Application-Layer QoS Interdomain Signalling with SIP Protocol

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Abstract - The QoS signalling across multiple domains is an open issue: in this paper we propose a QoS interdomain signalling solution for SIP-based multimedia sessions. Our solution refers to a signalling architecture proposed by ETSI in which the interdomain QoS signalling flows on the application layer along with the session signalling. In our solution we extend the precondition set attributes defined in the "Integration of Resource Management and Session Initiation Protocol (SIP)", RFC 3312, to allow the exchange of information about resources required by multimedia sessions and local availability of resources in each domain, between all the domains along multimedia session paths. Moreover in this paper we provide a signalling solution that integrates interdomain signalling and SIP end-to-end session negotiation signalling.

Keywords: QoS, multi-domain, SIP, SDP.

1.0 Introduction

The task of signalling service is to transfer signalling information originated by the terminal nodes between the switching and policing nodes of a network. In the past, carriers used specialized networks as those implemented for SS7 [1], to transfer signalling information but now, especially in backbones, they use the same IP networks to transfer signals and data information. Beyond this, in recent years the signalling task has became more complex and cumbersome for the addition of new services. Particularly, five elements have changed the situation: first the development of different types of telephony, each with different requirements, second the presence of data signals in the same channels of telephony, third the existence of multimedia signals such as those arising from videotelephony and video-streaming whose requirements are deeply different from those of telephony, fourth the implementation of many networks with different architectures and policies and whose boundaries are located at different OSI layers, fifth the need to assure Quality of Service (QoS).

In an environment supporting so many different services, the role of QoS is an essential one but it presents many issues which are possible to classify in issues regarding the policies, issues regarding the means needed to obtain the QoS the various services require, and issues regarding signalling that have to support the network system.

The issues of providing Quality of Service and Resource Reservation have obtained until now two different main solutions provided by the approaches of Integrated Services [2, 3] and Differentiated Services [4, 5].

In the first one all the network routers have to install and keep state information about the users flows and their QoS levels. It requires an end-to-end signalling providing information about the flows and their QoS levels to the network routers along the path from source to destination. The most known protocol which is able to perform this signalling is RSVP [6].

In Differentiated Services approach in each domain edge routers mark the packets of each flow according to the desired QoS level, and interior routers handle the packets on the base of their marks. So differentiated service approach does not require in-path end-to-end signalling, but usually each domain has a central resource manager entity that knows the resources state in its domain and instructs edge routers about the packets marking. In this paper we are not interested in providing a comparison of these two mechanisms but we provide a model that allows sessions with quality of services in multi-domain environments where each domain has its own QoS mechanism, i.e. where each domain can use its own reservation mechanism based on Differentiated or Integrated Services approach.

This problem has also been investigated by the IETF Next Step in Signalling (NSIS) working group, which is working to a new signalling architecture and related protocols able to accommodate multiple signalling needs as reserving resources, configuring middle boxes like Network Address Translators and collecting network information [7].

The issue of signalling supporting QoS is particularly heavy and cumbersome in multidomain networks since it includes a lot of items such as inter\intra domain QoS routing, resource booking, interface between transport layer entities and session layer entities, end-to-end negotiation signalling, inter and intra domain QoS signalling and so on. In this paper we focus our attention on the interdomain QoS signalling, i.e. on the signalling that has to transfer, to all the domains involved in multidomain sessions, information about quality of service required by the multimedia sessions and resource availability in each domain, in order to build a virtual path with QoS characteristics from source to destination. The proposal we present starts from a theoretical scheme developed by ETSI [8] and accepted also by ITU [9] which we have developed to its full extent and completed with the necessary SIP protocol [10] extension. Our proposal is based on the integration of end-to-end negotiation signalling and QoS interdomain signalling using a set of session SIP messages as carriers of the interdomain QoS signalling and a set of SDP attributes to describe the interdomain QoS information. Due to the interest in the interdomain architectural aspects and interdomain signalling, any treatment of the network architecture needed to support the various services with their different QoS requests is neglected. Moreover, also issues of intradomain assurance of quality and policies are out of scope of this paper.

The remaining part of this paper is organized as follows. In the first part of section 2 we present the two multidomain signalling architectures proposed by ETSI to establish sessions with QoS and we explain the reasons why we decided to study a SIP-based signalling model for the one in which the interdomain QoS signalling flows on the application layer. In the second part of section 2 we present the SIP entities and the SIP futures we use to build our interdomain signalling model. In section 3 we present the "precondition" object standardized in the IETF "Integration of Resource Management and Session Initiation Protocol (SIP)" RFC 3312 [11] to allow users to share the resource reservation state; following we present our proposal of a new set of attributes for the precondition that allows us to use the precondition as communication object between domains; we close this section with the description of our interdomain signalling model proposal.

2.0 Multidomain Architectures and Interdomain QoS Routing

In a multidomain network environment signals cross several networks with different structures and policies which have to collaborate to obtain the QoS the customers need. Each domain has to assure the required QoS or has to communicate a different QoS offer to the requiring party. Therefore there are two types of signalling: intradomain signalling that is used to assure the desired values of different QoS parameters in each crossed autonomous system; interdomain signalling whose aims are the exchange of information between the ending entities about their conditions, capabilities and policies, and the exchange of information between the entities that in the different domains are charged of the routing and the inner QoS services. The last problem, due to its complexity and relevance, has received in recent years a considerable attention [12, 13, 14, 15] and is still an open issue.

As introduced in section 1, the aim of this paper is to develop an interdomain QoS signalling architecture and the definition of a suitable protocol, based on SIP [1]. There are two main ways suitable to achieve end-to-end QoS signalling in a multidomain environment as described in the ETSI Tiphon project [1, 16]:

- By means of end-to-end QoS signalling within and between transport domains which share common policies, see Fig.1. The main signalling solution that meets the requirement of this architecture is RSVP [9] which provides a method for setting a path from source to destination with the QoS level required by the users;
- By means of end-to-end interdomain QoS signalling between service domains, and intradomain QoS signalling between service entities and transport entities of the same domain, as described in Fig. 2. This figure shows how in this architecture the session signalling and the QoS interdomain signalling have to cross the same domains of the multimedia flow.

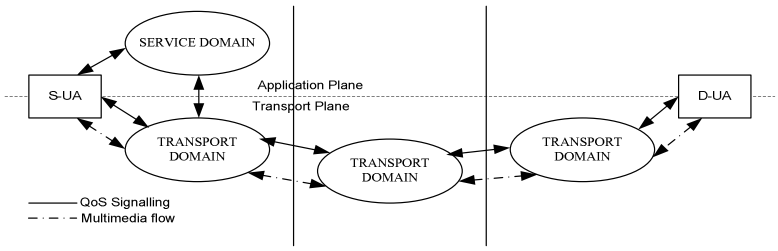

Fig.1. Multi-domain architecture with interdomain QoS signalling on the transport plane

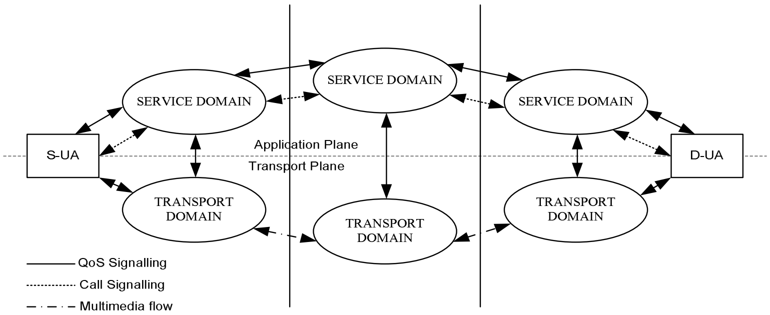

Fig.2. Multi-domain architecture with interdomain QoS signalling on the application plane

The main advantage of the last architecture is that it allows autonomous and independent reservation mechanisms in each domain: each domain has an application entity that receives QoS information in an application format (e.g. codec, media type) and from this information generates a set of transport parameters [16] conforming to the reservation mechanism used in its domain. These transport parameters are provided to a transport entity that controls the transport resources in its domain. In the following we call Quality Application Entities (QAE) the entities running on application layer that handle the QoS information, and Quality Transport Entities (QTE) the transport entities that control transport resources, as shown in Figure 3.

In the last section of this paper we present an interdomain QoS signalling solution that meets the requirements of the signalling architecture model described in Fig. 2. It uses SIP messages to carry interdomain QoS signalling along with information about the negotiated QoS level between users. We recall that, SIP was born as session signalling, but its architecture allows an easy extension of its futures and different SIP extensions have been proposed for supporting QoS in multimedia sessions in which SIP servers of both the access networks of the users are involved in the quality of service provisioning procedure. In this paper we propose a solution for interdomain QoS signalling in which all the domains along the path from source to destination deploy own SIP servers which are trigger point for the QoS information carried in session messages regarding both the session level desired by the user and the resource availability in the other domains, in order to allow autonomous and independent reservation and police methods in each domain.

2.1 Multidomain Signalling Architecture with SIP Entities and interdomain routing

SIP protocol defines two SIP entities:

- SIP user agents, usually running on the user terminal, are the endpoints of the session signalling.
- SIP servers, perform registration and location services and forward the SIP messages towards their destinations.

Since we propose to integrate QoS interdomain signalling in session signalling, we propose an architectural model that has a SIP server in each domain crossed by the data flow, see Fig. 3. Thus constraining the session signalling routing through these SIP servers, it is possible to provide the QoS information to each domain involved in the multimedia session. Particularly, these SIP servers have to communicate with the Quality Application Entities (QAE) to provide the QoS information contained in the SIP messages. The QAEs interact with the transport layer entities (QTEs) in order to activate resource reservation procedure in their domains and with the other QAEs in order to give them information about the resource availability in their domains.

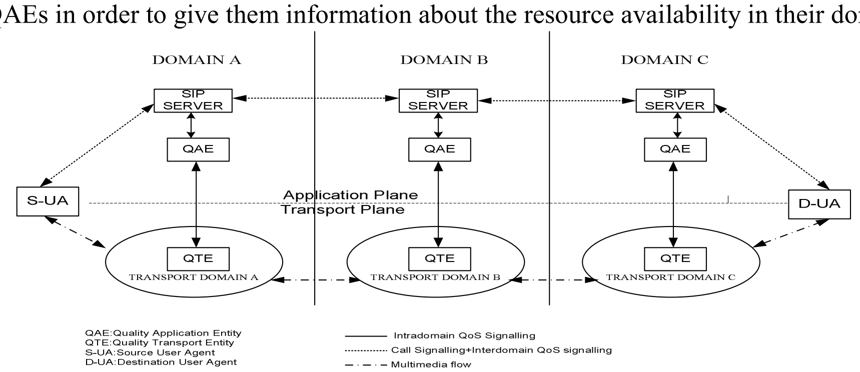

Fig.3. Multi-domain architecture with SIP entities

The interface between QAEs and QTEs has been object of different studies such as the ones shown in [21, 22] which propose to use COPS for this scope. In this paper we do not investigate about the interface between SIP servers and Quality Application Entities, and in what follows we refer to the Q-SIP proxy [17] as a physical element containing modules performing both the functions of SIP proxy and of Quality Application Entity. This hypothesis has the only purpose of allowing us an easier description of our proposal. Regarding the setup of signalling path from source to destination, we recall that the architecture shown in Fig.2, which we refer to, requires the signalling flows along the same domain of the data.

In multidomain networks there is usually more than one available inter-domain path from source to destination, see Fig. 4, and each path could guarantee different QoS levels. Therefore, to setup a multidomain session with QoS, the first step to achieve is to select the best inter-domain path from the caller to the callee. The inter-domain routing is a research issue [19, 20] out of the scope of this paper, and in the following we suppose that each access domain is able to discover the possible inter-domain paths towards the destination before starting the session setup, and that it is able to make an estimation of the best one (common parameters to make this estimation are total resources cost along the path, availability of security associations and settlements with the domains along the path). For having the QoS signalling crosses the same domains crossed by data flows, we propose the SIP server in the access domain of the source user agent sets the *route* header [10] of the SIP requests with the identifiers of the Q-SIP servers of the domains along the selected path for the data flow. In this way the SIP messages containing interdomain QoS signalling flow along the same domains of the selected data flow path.

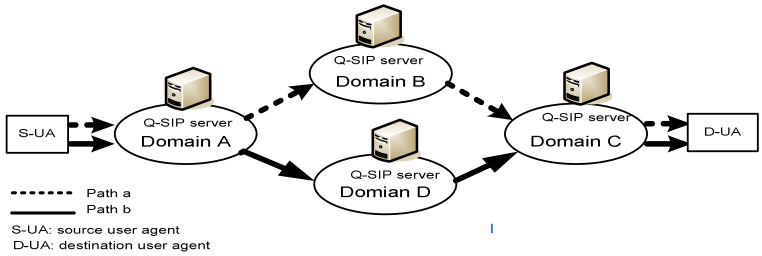

Fig. 4. Multidomain network environment with two available paths from the source to the destination

3.0 SIP end-to-end QoS Negotiation Model and Interdomain QoS Signalling

In this section we describe our signalling proposal using the network entities and the architecture described in the previous section. We propose an extension of the *precondition object* defined in the Integration of Resource Management and Session Initiation Protocol (SIP), RFC 3312 [11], to allow exchange of QoS information regarding resource availability in each domain between all the domains along the data path. We organize this section in three subsections: the first one contains a brief overview of the *precondition object* and the negotiation model proposed in the RFC 3312, in the second one we define a new set of SDP [18] parameters for the precondition object to describe the resource reservation result in each domain, and in the last one we describe the signalling model we propose to allow QoS interdomain signalling between all the domains involved in the path setup and the end-users.

3.1 RFC 3312 Overview

The RFC 3312 contains the IETF proposal about negotiation of QoS session levels between users involved in a SIP call, and introduces the concept of *precondition*. This is a set of constraints about the session, i.e. a defined QoS service level desired for the session. It is described with a set of SDP [18] attributes that are carried in the body of SIP messages. Examples of these attributes are the desired-status, the current-status and the conf-status. SIP users use, the first one to notify the desired QoS level to the peers endpoint, the second one to notify the current resource state, and the third one to ask confirmation of the resource reservation to the peers. The SDP elements characterizing the precondition are:

- *strength-tag ="mandatory" | "optional" |"failure",* it is used in the desired status to indicate whether (mandatory) or not (optional) the call setup can be made when the network fails to meet the preconditions; and it is used in the current status to indicate that there are not enough resources (failure);
- *status-type ="e2e" | "local" | "remote"*, it indicates whether resource reservation is desired in local access networks (send, recv), or end-to-end (e2e);
- *direction-tag = "none" | "send" | "recv" |sendrecv*", it gives the direction in which resource reservation is desired.

The model to negotiate the precondition is of offer/answer type and avoids the ringing of remote party phone if the resource reservation procedure fails. Each user has to communicate to the peer the owner *desired status* and *current status* to share the resource reservation state for the two data flows in both directions.
To begin the session the current status must be equal or greater than the desired status.

3.2 Extended-Precondition and SDP parameters

We propose an extension of the *precondition* described in the previous section, to use it as object to share, not only the end-to-end resource reservation state between users, but also the local reservation state in each domain between all the QAEs along the path, and the endpoint. We propose the Quality Application Entities write in the precondition the resource reservation result in their domains and provide this precondition to the peers Quality Application Entities on the session path and to the endpoints. To this scope we define three logical states for the current state variable of the precondition set:

- Resource reserved;
- Resource failed;
- Resource changed.

The first one is used by the QAE when it is able to book in its domain the resource required for the session. In this case the precondition's line describing the current state has the following content:
curr=QoS e2e sendrecv.

The *Resource failed* value is used when the domain is not able to provide the resource required for the session and the value of the strength tag in the desired status is *mandatory*, which means that users do not want to start a session with a lower quality level than the desired one, see section 3.1. In this case the QAE has to provide the identifier of its domain to the other application entities involved in the path setup and to the endpoints, along with information about the max resources level it is able to guarantee. To this scope we propose two new parameters for the current state variable:

- *Domain-identifier*;
- *Max-resource*.

So the content of the current state in the precondition when *Resource failed* happens is:
curr=QoS failure e2e sendrecv domain-identifier max-resource.

The third proposed value *Resource changed* allows continuing the session setup phase when a domain is able to guarantee a lower resource level than the desired one. This has to be used by the QAE only when the strength tag in the desired status variable is *optional*, which means that the users want to start a session also with a lower quality level than the desired one, see section 3.1. Moreover in this case we propose a new value for the strength tag of the current status: *changed*.
So the content of the current state in the precondition when *Resource failed* happens is:
curr=QoS changed e2e sendrecv domain-identifier max-resource.

In the following we call the above described precondition set with its new attributes *extended-precondition*.
The choice of messages to be used for notification of the extended-precondition content to all Quality Application Entities, and how to merge the session signalling with the interdomain signalling is explained in the following section.

3.3 QoS Interdomain Signalling and Session Signalling Integration Issue

In an IP SIP session, each multimedia flow has its own logical IP channel, and this allows activating resource reservation procedure separately and in a different instant for each flow. This has to be avoided in the interdomain signalling architecture which we refer, shown in Fig. 3, because each resource reservation procedure is performed with a cross-layer interaction between application entity (QAE) and transport entity (QTE) in each domain, and this could cause long delay in the session setup step. To meet the delay condition we propose to collect the QoS information of the two session flows (caller-callee flow and callee-caller flow) in one SIP message, the UPDATE. The QAEs can capture from this message all the QoS information they need to query resources booking to the transport layer entities only once for the bidirectional data flows. Moreover we propose to use the UPDATE message as carrier of the extended-precondition: each QAE before forwarding the UPDATE message to the next node (i.e. the next QAE along the path or the endpoint), has to put in the extended-precondition the result of the reservation in its domain. With this procedure each QAE can recognize the state of the resource reservation in all the previous domains crossed by the UPDATE message reading the content of the extended-precondition object. Particularly, in order to reduce the signalling complexity, we have proposed, see section 3.2, an appropriate signalling model and precondition structure. With this model only the QAEs of the domains which are not able to provide the desired resource level have to change the content of received extended-precondition before forwarding it to the next node.

In the following we resume the extended-precondition handling rules we propose for end users and QAEs:

- The user agent in the caller side has to generate the UPDATE message when it knows the QoS levels of both the directional flows. This user agent doesn't know which will be the reservation result in each domain from its own to the destination, but sets by default the current state variable of the precondition with the value *resource reserved*.
- The Q-SIP server of each domain crossed by the UPDATE message, if reads *resource reserved* or *resource changed* in the current state variable of the precondition, activates resource reservation in its domain and:

- If in its domain there are enough resources to meet the *desired* QoS level, it forwards the UPDATE message to the next node without changing the current state attribute;
- If it can guarantee resources for a lower QoS level and the strength tag of the desired status is *optional,* it has to set the current state variable with *resource changed*. If it is already in this state, it has to update its *domain-identifier* and *max resource* parameters, only if the amount of resources which it is able to guarantee is lower then the value contained in the received precondition.
- If it cannot guarantee enough resources for the desired QoS level and the content of the strength tag is *mandatory*, it changes the UPDATE body before forwarding the message, setting the current attribute in the state *resource failed*.

If the Q-SIP server reads the state *resource failed* in the current state variable, it forwards the UPDATE message without activating a local resource reservation procedure.

With the above described control procedure the callee user agent will read in the UPDATE message body:

- The amount of resources obtained for its session, that can be less then the desired one if it, or the peer endpoint, had set *optional* in the strength tag;
- Information about the domain in which there is not enough resource to satisfy its desired QoS level.

In the first case the callee user agent has to use the 200 OK (UPDATE), to inform the caller about the positive result of the resource reservation in all the domains and, eventually, the minimum amount of resources provided by the domains along the path, and has to continue the session setup procedure with the ringing message. In the second case the callee user agent has to close the session setup, using the 580 response message [11], because there are not enough resources to perform the mandatory desired QoS level. The 580 response message has to carry the failure's reason along with indication about the domain in which the resources booking has failed; allowing the domains along the path to release the previously booked resources. Moreover both the users' access networks can use the information about the domain which is not able to guarantee resources to verify the availability of another session path which does not include that domain (see section 2.1). Fig. 5 shows a call flow example about a multidomain session with QoS in which the offerer is the caller, along with the precondition content in each message. In this example we show a scenario in which 3 domains are involved in the interdomain session. One domain of them (B) is not able to provide the desired resources level, and since the desired status is *mandatory*, the session setup is closed.

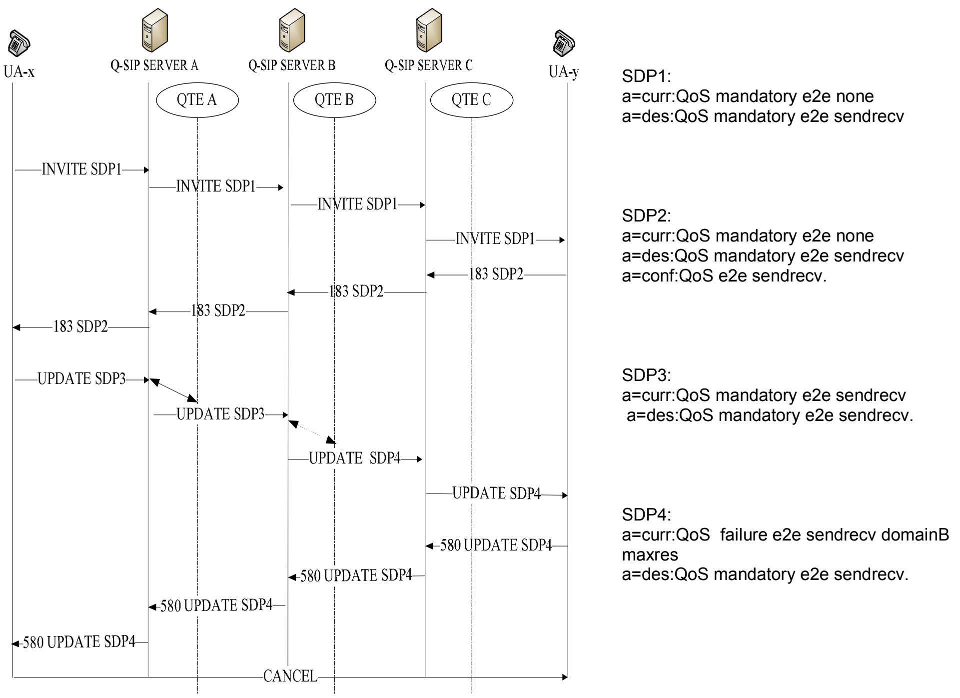

Fig.5. Multidomain SIP session with mandatory desired status. The extended-precondition is included in the UPDATE message body (SDP3) by the user agent x (UA-x), the Q-SIP server A forwards it without changes since it is able to book the desired resources. The Q-SIP server B is not able to perform the booking and sets failure in the extended precondition (SDP4). The Q-SIP server C forwards the received UPDATE without asking resource to its QTE. The user agent y (UA-y) closes the setup procedure with the 580 message and copies in its body the received extended-precondition

4.0 Conclusion

The work presented in this paper is a proposal of a new method to achieve the interdomain QoS signalling using a new set of SDP attributes carried in the body of the SIP messages already used for session signalling. We fully developed the extensions necessary to support this new functionality, introducing a necessary new tags set. The main advantages of our proposal are as follows: 1) it matches the restrictions about the architecture proposed by ETSI which allows different and independent reservation methods in each domain along a multidomain session path; 2) it does not require new functionalities in the IP network entities which are already able to recognize and deal with the well known SIP protocol; 3) the amount of traffic it introduces in the network is relatively small since it uses the messages exchanged at application level for the end-to-end negotiation signalling between SIP users. Future work is intended to determine the signalling round-trip-time and to compare it to that produced by a solution based on transport layer signalling.

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