QoS Mapping and Adaptation in Next Generation Networks

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Abstract

The end-to-end Quality of Service (QoS) control is one of the key factors to the success of next generation networks. Therefore, this paper presents a session-aware QoS mapping and adaptation mechanism that maps the session QoS requirements into the most suitable network service class across heterogeneous mobile networks as well as it adapts the session to the current network conditions. The proposed scheme allows mobile operators to keep network internals sufficiently opaque and to reduce operational costs by mapping and/or adapting sessions to groups of heterogeneous mobile users. Concurrently, the proposed scheme assures acceptable quality levels to on-going sessions, independently of the movement of users. In addition, an experimental evaluation in a QoS mobile multicast environment is presented.

1. Introduction

Next generation networks will support diverse types of group communication services over heterogeneous wireless environments. The heterogeneity may go from access and transport technologies, to mobile users with different devices and capacities [1]. Furthermore, in order to attract and keep customers, mobile operators are expanding their portfolio with the inclusion of services with different QoS requirements and destined to multiple mobile users.

Examples of the above services are mobile IPTV, file distribution and push media. In each of these services, a communication session can be composed by a set of flows, which we call session-flows, with well-defined priorities and rates (this generic definition accommodates common encoders, such as H.264, MPEG-2 and MPEG-4). Since each of these sessions is to be used by several users at the same time, we call them multi-user sessions. From the transport point of view, multicast is the most suitable technology for multi-user sessions, since it allows several users to get the needed packets while avoiding packet duplication and so saving network resources.

The transport of multi-user sessions raises several problems. This is mainly due to the end-to-end QoS guarantees required by the content to be disseminated and because networks have different underlying QoS models (e.g. IntServ, DiffServ and UMTS), links with different capacities [2], and different transport technologies (e.g. IP unicast or multicast).

To allow the distribution of multi-user sessions throughout heterogeneous networks the mapping of sessions-flows quality level requirements into the most suitable network service class seems to be mandatory. Moreover, the QoS mapping scheme should be independent of the QoS model and transport technology supported by each network and between them. Furthermore, in order to increase the level of user satisfaction, it is required to keep the on-going multi-user sessions with acceptable quality level, independently of the users' movement. However, when the QoS mapping control can not ensure the QoS committed for each session-flow, for instance due to the attachment of users to a congested access network, a QoS adaptation mechanism is required to adapt the session-flows to the network conditions. The adaptation mechanism aims to decrease the level of QoS degradation in the session by dropping or adding low priority session-flows, requesting the mapping of some session-flows to a different network class, or by requesting the adjustment of the network resources allocated to some network classes.

This paper aims firstly to analyze the requirements to perform multi-user session mapping and adaptation over heterogeneous mobile networks. In this study, heterogeneity means network capability and not network transport technologies. Secondly, we present our proposal for QoS mapping and adaptation, called *Session-aware QoS Mapping and Adaptation mechanism* (SOMA), together with an illustration of its capabilities based on an experimental evaluation.

The rest of this paper is organized as follows. Section 2 presents the related work. The SOMA proposal is described in Section 3. Section 4 presents an experimental evaluation. The conclusions and future work are presented in Section 5.

2. Related Work

The problem of QoS mapping has been addressed in several proposals. However, they aim to perform QoS mapping for single-user sessions, and use a centralized control scheme that requires the installation of proprietary modules in the end-system [3]. Ruy *et al* [4] propose a centralized QoS mapping approach to map session requirements into classes of service between different QoS models. However, it is focused on the QoS metrics used for QoS mapping and does not assess QoS mapping in heterogeneous networks. Mammeri [5] proposes a QoS mapping scheme that provides end-to-end QoS guarantees for unicast sessions across IntServ and DiffServ models, which is however dependent of the underlying QoS model.

Existing solutions of session adaptation require the implementation of proprietary modules on end-hosts to control the session quality level, by joining or leaving low priority session-flows [6] or need devices in specific places of the network to adapt the content coding to the available network bandwidth [7].

From the related work analysis it is evident that most QoS mapping approaches only support single-user sessions and require the installation of modules in end-systems. Moreover most of them were developed for specific QoS models. In what concerns QoS adaptation, the analyzed mechanisms present the drawback of requiring the installation of modules in end-systems or the installation of devices to change the content coding within the network.

To overcome the identified limitations we propose a Session-aware QoS Mapping and Adaptation mechanism (SOMA), which is part of the *QoS for Multi-user Mobile Multimedia* (Q3M) project [8]. SOMA aims to provide QoS mapping and adaptation to multi-user session over networks with different QoS models, without requiring changes to mobile devices. SOMA aims to decrease the complexity level of adaptation mechanisms by avoiding complex and time consuming application level re-coding.

3. Session-aware QoS Mapping and Adaptation

SOMA assumes that the sender of each session defines its QoS requirements and the priority of each session-flow. Each receiver gets the session information from the sender by any off-line or on-line means, and sends it to an agent in the network to which the receiver is connected at the time of session setup. Based on the information provided by the receiver, the network agent defines a *session object* composed by QoS performance parameters (e.g. bit rate, bandwidth guarantee, tolerance to loss, and delay jitter) and traffic metrics (e.g. packet size). The values of the session object parameters can be quantitative (e.g. ms or kb/s) or qualitative (e.g. low, medium or high). Beside the information collected in the session object, and exchanged between SOMA agents, the latter gets from operators information (quantitative or qualitative) about network classes, including the available bandwidth in a network or between networks.

SOMA agents can be implemented in a centralized or decentralized manner as illustrated in Figure 1. When SOMA is used in a centralized manner, it controls enforcement points in edge devices and interacts with a centralized network resource controller mechanism. When SOMA is used in a decentralized manner, SOMA agents are implemented directly in edge devices, interacting with an intra-network resource allocation scheme. The association of the centralized and decentralized approaches to different QoS models has only an illustrative meaning.

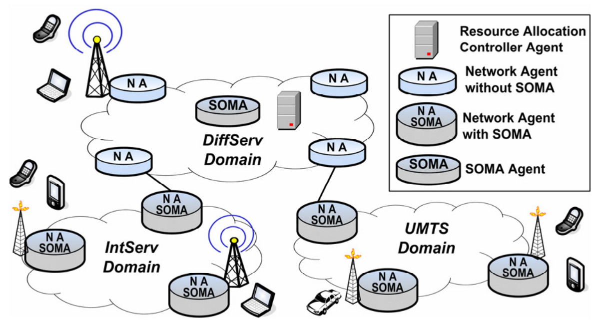

Figure 1 – Location of SOMA agents

SOMA mechanisms operate in a complementary manner. On the one hand, the mapping mechanism takes as input the session object and the information about the available network classes and maps the different session-flows to the appropriated network classes, based on three methods: perfect match, sub-perfect match and hybrid match. On the other hand, the adaptation mechanism receives the session object and the current network conditions, and performs the session adaptation when a perfect mapping is not possible. The adaptation mechanism encompasses the following three methods: dropping or adding session-flows, requesting a different mapping method to be performed, or requesting the allocation of different resources to certain classes.

The process to decide which mapping method to use can have a static or dynamic configuration. For example, it can be configured by the service provider according to its business model or on-demand by an external protocol or another SOMA agent, where:

- Perfect Match: Supports the full QoS requirements and bandwidth committed for all session-flows. When the suitable network class has not enough available bandwidth to assure, at least, the minimal packet loss rate of the session, the QoS adaptation should be triggered.
- Sub-perfect Match: Maps all session-flows to a network class that supports QoS parameters different from the ones described in the session object (e.g. it can be used in periods of congestion of a network class, when a perfect match is not possible and when keeping the session full rate is of major importance).
- Hybrid Match: Assures the allocation of at least the session-flows with high priority to the best network class. The remainder session-flows are mapped to a less suitable class.

While the perfect match is assumed to be the preferential method, it can trigger the adaptation mechanism if unsuccessful. The other two methods are seen as alternatives that can be triggered by the adaptation mechanism to selectively map low priority session-flows, or all session-flows to another class.

The QoS adaptation mechanism can reduce or increase the quality level of a session, by dropping or joining session-flows while taking their priority into account. During adaptation, a SOMA agent sends control information to upstream and/or downstream agents informing them that some session-flows must be released or added, improving the efficiency in the usage of network resources. Alternative, before changing the number of session-flows of a session, the adaptation mechanism can request to the mapping mechanism to try a different method, or can request the resource controller to allocate more resources to the selected network class.

The order by which these adaptation methods are used depends upon SOMA configuration, which can be different in each network. In its operations, SOMA uses open interfaces, allowing an easy deployment and its applicability to heterogeneous networks as follows: The Session/Application interface allows session or application protocols to send the session object and to configure the mapping and adaptation process. Furthermore, the Resource Allocation interface is used to exchange information about the network resources. Finally, the Access Control interface can give information (e.g. to mobility controllers) about the current quality level of sessions.

Figure 2 shows an example of the SOMA scheme to perform session mapping and/or adaptation between agents C and B and between agents C and E. This scenario has three domains with different QoS models, where one source is publishing one multicast session with three flows to be sent to two receivers.

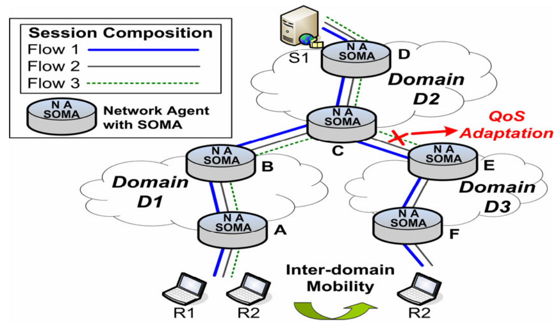

Figure 2 – Example of SOMA operation

In this example, a session S1 is being transported in multicast trees that have a branch in the edge router C. When R1 joins S1 in the edge router A, the SOMA agent in A is informed about the session object of S1. Since the session S1 is not present in A, the SOMA agent in A uses a signaling protocol to discover the nearest branch point in the direction to S1. Upon reaching the edge router C, the local SOMA agent requests information about the available network classes in the inter-domain link to a *Resource Allocation Controller* (RAC). Based on the response, SOMA mapping mechanism compares the session object with the capability of each network class, in order to perform a perfect match. After a successful match SOMA informs the RAC about the selected class. The QoS mapping process is then performed by all SOMA agents along the session path from C to A.

An example of QoS adaptation to reduce the number of flows of S1 is performed between agents C and E due to the movement of R2 to domain D3. Upon trying to select the most suitable class based on a Perfect Match method, the QoS adaptation is triggered by the QoS mapping mechanism because the selected class has not enough bandwidth to accommodate the less priority flow of S1 (flow 3). Since the adaptation mechanism is configured to try immediately the adjustment of the number of flows, flow 3 is removed from S1 in the outgoing interface of C to E. As a consequence SOMA keeps flow 3 state as 'sleeping' using that state to increase the number of flows of S1 when network resources become available again. A message is not sent to upstream SOMA agents in the direction of S1 (to release network resources associated with flow 3), because agent C has another branch of the same session that uses flow 3.

4. Experimental Evaluation

SOMA is implemented in a test-bed composed of Linux nodes that reproduce the scenario illustrated in Figure 2. The test-bed includes three DiffServ networks, with PIM-SSM/MLDv2 as the multicast control protocol. The source generates the session S1 by allocating one SSM channel to each flow. In addition, the Linux *Traffic Control* (TC) is used to provide *Assured Forwarding* (AF) DiffServ classes, the *mrd6* tool [10] represents the PIM-SSM and MLDv2 protocols, and the *mad-flute* tool [11] joins the multicast group and sends and receives the multicast data. The mobility is assured by the multicast protocol, using the remote subscription technique (i.e. the node joins all session-flows in each new access router). In terms of QoS, the percentage of packet loss of each flow must not exceed 5% and each flow is sent with a rate of 450Kb/s. SOMA was statically configured to use the perfect match mapping method and to adapt the session by dropping and adding flows. Figure 3 shows the throughput in R2, including its movement to domain D3 and returns to D1 (procedure not presented in Figure 2). In the first handover, the flow 3 is dropped and it is added after returning to D1 since the network resources become available again.

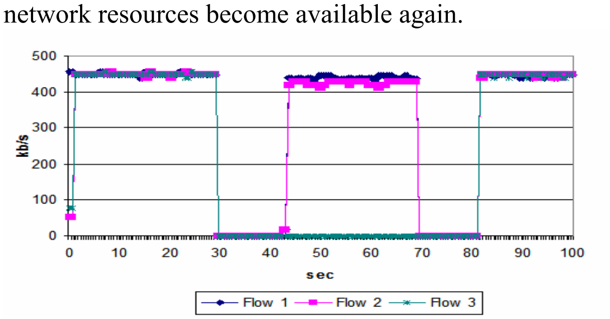

Figure 3 - Throughput in R2

The results reveal that SOMA succeed to map and adapt sessions according to the session priority, which can reduce the impact on the session quality level, since only the less important flows are affected by congestion. It also assures an acceptable quality level in the on-going session S1, independently of the movement of R2, since the session is not blocked, but adapted.

5. Conclusion and future work

We propose a Session-aware QoS Mapping and Adaptation mechanism (SOMA), which aims to provide QoS mapping and adaptation to multi-user session over networks with different QoS models, without requiring changes to mobile devices. Moreover SOMA aims to decrease the complexity level of adaptation mechanisms by avoiding complex and time consuming application level re-coding. The initial experimental evaluation shows that SOMA is a feasible approach to improve the way DiffServ classes are used to assure an acceptable quality level to on-going sessions, while reducing call blocking. Future plans include simulations with networks with different QoS models and link capacities. We also plan to extend SOMA to support heterogeneity of the used transport technologies.

6. References

[1] M. Carugi, B. Hirschman and A. Narita, "Introduction to the ITU-T NGN Focus Group Release 1: Target, Environment, Services and Capabilities", *IEEE Commun. Magazine*, vol. 43, issue: 10, October 2005, pp. 42-48.

[2] K. Knightson, N. Morita and T. Towle "NGN Architecture: Generic Principles, Functional Architecture, and Implementation", *IEEE Commun. Magazine*, vol. 43, issue: 10, October 2005, pp. 49-56.

[3] M. El-Gendy *et al*, "Paving the first mile for QoS-dependent applications and appliances", *IWQOS 2004, IEEE International Workshop on*, June 2004, pp. 245 – 254.

[4] M. Ruy *et al,* "QoS class mapping over heterogeneous networks using Application Service Map", *IEEE International Conference on Networking, International Conf. on Systems and International Conf. on Mobile Commun. and Learning Technologies*, April 2006, pp. 23-29.

[5] Z. Mammeri, "Approach for End-to-End QoS Mapping and Handling", *Wireless and Optical Commun. Networks. IFIP International Conference on*, March 2005, pp 265-269.

[6] T. Shanableh and M. Ghanabari, "Multilayer Transcoding with Format Portability for Multicasting of Single-Layered Video", *IEEE Transact. Multimedia*, vol. 7, February 2005.

[7] H. Chiu and K. Yeung, "Fast-response Receiver-driven Layered Multicast with Multiple Servers", *Commun, 2005 Asia-Pacific Conference on*, October 2005 pp. 259-263.

[8] E. Cerqueira *et al*, "A Unifying Architecture for Publish-Subscribe Services in the Next Generation IP Networks", to be published in *Procedures of IEEE 49 Globecom – MMComm Symposium*, November 2006.

[9] mrd6 (IPv6 multicast router), *http://artemis.av.it.pt/mrd6.*

[10] MAD-FLUTE project, *http://atm.tut.fi/mad*.