A NOVEL END-TO-END QOS FRAMEWORK OVER HETEROGENEOUS NETWORKS - AN ARCHITECTURAL APPROACH

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Abstract: End-to-end QoS (Quality of Service) provisioning over heterogeneous networks is a major challenge. The poor communication between Service Providers, the increasing complexity of the supported services, the need for fulfillment of end-to-end requirements represent the main problems to be solved by the new QoS frameworks. This paper presents a novel system architecture for an end-to-end QoS framework over heterogeneous networks, that aims to guarantee network performances and to provision end-to-end QoS over multiple autonomous systems.

Keywords: *end-to-end QoS, heterogeneous networks, architecture, autonomous systems.*

I. INTRODUCTION

The concept of Quality of Service (QoS) gathers many definitions. At network level, QoS represents the network's capability to deliver better services for selected flows over different technologies. The main goal of QoS is to provide priority including dedicated bandwidth, controlled latency and jitter, and improved loss characteristics, which represent the main QoS parameters. For the new emerging technologies, such as VoIP, video or audio streaming, bandwidth availability, controlled latency and improved loss characteristics are common requests from end-clients and service providers. Guarantying these constrains at the network level is a major challenge.

A computer network can be seen as heterogeneous from many points of view. There is a heterogeneity given by different transmission technologies deployed over different links across the network. Also, the usage of devices from different manufacturers with different operating systems creates a different type of heterogeneity in the network.

A comprehensive definition of heterogeneous networks is found in [1]: network portions may be managed by different Service Providers may use different transmission means such as cable, satellite, radio and may implement different protocols such as ATM, IP and MPLS; a network may also be heterogeneous from the point of view of users, who can require different services and have a different availability to pay for them.

From the point of view of this research, a heterogeneous network is considered to be a network of interconnected autonomous systems (AS), each AS having its own management entity.

The paper is organized as follows: Section II provides background information related to QoS technologies for both homogeneous and heterogeneous networks. Section III provides an overview of the latest end-to-end QoS realization techniques over heterogeneous networks. Section IV presents the proposed framework's architecture, the bandwidth organization and the admission and dynamic bandwidth reconfiguration process over a multi-domain network. Section V points the paths for further work and concludes the paper.

II. BACKGROUND

Several end-to-end QoS frameworks where developed over the years for homogeneous networks. Integrated Services (IntServ), Differentiated Services (DiffServ) or Multi-protocol Label Switching (MPLS) [2] [3] tried to optimize the performances of the networks by reducing congestion, improving resource utilization and increasing service availability.

Integrated Services reserve resource for each individual flow availing the Resource Reservation Setup Protocol (RSVP). The Differentiated Services architecture provides several service levels by classifying the traffic into a small number of forwarding classes and allocating resources based on these classes. MPLS uses a switching architecture and presents several advantages such as QoS support, traffic engineering support, support for virtual private networks (Virtual Private Network - VPN) or multimedia support. Traffic engineering is dealing with performance optimization of operational networks. The main objective is to reduce congestion allocation in network hot spots and to improve resource allocation within the network through traffic distribution management. Traffic engineer optimization objectives include: minimizing network congestion and packet loss, improving link usage, minimizing packets' total delay and increasing the number of served clients over the same network

The problem of quality of service across heterogeneous networks was approached by recently developed end-to-end QoS frameworks, such as Mescal project [4] (Management of End-to-end Quality of Service Across the Internet at Large) or Agave [5] (A liGhtweight Approach for Viable End-to-end IP-based QoS Services) project. Mescal

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approaches the problem of how current agreements between ISPs should be enhanced to propagate QoS information between domains, and, in the absence of any form of central control, how these agreements may be used together to guarantee end-to-end QoS levels across all involved domains of control. Agave approaches the problem of end-to-end QoS by studying, developing, and validating an inter-domain architecture based on the novel concept of Network Planes, which will allow multiple IP Network Providers to build and provide Parallel Internets tailored to end-to-end service requirements [6].

III. QOS APPROACHES FOR HETEROGENEOUS NETWORKS

The Mescal project proposed an approach that keeps the loosely coupled structure of the internet, because each SP establishes peer SLSs (pSLSs) only with adjacent SPs (SPs with whom there are existing BGP peering relationships).

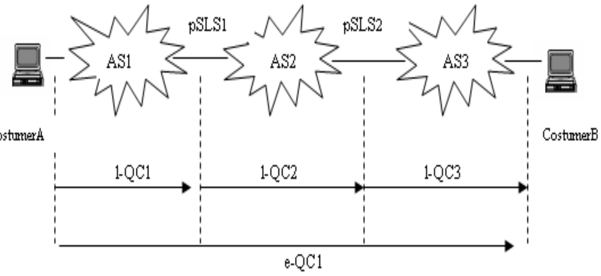

Figure 1. Mescal approach

From the point of view of end-to-end QoS realization Mescal introduced the QoS-class (QC) concept - a set of attribute-value pairs, which is used as a QoS intra-domain mechanism.

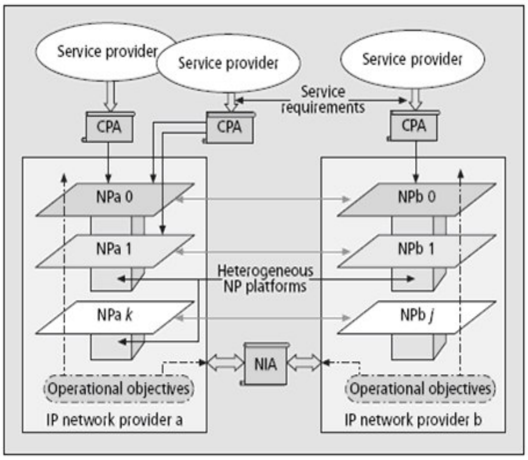

Figure 2. Agave approach [6]

In a single domain MESCAL defines local-QoS-class (l-QC), however to extend this concept to heterogeneous networks the extended-QoS-class (e-QC) concept is defined, by combining l-QCs or e-QCs.

AGAVE approach (Fig. 2) is based on realization of two novel concepts: network planes and parallel internets.

INPs must negotiate and establish INP interconnection agreements between each other to bind NPs with similar service characteristics and apply specific mechanisms to enforce the realization of individual PIs; each instance of PI can be implemented in a different way across multiple INPs (local decision in binding NPs to the PI). One of the INP function is to plan, select, and engineer its NPs to meet the SP requirements. A given NP can be used to convey service traffic managed by the same or distinct SPs in an aggregate fashion, resembling to the DiffServ paradigm. Thus the inter-domain QoS capability is PI-based.

IV. CURRENT WORK

The proposed framework assumes the business model of Mescal and Agave frameworks (Fig. 3).

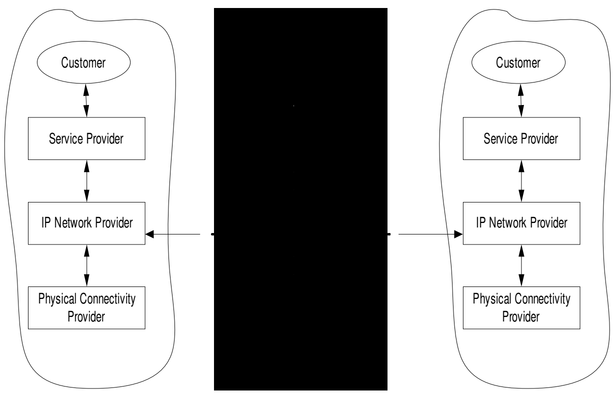

Figure 3. Business Model

At the top level the Service Providers interact with IP Network Providers on the basis of Service Level Agreements (SLAs). The IP Network Providers (INPs) are concerned in end-to-end QoS delivery across multiple domains and are responsible for their own network domains and for reaching peering agreements with other INPs to extend the scope of the QoS services that they can offer to their customers and other INPs. Physical Network Providers provide connectivity services between protocol-compatible equipment in determined locations. The Customers are the beneficiaries of the services provided by the Service Providers.

The presented framework represents an effort to extend a newly developed end-to-end QoS framework for homogeneous networks, called Self-Adaptive bandwidth Reconfiguration QoS framework (SAR) [7].

SAR framework allows the increase of the traffic volume it handles, guaranteeing end-to-end quality of service through network resources monitoring, admission control and resource reservation for new flows. The framework allows for redistribution of the bandwidth between the defined classes. SAR uses three approaches in controlling flows' resource allocation and admission, at the edge routers level: a centralized approach, a router aided approach and an edge-to-edge approach. In the centralized approach, a central network entity exists in the network that maintains bandwidth utilization and controls the admission and bandwidth reconfiguration decisions. In the router aided approach the core routers are responsible for those decisions. In the edge-to-edge approach the admission and bandwidth reconfiguration decisions are managed by the edge routers.

A downfall of SAR is its limitation to homogeneous systems. The proposed bandwidth organization and the functional architecture of the newly proposed framework try to extend SARs capabilities to heterogeneous networks. For our further development the centralized approach and the edge-to-edge approach present a real interest. The router aided approach is not feasible because core routers from an AS has no knowledge outside it's AS.

Bandwidth Organization

The proposed framework serves user networks and defines two types of routers, edge and core routers. At the edge routers level the bandwidth reconfigurations and the admission decisions for individual input flows are made.

The framework uses a hierarchical approach in order to organize link bandwidth as shown in Fig. 4. The Physical Line is divided into tree main section: a Guaranteed Link (GL), a local Common Link (l-CL) and a global Common Link (g-CL) section.

The first section, as in the SAR's case, is statically divided in several Guaranteed Class Links (GCLs). Each GCL is reserved for a traffic class and a one to one mapping exists between the traffic classes supported by the Physical Line and GCLs. Each GCL is divided in several trunks, each trunk being dedicated to an edge router. A trunk belonging to a GCL supports the flows belonging to the traffic class that corresponds to the considered GCL, originating from the edge router to which the trunk is assigned, irrespective to their destination. An edge router keeps track of available bandwidth of its assigned trunks and performs admission control locally, without hop-by-hop signaling through network. The bandwidth assigned to trunks has a minimum guaranteed value. A Virtual IP Path (VIP) is a path from a source ER to a destination ER for a traffic class, being a concatenation of trunks belonging to the source ER over a source-destination path.

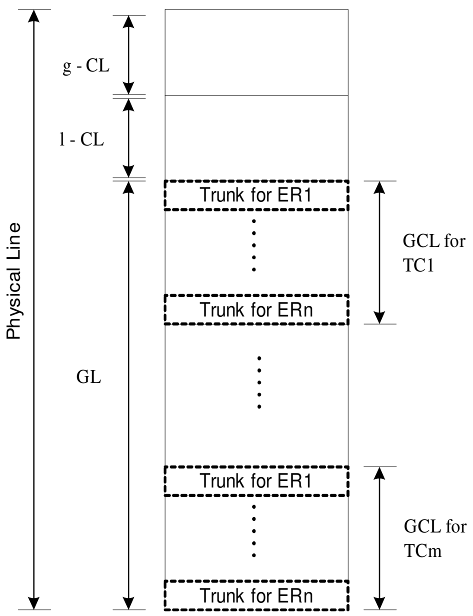

Figure 4. Bandwidth organization

By using the second section l-CL, the bandwidth inside an AS is dynamically adjusted function of the network's traffic modifications. The third section - g-CL is used for the dynamically adjustment of the shared bandwidth between ASs, and its value is SLA dependable (based on the agreed SLAs between the SPs). The g-CL section guarantees a minimum level of bandwidth assigned for inter-domain traffic.

The Architecture

Based on the agreed SLAs and SLSs between the autonomous management entities, the proposed framework provides a solution at INP level. Although the business relations between the different SPs, concerning the service level agreements, represent a crucial problem of heterogeneous systems, the goal of this framework is to guarantee end-to-end QoS at INP level, by means of specific network mechanisms.

At the lowest level, each AS has its own SAR implementation and manages its own domain. Thus SAR ensures intra-domain QoS realization.

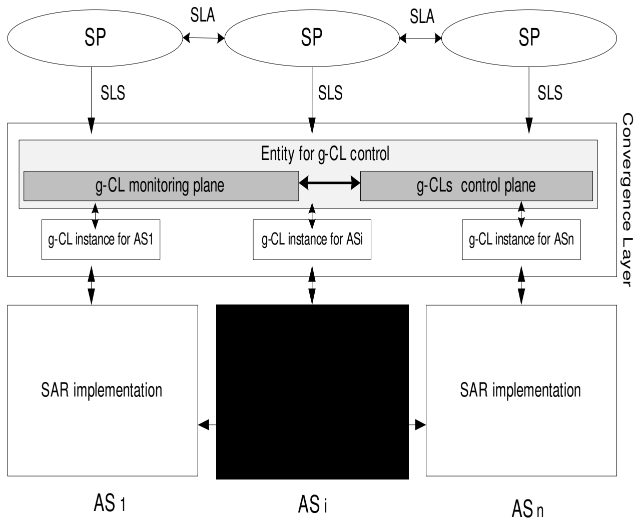

Figure 5. The proposed framework's architecture

The Convergence layer is mainly responsible for the g-CLs management through the usage of the Entity for g-CL control. The entity has a g-CL monitoring plane – that monitors the g-CL assignments on ASs, and the g-CL control plane - that controls the dynamic g-CL assignments, based on specific control signaling messages. Each AS has an instance of the Convergence layer. The Convergence layer is an abstraction used to hide the heterogeneity characteristic of the network and each AS exchange inter-domain information using this layer. Between directly connected ASs peering agreements exists, thus an AS has only a limited view of the heterogeneous system. The Convergence layer provides a centralized view of the entire system, being the one responsible for the end-to-end QoS realization.

At the top level, the SPs agree on the supported traffic characteristics over the heterogeneous system. The service level specifications are submitted to the Convergence layer, which has the role of a centralized control entity over the heterogeneous network.

The admission and dynamic bandwidth reconfiguration process will follow the next steps:

A. If the incoming flow's destination is inside the AS (l-flow), SAR framework will take the admission decision and the bandwidth allocation locally, based on the QoS class to which the flow belongs to and the appropriate VIP. Using the determined trunks and, if necessary the l-CL section, the flow will be admitted or rejected.

B. If the incoming flow's destination is in another AS (g-flow) then the instances of the Convergence layer of the transited ASs will assistant on the inter-domain admission decision.

The second case is relevant for our work from the heterogeneous perspective.

B1. Each of the transited ASs will locally determine the QoS class - to which the flow belongs to, and the VIP and the corresponding trunks. Based on this information, each AS will determine if it has enough bandwidth to accommodate the incoming flow and send this data to the g-CL instance. If all the participating ASs have enough bandwidth the g-CL entity will admit the flow and inform the ASs.

B2. If not all the ASs have enough bandwidth to accommodate the incoming flow they will use the g-CL sections to allocate additional bandwidth to the trunks on VIPs. The g-CL entity accounts the g-CL usage on each AS. If the additional bandwidth allocation is successfully the g-CL entity will admit the flow and inform the ASs.

B3. If the additional bandwidth allocation fails on any AS the g-CL entity will reject the flow and inform the ASs.

The concatenation of local determined VIPs from different ASs, resulting in a meta-VIP that spans across the heterogeneous networks, ensures service differentiation for both intra and inter-domain scope.

Another important task of the Convergence layer is its responsibility to map the incoming traffic, transiting from one AS to another AS, to a specific QoS class. Thus one AS does not have to know the specific QoS implementation of other ASs, this mapping taking place at the Convergence level.

V. CONCLUSION AND FUTURE WORK

This paper presents a work in progress for developing a new end-to-end QoS framework over heterogeneous networks. The bandwidth organization, the proposed framework's architecture and the admission and dynamic bandwidth reconfiguration process are described.

Guarantying QoS at network level over multi-domain systems is a challenge. Adding an abstraction layer with complex functions - called Convergence Layer and availing the bandwidth organization, the proposed framework extends SAR framework in order to create the premises for an end-to-end QoS realization over heterogeneous networks. In order to span QoS guarantees across the heterogeneous network, the abstractions had been defined to hide the heterogeneity characteristics of the network. By doing so, a homogenous communication model was obtained, in order to achieve end-to-end QoS quarantines. Thus, an integration of several communication methods - which are specific for each type of segment being present in the heterogeneous network, is not required.

The proposed approach is lightweight for SPs, as in the case of Agave, because the complexity is transfered to the INPs. Also, using the Convergence layer functions, the proposed framework tries to achieve a decoupling between the SPs and INPs.

The further development of the convergence layer and the design of control messages and mechanisms represent the next steps. Also, the development and implementation of bandwidth reconfiguration mechanisms based on predicted traffic characteristics - in order to reduce the network load brought by control messages represent a future objective. Two approaches will be considered for the management of the Convergence layer: a centralized approach and an edge-to-edge approach. In the centralized approach a central entity will be used for the management of the g-CL entities and in the edge-to-edge approach each edge router that has a peering connection with an edge router from a neighbor AS will manage a g-CL instance.

The implementation and testing perspectives are towards a simulation methodology using OPNET software. Due to complex planning, development and deployment processes, specific for heterogeneous systems, the simulation perspective is more feasible.

The simulation will assume several traffic classes, mainly UDP, audio, video and VoIP traffic classes. The tests will track the following end-to-end performance metrics: admission rate, packet transmission delay, connection setup time and signaling overhead - due to exchanged control messages. The framework's expected results are to provide end-to-end QoS guarantees over heterogeneous networks, at the IP Network Providers level, availing pre-established SLAs agreements between Service Providers and to ease the implementation of QoS-enabled applications.

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