End-to-End QoS Management Proposal for the ITU-T IMS/NGN Architecture

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Abstract: **The centralized management of the QoS in NGNs is currently one of the main lines of research in the networking sector. One of the tasks of the ITU-T organisation in this area is to develop a global architecture capable of managing end-to-end services to be used on future specifications. This paper presents a signalling architecture proposal for the end-to-end QoS management conforming the early ITU-T specifications for IMS/NGN networks, focusing on the transport sub layer. The viability of the architecture has been validated through the implementation of a GNU/Linux real testbed.**

1. INTRODUCTION

Various organizations have developed specifications related to Next Generation Networks (NGNs). The IEEE has focused on developing solutions for layer 2 issues, while the IETF has concentrated on layer 3 issues. ITU-T and ETSI are developing network architecture and control procedures [1]. Different agents have also taken part in the creation of the resource and QoS control architecture for NGNs: CableLab for HFC cable access networks, the DSL forum for DSL access networks, the 3GPP for mobile access networks and ETSI for generic access networks which work independently from transport technology while ITU-T has developed a generic end-to-end architecture which summarizes the aforementioned and comprises core and access networks.

ITU-T has elected the IMS (IP Multimedia Subsystem) architecture, developed by 3GPP, as a support of session-based services and other session initiation protocols (SIP) [2]. This architecture uses the reference points defined in the transport subjacent infrastructure to manage the negotiated QoS through the session signalling and the flow control at a network level.

The QoS management architecture proposed by ITU-T for NGNs is completely integrated and interoperable with IMS. This new architecture, IMS/NGN, presents a stratified division between the service plane in the upper layer, including the session control plane in the intermediate control sub layer, and the transport plane in the lower layer (Fig. 1).

In this latter case, the resource and admission control functions have been defined in the RACF entity [3], which is capable of managing the end-to-end QoS through both core and access heterogeneous networks. This architecture is presently under definition and therefore some of the reference points are still to be specified.

The establishment of a mechanism for end-to-end QoS control management in a heterogeneous IMS/NGN infrastructure is a complex task. The coexistence of multiple QoS technologies and different provider domains must be taken into consideration. One of the key aspects will be the study of the interconnection of the different providers and technologies. Therefore one of the main implementation difficulties will be in the efficient and dynamic exchange of policies between the different domains, as defined in their respective SLAs (Service Level Agreements).

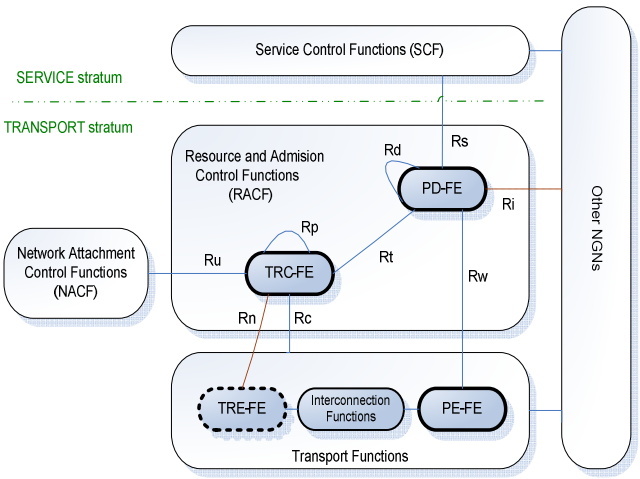

Fig .1. RACF architecture proposed by the ITU-T for IMS/NGN

The paper is organized as follows: in section II the RACF entity and its interfaces are introduced. In sections III and IV QoS control management is discussed from the intra-domain and inter-domain views respectively. In section V an end-to-end architecture based on the ITU-T recommendations for NGN is proposed. Finally, in section VI, the conclusions are presented.

2. THE RACF ARCHITECTURE

In order to provide efficient end-to-end QoS control management, IMS/NGN architecture has adopted the policy-based network management proposed by the IETF Policy Framework Working Group. The aim is to provide a centralized management system to control the end-to-end QoS of the multimedia sessions. The ITU-T has consequently

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developed the QoS management sub layer and has defined the RACF entity providing the SCF with an abstract vision of the network infrastructure (Fig.1). RACF carries out the policy-based physical resource control, establishes the availability of these resources, decides on admission and applies the controls required to enforce the accomplishment of the policy decisions. Even though different international organizations (ITU-T, ETSI-TISPAN, MSF, etc.) have proposed many alternative protocols to the network policies delivery in use in the Rw, Rc and Rn interfaces, industry has not opted for any of them.

The Policy Decision Functional Entity (PD-FE) takes the final decision over the resource and admission control and delivers it to the corresponding Policy Enforcement Functional Entity (PE-FE) through the Rw interface. ITU-T is currently studying three alternatives for this interface, as specified in the Q.3303.x sub-series [4]. Two of them have already been approved COPS-PR and H.248. The third, DIAMETER, is awaiting approval.

The Transport Resource Control Functional Entities (TRC-FE) deals with the control of the resources which depend on transport technology. These entities are responsible for preserving and maintaining the network topology and resource database (NTRD) of each subdomain. The Rc interface is used to check the network topology and the status of network resources. The TRC-FE assigns resources to each QoS requesting flow. ITU-T has approved two alternatives for this interface [3], which have been specified in the Q.3304.x sub-series [5]: COPS-PR and SNMP. The specific details of this interface are still under study.

According to [3] the scope and functions of the Rn interface are also still under study, though it does clarify that one of the functions of the TRC-FE entity is to assign the network resources for its application. Given that the functionalities of the Rc interface have been already defined, although not in full detail, the only interface able to accomplish the aforementioned functions is the Rn interface. It seems logical to think that new protocols will be proposed to address network policy delivery to meet requirements. However, ITU-T has not made any formal proposals. Some of the protocols which meet the requirements and have been used by ITU-T in other interfaces include SNMP and COPS-PR [6].

SCFs, RACFs and transport functions may collaborate with other NGN architectures in order to provide services to nearby domains and therefore achieve end-to-end QoS. When the collaboration takes place at the RACF level it is done through the Ri interface, which is also still under development.

Even though the transport resource control in NGNs includes QoS control, NAPT and firewall control, and NAT traversal, the scope of this paper is limited to QoS control.

3. INTRA-DOMAIN CONTROL OF QOS RESOURCES

The RACF entity defines two possible scenarios for the QoS control which are based on the type of sessions established by the user. Depending on the QoS signalling capacity of the terminals (CPE) that initiate the sessions and the access technology, the QoS resources control may be in push mode or in pull mode (Fig. 2).

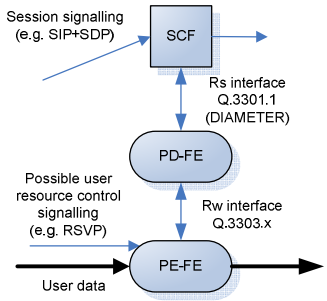

Fig. 2. Push or pull operation depending on the type of user terminal

The push mode is initiated through the session signalling when user resource control signalling does not exist. In this mode every time the PD-FE receives a QoS resource request from a SCF, it decides on authorization control and resources and then autonomously orders the transport functions to carry out these decisions, sending the QoS policy to the network transport equipment (PE-FE). This mode is employed by terminals without QoS negotiating capacity (type-1 CPE) or by those with only service stratum negotiating capacity (type-2 CPE)

The push mode is initiated when the transport functions require signalling to perform a flow (e.g. RSVP o NSIS). In this mode it is the PE-FE which sends a QoS resource request to the PD-FE through the Rw interface, so that the RACF may take the appropriate authorization decision and replay with the final policy decision to be applied. This mode is used by terminals that explicitly request the QoS resource request through path-coupled QoS signalling (type-3 CPE).

The two protocols proposed by the ITU-T to manage the Rw interface in core networks, DIAMETER and COPS-PR, have similar problems due to the natural client-server role (pull mode), which is inverted when the push mode is in use. In the original definition of the COPS-PR protocol, it works efficiently in pull mode but not so well in push mode. On the other hand, the original definition of the DIAMETER protocol also works correctly in pull mode but in this case the push mode is not contemplated. Two draft specifications have been proposed to solve this problem within both protocols [7][8]. In these drafts two extensions have been proposed to solve the problem and legitimate their utilization in push mode, making them as efficient as in the pull mode in both cases.

Therefore, while most of the protocols defined in RACF interfaces and routing elements of the transport layer are still under definition, the common protocol for all of them will

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probably be COPS-PR. An additional factor to consider is that the COPS-PR which manages policy delivery on a native level is already supported by most IP-IP gateways (routers) in present-day networks

On the other hand, although an extension for the SNMP protocol to manage network policies through the definition of the Policy Based Management MIB has been specified, as stated in [9], COPS-PR/PIB has some advantages over SNMP/MIB.

3.1 The COPS-PR protocol

The Common Open Policy Service (COPS) protocol was created to deliver QoS policies between the PD-FE and the PE-FE and it supports the two models of IP QoS policy management, one which focuses on the IntServ model and another which focuses on the DiffServ model. As stated before COPS was originally design to work in pull mode. Therefore the message exchanges in this mode are efficient and support a close relationship between the operations of the mentioned protocol and the state associated to the particular events detected by the PE-FE.

COPS-PR [6], the provisioning model, is the variation for the DiffServ model. Within this model, the PD-FE proactively sends the network policies to be applied to the PE-FE. As stated before, when COPS-PR is applied to the RACF entity, the protocol works effectively in pull mode, but not so well in push mode, even though it does work correctly. In Fig. 3 we can see how this latter mode incorporates appended messages between the PD-FE and the PE-FE when the states of the different events which appear (detected by the PD-FE) are associated to the specific operations of the protocol.

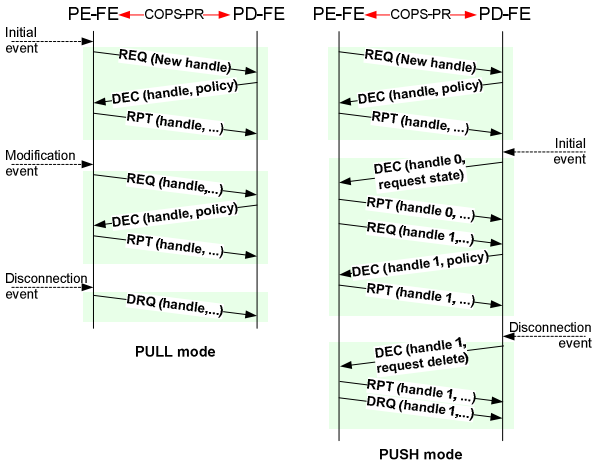

Fig. 3. COPS-PR signalling in pull mode and push mode

The proposal of modification of the COPS-PR protocol in [7] to optimize the push mode operation consists in removing some of the messages and creating a new value in the "New Decision" flag (Fig. 4). The problem with this proposal is that it involves modifying the protocol, and therefore loses interoperability, which is one of the main advantages of COPS-PR.

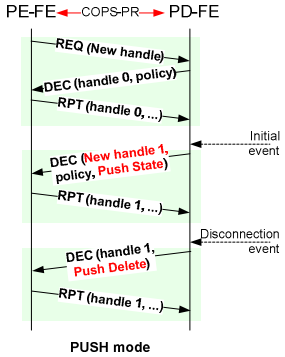

Fig. 4. Proposal of COPS-PR modification in push mode

4. INTER-DOMAIN CONTROL OF QOS RESOURCES

ITU-T defines the functions and processes needed to support QoS between different provider interfaces. In the inter-domain signalling between providers there are three ways to manage end-to-end QoS control: Through the application layer, through the Ri interface (RACF) and through path-coupled QoS signalling (e.g., RSVP-like). This is why under certain scenarios the intervention of the Ri interface may not be needed.

The use of the aforementioned interface has been proposed in the event of there being intermediate providers where the SCF cannot operate with the correspondent PD-FE (or if it has no application functions), where path-coupled QoS signalling does not exist or when the SCF of a core network can only communicate with the PD-FE of the access networks through its own core network PD-FE.

ITU-T does not address Ri interface protocols, although from the defined functionalities it is expected that those to be proposed will be dynamic service negotiation protocols. In [10] a comparative study of the dynamic network policies negotiation protocols proposed by different authors to be used in NGNs (RNAP, SrNP, DSNP, QoS-NSLP, QoS-GSLP and COPS-SLS) is presented. All of them negotiate SLS (Service Level Specifications) and even though there many types exist, these protocols negotiate mainly QoS SLS. The conclusion of [10] is that none of them are clearly better than the rest because each one has advantages and disadvantages.

Given that the proposed protocol to be implemented in the intra-domain interfaces for the QoS control is COPS-PR, and therefore is already implemented in the PD-FE, we propose COPS-SLS [11] as the protocol for the Ri interface. This election results in an internal resource optimization of the PD-FE and facilitates the interoperability between the resource assignation protocols of different interfaces.

However, a scalability problem appears in the SLS inter-domain negotiation when there is an important number of

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domains to interconnect. In [12] an architecture to solve the problem is proposed by applying a hierarchical structure to the PD-FE and creating local PD-FEs. The application of COPS-SLS in its hierarchical mode would permit the implementation of such a solution. It must be mentioned that this factor is not contemplated in the study by [10].

4.1 The COPS-SLS protocol

The COPS-SLS protocol is not a standardized extension of COPS for the inter-domain communication and it is able to dynamically negotiate the service levels between the users and their domain and between domains [11]. In the same way as COPS-PR, COPS-SLS uses a PIB to store the network policies representing the SLS information. This enhances the re-usability level of the protocol.

The negotiation process is organized in two phases (Fig. 5), configuration and negotiation, which allow the automatic configuration of the negotiation process. In the configuration phase the service provider informs the subscriber how to request a service level. If the process is successful then COPS-SLS proceeds to the negotiation phase.

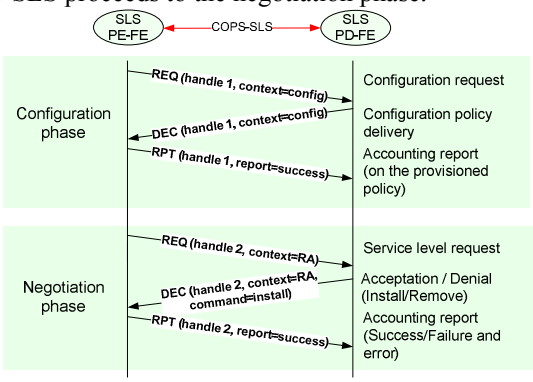

Fig. 5. COPS-SLS signalling sequence

In the case of an inter-domain negotiation, where the service has to pass through multiple domains, the resource request is propagated from PD-FE to PD-FE throughout the path until it reaches the last PD-FE where is confirmed. Then this confirmation is returns back to the initial PD-FE on the same path. Finally there is an end-to-end acknowledgement signalling. As it is a client-server architecture, PD-FE will have the double role of PD-FE and PE-FE.

5. PROPOSED ARCHITECTURE FOR END-TO-END QOS CONTROL

An implementation of a QoS Broker (QoSB) has been proposed to create centralized management of QoS resources, which some authors have denominated Bandwidth Manager (MSF) or Bearer Resource Manager (ITU-T).

The proposed QoSB assumes the PD-FE and TRC-FE functions. Nevertheless, its functions are not limited to those defined in RACF as it also takes on the network policy delivery to domain nodes which will probably be defined in Rn interface.

Thus, whenever a service flow resource is admitted in a given domain, the QoSB notifies the flow identification, the route and the QoS attributes to the edge nodes. These nodes will identify, classify, mark, policy and encapsulate the flow packets with the QoS information specified by the QoSB. If the service flow needs to pass through multiples domains, it will be the edge nodes (or gateways) which will interconnect the different domains through the specified inter-domain SLAs from the signalling aspect.

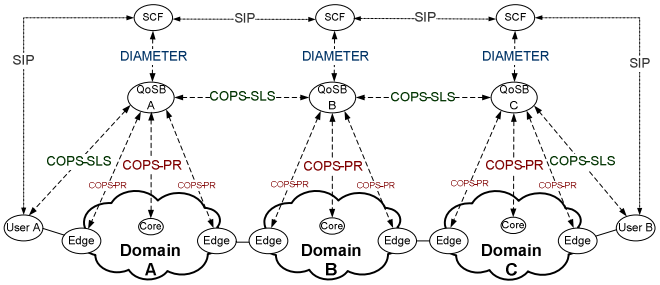

Fig. 6. Proposed architecture for end-to-end signalling

Fig. 6 summarizes the protocols proposed which conform with ITU-T specifications, where signalling between the QoSB and the nodes of the same domain will be carried out with COPS-PR, signalling between adjacent QoSB will be carried out with the COPS-SLS protocol and resource requests received by the SCF inside its own domain will be subject to the DIAMETER protocol.

5.1 Evaluation and results

The validation of the proposed architecture has been carried out through the implementation of a testbed (Fig. 7). The main goal of this test has been to achieve an overall system evaluation at the transport stratum, leaving more extensive performance and efficiency tests out of the scope of this paper. More specifically the test presented has been undertaken with type-1 users and therefore in push mode.

The testbed has three domains with GNU/Linux nodes. All of them have PE-FE modules supporting COPS-PR and COPS-RSVP with IPv4 and IPv6, even though ITU-T is still developing the signalling adaptation of the NGNs to IPv6 (recommendation ITU-T Y.2054).

It has been decided to use the same testing environment as in [9] in order to contrast the results. Therefore the implemented policies for the inter and intra domain communication have been the used in [9]. The same SLA between the two clients (Client-X and Client-Y) and Domain A have also been used, as well as the same traffic sources (6 UDP sources marked as EF, AF21, AF41 and BE), and the same congested link in 2001:720:818:4001:2::0/80.

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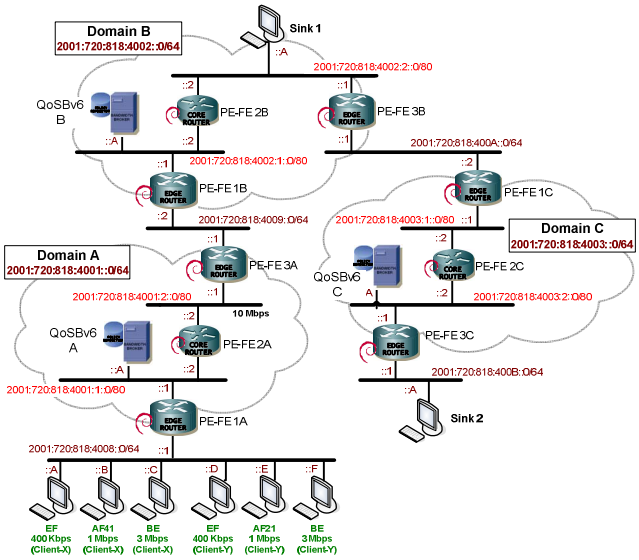

Fig. 7. Scenario implemented to evaluate the proposed architecture

As seen in Table I, once the policies are applied, the system stops dropping EF packets, it reduces the AF41 packets drop to 3.98 % and the AF21 packets drop to 5.62 % and increases the BE packets drop to 34.9 % (average of both sinks). These results are coherent with the policy applied since the EF queue has absolute priority and AF41 has a lower discarding probability than AF21. These results are very similar to the ones obtained in [9] with the SIBBSv6 protocol. The difference is the dynamic SLS negotiation carried out by the COPS-SLS protocol.

TABLE I. PACKETS DROPPED IN PERCENTAGE

	Sink 1		**Sink 2**	
	Without network policies	*With network policies*	*Without network policies*	*With network policies*
EF	12.28 %	0 %	15.91 %	0 %
AF41	19.71 %	3.98 %	-	-
AF21	-	-	20.35 %	5.62 %
BE	15.12 %	34.37%	16.26 %	35.09%

6. CONCLUSION AND FUTURE WORK

This paper has introduced and validated a signalling architecture proposal for end-to-end QoS Management according to the ITU-U specifications for IMS/NGN Networks.

The different protocols proposed by the ITU-T for the intra-domain management have been discussed and COPS-PR has been proposed as the common protocol. The ITU-T has not recommended any protocols for the inter-domain management so COPS-SLS has been suggested, which is able to dynamically manage the services, has a very scalable architecture and is completely compatible with COPS-PR.

A real testbed with three domains has been implemented to validate the proposed architecture at a transport stratum level. The results of the tests show the viability and operatability of the architecture even though no detailed study of the performance has been realized. Therefore there is no information about the its real efficiency and we cannot compare it to other protocols. We are currently working on these further tests as well as on the definition of a new terminal type (type-4 CPE) to support completely COPS-SLS

7. ACKNOWLEDGMENT

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