Mapping between QoS Parameters and Network Performance Metrics 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. We then present how our SLA monitoring system architecture can be used for SLA monitoring of IP backbone network service.

Keyword: SLA, Service Level Management, SLA monitoring, QoS parameter, Network Performance Metric, Measurement Mapping, Evaluation Mapping

Introduction

- Increased Importance of SLA
  - Liberalization and rapid evolution of the telecommunication market
  - Increased interest in service quality by customers
- Aggregated view of service behavior provided by SLA monitoring
- Various research on network monitoring

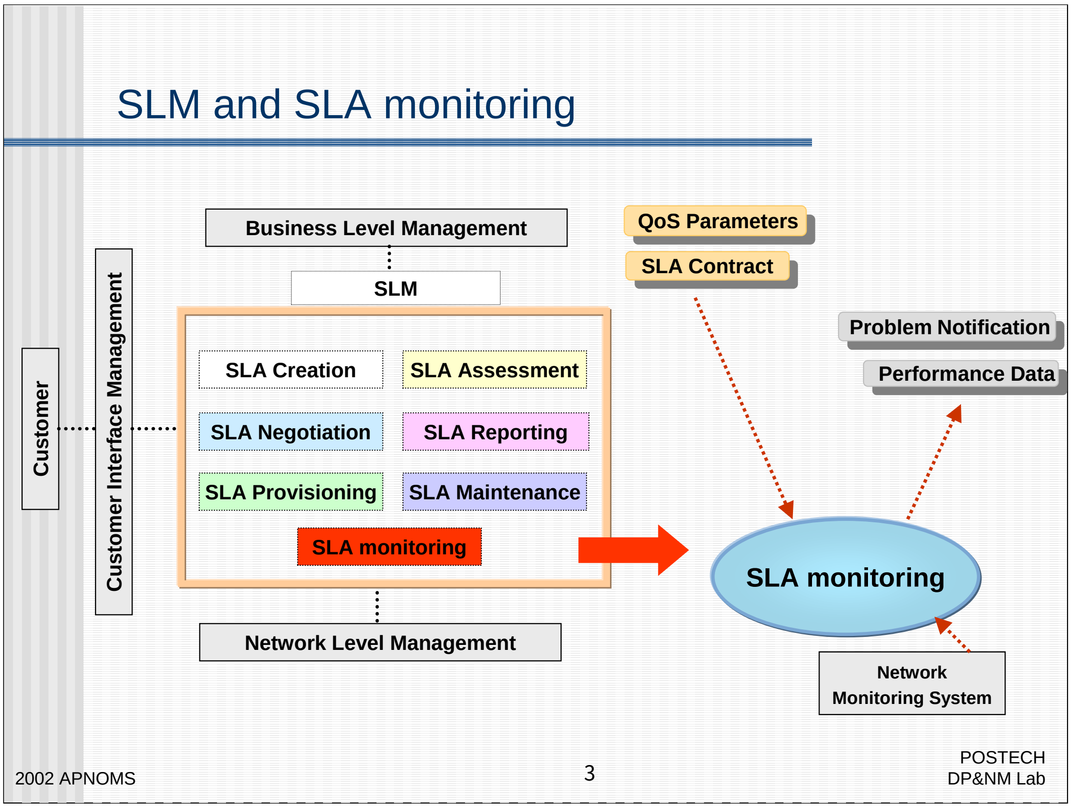
- Problem
  - Lack of Systematic QoS parameter to Network Performance Metric Mapping
  - Lack of Generalized SLA monitoring System Architecture

- Goals of Our Research
  - Define the concept of SLA monitoring
  - Define QoS parameter to Network Performance Metric Mapping
  - Design of Generic SLA monitoring System Architecture

SLA is a formal negotiated agreement between a service provider 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 5 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. With the importance of SLM, its concept and methods are mentioned in many other papers [13, 18, 19, 20].

SLA provisioning and SLA monitoring are critical parts to realize the SLA supported service in the network management layer. SLA Provisioning is to configure the network and system infrastructure for quality insured service. In the network service area, many networking technologies 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 a consideration of how to apply the result of network monitoring to SLA monitoring. And many service providers use their own proprietary SLA monitoring methods. So, further consideration about standardized SLA monitoring method is needed. Also the general guideline for SLA monitoring is necessary for the 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 sequence or its architecture [2].

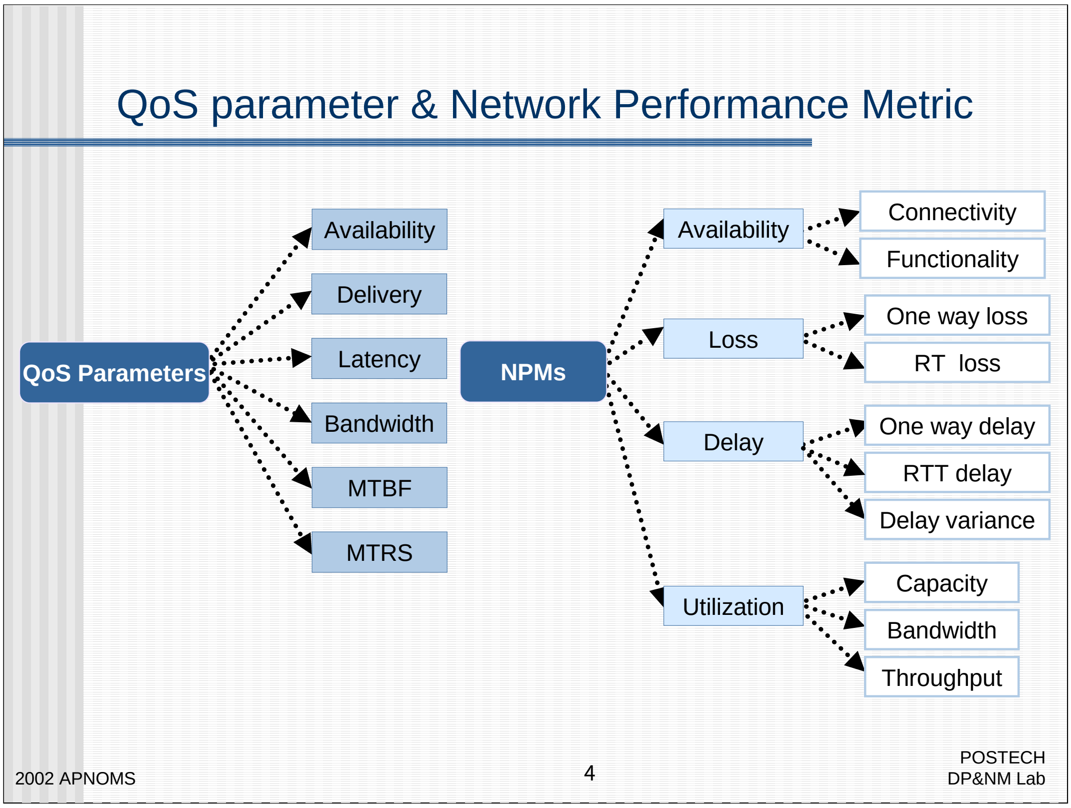
In this paper, we categorize SLM into seven functions. We define the concept of SLA monitoring in the network management layer. The most important factor in SLA monitoring is the mapping between QoS Parameters and network performance metrics (NPMs). We also define the concept of this mapping and the requirements of a 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.



In this slide, 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 recent telecommunication market place [2]. Service providers are classified into three types: NSP, ISP, and ASP. Customers are divided into three types: individuals, organizations and enterprises. A Service provided by a service provider is associated with other services. The service provider may be a customer of another service provider. SLAs contract with each other. Because they are diverse and complex, an efficient and systematic SLM is needed to support these various SLAs.

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 the left side of this slide. SLA Creation is a step to create SLA templete about 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 of QoS Parameters' degradation or violation, SLA monitoring is needed. When a violation of a QoS parameter during SLA monitoring 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 is a step to report the performance information to customers periodically or on-demand. Finally, SLA Assessment is a step to demand the payment and accommodate with a penalty to customers.

Among the functions proposed above, SLA Provisioning and SLA monitoring are 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 result in reporting and assessment. This paper presents new viewpoint of SLA monitoring. The concept of the SLA monitoring includes three processes of 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 kinds of input types in SLA monitoring, as illustrated in right side of this slide. 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.



In this slide, QoS Parameters and NPMs are presented 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. we describe the some examples of QoS Parameters and NPMs. QoS Parameters are the target of SLA monitoring and NPMs are needed to measure the network performance and guarantee QoS Parameters.

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 types of services. This paper presents generic QoS Parameters required in network service: ***Availability***, ***Delivery***, ***Latency***, ***Bandwidth***, ***MTBF*** and ***MTRS***. The definitions of these parameters are as follows. ***Availability*** is the percentage of the feasibility of service in every particular service request. In TMF701 [1], it is defined that ***Availability*** of service is the key parameter that customers are interested in. ***Delivery*** is the converse of packet loss. It means that a percentage of each service is delivered without packet loss. To some service providers, ***Delivery*** is packet delay. It also depends on the decision of service providers. ***Latency*** is the time taken for a packet to travel from an service access point (SAP) to a distant target and back. It usually includes the transport time and queuing delay. ***Bandwidth*** is 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*** is the mean time between failures of the service and ***MTRS*** is the mean time to restore service after reporting the fault. ***MTBF*** and ***MTRS*** are time-based, so they cannot directly be measured by NPMs.

Network performance metric (NPM) means the basic metric of performance measurement in the network management layer. On the right side of this slide, the NPMs are shown. 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*** consist 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.

Network Monitoring Methods

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

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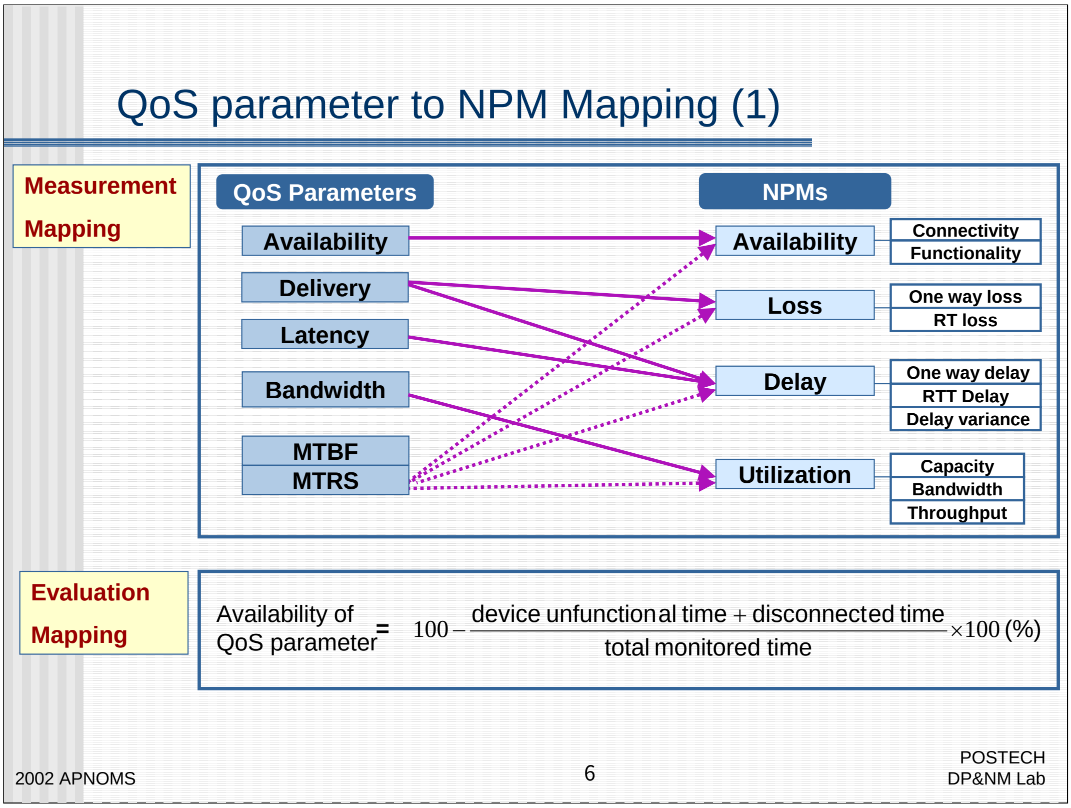
Network monitoring is very important to measure the value of NPMs. NPMs are measured by various network monitoring technologies. Traditionally, there are three methods of network monitoring, which are active monitoring [5, 10], passive monitoring [10, 11] and the method of using SNMP agent. This slide 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 from 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*** which is supported by most operating system. And system overload is very low because the amount of generated and analyzed traffic is small comparing to passive monitoring method. But test packets can be lost in the 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]. 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. But limited NPMs can be measured comparing 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 agent. The method of using SNMP agent is simple and scalable. But only the throughput of NPMs are measured by this method. Some related work on this are internet2[33] and MAWI[34]. Therefore, ***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 agent.

Although we may obtain various NPMs using these network monitoring methods, it is difficult to apply these values to QoS parameter directly. The contract between service providers and customers is performed using QoS Parameters and the network quality is measured using NPMs. To measure the QoS Parameters, first the NPMs for each QoS parameter should be decided. A QoS parameter can be mapped to one NPM or many. This mapping depends on the type of services 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 parameter in SLA monitoring. So we define a new concept of a mapping between QoS Parameters to NPMs in the next two slides.

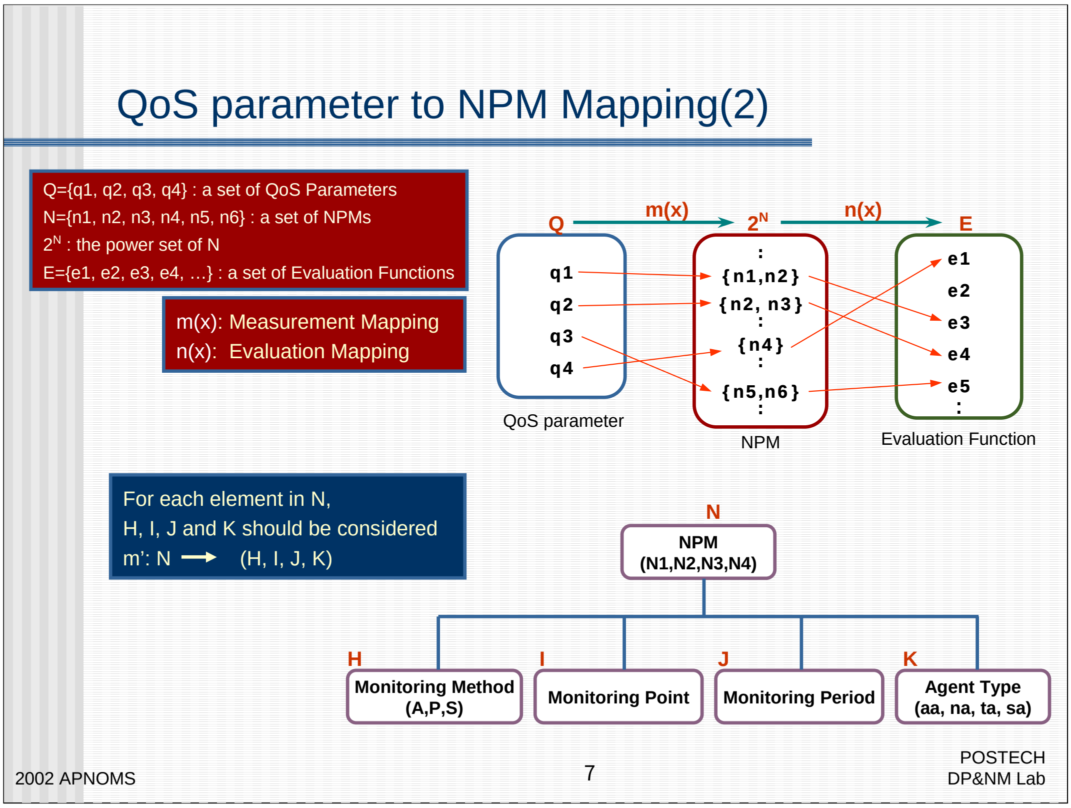


In this slide, we describe a mapping between QoS Parameters and Network Performance Metrics (NPMs). We divide this mapping into two steps: the measurement mapping and the evaluation mapping. Before we generalize our concept of QoS parameter to NPM mapping, we mention a specific example of mappings in network service. The QoS parameters and the NPMs in network service are described before as above figures.

First, we explain measurement mapping. Measurement mapping decides some NPMs given a QoS parameter. In network service, ***Availability of QoS parameter*** is mapped to ***Availability of NPMs.*** The ***availability of QoS parameter*** means the feasibility of service in every particular service request. On the other hand, the ***availability of NPM*** refer to the connectivity among network elements and functionality of the network elements. The functionality means whether the network elements work well or not. ***Delivery as the 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. The ***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 this slide, we show an example of evaluation mapping for ***Availability. Availability of QoS parameter*** is considered with connectivity and functionality in the network service. So we should check the connectivity and functionality of 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***.

These two mappings are highly dependent on the kind of services. The mappings introduced in this slide can be a guideline in network service. But it can be varied depending on the service provider. The measurement mapping and evaluation mapping is essential for SLA monitoring. When the available NPMs for QoS parameter are decided, the value of NPMs is measured using some network monitoring methods. Afterwards, we can apply the measured value of NPMs to the equation by evaluation mapping. After obtaining the value, we can assess QoS parameter in SLA.



In this slide, we define the generic mapping between QoS Parameters and NPMs from the example of previous slide. We formalized 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. The details are as follows.

First of all, 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 Q and 2^N is the measurement mapping: ***m(x)***, and the relationship between 2^N and E is the evaluation mapping: ***n(x)***.

m(x) represents a decision which NPMs are used to measure each QoS parameter. In ***m(x)***, we used the set of 2^N, not the set of N, because the mapping between set Q and set N may not be one-to-one mapping. Moreover ***Monitoring Method*** (H), ***Monitoring Point*** (I), ***Monitoring Period*** (J) and ***Agent Type*** (K) should be considered in ***m(x)*** for effective the measurement mapping, as shown in the lower side diagram of this slide. The ***Monitoring Method*** includes the active monitoring, passive monitoring and the method using SNMP agent. ***Monitoring Point*** is usually 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 that are used in network service are network agent(na) and traffic agent(ta).

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

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

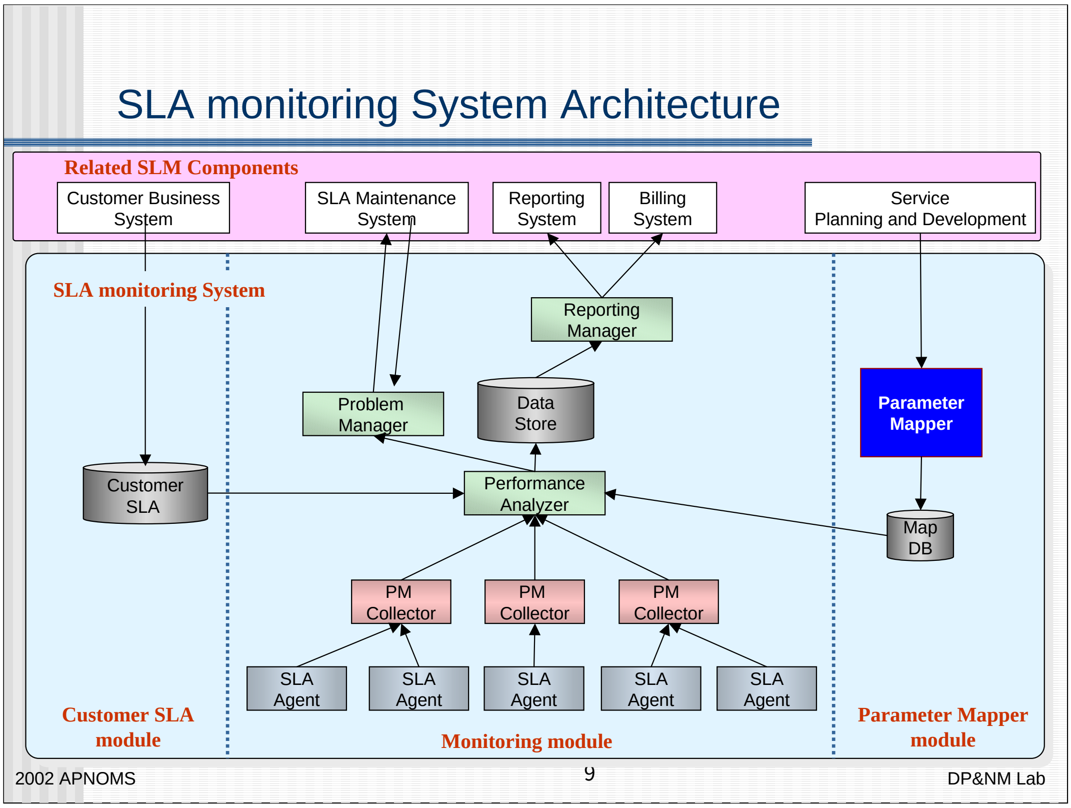
Design Issues of SLA monitoring System

- General Requirements of SLA monitoring System
  - Should be designed with no dependencies on SLA provisioning technologies.
  - Should be designed in a layered and distributed architecture
  - Should minimize the monitoring traffic and transferred data for management purpose
  - Should provide extendibility and flexibility for the variation of the number of customer and SLA contents
- Design Issues
  - Precise and concise QoS parameter to NPM Mapping
  - Decision of monitoring location, method, period and agent type
  - Decision of evaluation function for each Parameter
  - Design of communication method and data format between each functional modules
  - Design of the stored data format
  - Design of the period to keep data in the data store

In this slide we describe the design requirements of an SLA monitoring system for network services of NSP and ISP. The definition of the SLA monitoring system was already mentioned in the previous slide. 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 parameter to NPM 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 only based 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 regionally 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. The third is that 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. The 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 be varied 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 parameter to NPM mapping. Here you should also determine the monitoring location, method, period and agent type. There are three types of monitoring methods (active, passive and snmp-based) and 4 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 Parameters from network performance values gathered from SLA agents. One should also determine the stored data format and the period to be kept in the storage. The communication data format among each functional module is designed not to make high network traffic, and is another critical factor to be considered.



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 the right side of the above slide is to manage the QoS parameter to NPM mapping. For each QoS parameter a decision about NPM, monitoring location, period, method and agent type is made. From 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.

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

The center of this slide shows the monitoring module which is designed in a layered architecture. There can be several SLA agents for one service, because there can be several QoS Parameters for one service and several 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 at the Map DB and customer contract information at the customer SLA. 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, and the problem manager detects this failure or problem and sends an alarm message to an administrator or SLA Maintenance system immediately. Because MTTR is a very important QoS parameter, the problem in the service should be handled promptly in real time. The role of the reporting manager is to create a report for the billing system and the reporting system from the data store.

SLA monitoring for IP-Backbone Network Service

Service Configuration

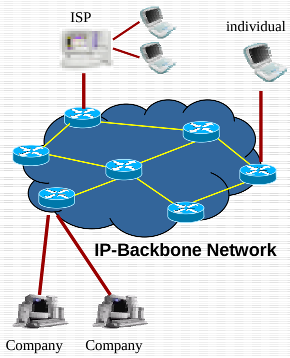
Service Provider	Network Service Provider such like KT, AT&T
Customer	company, organization, other service provider, individuals
Service	IP backbone network service

Measurement Mapping: m(x)

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

Evaluation Mapping: n(x)

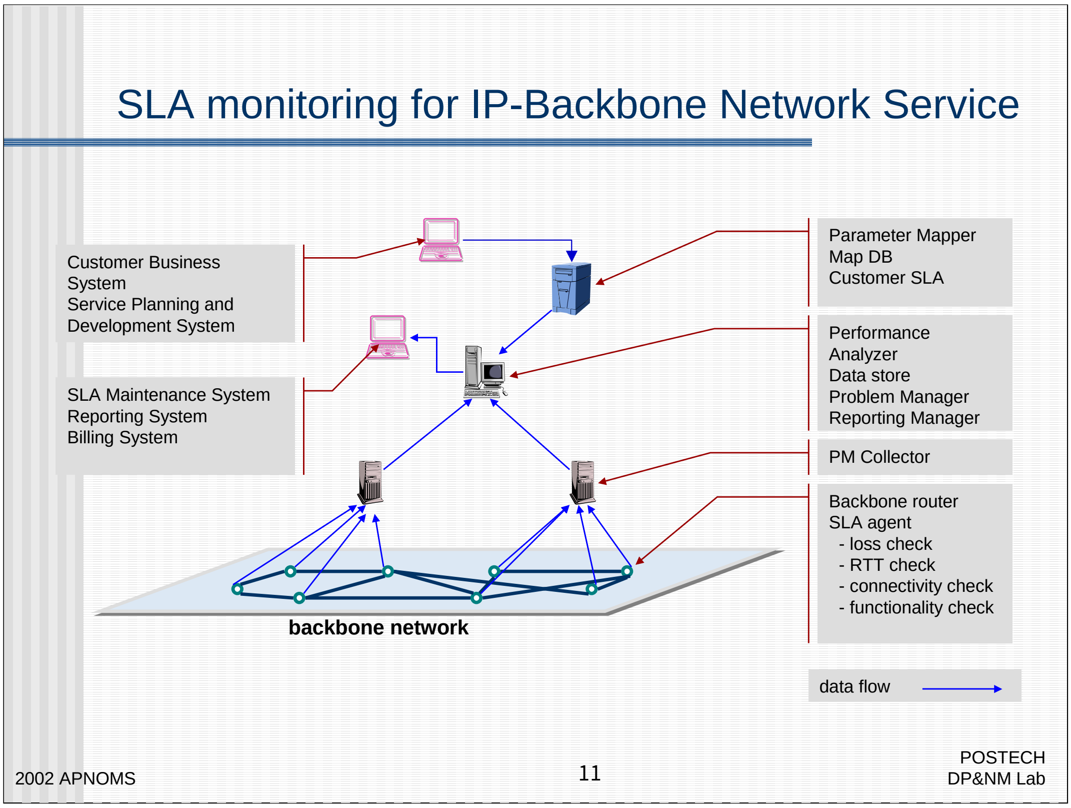
QoS parameter	Evaluation function
Availability	$100 - \frac{\text{device unfunctional time} + \text{disconnected time}}{\text{total monitored time}} \times 100 (\%)$
Latency	$\frac{\sum \text{RTT}}{\text{total number of RTT test packet}} (m \sec)$
Delivery	$100 - \frac{\text{number of lost packet}}{\text{total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



To validate our proposed architecture, we applied our theory to an IP-backbone network service and designed SLA monitoring system. The service provider of IP-backbone 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 Internet Service Providers (ISP) using leased line service, and individuals who are using xDSL service. The QoS Parameters in this service should be decided with the terms to represent whether the backbone network is in a healthy state or not.

Therefore we decided 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 RTT should be less than 50 msec. The delivery ratio should be more than 98.0%. From our definition of QoS parameter to NPM mapping there should be a decision about m(x) and n(x). First, we describe about m(x) which is illustrated in the above slide. The QoS parameter ***Availability*** is mapped to two NPMs; ***Functionality*** and ***Connectivity*** which is monitored at each edge router and every 5 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 ***RT loss***. By this m(x) mapping the monitoring method, point, period and agent type are decided. Among the IP-backbone network to monitor the given NPMs we should set up SLA agents at each edge router which generates test packet every 5 minutes and send the results to the upper layer ***PM collectors***.

To evaluate the quality of each QoS parameter, the n(x) functions are used. The numerical value of QoS parameter ***Latency*** is calculated as the average value of all ***RTTs*** from all test packets. We also defined the n(x) functions for ***availability*** and ***delivery***, as in the above slide. As mentioned previously, these evaluation functions are stored in the ***Map DB*** and are used by the ***performance analyzer***.



This slide 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 we defined in the previous slide 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*** are coexistent 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*** which receive data from out side systems are located at the same machine.

It is popular to use web technology as a user interface because of its efficiency and user-friendly properties. Therefore we use XML for transferred data format between each distributed components and HTTP for communication protocol. Every 5 minutes the ***SLA agents*** send the monitored data to the nearest ***PM collectors*** asynchronously in the form of XML. The PM collectors compress the NPM values from each ***SLA agents*** and send them to the ***performance analyzer***. We use Databases for ***Data Store***, ***Map DB*** and ***customer SLA***. By Web interface and the database the ***performance analyzer*** can construct a efficient reporting system.

In this paper we proposed a new concept of SLA monitoring: a QoS parameter to NPM mapping and a generic architecture of the SLA monitoring system. The QoS parameter to NPM mapping is the combination of measurement mapping and evaluation mapping. From this mapping one can decide what kind of SLA agents are used to evaluate the quality of the provided service in 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 a 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 are going to make an overall guideline of the QoS parameter to the performance metric for all other types of services such as hosting, application and content services. The refinement of the proposed SLA monitoring system architecture is also needed to apply to various services.

Conclusion & Future Work

- Conclusion
  - SLA monitoring is a basis for service maintenance and billing
  - QoS parameter to NPM mapping consists of
    - **Measurement Mapping**
    - **Evaluation Mapping**
  - A parameter mapping guideline for the network service
  - A generic SLA monitoring system architecture and one example
- Future Work
  - Implementation of SLA monitoring system we designed for IP-backbone service
  - Mapping guideline for other services such as application and content service
  - Adaptation of SLA monitoring system design for various services

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