QoS Parameters to Network Performance Metrics Mapping for SLA Monitoring

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Abstract

Service Level Agreement (SLA) is a formal negotiated agreement between a service provider and a customer. The service level management (SLM) is the integrated management of all functionalities in the SLA life cycle. When a customer orders a service from a service provider, an SLA is negotiated and then a contract is made. In the SLA contract, QoS parameters that specify the quality level of service that the service provider will guarantee are included. The service provider must perform SLA monitoring to verify whether the offered service is meeting the QoS parameters specified in the SLA. SLA monitoring involves monitoring the performance status of the offered service and provide relevant information to the service level management system. In order for the service level management system to verify whether the specified QoS parameters are being met, the system must gather performance data from the underlying network performance monitoring system and map such data to the QoS parameters. In this paper, we propose a formal mapping mechanism between QoS parameters in SLA and the network performance metrics. Although we focus on the network access service (e.g., leased-line service, xDSL service, VPN service) in this paper, we believe that our mapping mechanism can be easily used in SLA monitoring of other services (such as application, server hosting, contents). We also propose a general SLA monitoring system architecture that can be used to monitor service levels for various services offered by network, Internet and application service providers. Finally we present how our SLA monitoring system architecture can be used for SLA monitoring of IP backbone network service.

Keywords: SLA, Service Level Management, SLA monitoring, QoS Parameters, Network Performance Metrics, Measurement Mapping, Evaluation Mapping.

1. Introduction

SLA is a formal negotiated agreement between a service provider (SP) and a customer. Usually in measurable terms, SLA is defined as the quality of services the service provider will provide [1]. The liberalization and rapid evolution of the telecommunication market is one of the major reasons for the increased significance of SLA. By the supported service of SLA, the service provider can differentiate itself from its competitors and prioritize service improvement opportunities. From the viewpoint of the consumer, he may desire to access a service of his own inclination and to validate the quality of the service provided. This is another reason for the increased importance of SLA. The SLA life cycle consists of the following five phases: product/service development, negotiation and sales, implementation, execution, and assessment [2]. The service level management (SLM) is the integrated management of these five phases in the SLA life cycle. Given the importance of SLM, the concept and methods are described in many other papers [13, 18, 19, 20].

SLA provisioning and SLA monitoring are critical to realize the SLA supported service in the network management layer. SLA provisioning configures the network and system infrastructure for quality insured service. In the network service area, many new traffic engineering methods such as MPLS [3] and Diffserv [4] have been proposed, and much valuable research has been performed [3, 21] for QoS-based traffic treatment. The role of SLA monitoring is to monitor the service status for each customer according to the agreed QoS parameters in SLA and to provide a basis for the billing and reporting system. Although much research on network monitoring has been performed and the result of network monitoring is very essential to SLA monitoring, it lacks the considerations of how to apply the result of network monitoring to SLA monitoring. In addition, many service providers use their own proprietary SLA monitoring methods. Thus, further consideration should be given to a standardized SLA monitoring method. Also, the general guideline for SLA monitoring is necessary for service providers who newly start to launch SLA-based services. TM Forum mentioned the importance of SLA monitoring, but did not present the details of SLA monitoring method or its architecture [2].

In this paper, we categorize SLM into seven functions. We define the concept of SLA monitoring in the network management layer. The most important factor in SLA monitoring is the mapping between QoS parameters and network performance metrics (NPMs). We also define the concept of this mapping and the requirements of an SLA monitoring system. From this concept we present a generic SLA monitoring system architecture. To validate our theory we applied our design to an IP-backbone network service.

The organization of this paper is as follows. Related work is described in Section 2 and QoS parameters to Network performance metrics mapping is described in Section 3. Next, design issues of SLA monitoring system are provided in Section 4. We propose SLA monitoring system architecture in Section 5 and apply it to an IP backbone network service in Section 6. Finally, concluding remarks are given and possible future work is mentioned in Section 7.

2. Related Work

2.1 SLM and SLA Monitoring

In this section, we define the seven functions of SLM and make clear the concept of SLA monitoring, which is one of the seven functions of SLM. Various service providers and customers need SLAs in the current telecommunication market place [2]. Service providers are classified into three types: Network Service Provider (NSP), Internet Service Provider (ISP), and

Application Service Provider (ASP). Customers are divided into three types: individuals, organizations and enterprises. A service provided by a service provider is associated with other services. In this case, the service provider may be a customer of another service provider. So, they are in contract with each other. Therefore, the efficient and systematic SLM is needed to support SLAs which are diverse and complex.

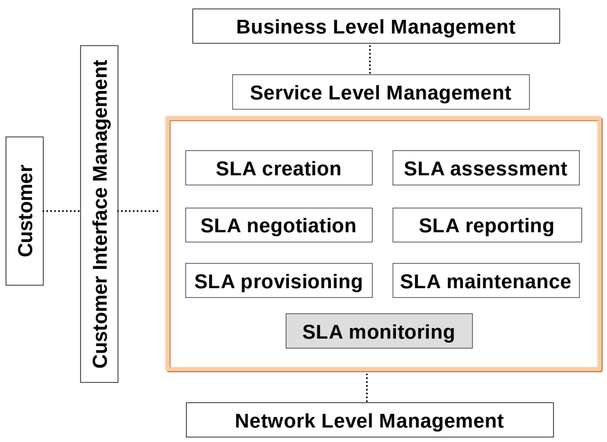


Figure 1. Service Level Management Functions

SLM is the integrated method to manage various SLAs from creation to assessment. We categorize the SLM into seven functions: SLA creation, negotiation, provisioning, monitoring, maintenance, reporting and assessment, as illustrated in Figure 1. SLA creation creates an SLA templete for specified services. SLA negotiation is the process of selecting applicable QoS parameters in SLA and negotiating the penalty in case of SLA violation. SLA provisioning means that service providers configure the network element or topology to provide the service. After provisioning, service providers must verify the degree of SLA assurance, which they contracted with customers. To perform surveillance on QoS parameter degradation or violation, SLA monitoring is needed. When a violation of a QoS parameter is detected, SLA maintenance analyzes the reason why degradation has occurred and which QoS parameter has degraded. Next, it notifies the SLA provisioning to restore the service. SLA reporting provides the performance information to customers periodically or on-demand. Finally, SLA assessment demands payments to customers and accommodates customers with a penalty when the violation occures.

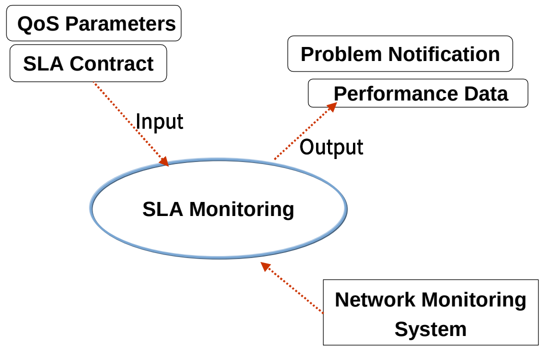


Figure 2. SLA Monitoring

Among the SLM functions described above, SLA provisioning and SLA monitoring are the most important in the network management layer. This paper focuses on SLA monitoring, which is important to assure the degree of QoS parameters and to use the monitoring results in reporting and assessment. In other words, this paper presents a new concept of SLA monitoring, including three processes of Telecom Operations Map (TOM) [6], which are network data management process at the network management layer, service problem management, and service quality management at the service management layer. There are two types of input in SLA monitoring, as illustrated in Figure 2. One is various QoS parameters according to services and the other is SLA contract for each customer. After SLA monitoring uses network monitoring system, the output of SLA monitoring is also dual. One is problem notification and the other is performance data.

2.2 QoS Parameters and Network Performance

Metrics in Network Service.

In this section, we explain QoS parameters and NPMs from the viewpoint of network service. There are many kinds of network services such as leased line service, IP-VPN service, xDSL services, Frame relay service, etc. Also, QoS parameters are the target of SLA monitoring and NPMs are needed to measure the network performance and guarantee QoS parameters.

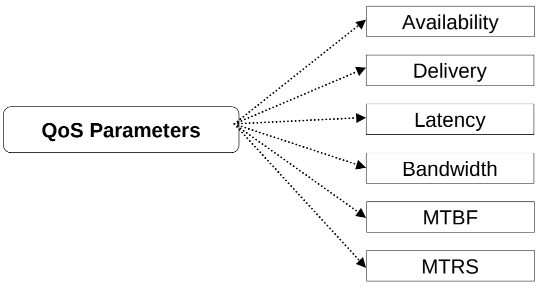


Figure 3. QoS Parameters for Network Service

QoS parameter is the instance to represent the quality of service to customers. It should be easy for customers to understand the degree of assuring the service. QoS parameters can be different according to the type of services. Figure 3 illustrates generic QoS parameters required in network service: ***Availability, Delivery, Latency, Bandwidth, MTBF (Mean Time Between Failure) and MTRS (Mean Time to Restore Service)***. The definitions of these parameters are as follows. ***Availability*** is the percentage of the feasibility of service in every particular service request. TMF701 [1] defines that ***Availability*** of service is the key parameter that customers are interested in. ***Delivery*** is the converse of packet loss, which means that a percentage of each service is delivered without packet loss. To some service providers, ***Delivery*** means packet delay. It also depends on the decision of service providers. ***Latency*** is the time taken for a packet to travel from a service access point (SAP) to a distant target and back. It usually includes the transport time and queuing delay. ***Bandwidth*** means the used capacity or available capacity. Service providers usually assure the maximum bandwidth to customers and it is stated clearly in SLA. The four QoS parameters mentioned above are technology-specific, so they can be measured straightforward by NPMs. ***MTBF*** and ***MTRS*** are time-based, so they cannot be directly mapped by NPMs.

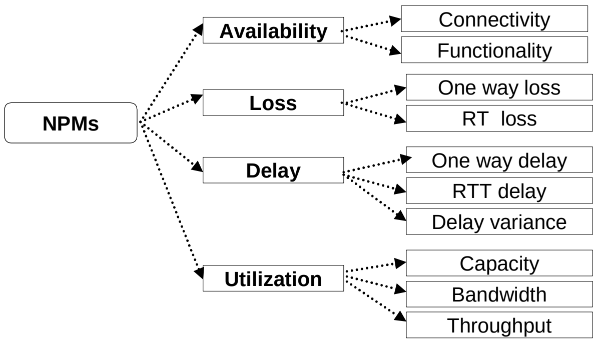


Figure 4. Network Performance Metrics

Network performance metric (NPM) means the basic metric of performance measurement in the network management layer. In Figure 4, we categorize the NPMs into four types: ***Availability, Loss, Delay*** and ***Utilization***. The meaning of each NPM is as follows. ***Availability*** means connectivity and functionality in the network management layer. Connectivity is the physical connectivity of network elements and functionality means whether the associated network devices work well or not. ***Loss*** is the fraction of packets lost in transit from sender to target during a specific time interval, expressed in percentages. ***Loss*** consists of two metrics: one-way loss and round-trip loss. ***Delay*** is the time taken for a packet to make the average round trip or one-way from the sender to the distant target and back. ***Delay*** consists of three kinds of factors: one-way delay, round trip delay and delay variance. ***Utilization*** is the throughput for the link expressed as a percentage of the access rate.

2.3 Network Monitoring

Network monitoring is the process of measuring the value of NPMs. NPMs are measured by various network monitoring technologies. Traditionally, there are three methods of network monitoring, which are active monitoring [5, 10], passive monitoring [10, 11] and the method of using SNMP agents [12, 33, 34]. Table 1 shows the mechanism and related projects of three network monitoring methods.

The active monitoring method obtains the current status of the network by setting up the test machine at the point which one wishes to measure, and then sending extra traffic from one machine to another during a specific time. Various NPMs can be measured by simple and easy tools, such as ping and traceroute. And system load is very low because the amount of generated and analyzed traffic is small compared to passive monitoring method. But test packets can be lost at low priority, so it is difficult to measure the exact network status. And test traffic may impose a burden on the current network. Some related work on this are RIPE NCC Test Traffic Measurement [5, 24], NIMI [25], Surveyor [26], NLANR AMP [27], PingER [28] and Skitter [29].

Table 1. Network Monitoring Mechanism and Related Projects

Monitoring Method	Mechanism	Related projects
Active Monitoring	♦ Generate test traffic periodically or on-demand ♦ Measure performance of test packet or response	♦ NIMI ♦ Surveyor ♦ NLANR AMP ♦ PingER ♦ Skitter
Passive Monitoring	♦ Capture the traffic by mirroring or splitting ♦ Analyze the captured packets	♦ CoralReef ♦ WAND ♦ WebTrafMon ♦ NLANR PMA
SNMP	♦ Using existing SNMP agents	♦ Internet2 ♦ MAWI

The passive monitoring method obtains the current status of the network by capturing the packet. Passive monitoring can monitor the network status without additional traffic. However, limited NPMs, such as utilization and throughput, can be measured easily compared to the active monitoring method. Some related work in this are CoralReef [30], WAND [31], WebTrafMon [11] and NLANR PMA [32].

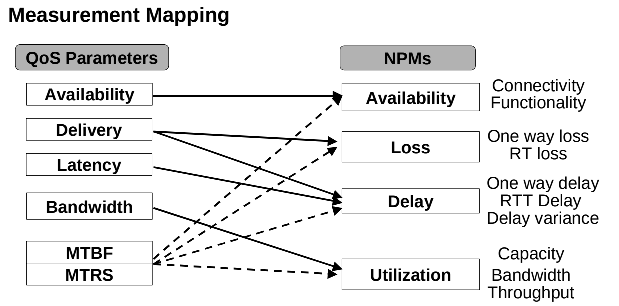
By using SNMP agents, we can measure the status of the network device. For example, RMON [12] monitors traffic information with SNMP agents. The method of using SNMP agents is simple and scalable. But only the throughput and functionality of NPMs are measured by this method. Some related work on this are internet2 [33] and MAWI [34].

Generally, ***Loss***, ***Delay*** and ***Connectivity*** are the NPMs that can be mainly measured by active monitoring. ***Utilization*** and ***Throughput*** are the NPMs which can be measured by passive monitoring. ***Functionality*** and ***Throughput*** can be measured using SNMP agents. Although we may obtain various NPMs using these network monitoring methods, it is difficult to apply these values to QoS parameters directly. The contract between service providers and customers is performed using QoS parameters and the network quality is measured using NPMs. In other words, the NPMs for each QoS parameter must be first decided before measuring the QoS parameters. A QoS parameter can be mapped to one NPM or many. This mapping depends on the type of service and can be very complicated. And the quality information of service should be presented in customer friendly form, QoS parameters, not NPMs. Therefore, it is necessary to translate the measured NPMs to QoS parameters in SLA monitoring. So we define a new concept of a mapping between QoS parameters to NPMs in Section 3.

3. QoS Parameters to NPMs Mapping

3.1 Mapping between QoS parameters and NPMs in Network Service

In this section, we describe a mapping between QoS parameters and NPMs. We divide this mapping into two steps: the measurement mapping and the evaluation mapping. Before we generalize our concept of QoS parameters to NPMs mapping, we mention a specific example of mappings in network service, as described in Figure 5.



Evaluation Mapping

$$\text{Availability of QoS Parameter} = 100 - \frac{\text{device unfunctional time} + \text{disconnected time}}{\text{total monitored time}} \times 100\,(\%)$$

Figure 5. Mapping Example in Network Service

First, we explain measurement mapping in network service. Measurement mapping is the process of determining some NPMs to a QoS parameter. ***Availability of QoS parameter*** is mapped to ***Availability of NPM***. ***Availability of QoS parameter*** means the feasibility of service in every particular service request. ***Availability of NPM*** refers to connectivity among network elements and functionality of the network elements. Functionality means whether network elements work well or not. ***Delivery of QoS parameter*** is mapped to ***Loss or Delay of NPM***, but this depends on the decision of service providers. ***Latency of QoS parameter*** means ***Delay of NPM***: one-way delay, round trip delay and delay variance. ***Bandwidth of QoS parameter*** is measured by ***Utilization of NPM***. ***Utilization*** means the throughout of link as a percentage. Contrary to these technology specific parameters, ***MTBF*** and ***MTRS*** are the QoS parameters which cannot be obtained from NPM directly. So service providers may satisfy these QoS parameters by computing the time when the violations of NPMs occurred.

Second, we explain the evaluation mapping. Evaluation mapping is mapped to evaluation function to verify QoS parameter from measured NPM values. In the bottom side of Figure 5, we show an example of evaluation mapping. ***Availability of QoS parameter*** is considered with connectivity and functionality in the network service. So we should check the connectivity and functionality of the network service. When a malfunction of a network device or disconnection occurs, we measure the unavailable time. Then by applying the unavailable time to the above formula, we can verify the ***Availability of QoS parameter***.

Measurement mapping and evaluation mapping are essential for SLA monitoring. These mappings are highly dependent on the kind of services. In this paper, we make a guideline only in network service. When the available NPMs for a QoS parameter are decided, the value of NPMs is measured by using some network monitoring methods. Afterwards, we can apply the measured value of NPMs to the evaluation function from evaluation mapping. After obtaining the value, we can assess a QoS parameter in SLA.

3.2 Generic Mapping between QoS parameters and NPMs

We present the generic mapping between QoS parameters and NPMs, as illustrated in Figure 6. We formalize the mapping using the theory of set and functions. Through this formalization, we make clear the concept of QoS parameters to NPMs mapping, which is a mandatory process in the construction of SLA monitoring system.

First, we define the three sets : Q, N and E. Set Q represents a set of QoS parameters, set N represents a set of NPMs and set E is the set of evaluation functions. Set 2^N is the power set of N. The relationship between set Q and set 2^N is the measurement mapping: ***m(x)***, and the relationship between set 2^N and set E is the evaluation mapping: ***n(x)***.

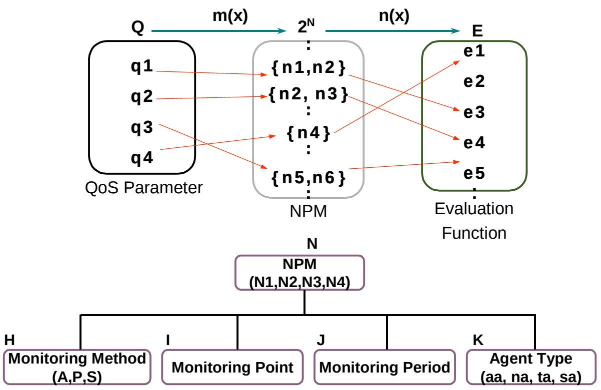


Figure 6. Generic Mapping Method

m(x) represents a decision which NPMs are used to measure each QoS parameter. In ***m(x)***, we use set 2^N, not the set N, because the mapping between set Q and set N may not be one-to-one mapping. Moreover, monitoring method (H), point (I), period (J) and agent type (K) should be considered in ***m(x)*** for the effective measurement mapping, as shown in the lower side of Figure 6. The monitoring method includes active monitoring, passive monitoring and the method using SNMP agents. Monitoring point is usually the service access point where customers get provided service. And monitoring period is the total time for NPM monitoring. There are four agent types: application agent (aa), system agent (sa), network agent (na) and traffic agent (ta) [13]. Among them, the agents used in network service are network agents (na) or traffic agents (ta).

n(x) represents a decision of evaluation function to verify a QoS parameter from measured NPM values. Evaluation function, which is element of set E, can be different for each element of Set 2^N. However, it is difficult to define the evaluation function according to QoS parameters, and it also depends on the type of service.

In this paper, ***m(x)*** and ***n(x)*** are defined as the QoS parameters to NPMs Mapping. Therefore, to evaluate QoS parameters in SLA monitoring, it should be decided which NPMs should be mapped and which evaluation functions should be applied to the selected NPMs.

4. Design Issues of SLA Monitoring System

In this section, we describe the design requirements of an SLA monitoring system for network services of NSP and ISP. The SLA monitoring system receives service contents, such as QoS parameters and customer SLAs as its inputs from the business process system, and uses network and system monitoring technologies to gather corresponding network performance values. Next, it evaluates the quality of a given service and gives the results to the upper layer systems, such as billing and reporting system. The consideration of the SLA monitoring system is based on the previously mentioned QoS parameters to NPMs mapping, and follows the basic structure described in the SLA Handbook [2] from TM Forum. The following gives the general requirements and some design issues for the SLA monitoring system.

First, the SLA monitoring system should be designed with no dependencies on the SLA provisioning technologies. In the network management layer there can be various traffic engineering methods [3, 21] to configure the QoS supported network service, but the quality of the SLA based service should be measured based only on the QoS parameters and corresponding NPMs. Second, the SLA monitoring system should be designed in a layered and distributed architecture. The customers of many network services such as IP-VPN, xDSL services are geographically widespread, so there can be many dispersed service access points in which an SLA agent should gather network performance values. So the distributed and layered architecture is suitable. Third, the monitoring packet and communication data should not overburden the underlying network. The functional modules and the communication data should be well defined, as well as the monitoring method. Fourth, flexibility and extensibility should also be considered. The SLA monitoring system evaluates the quality of a given service for each customer according to its contracted SLA. Over a period of time, the number of customers and the content of SLA can vary as well. To cope with this situation, the consideration of extendibility and flexibility is crucial.

Next, we are going to describe the design issues of an SLA monitoring system. The essential step is to define the QoS parameters to NPMs mapping. Here, one should also determine the monitoring location, method, period and agent type. There are three types of monitoring methods (active, passive and SNMP-based) and four types of agents (application agent (aa), system agent (sa), traffic agent (ta) and network agent (na)) [13]. The evaluation function should be determined for each QoS parameter from network performance values gathered by SLA agents. One should also determine the stored data format and the period to be kept in storage. The communication data format among each functional module is designed to avoid high network traffic, and is another critical factor to be considered.

5. SLA Monitoring System Architecture

In this section, we represent an SLA monitoring system architecture as illustrated in Figure 7. This architecture has three main components: the ***Parameter Mapper module***, the ***Customer SLA module*** and the ***Monitoring module***. The role of the ***Parameter Mapper module*** that is illustrated in Figure 7 is to manage the QoS parameters to NPMs mapping. For each QoS parameter a decision about NPMs, monitoring location, period, method and agent type is made. Based on this decision, the SLA agents are deployed at the proper site in the service network. Another important consideration in the ***Parameter Mapper*** is that the evaluation function for each QoS parameter is created and stored in the ***Map DB***. This evaluation function is used in the ***Performance Analyzer*** to validate the quality of a given service for each customer. Besides the evaluation function, the other mapping information is stored in the ***Map DB***.

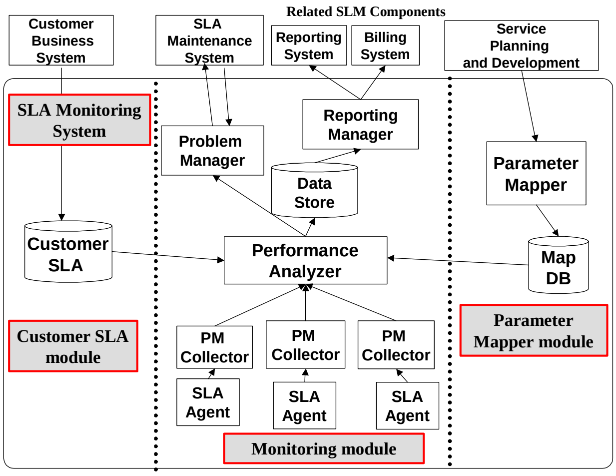


Figure 7. SLA Monitoring System Architecture

Customer SLA module in the left side of Figure 7 stores the information of each customer contract. This module should be designed with good flexibility because the amount of stored information can vary easily according to the popularity of the service. The LDAP [22] is one possible implementaion solution for the ***Customer SLA module***.

The center of Figure 7 shows the ***Monitoring module*** which is designed in a layered architecture. There can be multiple SLA agents for one service, because there can be multiple QoS parameters for one service and multiple NPMs can be mapped to one QoS parameter. Also, in some cases, multiple SLA agents should be deployed at a regionally dispersed place. The ***Performance Metric (PM) Collector*** gathers the performance data measured at each SLA agent and sends these to the performance analyzer. The quality evaluation for each QoS parameter and each customer SLA occurs in the performance analyzer. The performance analyzer evaluates the quality using the evaluation function stored in the ***Map DB*** and customer contract information in the ***Customer SLA DB***. The analyzed information is stored at the ***Data Store*** module for a certain time period. The stored data format and stored period is an important point to consider. If a problem such as SLA violation is detected, the ***Performance Analyzer*** sends an alarm message to the ***Problem Manager***, which detects this failure or problem and sends an alarm message to an administrator or SLA maintenance system immediately. The ***Reporting Manager*** is to create a report for the billing system and the reporting system from the ***Data Store***.

6. SLA Monitoring for IP-backbone Network Service

To validate our proposed architecture, we applied it to an IP-backbone network service and designed an SLA monitoring system. The service provider of IP-backbone network service belongs to NSP among our previous categorization such as KT, NTT and AT&T. The customer of this service can be any user who is connected to this IP-backbone network. These can be companies, organizations, other ISPs using leased line service, and individuals who are using xDSL service. The QoS parameters in these service should be decided with the terms to represent whether the backbone network is in a healthy state or not.

Therefore, we decided on the QoS parameters for the IP-backbone network service with the following three: ***Availability***, ***Latency*** and ***Loss***. The content of SLA negotiation may be as follows: The backbone availability over 99.99% should be assured. The average round trip time (RTT) should be less than 50 ms. The delivery ratio should be more than 98.0%. From our definition of QoS parameters to NPMs mapping, there should be a decision about ***m(x)*** and ***n(x)***.

Table 2. Measurement Mapping for IP-Backbone Network Service

QoS Parameter	NPM	method	point	period	type
Availability	Functionality	active	edge router	5 min	na
	Connectivity	active	edge router	5 min	ta
Latency	RTT	active	edge router	5 min	ta
Delivery	RT loss	active	edge router	5 min	ta

First, we describe about ***m(x)*** which is illustrated in Table 2. The QoS parameter ***Availability*** is mapped to two NPMs: functionality and connectivity, which are monitored at each edge router and every five minutes using an active monitoring method. The network agent (na) is used to acquire availability NPM value and the traffic agent (ta) is used for connectivity NPM value. In the same manner, ***Latency*** is mapped to RTT and ***Delivery*** is mapped to round trip (RT) loss. By this ***m(x)*** mapping the monitoring method, point, period and agent type are decided. For the IP-backbone network to monitor the given NPMs, we should set up SLA agents at each edge router which generates test packet every five minutes and sends the results to the upper layer ***PM Collectors***.

Table 3. Evaluation Mapping for IP-Backbone Network Service

QoS Parameter	Evaluation Function
Availability	$100 - \frac{\text{device unfunctional time} + \text{disconnected time}}{\text{total monitored time}} \times 100 (\%)$
Latency	$\frac{\sum \text{RTT}}{\text{total number of RTT test packet}} (m\sec)$
Delivery	$100 - \frac{\text{number of lost packet}}{\text{total number of test packet}} \times 100 (\%)$

Next, the ***n(x)*** mapping is used to determine the evaluation functions to measure the quality of each QoS parameter, as described in Table 3. As mentioned previously, these evaluation functions are stored in the ***Map DB*** and are used by the ***Performance Analyzer***.

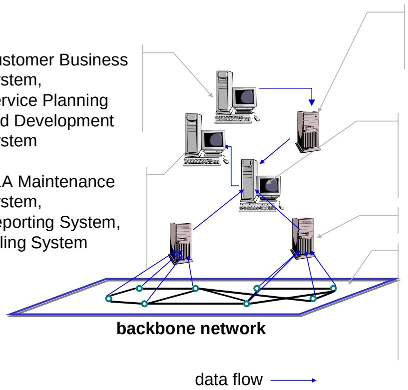


Figure 8. Layered and Distributed SLA monitoring System in IP Backbone Network Service

Figure 8 shows the SLA monitoring system we designed for the IP-backbone network service. The SLA agents which are deployed at every edge router measure network performance metrics using active method and send the measured NPM values to the ***PM Collectors***. There can be two or more ***PM Collectors*** because the backbone edge routers are located regionally far away from each other. It is necessary to deploy multiple ***PM Collectors*** to reduce the monitoring traffic.

The ***Performance Analyzer***, ***Data Store***, ***Problem Manager*** and ***Reporting Manager*** can coexist at the same machine because in this kind of monitoring system amount of data is smaller than that generated by passive traffic monitoring. In addition, the ***Parameter Mapper***, ***Map DB*** and ***Customer SLA DB*** which receive data from extraneous systems are located at the same machine.

7. Conclusion and Future Work

In this paper, we proposed a new concept of SLA monitoring: a QoS parameters to NPMs mapping and a generic architecture for the SLA monitoring system. The QoS parameter to NPM mapping combines measurement mapping and evaluation mapping. From this mapping one can decide which type of SLA agents are needed to evaluate the quality of the provided service in an easy and systematic way. We also provided a mapping guideline for network services. In the network service, the QoS parameters can be ***Availability***, ***Delivery***, ***Latency***, ***Bandwidth***, ***MTRS*** and ***MTBF***. We also provided the points of consideration in the design of the SLA monitoring system and presented its generic architecture. We believe that this paper can serve as a guideline for service providers who intend to deploy an SLA-based network service and set up an SLA monitoring system.

We plan to complete our validation with the implementation of the SLA monitoring system we designed for the IP-backbone network service. We intend to make an overall guideline of the QoS parameter to the performance metric for various services such as hosting, application and content services. A refinement of the proposed SLA monitoring system architecture is also needed to apply to various services.

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