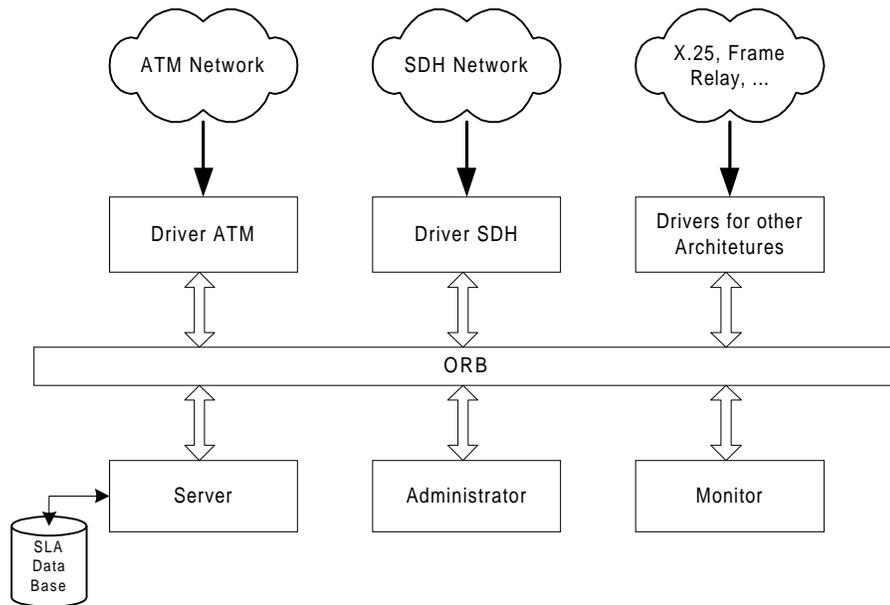


Figure 6 Management Architecture of Service Level Contracts

All modules were developed in Java Language, aiming platform independence, and it was used CORBA as the basis for distribution, providing open interfaces for making easy the integration with other systems.

5 SLA Manager Driver for ATM Networks

The SLA Driver for ATM networks operates as a service level agent, that collects the performance information on service access points. Typically it interacts with a performance management system, reading the performance data and consolidating it for SLA management purposes. It performs a first level consolidation in order to organize the large volume of collected information, preparing it for the SLA Server. The SLA Driver for ATM networks is presented in Figure 7.

An SLA Manager Driver obtains performance data information necessary for monitor the SLA. For each SAP the driver should obtain the information. It extracts the relevant information from raw

performance data, then it structures the information in a log, consolidated performance records and send them to the SLA Server in a structured format. The Server will then evaluate the criteria, match them against the defined thresholds. Violation records are built when the agreement is offended, and the corresponding management actions are triggered. The performance reports are composed and made available by the SLA Monitor, which will dispatch then according to the schedule, or under user demand. The reports can be made available through WEB pages, notifications, e-mail or file, depending on the customer's needs.

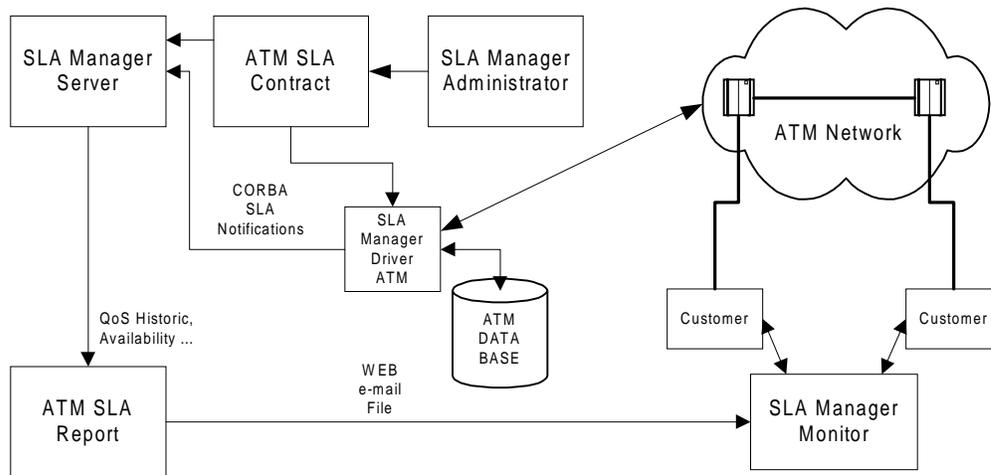


Figure 7 SLA Manager Driver for ATM

6 Results and Future Works

At time of writing this paper we have developed the service level management architecture proposed for frame relay networks and the SLA manager modules (Server, Administrator and Monitor). The SLA driver for ATM networks is being developed since January-1999. The service level profile for ATM services and the service level availability model for ATM has finished by the date of review of this paper. Currently we are implementing the driver for collecting the necessary information for service level calculation. The driver collects information about SLA using the Operation, Administration and Maintenance (OAM) cells and SNMP protocol.

7 Conclusion

This article presented a SLA Management System that can be applied to several telecommunication networks and which can be deployed in open environments. Particularly we discussed in deeper, the details of how it can be applied to ATM services. Its architecture presents a complete system, capable to accomplish the contractual quality of service management, periodic generation of service levels reports and a system for the service level contracts construction for several network architectures. Using this system the service providers will be capable to monitor the actual quality of service levels, and to report it to customers. Their customers have available a powerful mechanism that allows them to compare those services among several providers. The service providers will have available an efficient management tool, that will allow them to take pro-active actions in order to maintain the QoS levels, or when this is not possible, to adopt compensatory mechanisms in order to improve the customers' satisfaction.

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