Customer Service Management: An Information Model for Communication Services

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Abstract. Customer Service Management (CSM) offers a management interface between customer and service provider, which enables customers to individually monitor and control their subscribed services.
In order to model Customer Service Management for communication services, this paper proposes a protocol and technology-independent information model, which incoporates the individual quality of service parameters (QoS parameters) that are specified in customer-specific service level agreements (SLAs), and the logical infrastructure that is used to implement the communication service. The information model is validated for a real-life management environment.
This work has been carried out at the Leibniz Supercomputing Center (LRZ) in Germany as part of a research project that is supervised by the *German Research Network Organization* ("DFN-Verein"), and funded by the Federal Ministry for Education, Science, Research and Technology.

1 Introduction and Motivation

Communication services play a major role in the emerging universal service market: Intranets, Extranets, virtual private networks (VPNs) and the ubiquitous worldwide internet are and depend on communication services. Communication services are enablers for application services such as e-commerce, WWW, mail or news. Depending on the implementation, a communication service can be anything from an OSI layer 1 service to an OSI layer 4 virtual point-to-point connection with an individually specified (and enforced) service quality. In the simplest case, the communication service could be a locigal end-to-end connection with a specific bandwith between two access points; more often, the communication service is a complex VPN that consists of several logical end-to-end connections between many access points. To complicate things, communication services are typically layered on each other (e.g. IP over ATM over SDH).

The resulting service hierarchies illustrate the increasing need for service providers to establish an efficient and effective end-to-end service management, which includes the exchange of service-specific management information over organizational boundaries. Customer Service Management (CSM) [8] introduces concepts and principles to facilitate the exchange of management information between customer and service provider by offering the customer a logical view onto the service management of the service provider.

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In order to provide Customer Service Management for communication services, a protocol and technology-independent information model is needed, which incoporates the individual QoS parameters that are specified in the SLAs and the logical infrastructure that is used to implement the particular communication service. In [9], we introduced an information model suitable for IP communication services. Based on this experience, this paper proposes a **generic information model** for Customer Service Management that is suitable to deal with communication services independent of the position in the service hierarchy and incorporates individual service characteristics.
Section 2 describes the main problems associated with CSM in service hierarchies, identifies requirements that have to be met by the information model and points out, how existing approaches help to address these requirements. Section 3 proposes an information model that provides the neccesary information independent of the position in the service hierarchy. Section 4 discusses a scenario, for which the information model has been used. Section 5 gives a summary and discusses open issues.

2 Problem Analysis

2.1 Scenario

An example of a typical service hierarchy (IP over ATM) that involves several organizations can be found in Fig. 1. A *Carrier* offers a communication service based on ATM PVCs. An *IP-Provider* can use the ATM-PVC service to connect his IP routers, e.g. by means of RFC 1483 [4]. The resulting IP backbone offers an IP communication service, which can be used by an *Application Service Provider* (ASP). The ASP can set up value added services (VAS) on top of the IP communication service, e.g. WWW, email or news, which can be used by *End-Users*. In this scenario, each organization acts in a provider role to the higher layer, and in a customer role to the lower layer.

For the remainder of this paper, we focus on the management issues that result from this service hierarchy: It is very unlikely, that the management systems on each of those layers interoperate, because the management systems differ not only by their vendor (e.g. IBM/Tivoli, HP, CA), but also by the underlying management architecture (e.g. OSI/TMN, Internet, CORBA, Java/WWW, proprietary). Futhermore, the management systems incorporate technology-specific network resource models, as each organization implements an individual network infrastructure in order to manage the specific communication service (ATM and IP).

In this scenario, the goal of Customer Service Management is to mediate between the involved management systems: Each organization that acts in a provider role in Fig. 1 offers necessary management information and functionality to the adjacent organization acting in the customer role. This can be achieved by means of a service-specific CSM (e.g. CSM-ATM, CSM-IP). However, in the

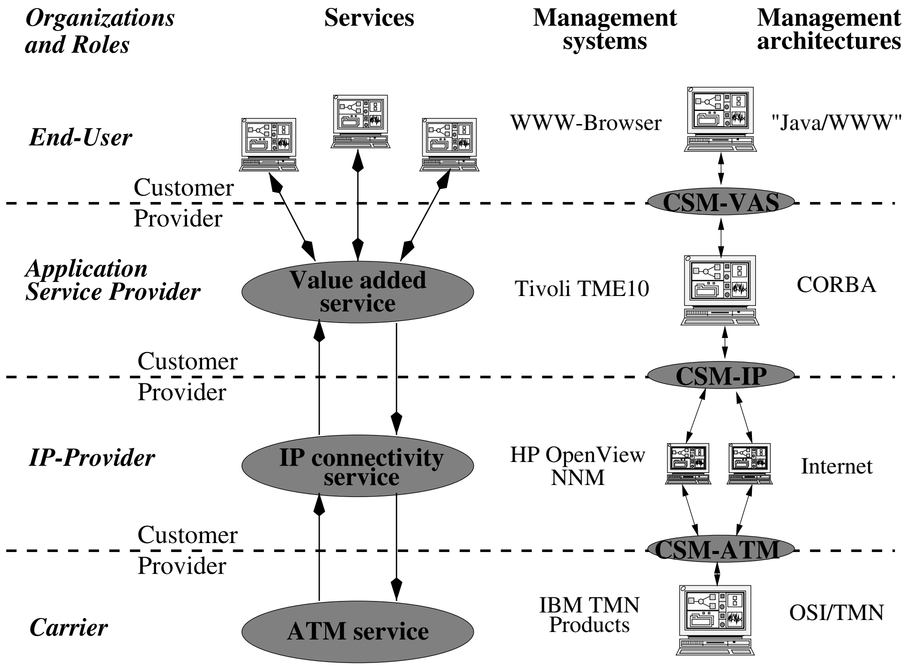

Fig. 1. A typical service hierarchy

context of this paper, we are not looking for an individual information model for each communication service; instead, we are looking for a generic and abstract information model that can be applied to a wide range of scenarios (i.e. communication services). Therefore, the following problems have to be addressed:

1. For the customer of a communication service, the knowledge about the resources, that make up the communication infrastructure, is of great importance. For example, the IP-Provider in our scenario needs configuration, performance and fault information about all subscribed ATM PVCs. Without this management information he is not able to manage his IP routers and subnetworks efficiently.
2. Besides this, the information model must incorporate information about the customer-specific SLAs and the contained QoS parameters. Without this information, a customer cannot monitor and control the individual service quality and hence cannot detect QoS violations. For example, the IP-Provider in our scenario needs service-specific management information about his subscribed ATM-PVCs from the lower layer in order to provide the IP service to the higher layer according to the specified SLAs.
3. The management systems on each layer of the service hierarchy must be interoperable with management systems on the lower and higher layer. As already pointed out, CSM has to deal with management systems that differ not only by vendors but also by the management architectures.

2.2 Requirements

Based on these three problems, the following requirements can be derived:

1. As already mentioned, the knowledge about the resources that make up the communication service, is of great importance for the customer of a communication service. Only by means of the knowledge about these resources and their dependencies, the customer can verify whether the communication service is configured according to his needs and requirements or performance thresholds are exceeded.
   a) For the scope of this paper, the information model only has to incorporate information that is necessary for the customer. For example, inventory details of a particular resource are not relevant for a customer. Instead, the information model must offer a simplified logical view onto the infrastructure as it is perceived by the customer. This shields the customer from the huge amount of managed objects representing the physical and logical resources.
   b) The information model must be applicable on different layers of the service hierarchy, i.e. it must abstract from the details of specific protocols and techniques (such as WDM, SDH, ATM, IP). In particular the information model must be capable of modeling connection-oriented protocols (e.g. ATM) as well as connectionless protocols (e.g. IP).
2. However, the sole knowledge of the logical infrastructure is not sufficient for the customer. In addition, he needs access to service-related management information, i.e. meaningful and aggregated information about the individual service quality. Hence, the information model must reflect the service characteristics of the provided communication services. The individual service characteristics are specified in service level agreements (SLAs) by means of QoS parameters.
3. Finally, CSM has to interoperate with various management systems based on different management architectures. This results in the following interoperability requirements:
   a) The information model must be specified in a description language that can be transferred into the information modeling languages used by the various management architectures (e.g. SNMP-SMI, OSI-GDMO).
   b) The information model has to be mapped onto the different network resource models implemented by the various management architectures. These systems offer the measurable values that are necessary to calculate the service characteristics.

2.3 Related Work

Two areas of related work can be identified from the requirement analysis: *Information modeling of networks* and *QoS modeling*. Due to the various approaches that exist, we cannot discuss all of them in detail here. See [10],[11] and [3] for a good overview over the corresponding areas. As an example of ensuring QoS

and in particular service levels across administrative boundaries see [2]. For the remainder of this section, we focus on those approaches that offer concepts and principles that help to solve our problems: G.805 for information modeling of networks and X.641 for QoS modeling.
ITU G.805: The "Generic Functional Architecture of Transport Networks" [6] describes the functional and structural architecture of transport networks in a technology-independent way. G.805 focuses on input/output flows and their bindings within certain processing functions, rather than on physical entities. Hence, G.805 defines abstract architectural components (such as **layer network, subnetwork, link** and **access point**), concepts for **partitioning** and **layering** networks, and **connection supervision techniques**. G.803 [5] and ATM M4 [1], for instance, apply these generic concepts for particular technologies (SDH and ATM) successfully.

G.805 is a very useful source of information for modeling transport networks in a technology-independent way. The "partitioning" and "layering" concepts can be used to decompose and model service hierarchies: Layering allows the hierarchical decomposition of network infrastructures into independent **layer networks**. Partitioning allows the decomposition of a complex layer network infrastructure into independent **subnetworks** (in the same layer network). **Access Points** provide access to subnetworks. However, as the scope of G.805 lies on the identification and definition of architectural components and building blocks, it does not detail the characteristics of the identified building blocks.

ITU X.641: The "Quality of Service Framework" [7] defines terms and concepts to develop or enhance quality of service issues in IT environments. It models **QoS characteristics** as quantifyable aspects of a system and identifies generic QoS characteristics that are of general importance. Further, it introduces concepts to specialize and derive QoS characteristics: **Specialized QoS characteristics** make QoS characteristics more concrete and useable. **Derived QoS characteristics** can be defined as (mathematical) functions of other QoS characteristics. In order to manage the quality of a service, **QoS management functions** are identified, which can be composed of a number of smaller elements, termed **QoS mechanisms**. Finally, the need of **QoS verification** is outlined as the process of comparing the requested QoS characteristics with the observed QoS characteristics.

X.641, although very complex, offers valuable input for modeling quality of service issues of communication services. It provides concepts to model QoS parameters and addresses QoS management aspects such as establishment, monitoring and maintenance of QoS parameters. For our purpose, we adopt some terms and concepts of modeling QoS parameters. The identified generic classses of QoS characteristics are used to derive and specialize network and service characteristics of communication services.

3 A CSM Information Model for Communication Services

The discussion in the previous section pointed out, that existing standards offer valuable concepts and principles that can be used to define a generic information model to be used for Customer Service Management for communication services. Section 3.1 gives an overview of the information model and highlights the concepts used. Sections 3.2 and 3.3 detail the information model.

3.1 Methodology

The basic idea of our approach is to define the information model for Customer Service Management based on the concepts of G.805 and X.641, and extend it by service-level information necessary to meet the requirements identified in section 2.2:

1. The information model must incorporate information about the customer-specific SLAs and the contained QoS parameters. We use some terms and definitions of X.641 and introduce "target QoS parameters" which reflect the individual quality of the communication service as has been negotiated between customer and provider. "Observed QoS parameters" represent the observed quality of the service as it is perceived by the customer when using the service. Furthermore, we add "measurable values", i.e. configuration and performance information about the underlying logical infrastructure, which can be derived from the management systems. According to QoS verification in X.641, we introduce an algorithmic mapping to close the gap between observed QoS parameters and measurable values, which can be described by means of a metric. All negotiated target QoS parameters of a communication service and the associated metrics are speficied in the customer-specific, individual SLA.
2. The information model must be able to model various communication services independent of a specific technology. We introduce a "logical infrastructure" that models the communication service as it is perceived by the customer. We identify generic building blocks of this logical infrastructure and attribute these with measurable values that can be extracted from management systems. Furthermore, we use the "layering" and "partitioning" concepts introduced by G.805 in order to model complex logical infrastructures.
3. We use the Unified Modeling Language (UML) as a graphical notation for the information model. UML provides a common understanding and can be mapped onto the information modeling languages used by different management architectures.

Using UML terminology, the CSM information model for communication services is modeled by two packages: `CSMService`, which contains information about the SLAs, QoS parameters, metrics and Actions, and `CSMNetwork`, which contains information about the logical infrastructure, as it is perceived by the customer. Both packages are described in more detail in the following subsections.

3.2 Package "CSMService"

The CSMService package (see Fig. 2) defines managed objects that represent SLAs for communication services as they are negotiated betwen customer and service provider. `Service` acts as a base class. As we focus on communication services in this paper, we subclass `CommunicationService`, and refine `Guaranteed-`

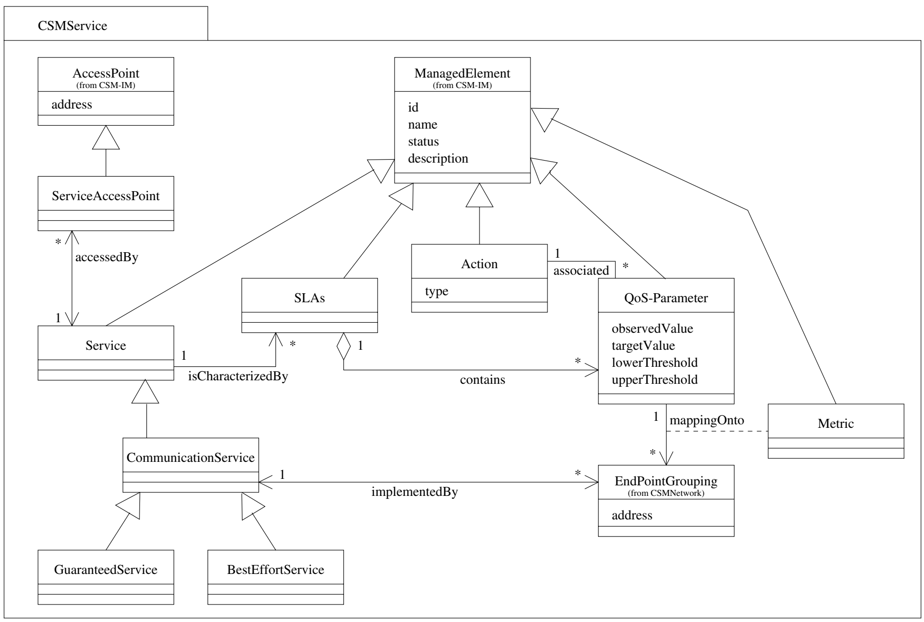

Fig. 2. Package "CSMService"

`Service` (e.g. ATM-PVC service) and `BestEffortService` (e.g. IP service). A service can be accessed by a `ServiceAccessPoint`, a refinement of an abstract superclass `AccessPoint`. A service is characterized by `SLAs`. A SLA contains QoS parameters, which are modeled by `QoS-Parameter`[1]. The QoS-Parameter class is attributed with `targetValue` and `observedValue`, which reflect the target and observed QoS parameters. If the thresholds specified in `lowerThreshold` and `upperThreshold` are exceeded for a particular QoS parameter, the associated `Action` is executed. Several `QoS-Parameter` instances can be associated with one type of `Action`.

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[1] The generic QoS characteristic of X.641 can be used to refine `QoS-Parameter`.

CommunicationServices are implemented by EndPointGroupings. EndPointGrouping is imported from package CSMNetwork and models the logical infrastructure that is necessary to implement the communication service. To allow for the mapping of the associated QoS, Metric is introduced, which contains the algorithmic description of the mapping between the QoS instance and the associated EndPointGrouping. Service, SLA, Action, QoS-Parameter and Metric are derived from a generic superclass ManagedElement, which acts as a common top-level container in the inheritance tree.

3.3 Package "CSMNetwork"

The CSMNetwork package (see Fig. 3) defines managed objects that represent the logical infrastructure that is necessary to implement a communication service. By means of the classes EndPointGrouping, Link, Node, Network

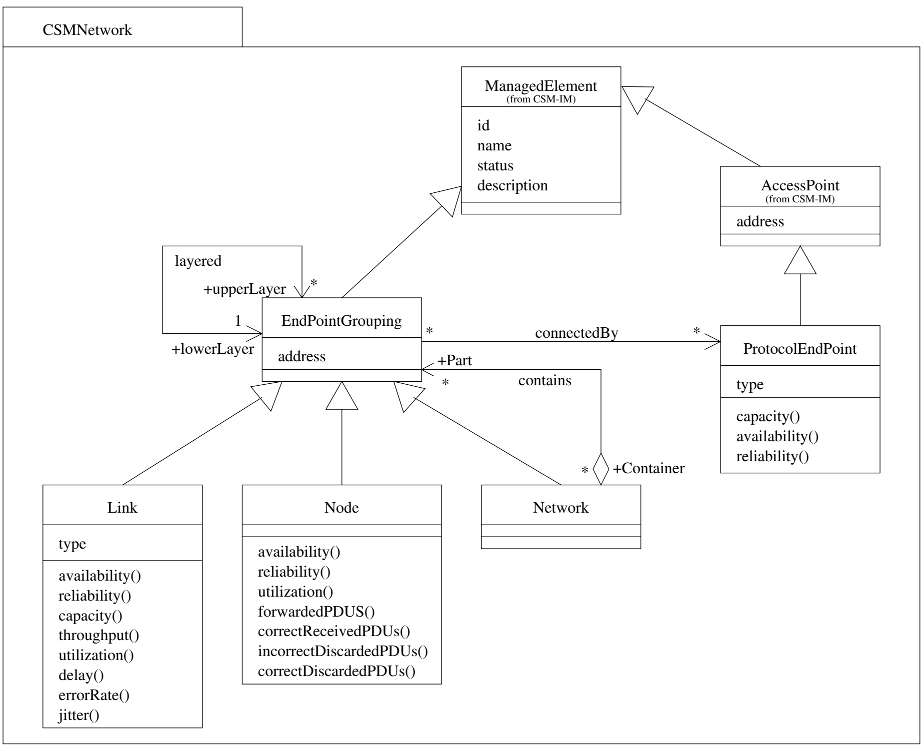

Fig. 3. Package "CSMNetwork"

and ProtocolEndPoint, large, layered networks can be modeled: EndPointGroupings are connected by ProtocolEndPoints, a refinement of the G.805 principle"access point". EndPointGrouping is a base class for the logical building blocks Link, Node and Network. Link is an abstraction of any kind of virtual connection (e.g. a physical link, an optical wavelength, a SDH trunk, ATM-VP, ATM-VC, an IP subnet, ...) and consists of serveral ProtocolEndPoints for the purpose of transferring data between them. A Node is an abstraction of a network component (e.g. WDM multiplexer, SDH cross-connect, ATM switch or IP router). Network models the G.805 principle of "partitioning": By means of the contains relationship between Network and EndPointGrouping, a network can contain EndPointGroupings, i.e. the building blocks Link, Node and Networks again. The self-association layered of EndPointGrouping models the G.805 principle of "layering": EndPointGroupings can be layered on EndPointGroupings in order to model hierarchies of infrastructures.

The building blocks, especially Link, Node and ProtocolEndPoint provide methods to access the "measurable values" as a function of time. Most of these measurable values are refinements of the derived and specialized characteristics of X.641. For instance, the methods availability(), reliability(), capacity(), throughput(), utilization(), delay(), errorRate() and jitter() of class Link offer access to measurable values that are typical for virtual connections. Furthermore, the type attribute indicated the topology and direction (e.g. unidirectional/bidirectional point-to-point or bus, ...). Class Node provides access to the typical measurable values of network components by means of the methods availability(), reliability(), utilization(), forwardedPDUs(), correctReceivedPDUs(), incorrectDiscardedPDUs() and correctDiscardedPDUs(). Finally, ProtocolEndPoint provides methods capacity, availability and reliability for the same reasons; the type attribute indicates the protocol used for transmission.

4 Integration in the Management Environment

The information model has been developed within a research project that is supervised by the *German Research Network Organization* ("DFN-Verein"), and funded by the Federal Ministry for Education, Science, Research and Technology. This section outlines the scenario and shows, how the information model can be applied for this scenario.

4.1 Scenario

The DFN-Verein operates a nationwide network (Broadband-WiN, B-WiN), a VPN based on an ATM cross connect infrastructure. Based on the B-WiN, the DFN-Verein offers various services to its customers, in particular an IP communication service, which provides IP connectivity within Germany and to the worldwide internet. The customers of the DFN-Verein are German universities and research organizations; the Leibniz Supercomputing Center (LRZ) is one of those customers.

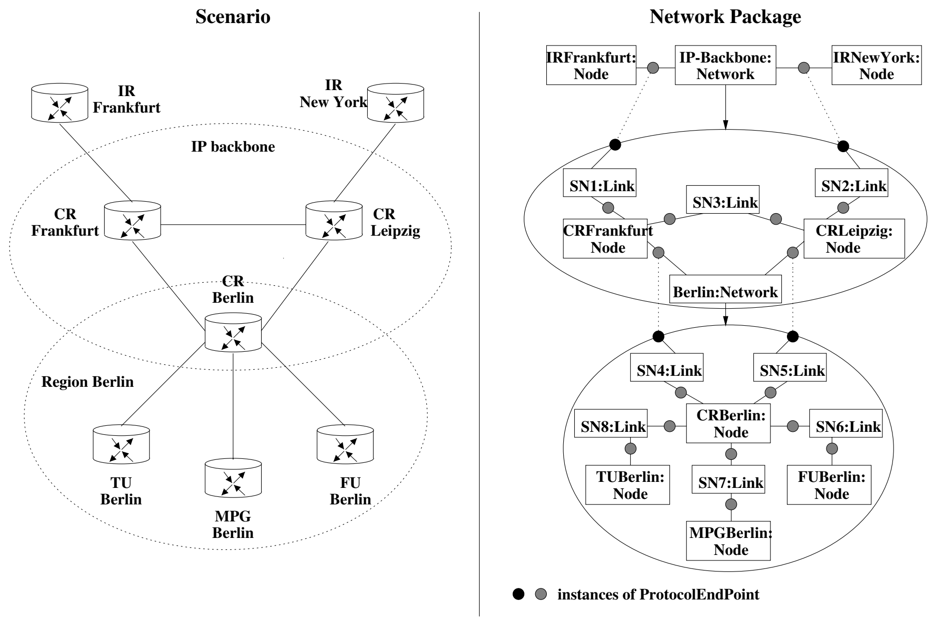

Fig. 4. Modeling the IP infrastructure

The left-hand side of Fig. 4 outlines a simplified view onto the B-WiN[2]: The IP infrastructure consists of an IP backbone that is connected to the US Internet and the European Research Network by means of the international routers (IR) IR New York and IR Frankfurt. The IP backbone and these two routers are linked by two IP subnets, which are visualized by a connecting line between them. The IP backbone consists of three central IP routers (CR) in Berlin, Leipzig and Frankfurt connected by three IP subnets in a ring-like topology. Each CR connects a geographical region to the IP backbone. For example, the three IP edge routers (ER) in the metropolitan area of Berlin (ER TU Berlin, ER MPG Berlin, ER FU Berlin) are connected to the CR Berlin by three IP subnets based on a star topology.

In the B-WiN, no individual SLAs have been negotiated between the DFN-Verein and customers. The DFN-Verein is currently rolling out the successor of the B-WiN, the "Gigabit-WiN" (G-WiN), where customer-specific SLAs are an important issue. For this purpose, the LRZ specified several QoS parameters for the G-WiN, which could be incorporated into the individual SLAs. One of these QoS parameters is the "Availability of the IP backbone".

To demonstrate, how a SLA could look like in the G-WiN, an exemplary SLA is described for the customer LRZ. The target availability for this QoS parameter over a day must be at least 85%; the target availability over a year

[2] This scenario details only a subset of all regions, nodes and links in the B-WiN.

must be at least 99,5%. According to the SLA, the observed availability A of the IP backbone in any given time interval $[t, t']$ is calculated from the availability of all n IP routers N_i, $i \in 1..n$ of the IP backbone:

$$A_{IPBackbone}([t, t']) = 1/n * \sum_{i=1}^{n} A_{N_i}([t, t']) \tag{1}$$

The availability of an IP router A_{N_i} is calculated by the availability of all its m interfaces $I_j, j \in 1..m$, :

$$A_{N_i}([t, t']) = 1/m * \sum_{j=1}^{m} A_{I_j}([t, t']) \tag{2}$$

X.641 [7] defines the availability A as

$$A = \frac{MTBF}{MTBF + MTTR} = 100\% - \frac{MTTR}{MTBF + MTTR} \tag{3}$$

where $MTBF$ is the "Mean Time Between Failures" and $MTTR$ is the "Mean Time To Repair". Accordingly, the availability of an interface A_{I_j} is defined as

$$A_{I_j}([t, t']) = 100\% - \frac{MTTR([t, t'])}{t' - t} \tag{4}$$

with $MTBF([t, t']) + MTTR([t, t']) = t' - t$.

Within the SLA, $MTTR$ and $MTBF$ of an interface are mapped onto the reachability from a central management station, which polls the current state of the interfaces of their managed nodes using "ping". The polling results are used to calculate the availability of an interface as follows: $MTTR$ is the time interval, the interface is not reachable from the management station; $MTBF$ is the time interval, the interface is reachable. Finally, the SLA sets the time interval $[t, t']$ to 5 minutes in order to achieve a good compromise between granularity of the reachability information and resulting management traffic. So far, no action is specified in the SLA, when the observed availablility does not meet the target availability of the IP backbone.

4.2 Modeling the Scenario

The right-hand side of Fig. 4 shows, how the CSMNetwork package can be used to model this scenario: Routers are represented by instances of `Node`, subnetworks are represented by instances of `Link`. The IP backbone and the region Berlin are modeled using instances of `Network`. Interfaces are modeled as instances of `ProtocolEndPoint`, which are connected by `Links` to `Nodes`. The `Network` instance IP backbone contains the `Network` instance region Berlin and illustrates, how the partitioning concept can be used to decompose a complex IP infrastructure.

In order to add characteristic details of a particular technology or protocol (such as IP in our scenario), the classes of the CSMNetwork package can be refined. For the IP communication service of the B-WiN, this has been done in [9].

To model the described SLA for customer LRZ, one instance of `SLA` is created for customer LRZ. The SLA instance contains two instances of `QoS` in order to model the daily target availability and the yearly target availability of the IP backbone: The `targetValue` attributes are set to 85% and to 99,5% respectively. The `observedValue` attributes can be calculated by the algorithm (1),(2),(4) described above, which can be specified using the `description` attribute of class `Metric`. The measureable values, i.e. the reachability of all interfaces, are provided by the `status` attribute of class `ProtocolEndPoint`, inherited from class `ManagedElement`.

4.3 Prototypical Implementation

In order to provide management information about the IP communication service to the German universities and research organizations, a distributed client/server application based on the "WWW/Java/CORBA" approach has been implemented. Fig. 5 is a screenshot of the Java-GUI. On the left-hand side, the IP infrastructure can be navigated using a hierarchical tree structure. The right-hand side visualizes the same infrastructure using maps, which represent the various regions. Colours indicate the current state of the IP infrastructure. IP subnetworks are attributed with current configuration and performance information such as *capacity* [MBit/s], *throughput* [MBit/s] and *utilization* [%].

The maps are a visual representation of the IP backbone and the various regions (e.g. Berlin). Each map contains regions, IP routers and IP subnets that represent the logical infrastructure for the customer. The reachability information is already implemented and could be used to calculate the observed availability of the IP backbone.

5 Summary and Open Issues

The exchange of management information between customer and service provider is facilitated by means of a service-oriented management interface called "Customer Service Management" (CSM). CSM enables customers to individually monitor and control their subscribed service.

In order to model Customer Service Management for communication services, this paper proposes a protocol and technology-independent information model, which incoporates the individual QoS parameters that are specified in the SLAs and the logical infrastructure that is used to implement the particular communication service.

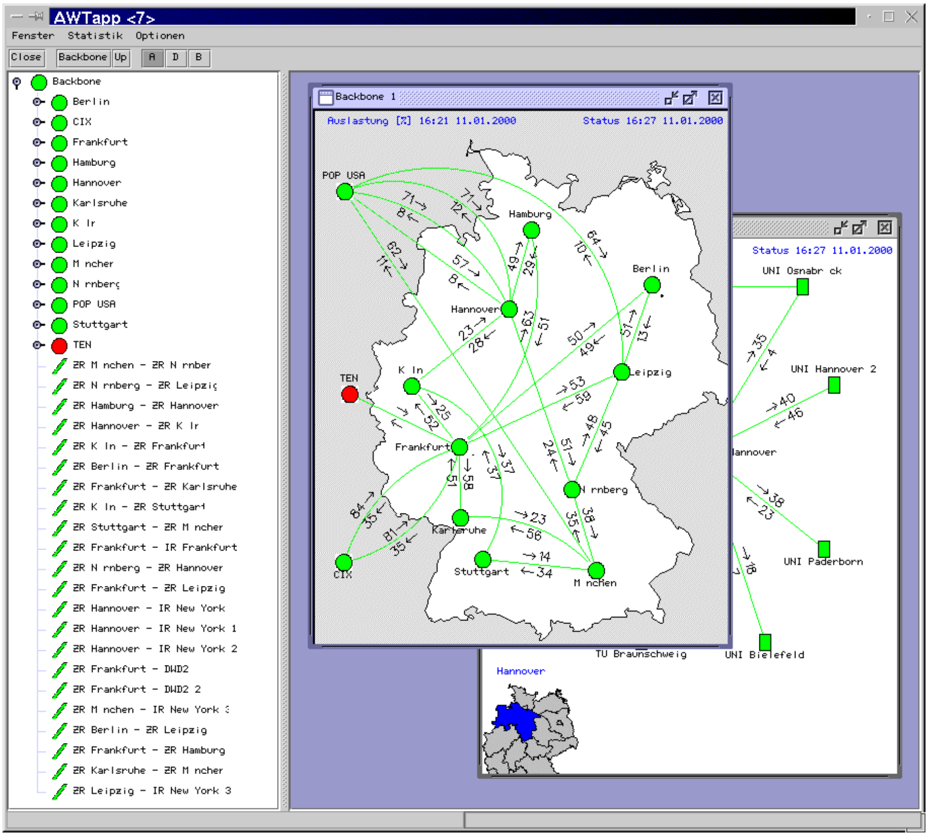

Fig. 5. Customer view of the IP backbone

Using UML as a graphical notation, X.805 concepts of layering and partitioning for describing a logical view onto the network infrastructure, and X.641 terms and concepts for QoS modeling ensures, that the proposed information model is independent of the position in service hierarchies and that it can be applied to a wide range of scenarios.

Beside an IP communication service, we are going to instantiate the information model for other communication services, probably an SDH point-to-point service. Furthermore, we are going to model other QoS parameters using the CSMService package, such as the overall throughput in the IP backbone. The research activities will focus on the mapping techniques that are used to close the gap between observed QoS parameter and measureable values.

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