A Common Framework for Inter-Provider IP Quality of Service Specification

Slavica V. Bostjancic[1], Valentina V. Timcenko[2], Mirjana D. Stojanovic[3]

Abstract – **In this paper, we propose a framework for inter-provider Quality of Service (QoS) specification in an all-IP environment. The framework encompasses service level specification format and conformance matching rules. Proposed specification format allows administrators to describe service classes in their own domains independently of the network technology and the applied QoS model. We further define and investigate a conformance matching scheme (CMS). The objective of CMS is to assess the degree of correspondence between the required and offered QoS at the network-to-network interface. Additionally we present numerical example that demonstrates operating of proposed framework.**

Keywords – **All-IP network, Conformance matching, Quality of Service, Service Level Specification.**

I. INTRODUCTION

The term "All-IP Network (AIPN)" refers to an IP based telecommunication network backbone and different access networks. New environment encompasses a set of independently administered domains, each providing different Quality of Service (QoS) model, such as Differentiated Services (DiffServ [1]) for core network, Integrated Services (IntServ, RFC 1633) for wired access network, services defined for the Universal Mobile Telecommunication System (UMTS [2]), etc.

Providing different QoS levels requires alteration of traditional static IP service negotiation approach in the sense of more frequent QoS renegotiation, due to changes of network resource state. Standardization of the Service Level Specification (SLS) is a prerequisite for dynamic QoS negotiation between the Internet Service Providers (ISPs), and it can facilitate a high level of network management automation.

SLS defines technical aspects of service and together with financial and legal aspects related with particular service builds a Service Level Agreement (SLA). Interoperability in a multi-domain network assumes mapping of service classes and their associated QoS parameters at domain boundaries. For that purpose, unification of SLS format is required [3-6]. In the past few years, a lot of research work has been focused towards solving that problem and resulted in different proposals of SLS formats and QoS mapping. For example, Generic Service Specification (GSS) model [7] proposes a format of service level specification and an intelligent mapping algorithm. The algorithm takes into consideration every SLS parameter, which is previously marked (by user) with one of 11 weights. Parameter weight actually represents its relevance for achieving required QoS. Based on comparison of weighted parameter values with the ones available in particular network, the algorithm at the output generates selected service class together with the associated degree of correspondence with the required service level.

This paper addresses problem of QoS negotiation and mapping in AIPN environment at "network-to-network" interfaces. We propose a common framework for inter-provider IP QoS Specification which encompasses SLS format and Conformance Matching Scheme (CMS). The aim of the proposed model is to express QoS requirements by means of common format and to define an efficient mapping of QoS parameters at domain boundaries, in the sense of minimum resource and time consumption. In order to avoid exhaustive computations, we assume coarser granularity of weighting factors, i.e. each parameter can be mandatory, preferential or not relevant. Further, if two or more classes satisfy the required QoS, the CMS forces selection of the class that most tightly matches with the required SLS. For example, if medium delay is mandatory required, CMS will select a class with medium delay, rather than class with low delay, thus preserving the overall resource consumption for each class. Finally, in addition to calculating the overall degree of correspondence, CMS defines minimum threshold for each mapped value, with the objective to assure satisfying degree of correspondence for each mandatory parameter.

II. FRAMEWORK FOR END-TO-END QOS PROVISIONING

End-to-end QoS provisioning implies existing of traffic control and resource management in each domain that end-to-end path traverses. Each QoS model defines its own mechanisms and parameters for traffic control and resource management, depending on applied service classification. It also defines a set of classes to which traffic with similar QoS requirements is grouped. Every service class defines specific combination of limitations of performance metrics and provides specific packets forwarding behavior.

End-to-end QoS provisioning assumes mapping of QoS requirements between different types of network and QoS models. The main prerequisite for interworking is unification of QoS representation (SLS).

[1] Slavica Bostjancic is with Mihailo Pupin Institute, Volgina 15, 11060 Belgrade, Serbia, E-mail: slavica@kondor.imp.bg.ac.yu

[2] Valentina Timcenko is with Mihailo Pupin Institute, Volgina 15, 11060 Belgrade, Serbia, E-mail: valentina@kondor.imp.bg.ac.yu

[3] Mirjana Stojanovic is with Mihailo Pupin Institute, Volgina 15, 11060 Belgrade, Serbia and with Faculty of Traffic and Transport Engineering, Vojvode Stepe 305, 11000 Belgrade, Serbia E-mail: stojmir@kondor.imp.bg.ac.yu

Proposed framework for inter-provider IP QoS specification consists of SLS format and CMS. Using this format administrator is able to define service classes in its own domain, which is prerequisite for enabling CMS. CMS at edge routers executes conformance check to find most suitable class for ingress traffic flow that will provide requested end-to-end QoS performance.

Fig. 1 illustrates an example of SLS coordination and QoS mapping in a two-domain network. The User A negotiates SLA 1 with the UMTS provider and requests a connection with the DiffServ (user B) for sending of flow with certain QoS parameters and traffic profile.

The UMTS provider checks its own resources and negotiates SLA 2 with the DiffServ provider. Every SLA negotiation implies QoS mapping, i.e., parameters from SLS 1 are mapped to corresponding parameters in SLS 2.

The Third Generation Partnership (3GPP) defines four service classes for the UMTS [2]: 1) *conversational service*, intended for very critical real time applications like Voice over IP (VoIP); (2) *streaming service*, designed for asymmetric continuous traffic flows like video streaming; (3) *interactive service*, proposed for asymmetric interactive applications that require certain delay guarantees, like searching engines and (4) *background service*, intended for delay insensitive applications like e-mail.

The DiffServ model defines two Per Hop Behaviours (PHBs) besides best effort: the *Expedited Forwarding* (EF PHB) and the *Assured Forwarding* (AF PHB). EF PHB is a guaranteed peak rate service, which is optimized for very regular traffic patterns and offers small or no queuing delay. AF PHB relies on statistical QoS provisioning and may define a number of service classes with different levels of packet drop precedence inside each class. IETF defines four classes of AF PHB (AF1 – AF4), each with maximum three levels of packet drop precedence [8].

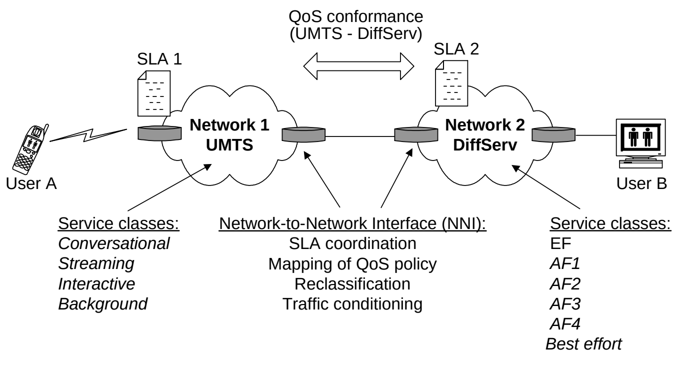

Fig. 1. An example of end-to-end QoS provisioning

A single performance metric μ_i in domain i maps to the corresponding metric μ_{i+1} depending on metric type and considering its maximum value $\mu_{i,\max}$ between the ingress and egress router of domain *i*. Equations (1), (2) and (3) stand for additive, multiplicative and concave metrics, respectively.

$$\mu_{i+1} = \mu_i - \mu_{i,\max}\,, \qquad (1)$$

$$\mu_{i+1} = 1 - \frac{1-\mu_i}{1-\mu_{i,\max}}\,, \qquad (2)$$

$$\mu_{i+1} = \min\{\mu_i\,, \mu_{i,\max}\}\,. \qquad (3)$$

Typical examples of additive metrics are delay, jitter and round trip delay; packet loss ratio is implicitly multiplicative metric, while bit rate, burstiness and packet size are examples of concave metrics.

III. Service Level Specification Format

The Internet Engineering Task Force (IETF) defines SLS as "a set of parameters and their values which together define the service offered to a traffic stream" [9].

A standard for the SLS format is still missing, as well as a recommendation for formal descriptive language that should be used for representation of SLS.

Fig. 2 represents a proposal of formal service level specification. It encompasses descriptors and associated parameters that unambiguously describe traffic flow and QoS requirements. Since QoS is negotiated between service providers, relevant SLS parameters should be expressed quantitatively rather than qualitatively. Parameter is not specified if its value is not relevant for specific service class.

We adopt the following syntax for purpose of formal SLS description:

```
Descriptor:
- Parameter: <option 1> <option 2>
```

```
Beginning of SLS:
 Traffic flow:
  - Communication type: <1→1> <1→N> <N→N>
  - Addresses: <source and destination addresses>
  - Interfaces: <source and destination port IDs>
  - Transport protocol: <TCP> <UDP> <RTP> ...
 Traffic profile:
  - Packet size: <minimum> <average> <maximum>
  - Bit rate: <peak> <average>
  - Burstiness: <peak> <average>
  - Time To Live: <value>
  - Adaptability: <elastic> <non-elastic> <no>
  - Excess traffic: <dropping> <re-marking>
                    <shaping>
 Performance metrics:
  - Maximum delay: <value> <not specified>
  - Maximum round trip delay: <value>
                              <not specified>
  - Maximum jitter <value> <not specified>
  - Maximum packets loss probability:<value>
                                     <not specified>
 Reliability:
  - MTBF <value> <not specified>
  - MTTR <value> <not specified>
 Availability: <value>
 Service schedule:
      <day/beginning – end of period> <7days/24h>
 Service re-negotiation: <yes> <no>
End of SLS
```

Fig. 2. Proposal of the common SLS format

Descriptor of the individual traffic flow encompasses the type of communication and 5-tupple in the IP packet header (source and destination addresses, port numbers and transport protocol type). *Traffic profile descriptor* includes: packet size, bit rate, burst size, TTL (Time To Live), adaptability and treatment of the excess traffic. Adaptability denotes the ability of application to adjust bandwidth consumption to network conditions. If adaptive, ingress flow can be elastic or non-elastic. Elastic flow can tolerate certain delay variations but poses strict requirements with respect to low packet loss. Non-elastic flow can tolerate certain degree of packet loss, but implies strict requirements in the sense of delay guarantees. Treatment of the excess traffic refers to dropping, re-marking or shaping of the traffic that exceeds negotiated profile. *Performance descriptor* encompasses performance metrics like: delay, round trip delay, jitter and packet loss probability (all values are defined from ingress to egress point). *Availability descriptor* describes percentage of total time of service availability. *Reliability descriptor* encompasses parameters like mean time between failures (MTBF) and mean time to repair (MTTR). *Service scheduling descriptor* specifies time interval in which the service is available. *QoS renegotiation descriptor* explicitly defines whether administrator is allowed to offer service of worse characteristics if the network can not meet user's requirements.

For purpose of parameters mapping, priority is assigned to each SLS parameter, i.e. it is mandatory, preferential or irrelevant. *Mandatory parameters* must be satisfied during mapping. *Preferential parameters* are analyzed if CMS gives more then one class at its output, with the aim to facilitate proper choice of class. Irrelevant parameters are ignored during conformance matching.

IV. Conformance Matching Scheme – CMS

CMS is an algorithm that provides mapping of QoS parameters between neighboring domains that focuses on satisfying mandatory SLS parameters, with minimum resource and time consumption.

Inter-domain QoS mapping by means of CMS assumes that administrators use previously described SLS format for detailed characterization of each service class in their own domains.

Fig. 3 presents CMS algorithm described using XML (Extensible Markup Language) language.

CMS performs automatic selection of the appropriate service class. The input parameters for the CMS are SLS and specification of all service classes that are available in particular network. CMS establishes the most appropriate degree of correspondence (DC) between the requirements for particular session and a class from the available set of service classes. DC is a function of required SLS parameter and offered parameter of considered class in ingress domain:

$$DC^{n}_{(i,i+1)}(\mu) = f(\mu_{req}, \mu^{n}_{off\,(i+1)}), \quad (4)$$

where μ is considered SLS parameter, μ_{req} represents required value of SLS parameter in egress domain and $\mu^{n}_{off\,(i+1)}$ is a value of offered parameter of class n in ingress domain.

CMS extracts a set of mandatory parameters from particular SLS and then retrieves the set of available service classes to select candidate classes, i.e. classes that satisfy the set of required values with some degree of correspondence. DC value of mandatory parameters for each candidate class is calculated according to:

$$DC^{n}_{(i,i+1)}(\mu) = \frac{\mu_{req}}{\mu^{n}_{off\,(i+1)}} \quad (5)$$

```
<CorespondenceMatchingScheme>
 <DegreeOfCorrespondenceCalculation>
   <find mandatory parameters> => <mi1,.., miX>
   <find candidate classes> => <Ci,..Ck>
     <for each candidate class n, n ∈ {1, ..., k} >
     <calculate DC values for selected parameters> =>
      <DCn(mi1),..,DCn(miX)>
        <compare DC values to predefined threshold value TR>
          if(DCn(mi))<TR){
          DCn=0
          n=n+1
        <calculate DCn(mi) for the next class>
       }else{
          < calculate sum of DCn(mi1),...DCn(miX)> => <DCn>
       }
     <find maximum DCn> => <DCn_max>
       if(there is more than one identical DCn_max){
          <find preferential parameters> => <mi1,.., miY>
          <calculate DC for preferential parameters> =>
          <DCn(mi1),...DCn(miy)>
            <calculate sum of  DCn(mi1),...DCn(miY)> => <DCn>
            <find maximum DCn> => <DCn_max>
            <selected class=n>
       }else{
          <selected class=n>
     }
        <class n is recommended for SLS negotiation>
 </DegreeOfCorrespondenceCalculation>
</CorespondenceMatchingScheme>
```

Fig. 3. QoS translation according to CMS

If any of DC values is lower then predefined threshold value, CMS eliminates this class from further consideration by setting its $DC^{n}_{(i,i+1)}$ to zero and continues to analyze next candidate class. The purpose of the threshold is to restrict the set of candidate classes to those with satisfying values of all mandatory parameters. After all candidate classes have been analyzed an overall DC value for each class is calculated according to:

$$DC^{n}_{(i,i+1)} = \sum_{j=1}^{m} DC^{n}_{(i,i+1)}(\mu_j), \quad (6)$$

where m is number of mandatory parameters.

After determination of $DC^{n}_{(i,i+1)}$ for each candidate class, the offered class is selected according to:

$$DC \text{ of offered class} = \min\{|m - DC^{1}_{(i,i+1)}|, \ldots, |m - DC^{n}_{(i,i+1)}|\}, \quad (7)$$

Usually, CMS algorithm generates one class that corresponds best to required mandatory parameters; however sometimes two or even more classes can have the same DC value. In that case, CMS calculates DC values of preferential parameters for each of concurrent classes and then the maximum DC value of preferential parameters determines class that gives the best correspondence to required SLS parameters. Calculation of DC values of preferential parameters is also performed according to Eqs. (5) - (7).

V. Operating of CMS: A Numerical Example

Let us now reconsider the example from Fig. 1 and suppose a distributed data base application which negotiates SLA 1 with the UMTS provider. Suppose that SLS 1 requirements for packet loss probability and delay are PLP_1=1s and $D_1=2*10^{-3}$, respectively. PLP is mandatory parameter, while D is preferential parameter. According to class specification from Table I, this traffic flow is associated to interactive class of UMTS domain.

TABLE 1 UMTS and DiffServ classes specification

	Delay (ms)	Jitter (ms)	Packet loss probability
UMTS			
Conversational	<100	<20	$<10^{-4}$
Streaming	<300	<80	$<10^{-3}$
Interactive	<400	-	$<10^{-3}$
Background	-	-	$<10^{-2}$
DiffServ			
EF	<100	<10	$<10^{-5}$
AF1	<400	<40	$<10^{-4}$
AF2	<600	-	$<10^{-4}$
AF3	<800	-	$<10^{-3}$
AF4	<1000	-	$<10^{-3}$
Best effort	-	-	-

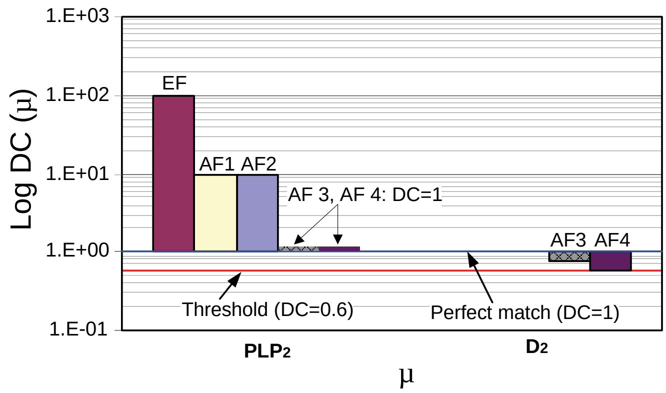

Fig. 4. DC values of mandatory and preferential parameters for each candidate class

Further, SLA 2 is negotiated between UMTS and DiffServ domains. SLS 2 requirements are calculated according to Eqs. (1) and (2): D_2=600 ms and $PLP_2=10^{-3}$.

For every candidate class of DiffServ domain DC value of mandatory parameter (PLP) is calculated according to Eq. (5). We can see from Fig. 4 that all DiffServ classes except best effort satisfy the required threshold value (tr=0.6), while AF3 and AF4 show perfect DC match. Now, since there are two classes with equal DC values, CMS calculates DC values of preferential parameter (D) for those two classes and obtains 0.75 for AF3 and 0.6 for AF4. Hence, according to Eq. (7), the selected class is AF3. Fig. 4 illustrates the process of class selection.

VI. Conclusion

This paper addresses QoS mapping in AIPN environment at network-to-network interfaces. We propose a framework for inter-provider IP QoS specification, which encompasses a common SLS format and efficient mapping algorithm CMS in the sense of minimum resource and time consumption.

The format of service level specification contains a set of descriptors and their associated parameters that describe the required service class independently of the network technology (e.g. wired, wireless) and the applied QoS model. Every SLS parameter is marked with one of three weighting factors (mandatory, preferential, irrelevant).

CMS performs mapping of SLS requirements to the most suitable class based on assessed DC value between the required and offered QoS. Mandatory parameters are crucial for mapping, while preferential help to select a suitable class in the case of two or more classes as a CMS output with equal DC values for mandatory parameters. CMS also identifies minimum threshold for each mapped value to assure satisfying DC value for each mandatory parameter.

References

[1] S. Blake et al., "An Architecture for Differentiated Services", RFC 2475 (Informational), IETF, 1998.
[2] "End to End Quality of Service Concept and Architecture", 3rd Generation Partnership Project TS 23.207, Release 5, June 2003. [Online]. Available: http://www.3gpp.org.
[3] IST Project "Traffic Engineering for Quality of Service in the Internet at Large Scale (TEQUILA)", EU 5th Framework Programme, 2000-2002. [Online]. Available: http://www.ist-tequila.org.
[4] C. Bouras, A. Sevasti, "Service Level Agreements for DiffServ-based Services Provisioning", *Journal of Network and Computer Applications*, vol. 28, 2005, pp. 285-302.
[5] M. Stojanovic, V. Acimovic-Raspopovic, *Teletraffic Engineering in Multiservice IP Networks*, Faculty of Transport and Traffic Engineering, University of Belgrade, October 2006. (In Serbian).
[6] S. Bostjancic, "Quality of Service Negotiation in IP Networks with Differentiated Services", Master Thesis, Faculty of Transport and Traffic Engineering, University of Belgrade, 2007. (In Serbian).
[7] S. Maniatis, E. Nikolouzou, I. Venieris, "End-to-End QoS Specification Issues in the Converged All-IP Wired and Wireless Environment", *IEEE Communications Magazine*, vol. 42, no. 6, June 2004, pp. 80-86.
[8] J. Heinanen et al., "Assured Forwarding PHB Group", RFC 2597 (Standards Track), IETF, June 1999.
[9] D. Grossman, "New Terminology and Clarifications for DiffServ", RFC 3260 (Informational), IETF, 2002.