QoS Mapping and Adaptation Control for Multi-user Sessions over Heterogeneous Wireless Networks

Eduardo Cerqueira, Luis Veloso, Marília
Curado and Edmundo Monteiro
University of Coimbra, 3030029, Coimbra, Portugal
{ecoelho, lmveloso, marilia and edmundo}
@dei.uc.pt

Paulo Mendes
DoCoMo Euro-Labs
Landersbergerstr 312
80687, Munich, Germany
mendes@docomolab-euro.com

ABSTRACT

The *Quality of Service* (QoS) support for multimedia multi-user sessions is essential to the success of fourth generation mobile networks. However, it requires the QoS control for those sessions independently of the movement of users, QoS model, and link capacity supported by wired and wireless networks in the end-to-end session path. This paper presents the *Multi-user Session Control* (MUSC) mechanism to provide QoS mapping and QoS adaptation of multi-user sessions over heterogeneous and mobile networks. The coordination of the QoS mapping and QoS adaptation controllers allows the adaptation of the session to the current network conditions and the dynamic selection of the most suitable network service class to map the session. The MUSC control is based on the session requirements, existing services class and their available bandwidth. Performance evaluation shows the impact of the MUSC proposal by analysing its convergence time, as well as the one-way delay and throughput of multi-user sessions in a QoS-aware mobile scenario.

Keywords

QoS Mapping, QoS Adaptation, Multi-user sessions, Wireless.

1. INTRODUCTION

The *Quality of Service* (QoS) control is an important research topic in fixed and mobile networks, due to the heterogeneous capacity of networks, the dynamic behavior of wired and wireless resources, and the emergent market of real-time packet-based communications. Examples of these communication sessions are IPTV, video streaming and other multimedia-alike services. Since the content is simultaneously destined to multiple users, this type of sessions are called multi-user sessions.

Based on well-know codecs, such as MPEG4, multi-user sessions can also be scalable. Each scalable session can be composed by a set of flows, with well-defined priorities, rates and QoS requirements. The importance of each flow must be used to adapt the overall quality of the session to the capability of different networks service classes. This scheme allows the network to be independent from the encoders, which does not happen with transcoding approaches [1]. Figure 1 illustrates an example of an IPTV multimedia session, where a published multi-user session is subscribed by different mobile devices and distributed according to importance of each flow (from higher to lower).

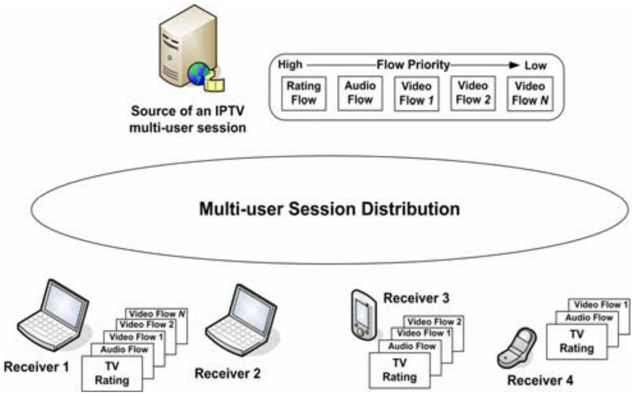

Figure 1. Example of multi-user session

The multi-user session distribution over heterogeneous mobile networks must be performed independently of the QoS model supported by the networks along the session path. For instance, *Differentiated Service* (DiffServ) or *Integrated Service* (IntServ) can be implemented to provide QoS assurance for flows of sessions in wired links, while IEEE 802.16 and IEEE 802.11e can be used in wireless links.

Network services supported by class-based QoS models (e.g., DiffServ, 802.16 and 802.11e) offer different forwarding behaviors to packets. Hence, each QoS class is defined based on a set of performance metrics such as, bandwidth guarantee, tolerance to loss, delay and jitter. In each network along the end-to-end heterogeneous session path, flows of multi-user sessions with similar QoS requirements must be mapped into the appropriated service classes. However, static approaches of QoS mapping between session requirements and network service classes or even guidelines for IP QoS mapping [2] alone are not sufficient to assure the quality level of sessions. This is mainly due to the emergence of sessions with new QoS requirements and QoS models with different configurations and class of services. Moreover, the service classes can be configured by different manners (using different performance metrics) in order to satisfy the business scheme of each operator.

In addition, due to the existence of links with distinct capacities and the dynamic bandwidth behavior of the network resources allocated for service classes, QoS mapping operations must be accomplished together with QoS adaptation support. The latter avoids multi-user

MOBIMEDIA 2007, August 27-29, Nafpaktos, Greece

DOI 10.4108/ICST.MOBIMEDIA2007.1556

session blocking and keeps those sessions with acceptable quality level, independently of the movement of users or even re-routing events caused by a link or network agent failure. For instance, in a congestion period, a QoS adaptation mechanism must be used to adapt the session to the current network conditions, by requesting the re-mapping of the session to a different class or controlling the quality level of the session by dropping/adding low priority flows.

Summing up, the end-to-end control of QoS for multi-user sessions must be done independently of the QoS models, the capability of the links and the mobility of users. Moreover, this control must be provided for unicast or multicast sessions, in which the QoS characteristics and current network conditions of the path from the sender to receivers must be taken into account. Furthermore, in mobility situations, the QoS support for ongoing multi-user sessions must be accomplished independently of the used mobility scheme, such as the bi-directional tunneling based on the *Mobile IP* (MIP) [3], the approaches based on the *Session Initiation Protocol* (SIP) [4] or the *Multicast Remote-Subscription* [5] approaches.

Our previous work [6] describes the benefits of combining QoS mapping and adaptation mechanisms in the session quality level. It also presents the impact of that proposal in a QoS-aware multicast test-bed, by measuring only the throughput in a receiver when the system is configured to adapt sessions by dropping and adding low priority flows of sessions. This paper extends our previous work by introducing the *Multi-user Session Control* (MUSC) solution to control the quality level of multi-user sessions in heterogeneous and wireless networks. It also presents a signaling protocol to coordinate QoS mapping and adaptation mechanisms along the session path. Additionally, performance evaluation of the MUSC scheme in a QoS mobile environment was carried out. Simulations show the latency of our proposal in handover times and the impact on the expectation of receivers by verifying throughput and one-way-delay of sessions when several QoS mapping and adaptation methods are used to assure acceptable quality levels to ongoing sessions.

The remainder of this paper is structured as follows. Section 2 presents the related work. The MUSC QoS control proposal is described in Section 3. Next, examples of MUSC functionality are depicted in Section 4. Performance evaluations are presented in Section 5. Conclusions and future work are shown in Section 6.

2. RELATED WORK

The static mapping of unicast sessions across IntServ and DiffServ QoS models is addressed by existing approaches [7]. However, they are dependent of the underlying QoS model. Another static solution is focused on the mapping between *Universal Mobile Telecommunications System* (UMTS) QoS classes into IP QoS classes, which follows the guideline provided by the ITU-T Recommendation Y.1541 [8]. In addition, several guideline-based QoS mapping solutions only control the mapping of sessions from the DiffServ or IntServ models to the 802.16 QoS model [9]. Furthermore, other solutions require the installation of proprietary modules on the end-hosts [10] or the use of a centralized approach [11] to perform the session QoS mapping among networks with different QoS models, which reduce the system flexibility and scalability. Moreover, these QoS mapping proposals assume that all neighboring networks configure their classes with the same QoS performance metrics.

QoS adaptation control mechanisms are used to adjust the session quality level to the current network conditions. However, existing receiver-based solutions require the implementation of proprietary modules on the end-hosts to join or leave flows of multicast sessions based on notification about the network conditions [12]. On the other hand, transcoder-based proposals need network devices to adapt the content coding (re-coding) to the available bandwidth [13], making the network deployment dependent from multimedia encoders. In addition to the previous receiver and transcoder-based approaches, sender-based scheme performs poorly in a heterogeneous multi-user environment [14], because a single transmission rate can not be used to satisfy the requirements of heterogeneous receivers and networks.

The analysis of related work has shown that most QoS mapping proposals use a static guideline scheme to map the sessions without taking into account the current bandwidth of the service classes. In addition, existing mapping schemes were developed to be used in networks with specific QoS models or need the implementation of proprietary modules in mobile devices. In what concerns QoS adaptation, the analyzed approaches present the drawback of requiring changes on the end-hosts or the installation of devices to modify the content coding within the network. To overcome the identified limitations, it is proposed the MUSC QoS control solution, which is being developed in the *QoS for Multi-user Mobile Multimedia* (Q3M) project [15].

3. MUSC QoS CONTROL

MUSC provides a QoS control solution for multi-user sessions over heterogeneous mobile networks. MUSC uses a signaling protocol, called MUSC-P, to coordinate QoS mapping and adaptation mechanisms along the end-to-end session path. In addition, an interface with resource allocation controllers allows MUSC to select the suitable service class to which a multi-user session must be mapped to among networks with different service classes, network resources and/or QoS models (e.g., by taking *Service Level Specifications* (SLS) into account). The proposed solution does not require changes on the mobile devices, allows operators to keep network internals sufficient opaque and assures acceptable quality levels to sessions even during handover.

The MUSC control provides a flexible approach to allow QoS support for ongoing multi-user sessions. For instance, by interacting with seamless handover controllers, such as *Seamless Mobility of Users for Media Distribution Services* (SEMUD) [16], MUSC controls the setup of QoS-aware sessions over heterogeneous networks in advance. Another example is the communication between MUSC and hard handover schemes, such as MIP, which allows MUSC to control the quality level of the multi-user session also in the path from the home agent to the mobile device attached to a new access-network.

This approach assumes that each multi-user session is described in a *Session Object* (SOBJ) that is identified by a unique session identifier. A multi-user session can be composed by a set of flows, whose QoS parameters are described based on the QSPEC object [17]. It is also assumed that mobile receivers get from the source, by any off-line or on-line scheme (e.g., via HTTP or any session advertisement mechanism) information regarding the available multi-user sessions, encompassing the SOBJ and QSPEC objects.

Each QSPEC object includes the priority of each flow, performance parameters (e.g., bit rate, tolerance to loss, delay and jitter) and traffic metrics (e.g., packet size and burstiness). These values can be quantitative (e.g., ms or Mb/s) or qualitative (e.g., low, medium or high). Besides the QoS information collected in the SOBJ, and exchanged between MUSC agents, the MUSC collects from operators information regarding the network classes (quantitative or qualitative), including the available bandwidth inside or between networks. This information can be collected by static configuration or on-demand via network resource controllers.

The MUSC functionalities are implemented by MUSC agents. These agents can be configured in a centralized or decentralized manner. Centralized agents control enforcement points in edge network devices. Decentralized MUSC agents are collocated directly in edge network elements. Furthermore, the use of MUSC interfaces allows an interaction with resource allocation and handover controllers in heterogeneous networks.

As an overview, after receiving the session announcement, the receiver sends the SOBJ, including the QSPEC object, to a network agent (e.g., SIP Proxy) by using SIP and *Session Description Protocol* (SDP) [18]. This agent informs the SOBJ to the MUSC agent located in the access-router to which the receiver is connected. Alternatively, the SOBJ object can be received by MUSC via handover controller agents such as *Context Transfers Protocol* (CTXP) [19] or home agents supported by MIP-alike solutions. This way, upon receiving the SOBJ, the MUSC agent uses MUSC-P to coordinate with other edge agents the quality level of the session on the path from the sender (or home agent). In what concerns the mapping and adaptation mechanisms, they operate in a complementary manner. The mapping mechanism takes as input the QSPEC object of each flow and the information about the available network classes. Afterwards, it maps each flow into the suitable network classes, based on three methods: *perfect*, *sub-perfect* and *hybrid* matches.

The adaptation mechanism receives the QSPEC and the current network conditions, and performs the session adaptation when a perfect mapping is not possible. The session quality level adaptation is based on the following methods: dropping or adding low priorities flows of a session, requesting the use of a different QoS mapping method or the request of extra resources to certain network classes. The process to decide which QoS mapping and adaptation methods to use can be either static or dynamic configuration (e.g., MUSC can be configured by mobile providers according to their business models or on-demand via MUSC-P signaling messages).

3.1 Mapping Control

The *Perfect Match* is assumed to be the preferential method. It supports the full QoS requirements and bandwidth committed for all flows of a session. When the preferred class has not enough available bandwidth to assure the minimum packet loss rate for the session, the QoS adaptation is triggered. The *Sub-perfect Match* maps all flows of a session to a service class that supports QoS parameters different from the ones described in the QSPEC. This method aims to avoid session blocking and re-ordering of packets. It can be used in periods of congestion of the most suitable network class, while keeping the session full rate. The *Hybrid Match* assures the allocation of, at least, the high priority flows of a session to the preferred class. The remainder flows are mapped to a less significant class. It can be used when the packet re-ordering is not crucial. For instance, it can be suitable for scheduled video and audio, where it is more important to ensure an intelligible audio flow than a perfect video.

3.2 Adaptation Control

The quality level of sessions can be adapted by *dropping or joining* flows while taking their priority into account. When the resources in the preferred class can not assure the QoS committed for a low priority flow, this flow is removed from the outgoing interface and put in sleeping state by MUSC. Sleeping flows are awaked by MUSC when the network capability becomes available again. Both operations are done by interacting with the resource allocation controller. On the other hand, the *Re-mapping* adaptation method requests, to the mapping mechanism, the mapping of the session to another class. Alternatively, the *Over-reservation* method aims to keep the QoS required for the session by requesting, to the resource controller, the allocation of more resources to the preferred network class. The latter triggers resource controllers to re-distribute available bandwidth.

3.3 Signaling Protocol

MUSC-P is used to exchange information between MUSC agents using a soft-state approach to maintain per-session and per-flow state (including the QSPEC of each flow, which is necessary in re-routing or mobile events). MUSC-P is being specified based on the *Next Steps in Signaling* (NSIS) framework [20], in which it can be included as an extra *NSIS Signaling Layer Protocol* (NSLP). MUSC-P operates in a receiver-driven approach, since it is triggered at access-agent (agent located in wired or wireless access-router). It is source-initiated since MUSC starts the QoS configuration of its agents at the agent nearest to the source, or at the first agent in the path towards the source that contains the requested session. When MUSC is triggered by MIP-alike approaches, only source-initiated functions are done to control the quality level of sessions from the home agent to the receivers.

4. EXAMPLE OF MUSC FUNCTIONALITY

This section shows examples of MUSC functionality to accomplish QoS mapping and adaptation for an ongoing multi-user session due to an inter-network handover. The first example describes only MUSC mapping operations, while the second scenario combines MUSC mapping and adaptation procedures to control the session quality level due to congestion in an inter-network service class. The mobility and the service classes are controlled by a MIP-based bi-directional tunneling approach and resource allocation controller respectively. The MUSC agents are collocated with the network resource controller at the edges of the networks. In this example the *Home Agent* (HA) and *Foreign Agent* (FA) are placed in the unique ingress point of access networks. Since handover controllers are not the focus of this paper, it is assumed the use of MIPv4. If MIPv6 would be supported, the FA would not be used.

4.1 QoS Mapping

The scenario of Figure 2 has three networks with different QoS models, where one multi-user session (*S1*) with three flows is multicasted for two mobile receivers (*R1* and *R2*). Thus, when *R2* moves to the access-agent *N.3.1*, it receives a router advertisement message and acquires a care-of-address on the foreign network. After that, *R2* registers its new address with its

HA thought exchange of registration messages. Upon finishing the registration process, the HA placed in *N1* notifies the MUSC agent *N.1.3* to control the session quality level on the path towards *N.3.1* (which includes QoS-aware tunnels between the HA and FA). Based on the session identifier associated with *R2* and supplied by the HA, MUSC in agent *N.1.3* consults its state and retrieves the correspondent QSPEC object. After that, MUSC triggers the resource allocation controller to query information about the available network services and their QoS characteristics of the inter-network link between the agents *N.1.3* and *N.2.2*.

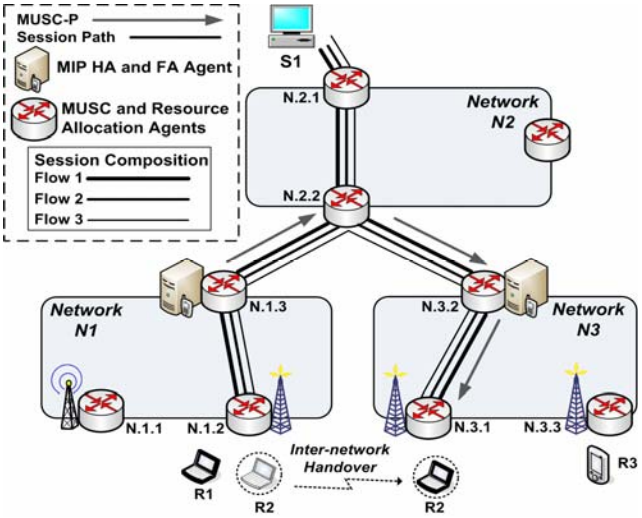

Figure 2. Example of MUSC mapping control

Based on the response and QoS parameters collected in the QSPEC object, MUSC mapping mechanism compares, one by one, the QSPEC object parameters of each flow with the capability of each class. After a successful match, it selects the most suitable service class for each flow. According to the priority of each flow, the resource allocation controller is triggered to configure the required bandwidth in the preferred class in the inter-network path from *N.1.3* to *N.2.2*. When the resource controller verifies that there are available resources to be used for all flows of *S1* in the preferred service class (i.e., admission control functions), MUSC is triggered to control the session quality level on the remainder path. Hence, a MUSC-P message is sent to the agent *N.2.2*, which verifies the QSPEC object of each flow and interacts with the resource allocation controller of its network in the same way as explained before. This procedure is done by all MUSC agents on the new path towards *R2*. In agent *N.3.1*, MUSC selects the preferred class for the session based on the wireless classes (e.g., 802.11e or 802.16) and resources.

4.2 Combination of Mapping and Adaptation

Figure 3 presents an example of MUSC QoS mapping and QoS adaptation operations to control the quality level of the ongoing session on the new path caused by congestions in an inter-network service class. To simplify the explanation, this example uses the same mobility scenario as explained in Section 4.1.

Upon receiving a notification from the HA in *N.1.3* agent, MUSC starts its QoS mapping control operations. Since there are available network resources for the flows of the session between the *N.1.3* and *N.2.2*, a QoS-aware path is configured and MUSC is triggered in agent *N.2.2* to continue the QoS control on the downstream path. Hence, MUSC requests information of the available network classes towards *R2*. Based on the response and QSPEC object, MUSC selects the appropriate network service and triggers the resource allocation controller to configure the required bandwidth in the selected class (from *N.2.2* to *N.3.2*).

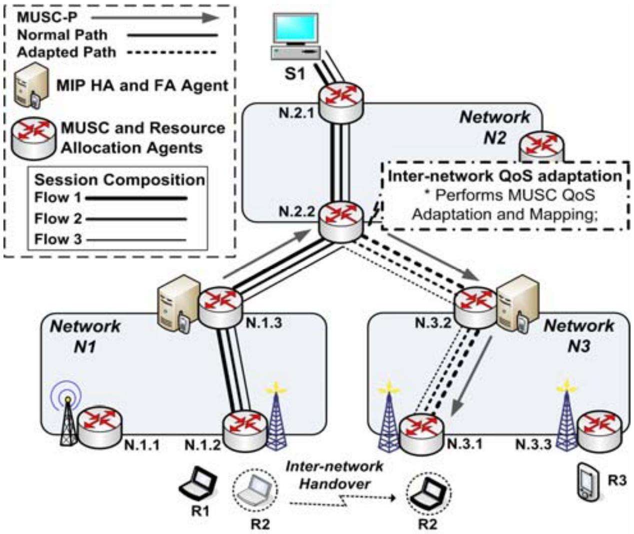

Figure 3. Example of MUSC re-mapping adaptation control

After admission control procedures, MUSC is notified because the preferred service class has not enough resources to accommodate the less priority flow of the session. Since MUSC supports flexible methods to control the session quality level, it can be configured by operators with different profiles. For example, based on the local configuration, MUSC uses a combination of the *Re-mapping* adaptation and *Hybrid Match* mapping methods to decrease session blocking probability. Thus, MUSC requests the allocation of the highest priority flows into the preferred network class while the remainder flows are mapped to a less important class. After all QoS control operations performed by MUSC and the resource allocation controller in the agent *N.2.2*, MUSC-P is triggered to signal the remainder downstream agents. All agents along the signaling adapted path will accomplish the same QoS control operations as explained before as a way to resume the creation of a QoS-aware path for the ongoing session.

Alternatively, Figure 4 depicts a dynamic session adaptation control started in the agent *N.2.2*, where MUSC is configured to adapt the session quality level by *dropping* low priority flows. Thus, upon selecting the preferred service class between *N2* and *N3*, MUSC is triggered by the resource allocation controller to adapt the session. Since the adaptation mechanism is configured to adjust the number of flows, *Flow 3* is removed from *S1* and the remainder downstream agents are signaled to control quality level only for *Flow 1* and *Flow 2*. In addition, MUSC agent *N.2.2* keeps *Flow 3* state as sleeping using that state to increase the number of flows of *S1* when network resources in the preferred class become available again. For instance, when the bottlenecked inter-network class becomes available again, MUSC agent *N.2.2* puts the *Flow 3* in "awake state", where it triggers the resource controller to reserve resources for this flow and signals downstream agents to continue the QoS control for *Flow 3* towards the receiver.

In order to avoid the waste of network resources associated with *Flow 3*, a MUSC-P message is sent from the agent *N.2.2* to the agent *N.1.3*. This message informs MUSC to release its resources about *Flow 3*. Upon removing *Flow 3* state, MUSC notifies the resource controller and the HA to delete their state associated with *Flow 3* on the new path. The resources allocated for this flow in the end-to-end old path are not removed, because the agent *N.1.3* has another receiver for *S1* that uses *Flow 3*.

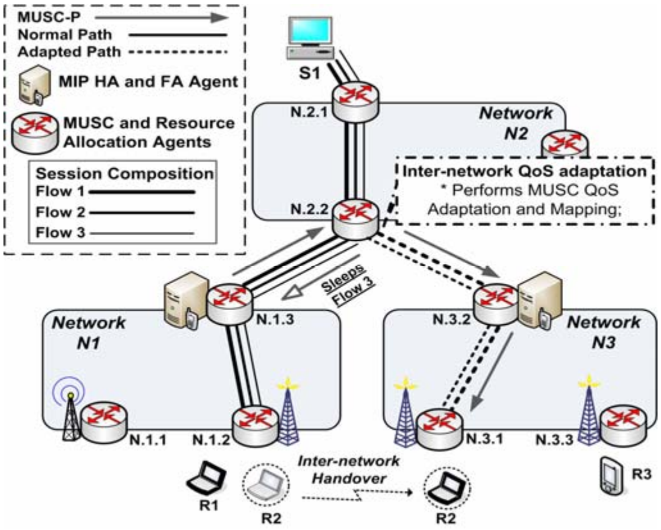

Figure 4. Example of MUSC drop/add adaptation control

5. PERFORMANCE EVALUATION

Performance evaluation of the MUSC proposal in a mobile environment was carried out by using the *Network Simulator 2* (NS2). The objectives of this MUSC evaluation are twofold: (*i*) analyze the MUSC latency to control the session quality level on new paths; (*ii*) analyze the impact on receivers' expectation by measuring throughput and one-way delay of sessions with and without inter-network QoS adaptation. First, MUSC is evaluated only with the QoS mapping mechanism. This way, the session is blocked if the full QoS requirements can not be assured in the preferred class (it is called *NO* adaptation profile, *N_ADP*). MUSC impact on receiver's expectation is also evaluated while using MUSC mapping and adaptation mechanisms configured with three profiles: Firstly, MUSC adapts sessions by dropping and adding flows (called *ADP_Drop*). Secondly, the profile is based on hybrid match, where flows with high priority are mapped to the preferred class and flows with low priorities are re-allocated to a less important class (called *ADP_Hyb*). Hence, the session is blocked only if the full rate of high priority flows can not be assured in the preferred service class. Finally, MUSC uses the QoS profile sub-perfect match to adapt the session, where it re-maps all flows to a less important class (called *ADP_Sub*). In the last profile, the session is blocked if the full rate of the session can not be assured in the misplaced class.

The topology was generated randomly by BRITE and is composed by three networks, following the same inter-network connectivity scenario illustrated in Figures 2-4 (*N1<->N2* and *N2<->N3*). DiffServ and 802.11e are configured as the QoS models. Each network has twelve interior routers and three edges (including two access-routers in the access-networks - *N1* and *N3*). The propagation delay is attributed by BRITE according to the distance of each device. The mobility is controlled by MIPv4 and receivers are connected to IEEE 802.11e wireless access-agent. Each edge MUSC agent is put together with a resource allocation controller, being the latter responsible to provide notification about available classes, admission control and service class configuration. In the ingress points, MUSC is also collocated with MIP HA and FA, where the former manages the mobility and triggers MUSC to control the session quality level on new paths, as exemplified in Section 4. The bandwidth capacity of intra and inter-network links is 100 Mb/s and 10 Mb/s respectively. The wireless links have a bandwidth of 11 Mb/s.

As suggested in [21], the assignment of the link bandwidth to each class is 20% for Premium (*Expedited Forwarding* (EF)-alike class), 20% for Gold (*Assured Forwarding* (AF)-alike class), 20% for Silver (AF-alike class) and the remaining 40% for Best-effort. The Premium class is configured with the best QoS parameters in terms of loss, delay and jitter tolerance, while Silver supports less suitable configuration. Furthermore, each session has one source and three flows with the same QoS requirements. Although MUSC can handle any number of flows, three flows allow a good trade-off between quality and bandwidth, and additional flows only provide marginal improvements. Additionally, each flow has different priorities and exponential rates, which are common in scalable codecs [22]. Each flow has a *Constant Bit Rate* (CBR) of 32 Kb/s, 64 Kb/s and 128 Kb/s, starting from the most important to the less important one respectively. It is assumed intolerance to loss as the major requirement and a loss limit of 2.5 % as the maximum degradation allowed in the QSPEC object. This limit is based on previous studies [23], where it is presented that in MPEG-2 with *Signal-to-Noise Ratio* scalability, 5% of losses in the most important flow introduces 100% of losses in all other flows. Furthermore, the one-way delay required for the sessions must be less than 100 ms as suitable for real-time sessions.

From the handover point of view, the home and foreign networks have ten and twenty receivers respectively, where each one subscribed one session following the Poisson distribution (five and ten receivers in each access-router in the home and foreign networks respectively). A Poisson distribution is also used to generate QSPEC objects for each session, which is used by the mapping and adaptation mechanisms. To simplify the experiments, each mobile receiver moves to an access-agent in the foreign network 25 s after its subscription and returns to its previous access-agent in the home network 65 s latter. The movement pattern follows a constant speed of 30 m/s. Since inter-network adaptation is the focus of this evaluation, the bandwidth required for all the sessions exceed in 12% the amount of resources allocated for all service classes in the inter-network link from the network *N2* to the network *N3*. A value higher than 12% of overload causes 100% of blocking for incoming sessions.

The results reveal that during handovers, MUSC introduces an average latency of 15.8 ms to configure its QoS mapping and adaptation mechanisms along new session paths. This value is an average of all handovers and represents 0.09 % of the delay consumed during the mobility process, which can be considered negligible. The use of MUSC contributes to the creation of QoS-aware sessions and does not introduce high latency in handovers.

Figure 5 depicts the average throughput measured by the moving receivers in the foreign network. In all situations, the session associated with *R10* is refused due to unavailability of resources in the network services. The *N_ADP* profile keeps the session full rate only for 40% of the receivers, while 60% of the sessions are blocked. Using the profile *ADP_Drop*, MUSC controls the session quality levels and keeps them with acceptable quality, because only the less importance flow of the session is affected in handovers. Thus, 90% of the receivers access the sessions in the foreign network. This is, *R1*, *R5*, *R8* and *R9*, get the session full rate, while *R2*, *R3*, *R4* and *R7* receive only *Flow 1* and *Flow 2*. When *ADP_Hyb* and *ADP_Sub* are used, the session full rate is assured by using resources available in other service classes. The *ADP_Hyb* profile keeps the session full rate for 60% of receivers, in which three sessions are re-mapped to other classes. The *ADP_Sub* adapts 20% of sessions to less important classes, but it assures the session full rate for *R1*, *R2*, *R3* and *R4*. The drawback of these last two profiles is the fact that adapted ongoing sessions consume network resources of other classes, which increase the call blocking of sessions best suited to those classes. Therefore, the session associated with *R7* is refused because other misplaced sessions are using resources allocated for its preferred class.

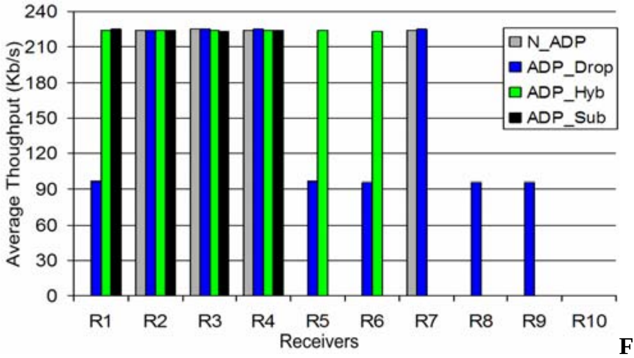

Figure 5. Average throughput in moving receivers in the foreign network

Figure 6 shows in detail the throughput measured in *R6* when the *ADP_Drop* and *ADP_Hyb* profiles are being used. The ongoing session of *R6* is blocked in the foreign network when the *ADP_Sub* and *N_ADP* profiles are configured.

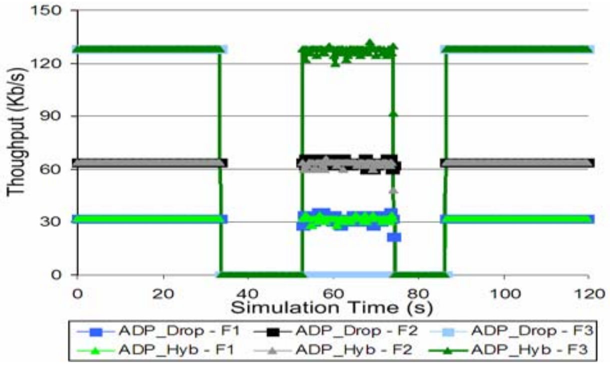

Figure 6. Throughput and latency in R6 when the ADP_Drop and ADP_Hyb are being used

In the home network, the session full rate is assured, since there are available resources to accommodate the flows in the preferred service class. The throughput is zero when *R6* is moving to the foreign network (33.2 s to 53 s) and during its return to the home network (74 s to 86.8 s). When *ADP_Drop* and *ADP_Hyb* are configured, ongoing sessions are not terminated due to inter-network congestions caused in the first handover, but adapted. The *ADP_Drop* adapts multi-user ongoing sessions according to the priority of each flow, which reduces the impact on the session quality level in the foreign network and keeps the full rate of *Flow 1* and *Flow 2*. In this case, *Flow 3* is put in sleeping state and it is awaked only after the return of *R6* to the home network. In comparison with the *ADP_Drop,* the *ADP_Hyb* improves the session quality level, because the full rate of each flow is assured by using the available resources of another service class to accommodate the *Flow 3*. Additionally, Figure 7 shows a detailed analysis of the throughput in *R1* when the system is configured with all MUSC QoS profiles. The results show that *ADP_Hyb* and *ADP_Sub* profiles assure the full rate of the session in the foreign network, while the *ADP_Drop* keeps the full rate for the most important flows. In all profiles, the session full QoS requirements are assured when the receiver is connected to its home network.

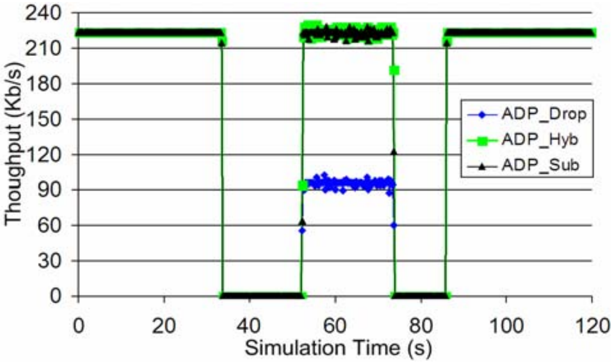

Figure 7. Throughput and latency in R1 with all profiles

As explained before, the full rate of ongoing sessions is assured by the *ADP_Hyb* and *ADP_Sub* profiles, while the one-way delay is degraded. The latter is an important QoS metric especially for real-time sessions and must be kept with an acceptable quality level. The one-way delay of the session of *R1* is presented in Figure 8.

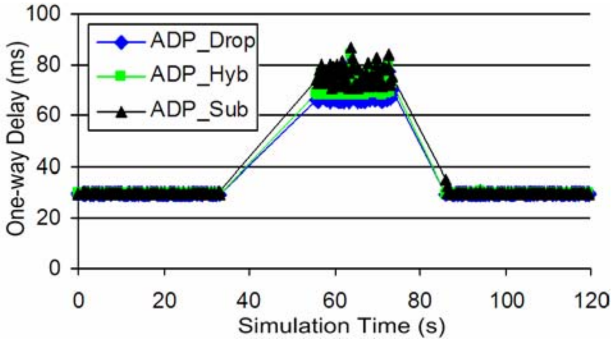

Figure 8. Delay and latency in R1 with all profiles

On average, the one-way delay in the home network where the session is mapped into the preferred class is of 29.7 ms. In the foreign network, the one-way delay is increased due to the use of MIP tunnels to encapsulate/decapsulate the packets of the session. In addition to the time consumed by the QoS-aware tunnels, the session adaptation to a service class that offers different delay tolerance also influences in the one-way delay. Thus, *R1* needs to wait on average 70 ms, 73 ms and 77 ms when the *ADP_Drop*, *ADP_Hyb* and *ADP_Sub* profiles are being used respectively. In the worst case, as occurs with the *ADP_Sub*, *R1* waits approximately 5 % and 10 % more to get the session compared with the *ADP_Hyb* and *ADP_Drop* methods respectively. However, this value remains acceptable for the ongoing session as required in the QSPEC object. If the maximum one-way delay in misplaced classes is not assured, the session is blocked.

6. CONCLUSION AND FUTURE WORK

This paper introduces the MUSC proposal, which provides QoS mapping and adaptation for multi-user sessions over heterogeneous mobile networks. MUSC controls the session quality level for fixed and mobile users independently of the QoS model, service classes and current network conditions on the path from the sender to the receivers. MUSC does not require changes on mobile devices and session coding, which decreases the complexity level of mapping and adaptation mechanisms and avoids the time required by application level re-coding. Even though MUSC was exemplified with MIP bi-directional tunnelling, it has interfaces, allowing operators to use any other mobility scheme of their choice, such as *Protocol Independent Multicast for Source Specific Multicast* (PIM-SSM) based remote subscription.

The performance evaluation reveals that MUSC introduces low latency in handover times to control the session quality level on new paths. This represents on average 0.09 % of the delay spent in all handovers. In terms of percentage of satisfied receivers, the *ADP_Drop* allowed the access of the sessions in the foreign network for 90% of receivers, while the *ADP_Hyb* and *ADP_Sub* allowed 60 % and 40 % of the receivers to access the session respectively. The average throughput measured by moving receivers in the foreign network when *ADP_Drop*, *ADP_Hyb* and *ADP_Sub* are being configured is of 153 Kb/s, 223 Kb/s and 224 Kb/s respectively. An acceptable degradation in the session rate is done by the *ADP_Drop* to avoid the call blocking, while the session full rate is assured by using resources allocated for other classes when the other profiles are used. The session one-way delay is increased in the foreign network due to the creation of MIP tunnels and it is also influenced by the QoS profile method used in the system, where the *ADP_Sub* is expected to introduce the highest one-way delay. Finally, MUSC simulation and prototyping with networks with large number of mobile receivers, different QoS models and link capacities will be done in future work. The behaviour of MUSC due to a re-routing event will also be done.

7. REFERENCES

[1] T. Shanableh and M. Ghanabari, “Multilayer Transcoding with Format Portability for Multicasting of Single-Layered Video”, *IEEE Transaction Multimedia*, v. 7, February 2005.

[2] J. Babiarz, K. Chan and F. Baker, “Configuration Guidelines for DiffServ Service Classes”, *RFC 4594*, August 2006.

[3] D. Johnson, C. Perkins and J. Arkko, “Mobility Support in IPv6”, *RFC 3775*, June 2004.

[4] J. Rosenberg *et al*, “SIP: Session Initiation Protocol”, *RFC 3261*, June 2002.

[5] Y. Min-hua *et al*, “The implementation of multicast in mobile IP”, *In Prof. of IEEE Wireless Communication and Networking*, New Orleans, USA, March 2003.

[6] E. Cerqueira *et al*, “QoS Mapping and Adaptation in Next Generation Networks”, *In Proc. of IEEE International Symposium on Applications and the Internet Workshop*, Hiroshima, Japan, January 2007.

[7] Z. Mammeri, “Approach for end-to-end QoS mapping and handling”, *In Proc. of IEEE/IFIP Wireless and Optical Communications Networks*, Dabai, UAE, March 2005.

[8] R. Ben Ali *et al*, “UMTS-to-IP QoS Mapping for Voice and Video Telephony Service”, *IEEE Network*, April 2005.

[9] J. Chen *et al*, “An integrated QoS control architecture for IEEE 802.16 broadband wireless access systems”, *In Proc. of IEEE Global Telecommunications Conference*, St. Louis, USA, November 2005.

[10] M. El-Gendy *et al*, “Paving the first mile for QoS-dependent applications and appliances”, *In Proc. of IEEE International Workshop on QoS*, Montreal, Canada, June 2004.

[11] M. Ruy *et al*, “QoS class mapping over heterogeneous networks using Application Service Map”, *In Proc.* of *IEEE International Conference on Networking, International Conference on Systems and International Conference on Mobile Communications and Learning Technologies*, Washington, USA, April 2006.

[12] Q. Zhang *et al*, “Sender-adaptive and receiver-driven layered multicast for scalable video over the Internet”, *IEEE Transaction on Circuits and Systems for Video Technology*, v. 15, April 2005.

[13] R. Hayder *et al*, “Scalable Video TranScaling for the Wireless Internet”, *EURASIP Journal on Applied Signal Processing*, n. 2, February 2004.

[14] P. Wu *et al* “On the Use of Sender Adaptation to Improve Stability and Fairness for Layered Video Multicast”, *In Prof. of International Workshop on Quality of Service in Multi-service IP Networks*, Milan, Italy, February 2003.

[15] E. Cerqueira *et al*, “A Unifying Architecture for Publish-Subscribe Services in the Next Generation IP Networks”, *In Proc. of IEEE Global Telecommunications Conference*, San Francisco, USA, November 2006.

[16] L. Veloso *et al*, "Seamless Mobility of Users for Media Distribution Services", *In Proc.* of *IEEE International Performance Computing and Communications Conference*, New Orleans, USA, April 2007.

[17] J. Ash *et al*, “QoS NSLP QSPEC Template”, *IETF Internet Draft (working in progress)*, February 2007.

[18] M. Handley, V. Jacobson and C. Perkins, “SDP: Session Description Protocol”, *RFC 4566*, July 2006.

[19] J. Loughney *et al*, “Context Transfer Protocol (CXTP)”, *RFC 4067*, July 2005.

[20] R. Hancook et al, “Next Step in Signaling (NSIS): Framework”, *RFC 4080*, June 2005.

[21] Z. Di and H. Mouftah, “Performance Evaluation of Per-Hop Forwarding Behaviours in the DiffServ Internet” *In Proc. of IEEE Symposium on Computers and Communications*, Antibes-Juan les Pins, France, July 2001.

[22] K. Rose and S. Regunathan, “Toward optimality in scalable predictive coding”, *IEEE Transaction on Image Processing*, vol. 7, July 2001.

[23] J. Kimura *et al*, “Perceived quality and bandwidth characterization of layered MPEG-2 video coding”, *In Proc. of SPIE International Symposium*, USA, September 1999.