An architectural framework for Inter-domain quality of service provisioning

M. Howarth, P. Flegkas,
G. Pavlou, P. Trimintzios
University of Surrey, Guildford ,UK
{m.howarth, p.flegkas,
g.pavlou, p.trimintzios}@surrey.ac.uk

H. Asgari
Thales Research & Technology Ltd.
Reading, UK
hamid.asgari@thalesresearch.com

D. Griffin, J. Griem
University College London, London, UK
{dgriffin, jgriem}@ee.ucl.ac.uk

M. Boucadair
France Telecom R&D, Caen, France
mohamed.boucadair@francetelecom.com

P. Georgatsos
Algonet SA., Athens, Greece
p.georgat@egreta.gr

Abstract

This paper presents an architecture that supports inter-domain quality of service (QoS) across the multi-provider commercial Internet. The architecture describes the full set of functions in the management, control and data planes required for network providers to work together to deliver end-to-end QoS-based IP connectivity services. We use the concept of QoS Classes and show how these can be combined together using service level specifications (SLSs) agreed between adjacent domains to construct a defined end-to-end QoS that is supported across multiple domains.

Keywords

QoS, inter-domain, traffic engineering, service level specification, SLS

1. QoS-based services and QoS classes

Services that provide QoS-based value are offered on the basis of service level agreements (SLAs). The Service Level Specification, *SLS* [1], is an integral part of a SLA, defining technical aspects such as bandwidth, QoS and availability. *Peer SLSs* (*pSLS*) are established between IP Network Providers (INPs) to expand the geographical span of their QoS services, & *customer SLSs* (*cSLS*) are between an INP and its customers.

A *QoS class (QC)* denotes a *QoS transfer capability* of a single provider's domain. It defines a set of attribute-value pairs, the attributes being performance parameters such as one-way delay, packet loss and inter-packet delay variation (jitter). We divide QCs into *local QoS classes (l-QC)* and *extended QoS classes (e-QC)*:

- *l-QC* denotes a QoS transfer capability that is provided entirely within the local provider domain. A l-QC is similar to DiffServ Per-Domain Behaviour (PDB);
- *e-QC* is a QoS transfer capability that uses both the local and adjacent (service-peering) domains, combining a local l-QC with the other domain's l-QC or e-QC.

2. The cascaded Inter-domain QoS peering model

In general, providers prefer to offer services that reflect the current loosely coupled Internet structure, and we therefore define a *cascaded* model [2]. Each INP contracts pSLSs with its adjacent INPs. Thus, QoS peering agreements are between neighbours, but not between providers more than "one hop away". This type of peering agreement may be extended to provide QoS connectivity from a customer to reachable destinations that are several domains away. In Figure 1, l-QC_1, l-QC_2 and l-QC_3 are supported by AS1, AS2, and AS3 respectively. AS2 negotiates a contract (pSLS2) with AS3, enabling AS2's customers to reach destinations in AS3 with e-QC_2. AS1 can then negotiate with AS2 (pSLS1), to enable AS1 customers also to reach destinations in AS3 with e-QC_1, although at no point do AS1 and AS3 negotiate directly.

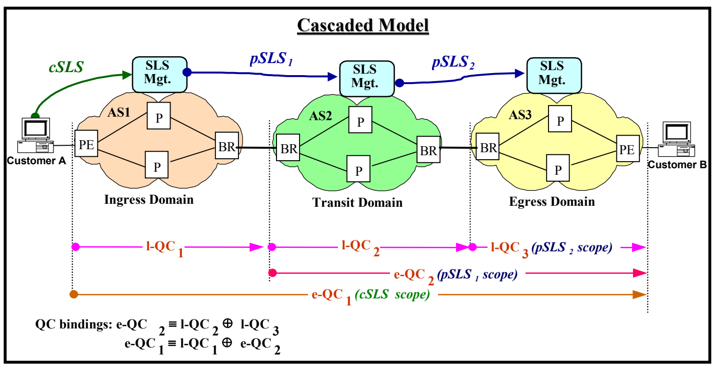

Figure 1. Cascaded QoS peering model.

3. Functional architecture

Figure 2 decomposes the functions required for an INP to provide inter-domain QoS services. This functional architecture [3] is divided into three planes: management, control and data. The management plane is responsible for (a) interacting with customers and service peers to negotiate contracts and (b) implementing the business decisions of the INP through planning, dimensioning and configuring the network. The control plane covers intra- and inter-domain routing, traffic admission and dynamic resource management. Finally, the data plane is responsible for per-packet treatment, and is configured by the control plane.

Service planning and QoS capabilities exchange

QoS-based Service Planning encompasses the business-related activities responsible for defining the services a provider offers. These include l-QCs within the INP's network and e-QCs that result from combining its local QoS-based services with those offered by adjacent peers. A provider uses the *QoS Capabilities Discovery* function to discover from potential peers their QoS capabilities to destinations, and their costs. Once l-QCs and e-QCs have been defined and engineered in a domain, the *QoS Capabilities Advertisement* function promotes the offered services to customers and peers.

Network planning and provisioning
Network Planning includes the offline processes responsible for determining the physical resources (e.g. points of presence, IP routers and links) required by an INP.

Offline traffic engineering (TE)
Traffic Forecast aggregates and predicts traffic demand. The set of subscribed pSLSs is retrieved from *SLS Order Handling*, and a traffic matrix (TM) is derived from these and any forecast pSLSs. The TM is then used by offline TE to calculate and provision the required intra- and inter-domain resources, including requesting *pSLS Ordering* to negotiate new pSLSs with downstream providers.

Although we divide TE into inter- and intra-domain functions, it is important to recognise that an optimal TE solution for end-to-end QoS requires the two to work together to ensure that both inter- and intra-domain resources are used optimally.

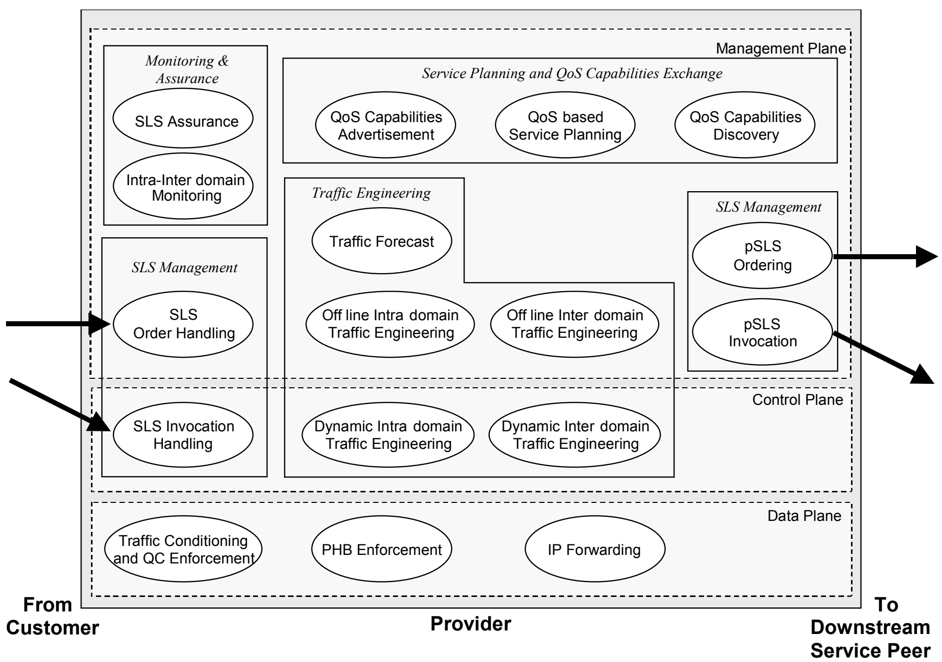

Figure 2. Functional architecture for inter-domain QoS delivery.

Dynamic traffic engineering
Dynamic Inter-domain TE is responsible for inter-domain routing. An example of how this could be implemented is by a QoS-enhanced version of the Border Gateway Protocol (BGP). *Dynamic Inter-domain TE* also dynamically performs load balancing between the multiple paths defined by *Offline Inter-domain TE*. It uses real-time monitoring information, changing appropriately the ratio of the traffic mapped to the inter-domain paths.

Dynamic Intra-domain TE includes routing, load balancing and dynamic bandwidth assignment for managing in real-time the resources allocated by *Offline Intra-domain TE*, in order to react to statistical traffic fluctuations and other conditions.

SLS management
This includes two distinct phases: ordering, i.e. establishing contracts between peers, and invocation, i.e. committing resources before traffic can be admitted.

pSLS Ordering receives requests from *Offline Inter-domain TE* for new pSLSs, and negotiates them with *SLS Order Handling* in the downstream peer. *SLS Order Handling* in turn performs subscription level admission control (AC). It takes incoming pSLS requests and investigates based on information from Offline TE whether there is sufficient intra- and inter-domain capacity.

For invocation, AC ensures that the network is not overwhelmed with traffic; this allows the network to adopt a policy of subscription level overbooking. *pSLS Invocation* requests admission. *SLS Invocation Handling*, in the downstream peer, contains the AC algorithm, & receives invocation requests from peers. It checks if the invocation conforms to the subscribed SLS and whether there is sufficient capacity in the local AS (and, if the traffic is not terminated locally, the inter-domain links).

Data plane functions
Traffic Conditioning and QC Enforcement is responsible for packet classification, policing, traffic shaping and marking in accordance with the SLSs. At ingress routers *Traffic Conditioning* classifies incoming packets based on their e-QC and marks them with the appropriate DiffServ Code Point (DSCP) for the required l-QC. At the egress router the *QC Enforcement* function remarks outgoing packets with the correct DSCP as agreed in the pSLS. Thus *QC Enforcement* implements the binding between l-QC and downstream e-QC. *PHB Enforcement* represents the queuing and scheduling mechanisms required to realise the different per-hop behaviours (PHBs).

Monitoring and SLS assurance
Monitoring records the behaviour of the network; *SLS Assurance* confirms the agreed service levels are met by comparing the monitored data with the SLS requirements.

4. Summary

The delivery of end-to-end QoS across the multi-provider commercial Internet requires different INPs to cooperate so as to deliver the required service. In this paper we have established a QoS vocabulary and presented an architecture that encapsulates the functions required to support end-to-end QoS.

Acknowledgement

This work was partially funded by the EU IST MESCAL project, IST-2001-37961.

References

[1] D. Goderis et al., “Service level specification semantics, parameters and negotiation requirements,” IETF Internet-Draft, draft-tequila-sls-02.txt, Feb. 2002.
[2] A. Asgari et al., “Issues in MESCAL Inter-domain QoS Delivery,” MESCAL project deliverable D1.4, available at www.mescal.org, 30 Jan 2004.
[3] M. Howarth et al., “Initial specification of protocols and algorithms,” MESCAL project deliverable D1.2, available at www.mescal.org, 30 Jan 2004.