Enthrone Core Networking Elements for End-to-End QoS Provision over Heterogeneous Settings

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Abstract— ENTHRONE[1] covers an entire audio-visual service distribution chain, including content generation and protection, distribution across QoS-enabled heterogeneous networks and delivery of content at user terminals. It aims to harmonise the functionality of the chain elements in order to support an end-to-end QoS architecture over heterogeneous networks, applied to a variety of audio-visuals services, which are delivered at various user terminals. The paper deals with Enthrone core networking elements for end to end QoS provision over heterogeneous networking domains. Specifically, it presents the Enthrone functional architecture, a cascaded QoS peering approach for inter-providers' interactions for service realisation across multiple domains, a signalling protocols suite for providing end to end QoS over heterogeneous autonomous systems and a Policy Based Network Management (PBNM) architecture.

Index: Network Management, PBNM, QoS, Signaling Protocols, SLA

I. INTRODUCTION

ENTHRONE targets to provide end-to-end QoS-enabled services in an inter-domain heterogeneous environment, developing an integrated management solution covering an entire audio-visual service distribution chain: content generation, protection, distribution across networks and reception at user terminals. A key functional component of ENTHRONE is the Integrated Management Supervisor (IMS), which allows to create a unified management environment of heterogeneous networks and which controls the QoS level in various points, in the content generation and through the different networks. The project's approach is based on a distributed model, where diversified QoS policy based management functions are performed in many geographically distributed environments (content generation, networks, and terminals) [1].

The key networking objective of ENTHRONE is to define, a distributed architecture and to specify, design and implement a networking infrastructure supporting heterogeneity and end to end QoS features. It can support various business models for service offering and is flexible in the sense that it can be used in various settings for IMS, depending on actual needs of inter-domain configurations. The infrastructure may include heterogeneous networking domains of various technologies. The current ENTHRONE core networking setting consists in IP and DVB autonomous systems, while UMTS, WLAN and DVB will be used as alternative access technologies [2], [3].

The paper discusses the Enthrone core networking elements for end-to-end QoS provision over heterogeneous networks, i.e.., Enthrone functional architecture (Section II), a cascaded QoS peering approach for inter-providers' interactions for service realisation across multiple domains (Section III), a signalling protocols suite as a vehicle for providing end to end QoS over heterogeneous autonomous systems (Section IV) and a Policy Based Network Management (PBNM) architecture (Section V). Finally, Section VI concludes the paper.

II. ENTHRONE FUNCTIONAL ARCHITECTURE

The high level view of the ENTHRONE architecture in terms of service and network provisioning for inter-domain QoS delivery is depicted in Figure 1 [4]. The figure shows an abstract view of architecture for a network provider, independent of network technologies and defines the functions within the architectural planes.

[1] IST-FP6 ENTHRONE IP project, which is partially funded by the Commission of the European Union. For more information visit http://www.enthrone.org/

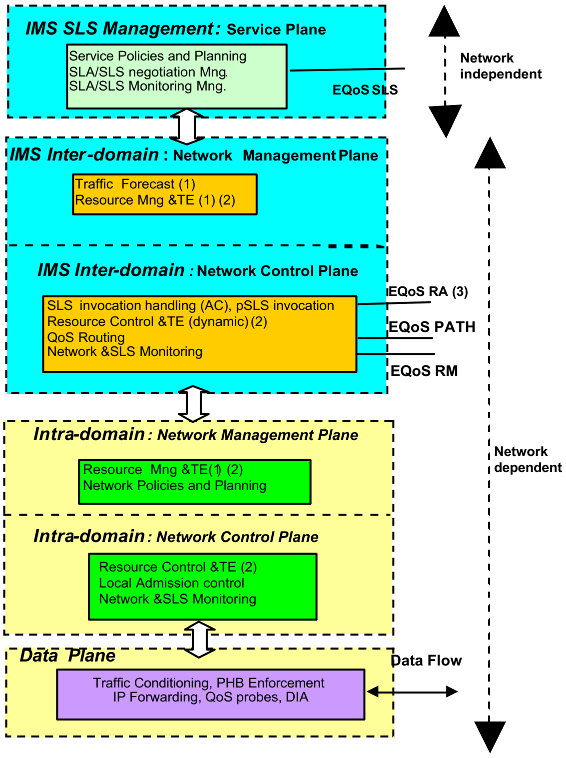

Figure 1 Overall view of the architectural planes (a Network Provider's view)

The Enthrone architecture allows presence of different business actors like Network Providers (NP), Service Providers (SP), Content Providers (CP), and Content Consumers (CC). The service management is based on Service Level Agreements (SLAs) and Service Level Specification (SLS) concepts. The SLAs describe the characteristics of the service offering and the responsibilities of the parties involved. The SLS is the technical part of the SLA. While SLAs between SPs and consumers (cSLAs) are used to formulate the customer requests as well as customers' and providers' service commitments, the provider level service agreements (pSLAs) are between SPs and NPs and between NPs to extend their geographical scope beyond their boundaries.

The *Service Plane* establishes appropriate SLAs/SLSs among the operators/providers/customers that participate in the ENTHRONE infrastructure. That is, each NP's management system has the functionality of SLS Management. Information on SLA/SLS assurance is available at this level. The *Management Plane (MPl)* performs long term actions related to resource and traffic management in order to assure the desired QoS levels for the users and also efficient utilization of the network resources. The *Control Plane (CPl)* performs the short term actions for resource and traffic engineering and control, including routing.

ENTHRONE concerns multi-domains, therefore the *MPl* and also *CPl* are logically divided in two sub-planes: inter-domain and intra-domain. This approach allows each domain to have its own management and control policies and mechanisms while they can still be integrated into ENTRONE framework.

The *Data Plane* is responsible to transfer the *Digital Items* flows having activating the traffic control mechanisms to assure the desired level of QoS.

The end-to-end QoS guarantees for users are realized through establishing end enforcing traffic contracts SLA/SLS. The provider entities involved in the SLA/SLSs negotiation and subscriptions are the IMS module at the SP and the IMS distributed component at the NPs. Between the providers, the network resources (bandwidth, PHBs, etc.) are negotiated and established at aggregated level during so called *network provisioning cycles* by using the appropriate information on traffic estimation and QoS classes offered by neighbouring domains. Therefore the provider-level SLA/SLs negotiating process does not handle individual streams requests but aggregated ones which requires certain end-to-end QoS class. This assures the scalability of the solution. The actual resource allocation is performed in a distinct process when the SLSs are invoked to be activated in order to allow the traffic passing.

III. SERVICE LEVEL QOS PEERING

In the context of ENTHRONE, the implementation of QoS-aware agreements between the autonomous domains for end-to-end QoS delivery across heterogeneous networks is based on SLA, SLS, and service level QoS peering between interconnected domains. The SLSs give the technical characteristics of the service offered in the context of a SLA. Refering to the provisioning aspects of the service e.g. request, activation and delivery aspects from network perspectives. Non-technical service provisioning aspects such as billing and payment aspects are part of the overall SLA and not part of the SLS. A SLS is an integral part of a SLA, and conversely a SLA includes SLS.

In ENTHRONE, the entities that are involved in the pSLAs negotiation and subscriptions are the IMS module at the SP and the IMS distributed component/Bandwidth Brokers (BBs) at the NPs. Network resources (such as bandwidth, PHBs, etc.) are allocated in an aggregated level through different means of provisioning, after the subscriptions have taken place and during network provisioning cycles. After the resources are allocated, the service may be invoked for sending user traffic. It should be mentioned that the provider-level SLAs are not here to handle individual streams but for aggregated flows, which requires certain end-to-end QoS class.

There are many models for the interconnection and service-level interactions between providers' networks for offering QoS services across multiple domains. These models are for the support of inter-operator IP-based services for establishing a complete end-to-end service. These models are strongly influenced by experience in the telecommunications industry related to the provision of international telephony and other services for which network interconnection is a requirement, both in commercial and regulatory terms. The **Forward Cascaded model** is proposed, as a new approach devised, for use in ENTHRONE (see Figure 2).

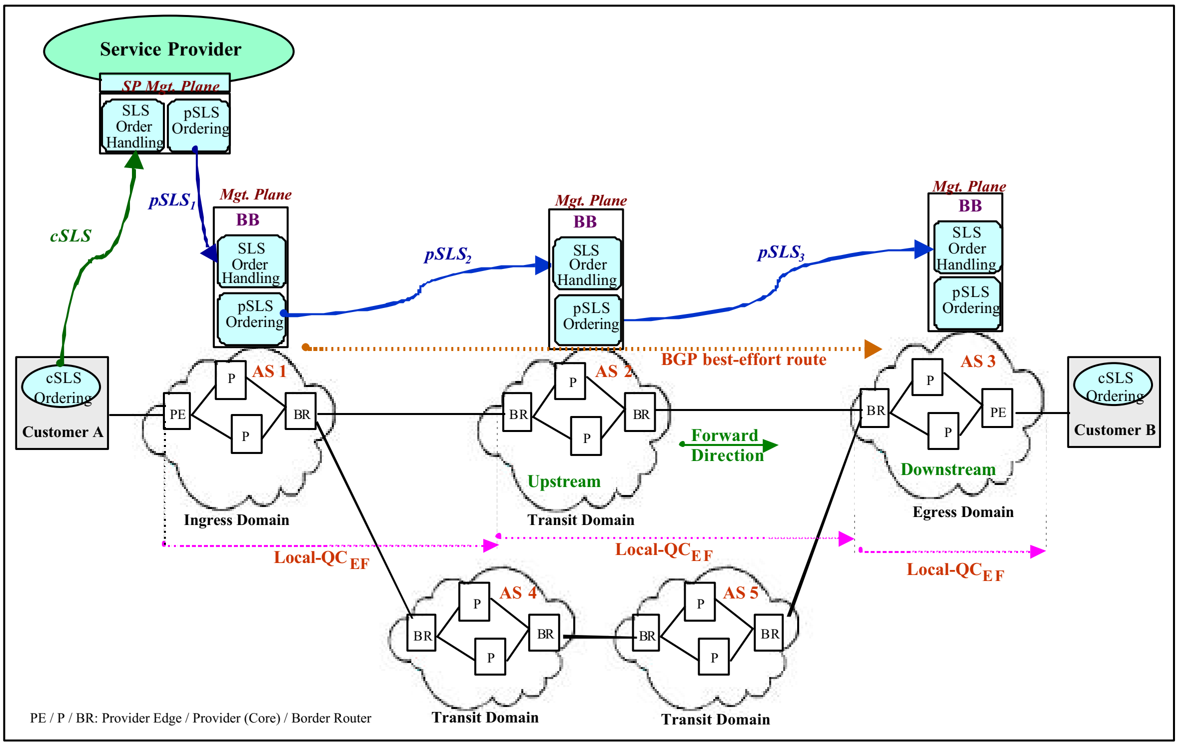

Figure 2 Forward Cascaded Model

In the Forward Cascaded model, each AS makes pSLS (provider SLS) contracts with its immediate downstream interconnected domain/s. That is, neighbouring domains establish pSLSs between themselves in forward direction. Thus, the QoS peering agreements are between BGP peers, but not between providers more than "one hop away". This type of peering agreement is used to provision the QoS connectivity from a customer to reachable destinations that may be several domains away. It is each provider's responsibility to make appropriate pSLSs with the immediate downstream provider making it possible for individual customer IP QoS services to be created and managed along the entire route.

The role of SP as a distinct entity is separated from the NP. When the SP is willing to establish QoS-Based services across multi-domain network from an Ingress domain (AS1) to a Egress domain (AS3) which may be several AS hops away in order to serve and fulfil the requirements of its customers like A and B, the SP communicates with management entity (SLS Request handling of BB of Ingress AS (AS1) for pSLS negotiation requesting a specific QoS service (E2E-QCEF). Then, the SP delegates negotiation of pSLS (at the network level) to its host NP (AS1). The SP provides AS1 with the Egress AS (AS3) address and QoS class requirements (e.g. Local-QCEF). Using BGP routing information, the BB of AS1 finds the best-effort path towards the AS3 and identifies the next AS hop (AS2) towards destination. The AS1 negotiates and may consequently establish the appropriate pSLS with its identified neighbour (AS2). The AS1 passes the QoS class request and the AS3 address to AS2. AS2 uses BGP routing information to find the path towards the AS3 and identifies the next AS hop (if any) towards destination. This procedure is repeated until the appropriate pSLSs are established from Ingress AS to the Egress AS in the cascaded fashion. The Egress AS may send a reply message back to the Ingress AS informing it the request is fulfilled. Alternatively, if the pSLS establishment failed anyhow, a failure message can be sent back to the Ingress AS. Transit domains can aggregate the demands based on some criteria and request for specific pSLSs irrespective of source and destination of IP traffic.

IV. SIGNALLING PROTOCOLS SUITE

The end-to-end QoS (EQoS) signalling protocols suite constitutes one of the main Enthrone vehicles for providing end-to-end QoS over heterogeneous autonomous systems. This suite allows for (1) automating the QoS negotiation process between peering domains (EQoS-SLS), (2) discovering and installing of end-to-end QoS-enables paths (EQoS-PATH), (3) establishing, maintaining, and removing resources allocation in network elements (EQoS-RA) and (4) performing QoS monitoring reporting (EQoS-RM). EQoS-SLS and EQoS-RM protocols are completely designed and specified. For EQoS-Path and EQoS-RA protocols, high level specification has been given.

For designing the EQoS protocols suite, Enthrone followed the layering architecture model of the NSIS framework. In this end, the EQoS protocols suite is structured in two layers (see Figure 3):

· An EQoS Transport Layer Protocol (EQoS TLP), which is independent of any particular signalling application. It is composed of two sub-layers: the packaging sub-layer and the convergence sub-layer;

· An EQoS Application Layer Protocol (EQoS ALP), which contains signalling-specific application functionalities.

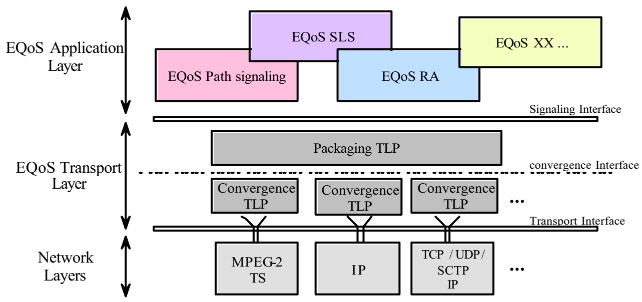

Figure 3 EQoS Protocol Layered Architecture

In the EQoS TLP, the EQoS Packaging Sub-Layer is based on XML message representation while the convergence sub-layer allows the transmission of EQoS messages on wide area of network technologies including narrowband links and memory less devices.

The **EQoS-SLS** role is to carry the messages and organize the dialogue for the negotiation of cSLS and pSLS between two entities. It can be used, with some adaptations, for c/pSLAs or SLSs. The EQoS-SLS runs at the subscription time in order to support the outcome of an agreement between two parties: a customer (requesting the SLA/SLS) and a provider (offering the SLA/SLS). The negotiation can also happen in practice at service invocation times, provided that subscriptions are immediately followed by invocations is allowed. The EQoS-SLS facilitates the automated service subscription. The contract between parties is concluded on one instance of SLA/SLS. The EQoS-SLS has the feature of a general negotiation protocol being adapted to the **ENTHRONE** system needs. It is a client-server half-duplex negotiation protocol between two negotiation entities and allows for:

- **Simple negotiation** - proposal of the client (one negotiation object) accepted or refused by the server;
- **Complex negotiation** - the server (at client request) can return several alternatives if possible, on which the client can react in a selective manner (accept/refuse) or make counter-proposals. The process can go on this way until successful contract is agreed or negotiation fails;
- **Contract Modification Session** - similar to the contract establishment session but the first client proposal is not new - it related to a previous contract and contains modified data (i.e. modifications that the client wishes to make);
- **Contract Deletion Session** – a previous established contract can be deleted;
- **Advanced feature: delaying the conclusion of a contract** – at client request, the server responds with a proposal to delay the conclusion of the contract for a time interval greater than usual, hoping that at some later time it will be able to serve the client request. The client may accept or not this proposal.

EQOS-PATH is concerned with two basic issues:

- Route selection - discovering a path across multiple ASs between given end-points, which can then be used as a basis for negotiation of pSLSs which span the path. The path selection is based on the discovery of the QoS capabilities of the AS domains;
- Route placement - once a path is selected and the pSLSs negotiated along it, the route needs to be installed along the path so that the data path follows this route.

A further issue, which may be considered in **ENTHRONE**, dependent on progress in the project and design decisions made elsewhere, is that of selecting optimal paths for DI delivery over sets of established pSLSs, where more than one QoS-enabled path supported by pSLSs exists between the given source and receiver.

The ro le of **EQOS-RA** protocol is to be used for resource allocation purposes in inter-domain environment. In **ENTHRONE,** some issues related to service invocation and resource allocation for cSLS and pSLS are still open, in order to get a good trade-off between scalability, efficiency, user satisfaction and network operation needs.

In [5], there are four main signalling phases related to CC/SP/NP subscription and invocation:

- pSLS (between SP/NP/NP...) agreement;
- pSLS invocation (SP/NP/NP …);
- cSLA (subscription) CC/SP;
- Service request (CC/SP) that results to a cSLS invocation (SP/AN, SP/NP).

The invocation phases are related to resource allocation. Here the role of EQoS-RA comes into play. It runs between inter domain PDP (part of IMS NM) to solve the problem of pSLS resource allocation. EQoS-RA is a data_path_decoupled, out_of_band signalling protocol, running between instances of the IMS Network Manager, and so, it is not like the RSVP protocol in this respect.

The inter-domain QoS monitoring signalling protocol (**EQOS-RM**) is dedicated to the end-to-end service monitoring task. Like EQoS-SLS, EQoS-RM operates at the IMS inter-domain level of both NP, and SP. As the requirements analysis and design of this sub-protocol progress, its functionality may be merged with other EQoS sub-protocols (e.g. EQoS-SLS). EQoS-RM is intended to be manageable to carry the information required by the monitoring system and will be implemented as a separate layer above an underlying transport layer protocol (EQoS-TLP or other). The protocol EQoS-RM follows the principles of the client/server protocol model. Two types of messages are used: EQoS-RM-Request messages and EQoS-RM-Reply messages. Both of them can have several types (i.e., Setup, Start, Report, Stop, and Locate) in order to accommodate the *three* service monitoring phases envisaged in **ENTHRONE** (i.e. *Service Monitoring Setup/Configuration,* *Continuous Service Monitoring*, and *On-Demand Service Monitoring)*.

V. ENTHRONE POLICY BASED NETWORK MANAGEMENT (PBNM) ARCHITECTURE

The ENTHRONE Policy Based Network Management (PBNM) architecture (see Figure 4) consists in:

- Policy entry console / Policy management tool (PMT): a management tool through which the network manager defines and edits policies applicable in the administrating domain. Typically, it is Web-based;
- Policy Decision Point (PDP): a policy server that retrieves policies from a repository and makes decisions on behalf of Policy Enforcement Point (PEP). It enables differentiated services, automates QoS configuration and provisioning, and makes efficient use of bandwidth. ENTHRONE PDP is composed of Intra-domain PDP and inter-domain PDP;
- Policy Enforcement Point (PEP): it is installed on network devices, such as routers, switches and firewalls to enforce policy decisions via access lists, queue management algorithms and other means. The PEP receives configuration from the Policy Server using COPS protocol (or similar protocols). It then configures internal data on the devices. In ENTHRONE, we distinguish between two types of PEP: Edge PEP (ePEP) and Core PEP (cPEP);
- Policy Repository / Policy Storing Service (PSS): policies are stored into a repository. In general, it is Lightweight Directory Access Protocol (LDAP)-compliant directory server.

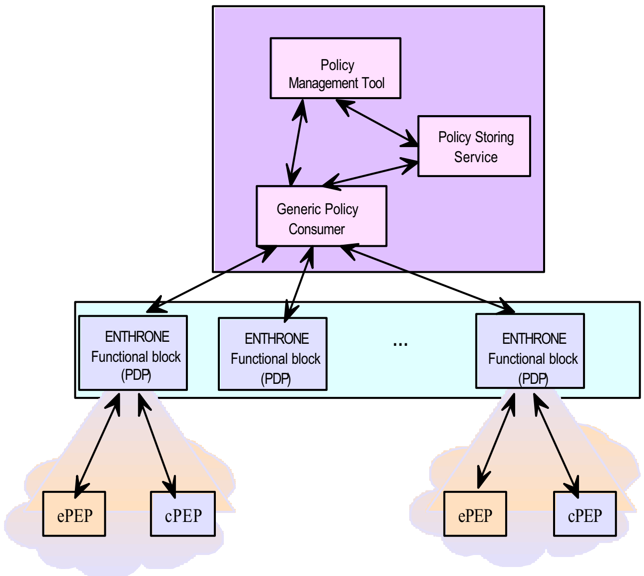

Figure 4. ENTHRONE PBNM architecture

VI. CONCLUSION

In ENTHRONE, the whole content delivery chain is considered, including different stakeholders (network providers (NPs), service providers (SPs), content providers (CPs), content consumers (CCs), etc.). In ENTHRONE, prior to fulfilling the customer service requests, resource provisioning is performed in advance. This creates a scalable solution when there is no need to go through the chain of Service Provider to Network Provider and between Network Providers to provision the involved networks for every requested service. The MPEG-21 data model [6] is used to provide the common support for implementing and managing the resources' functionality. ENTHRONE is concerned with end-to-end QoS in terms of performance, at both the user and network levels, and with mapping between these levels. This paper dealt with Enthrone core elements for end to end QoS provision over heterogeneous networking domains. Specifically, it presented the Enthrone functional architecture, a cascaded QoS peering approach for inter-providers' interactions for service realisation across multiple domains and a signalling protocols suite for providing end to end QoS over heterogeneous autonomous systems. Concluding, we consider the presented core networking elements as scalable and flexible integrated management solutions to offer multimedia QoS-based services to a large number of customers.

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