Service Management for End-to-End QoS Multimedia Content Delivery in Heterogeneous Environment

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Abstract

Integrated service management aims to support efficient cooperation between various business entities, in order to offer end-to-end QoS based services to end users. This is challenging, especially in the context of heterogeneous technologies (IP, DVB-T/S, UMTS, GSM/GPRS, etc.). This paper proposes a service management (SM) architecture, involving several actors such as Service Providers (SP), Content Providers (CP), Network Providers (NP) and Content Consumers (CC). The SM framework presented is an architectural component of an Integrated Management System (IMS), having as a prime objective the support of end-to-end QoS based services through the integrated management of content, networks and terminals in heterogeneous networks contexts.

1. Introduction

A major objective of management systems in next generation networks is to provision and control the resources for guaranteeing *End-to-End (E2E) Quality of Service (QoS)* for value-added services. In this E2E chain, various business models are possible, involving several entities such as *Service Providers (SP), Content Providers (CP), Network Providers (NP), Content Consumers (CC), Access Providers (AC), Brokers/Resellers,* etc. A management system should support effective and efficient cooperation among such entities. All these "dimensions" make the architectural design and development of service and network management systems, very challenging, especially in the context of heterogeneous interconnected networks.

Service Management (SM) is an important part of any service-oriented management system. The current trend is to distinguish between *service* and *resource /network* related management functions. This is reflected in defining SM as a separate component.

The work reported in this paper has been conducted in the framework of the EU IST project ENTHRONE [8], [9], [10] [11]. The development of an architecture for SM is seen as a main component of an *Integrated Management Supervisor (IMS)* [12**].** This paper proposes a specific SM framework, based on *Service Level Agreement/ Specification (SLA/SLS)* concepts, applied in heterogeneous multidomain contexts, in conjunction with a particular inter-domain QoS peering approach. SLAs formalize the service-level dialogue between the *Customer* (CC) and SP, for requesting and receiving a specific QoS-based service. SLS provide a level of abstraction that allows negotiation at the network-based resource layer, mainly between providers, especially SP/NP or NP/NP. The

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negotiations result in the establishment of a logical overlay network (consisting of a set of aggregated pipes) deployed across heterogeneous networks, which is then used as a base for implementing the planned and provisioned end-to-end services offered to the Customers or CCs. This paper presents the SM functional components, for both SPs and NPs.

A service scenario is described, to clarify the role of the stakeholders and the processes involved. An overview of service level management is presented, as it applies to the stakeholder roles.

The paper is organized as follows. Section 2 briefly discusses some previous and current related work. Section 3 introduces the ENTHRONE SM framework, presents how SLA/SLS concepts are used, explains the role of business actors and describes the SM components. An example of a service scenario is presented in Section 4 and finally, some conclusions are presented in section 5.

2. Related Work to Service Management

The SM is a main component of an E2E QoS architecture. We summarize the solutions and achievements related to SM mainly in EC funded research projects, while being aware of other approaches proposed in the literature.

The IST project AQUILA, [1], implemented a QoS-based architecture for controlling, monitoring, and accessing the resources in DiffServ networks by developing a *Resource Control Layer (RCL)* as an overlay network over DiffServ. AQUILA did not consider any business-related or technical layer aspects in service offering, such as SLAs, business processes, billing, etc. It did not consider the roles of different stakeholder roles at the service, access, and network levels.

The IST project TEQUILA, [2], proposed a set of *connectivity services* and *Traffic Engineering (TE)* tools to obtain quantitative E2E QoS guarantees in a single domain through planning, dimensioning and dynamic control of scalable and qualitative traffic management techniques across a *single* IP domain. An IP connectivity service is described by a set of SLS and is the result of a negotiation between a provider and a customer. The TEQUILA approach distinguishes between *service* and *resource* functions and its proposed system consists of the following subsystems: S*ervice Management (SM), TE* and *Monitoring Subsystem (MS)*. The IST project MESCAL [3], is a follow-up to TEQUILA, extended to multiple IP domains. The interactions between SP-NP, NP-NP and NP-Access Providers (AP) are outside the scope of MESCAL. Neither TEQUILA nor MESCAL considered the process of (automated) service definition and service offering by the SPs. Neither project developed an end-user application service framework, taking into account the business-related aspects of high-level service offerings.

A service oriented architecture is developed in IST project CADENUS [4], including functional blocks at the user-provider interface, within the SP domain, and between the SP and the NP. The CADENUS business model considers the SPs and NPs and service creation and offering process. It does not, however go into details of how static and dynamic resource management and traffic engineering are achieved at the network level.

The objective of the ongoing IST project EuQoS [6], is to integrate and validate end-to-end QoS networking technologies to support advanced QoS-aware multimedia applications over multiple, heterogeneous network domains. The focus is on the development of an integrated resource management system called "EuQoS System" and an associated EuQoS signaling protocol. The EuQoS limits its scope to end-to-end network resource management only.

3. ENTHRONE Service Management Framework

The ENTHRONE project, [8], [9], [10], [11], [12], has as its overall objective to cover an entire audio-visual service distribution chain, including content generation, protection, distribution across QoS-enabled heterogeneous networks and delivery of content at user terminals. The whole content delivery chain (CC, SP, NP, CP) is considered.

A *cascaded* QoS peering model has been selected ([5], [10]) to establish the necessary contracts between providers; it has the advantage of a better scalability, because an SP does not need to know the inter-domain topology and routes. An SP does not need to interact with all NPs in the chain. Prior to fulfilling the customer service requests, resource provisioning is performed in advance, [10], [11]. The provisioning is done in the chain of ASes at aggregated levels, with such actions being performed infrequently. This is a *scalable* solution because there is no need to go through the chain of SP/NP and NP/NP to provision the involved networks for every individual requested service. On the other hand, the dynamicity and efficiency of resource allocation is assured at the invocation phase by separately controlling the resource usage invocation for the aggregated pipes and also for individual requests at the ingress point of the pipe. ENTHRONE is concerned with E2E QoS in terms of

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performance, at both the application and network levels, and deals with mapping between these levels.

Another ENTHRONE goal is to provide a bridge between the content provision environment and the networking world, resulting in cross-industry co-ordination on both network and content management issues, and bringing focus to mutually advantageous standards such as MPEG-21. This is a major motivating factor in choosing the MPEG-21 data model and metadata descriptions, in order to provide the common support for implementing service and resource management.

3.1 SLA and SLS Concepts Applied

ENTHRONE uses SLA templates to define a description of the service offered, including some technical, commercial and legal parameters. The technical characteristics of an SLA are used to form the SLS, which is a subset or derivation of the SLA [7], with reference to the provisioning aspects of the service e.g. request, activation and delivery aspects from network perspectives. ENTHRONE deals with a subset of services, described in [8]. The parameter list of an SLS is given in [11]. In view of ENTHRONE, an SLA template may include elements such as, [7], [2]: *Resource, Scope, Type of service, Service schedule & Activation time, Application level (Traffic and Performance) requirements/constraints, Terminal capability, Content adaptation models, Connectivity/ Access, Availability Guarantees, Reliability Guarantees, Security, Billing, etc.* Each such element can have one or more attributes.

3.2 Business Actors

This section gives an overview of the roles of the business actors participating in a service request and service delivery chain.

An *end-user* or *Content Consumer* (CC) is an entity (human/process) associated with and named by the Customer for using the services bought by the Customer. A *Customer* has the legal ability to subscribe to QoS-based services offered by SPs. When a customer establishes a SLA, it can nominate a set of end-users that are to be the target recipients of the services.

A *Content Provider* (CP) is an entity (organization) which gathers/creates, maintains, and distributes digital information. It owns/operates network hosts that are the source of downloadable content but it might not own any networking infrastructure. The content is offered directly to the customers or to SPs. The CP can contain a *Content Manager (CM)* and several *Content Servers (CS)*. The CM keeps track of all material (video, audio), associated information, and provides browsing and search facilities to its clients (e.g. SPs). It negotiates with them the content to be delivered and the delivery conditions. A CS (e.g. video server) is controlled by CM and provides physical storage and streaming facilities for the content material.

A *Service Provider* (SP) aggregates content from multiple CPs and offers/delivers this content to consumers with some QoS-based guarantees. SPs may or not necessarily own and administer a networking infrastructure

A *Network Provider* (NP), in IP-space, offers QoS-based IP connectivity services. NPs own and administer IP networking infrastructures and interact with each other for the purpose of expanding the geographical span of the offered connectivity services. In DVB-space, NPs provide broadcasting coverage. Also *Access Network Providers* (ANP) may exist in the E2E chain as separate entities.

We assume that an end user has only a high-level view of the service and is not interested in the technical aspects associated with the service. The SP might not need to have knowledge about the specific networking technology managed by the NPs. The NP needs to know about technical aspects associated with a particular service in terms of the delivery.

3.3 The Service Management Architecture and Components

The ENTHRONE general architecture contains four planes: the *Service Plane (SPl)* establishes appropriate SLAs/SLSs among the operators/providers/customers. The *Management Plane (MPl)* performs long term actions related to resource and traffic management. The *Control Plane (CPl)* performs the short term actions for resource and traffic engineering and control, including routing. In a multi-domain environment, the *MPl* and *CPl* are logically divided into two sub-planes: inter-domain and intra-domain. This allows each domain to have its own management and control policies and mechanisms. The *Data Plane(DPl)* is responsible for transferring the multimedia data and for setting the DiffServ (for IP) or DiffServ-like (for DVB) traffic control mechanisms to assure the desired level of QoS.

A basic architectural requirement for ENTHRONE management system [9], [10], [11], [12], is to assure compatibility with different legacy management systems of SPs, NPs, CPs and CCs. Towards this goal, ENTHRONE includes in its IMS the whole SPl, but only the "upper", interdomain-related part of the CPl, and SPl. ENTHRONE implements the upper layer of the architecture, while the intra-domain management, control and data plane functions are left intact in each AS.

In ENTHRONE, the end-user selects a service with a given or chosen QoS, based on subscription to services either with published/well known SLAs, or dynamically negotiated SLAs which are translated by a provider into a set of SLSs, required for network configurations. Service provisioning is accomplished using SLS, defined for DiffServ-enabled networks.

The IMS is a distributed system and hence has a number of functional facilities/ components for each entity/organization (SP, CP, CC, NP). Therefore, its functional components, which are listed below, can be present or absent in each organisation/entity, depending on the entity role in the E2E service delivery chain.

- The *Content Manager (CM)* keeps information related to the content, and supports operations related to any subscriptions for the use of content
- The *Terminal Device Manager (TDM)* deals with service subscription/negotiation and monitoring.
- The *IMS Dispatcher* and especially its SM located at the SP deals with the customer subscriptions (cSLAs), contracts with NPs (pSLSs), the services and the access to the chosen service. This is limited to the services owned by the SP. The SM at the NPs deals with pSLSs.
- The *Network Manager (NM)* deals with inter-domain issues: QoS discovery, QoS-based route selection and the different types of QoS services that can be offered. The NM has some knowledge of the resources and control layers, with the inter-domain vision for QoS service set-up in advance. Figure 1 shows the Service Provider view of Service Management.

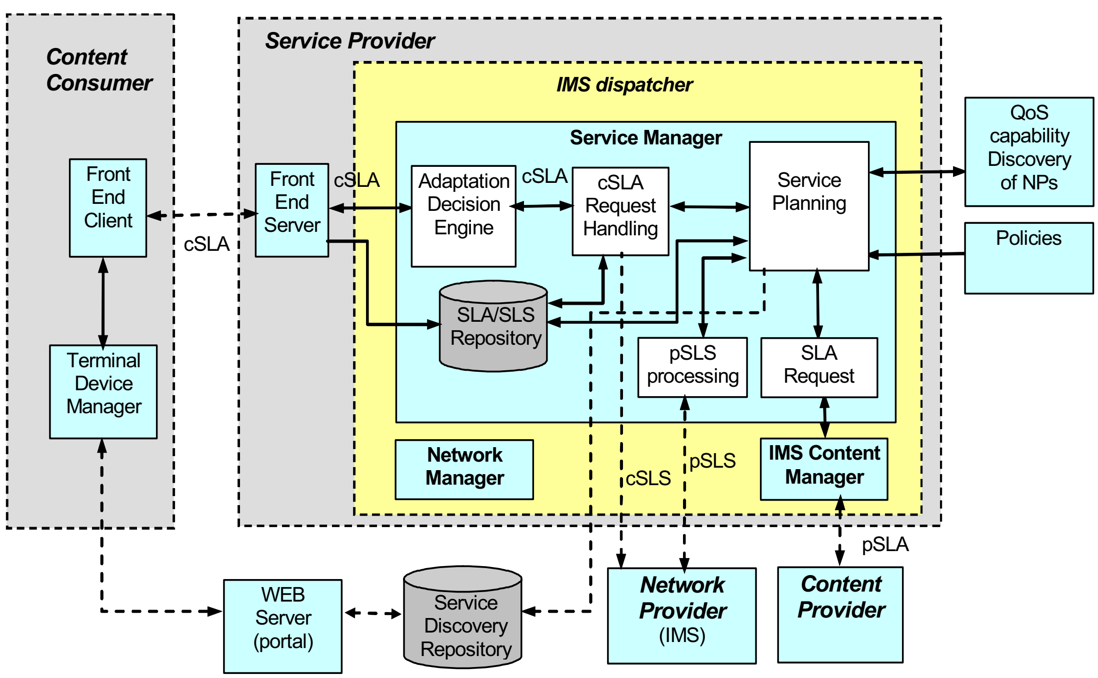

Figure 1. Service Provider view of Service Management

The *Intra-domain Resource Manager (RM)* does not belong to the IMS, but is owned by the AS. It controls and manages the resources inside the domain to support QoS and is technology-dependent.

The SP can offer its services via a *Front-End (FE)* facility. In addition, it may advertise its services through a portal. When a customer wishes to request a particular service offering, the portal redirects the customer to the appropriate SP FE.

The ENTHRONE architecture envisages a suite of protocols as vehicles to transport information for: QoS related negotiation process between peering domains (*EQoS-SLA/SLS-NP*), discovery and installation of end-to-end QoS-enabled paths (*EQoS-PATH*), request/response for allocation of the resources (EQoS-

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RA) and QoS monitoring and reporting (*EQoS-RM*). As the upper layers of IMS are based on MPEG-21, the EQoS suite of protocols are also compliant with MPEG-21 data models.

4. Service Scenario

Initially, before accepting any customer cSLAs, the SP, through its IMS SM, will establish contracts with some CPs (via pSLAs) based on its initial knowledge delivered by a service discovery function. Then, a set of QoS-enabled paths (aggregated pipes) between NPs are established, via pSLS contracts, agreed between SP and access NP, and between pairs of NPs (cascaded model).

The inter-domain paths may be obtained by special path finding protocols, the description of these being outside the scope of this paper. In the simple case, the BGP best-effort may be used ("QoS-enabled" by the setting up these SLSs). Then the associated pipes (to distribute contents from CSs to CCs) are put in place, so that the SP can start to accept customer requests (cSLAs).

An SP portal allows the user to select a service with a given or chosen quality of service. The IMS Dispatcher receives a cSLA (e.g., video on demand with Gold service) from the FE and performs initial checks. It can also do some adaptation, in the sense of by considering the initial CC selection, the IMS can provide him/her with the appropriate level of quality by executing an adaptation procedure (based on the terminal capability, user profile that may include any financial restriction, network path capacity, etc.). Then, the adapted cSLA request is passed to the Service Manager module of the IMS Dispatcher.

The SM translates the customer cSLAs into SLSs. After retrieving the service availability from an SLS repository, the SM performs admission control to decide whether to accept or reject the request.

Through a portal interface, users can negotiate access to a wide choice of services. The details and costs of the services are retrieved from a *Service Discovery Repository (SDR),* which is also MPEG-21 compliant. Each SP is responsible for the creation of new services and their presentation in the SDR. The SP maps the pSLS into human readable cSLAs for offering to customers and also maps the cSLA into the associated cSLS(s) to be instantiated in co-operation with the NM of the NP providing IP connectivity to the SP's customers. The cSLA is seen as an interface between the customer and the SP. The interface SP/NP is the c/pSLS, ensuring the independence from both the high level view of a service and the specific network architecture employed. SLS enforcement is achieved by means of a policy-based approach as explained in [9].

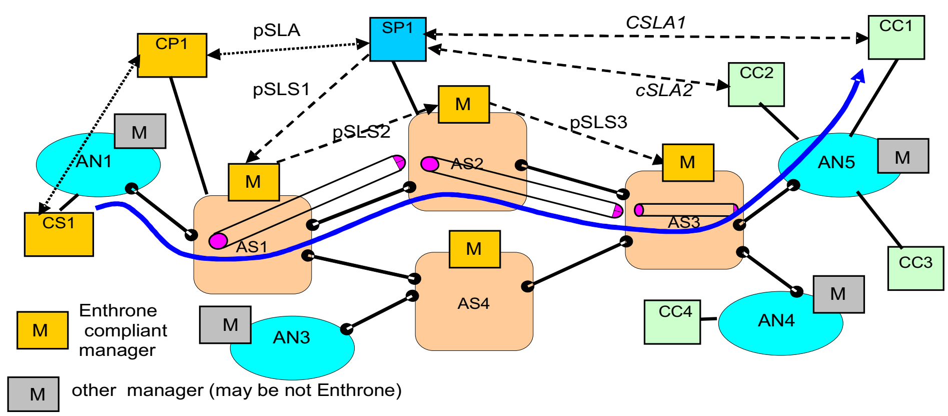

Figure 2. The SLA/SLS relationships in ENTHRONE service management

Figure 2 shows a simplified example of a multi domain environment including four ASes and business entities SP, CP, CS, CC, AN. Via appropriate out of band, path decoupled signaling between managers (M), the pSLAs (between CP1-SP1), pSLSs (between SP1-NP1[1], NP1-NP2, and NP2-NP3) and cSLAs (between CC1-SP1, CC2-SP1, etc.) are established. Eventually the digital item from CS1 (owned by CP1) is delivered at request to CC1 (shown in Figure 1), CC2, etc. when the service is invoked by each CC.

Establishing the chain of pSLS can be accompanied by negotiations between providers SP and NP1, NP1 and NP2, and so on. A Service Planning functional block at SP is the entity which starts the pSLS negotiation process, after it has

[1] NP1, NP", NP3, NP4 are the owners of AS1, AS2, AS3, AS4 respectively.

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concluded a contract with one or several CPs. It is supposed that some traffic forecast functions in the SP offers to the Service Planning the required information to allow for service provisioning. Towards this direction the SP will establish the pSLS pipe.

The AN is considered separately from the rest of the AS chain, because AN may or may not have an ENTHRONE compliant manager. In the latter case, in order to achieve E2E QoS, one should use additional means to complete the QoS-enabled pipe (e.g. data link layer methods). It is assumed that for CC-SP cSLA negotiation there exist some knowledge of an SLA/SLS which covers the ANP → CC access "last mile" – this AN SLS is either known in advance by the SP (by some relationship with ANPs) or is known by the CC and used in its calculation of its proposed cSLA.

Figure 3 shows a typical scenario illustrating an example containing all main signalling phases, [11]:

T0 phase: Service and QoS framework set-up: the service and QoS framework of the system (SP and the ASs of each participating NP) are initially set-up. The necessary pSLSs are established between all NPs along the delivery chain from the DI Content of CP1 to the requesting CC1. (Steps (1) to (6)):

(1)SP-CP: pSLA Negotiation

(2-4) SP-NP & NP-NP: pSLS Negotiations

(5)Uni-directional QoS-enabled Pipe (can also bi-directional if required

(6) SP-SDR: Service Advertisement

Service Request phase: A CC requests a service from an SP (for delivery of a DI), resulting in a cSLA agreement. The agreement of a cSLA assumes that a particular path has been chosen for the provision of the specific DI. Some form of provisioning/ reservation at the network level is already carried out, through pSLSs, in order to offer some guarantee that the DI can be supplied at the agreed QoS level. (Steps (7) to (9)):

(7)CC-SPs Web Server: DI Search

(8) CC-SP: cSLA Request

(9)SP1-CC1: cSLA Response

Service Invocation phase: This phase precedes the actual DI content transfer, during which any admission control and resource commitments required on the access network for the content transfer are made. This phase is not mandatory and could happen implicitly at the subscription phase, depending on the service schedule. (Steps (10) to (12)):

(10) SP-NP: Access Network Resource Provisioning;

(11) SP-NP: Traffic Conditioning

(12)CC-CP server: Content Request

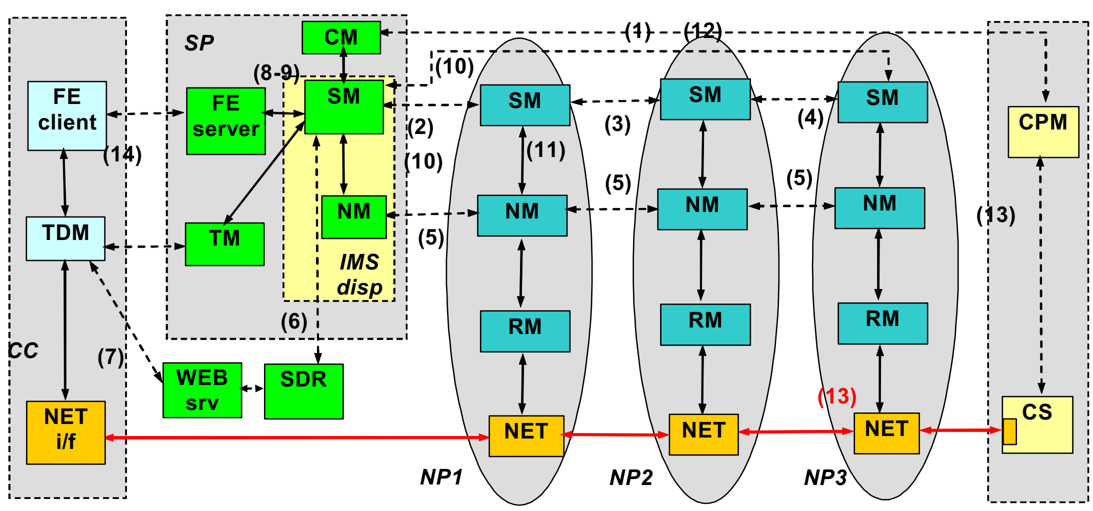

Figure 3. Service scenario example showing phases to establish a data pipe for Digital Item delivery.

Data Transfer phase: The DI is transferred between the CS on the network providing it and the CC. (Step (13)):

(13)CP server-to-CC1: Content Dispatch

Service Completion Phase: Once the DI request has been completed (and the service schedule is complete), the current data transfer is terminated. The

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relevant cSLA in the repository is deleted or updated if the CC requests this. Note that the cSLA can remain valid to allow future invocations.

5. Conclusions

A Service Management (SM) architecture for E2E QoS based services in multi-domain heterogeneous environment has been presented. Heterogeneity is supported by means of an SM framework that operates on top of the networking infrastructure, being independent of particular domain technology (core or access, IP or non-IP). The approach is based on SLA/SLS concepts applied on a flexible business model containing actors such as SP, NP, CP, and CC. The SM operation is scalable, as the Enthrone QoS solution uses a cascaded QoS peering model for providers to set-up, in advance, the aggregated inter-domain pipes. The flexibility and dynamic character of the actual resource allocation is assured by the two-phase approach of service registration while allowing dynamic invocation for both provider and customer requests. Currently the ENTHRONE consortium is implementing the proposed system. Open issues remaining include the further refining of inter-domain QoS path finding, service discovery, and access network QoS provisioning.

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