On QoS Adaptation of Multimedia Communications Using IMS

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ABSTRACT

This paper presents a framework on providing adaptive multimedia services across heterogeneous wireless access networks using the IP Multimedia Subsystem (IMS) subsystem. The adaptation is performed at the MRF function when the user performs a vertical handoff so that the service is adapted to meet the wireless bandwidth constraints. This paper describes how this adaptation experience can be implemented over a hybrid 3G and WLAN network through the IMS. The performance analysis of the proposed framework demonstrates the level of adaptation as well as signaling overhead required to stress MRF in order to perform video adaptation.

Keywords

IMS, video streaming, seamless vertical handoff, multimedia provisioning.

1. INTRODUCTION

Multimedia services have moved from a collective and passive approach to more personal and active behavior, hence fueling the network evolution and the convergence of heterogeneous technologies. The abundance of heterogeneous terminals and networks that are able to support high quality audio-visual content requires efficient delivery mechanisms that incorporate unicast, multicast, broadcast and peer-to-peer networking. In the heart of this heterogeneous environment, securing the broadband delivery of multi-play services across different access technologies lays the IMS platform [1] [2].

IMS was first defined by the 3rd Generation Partnership Project (3GPP) in Release 5 as the core network architecture for the 3G wireless cellular system. Later releases have incorporated different access networks, as WLANs (R6), Fixed networks (R7), emphasizing its independence of the access technologies used. The IMS makes the realization of the concept of an All-IP based infrastructure for unified service provisioning possible, by separating the signaling and the media infrastructure. Thereby, the signaling infrastructure is mainly needed for establishing the communication sessions between the users and does not have to deal with media transport. Moreover, the distributed architecture nature separates subsystems providing end-to-end connectivity for the application.

In addition to that, multimedia provisioning for users that may roam across heterogeneous access networks requires the maintenance of session continuity and end-to-end QoS support. In fact, supporting seamless session continuity across heterogeneous networks is a challenging task, since each access network may exhibit different mobility, QoS and security requirements. Furthermore, multimedia applications such as VoIP, streaming video, IPTV, have stringent performance requirements in terms of end-to-end delay, packet loss and percieved QoS. Vertical handoffs (the users move across heterogeneous networks), stress the performance bounds to their limits by introducing overheads due to discovery, configuration and binding update procedures towards the new network point of network association. The effect is even more profound for video streaming services, where an excess delay or packet loss during handoff, will interrupt the continuity of the service and cause severe deterioration of the perceived video quality.

This paper aims to investigate the employment of the IMS platform (and more specifically the employment of MRF) during vertical handoffs between a 3G and a WLAN access network and its ability to achieve seamless video session continuity. This can be accomplished by adapting video rate to the constrained imposed by the new network. The performance analysis is based on a real networking environment, where a mobile user is hands-off across the 3G and the WLAN access networks. Since video streaming is very sensitive to packet loss, IMS is instructed by the end-user to

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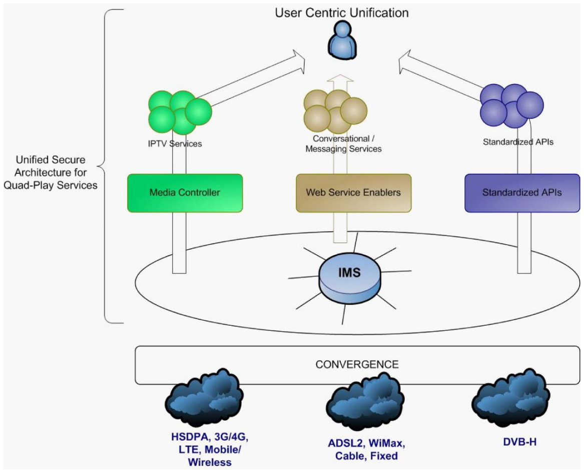

Figure 1: Vision of NGN based on IMS platform

perform video adaptation in accordance to current access network conditions. Video adaptation is a very common procedure in video communications when a network cannot support the application's demands for minimum available bandwidth. Video bit rate is reduced at the expense of increasing coding distortion. It is expected that this distortion will have less severe impact than packet loss the Quality of Experience (QoE) of the end-user. In this study, video adaptation is requested by the mobile user prior to a handoff and is performed by the Media Resource Function (MRF) server of the IMS platform.

The rest of the paper is organized as follows. Section 2 presents the IMS architecture as well as its modules and functionalities. Current video adaptation techniques are described in Section 3, while Section 4 analyzes the system model and performance evaluation of the proposed framework. Finally, Section 5 concludes the paper.

2. IMS OVERVIEW

The IP Multimedia Subsystem is the key enabler in the mobile world for providing rich multimedia services to the end-users and it is currently being standardized by 3GPP (IMS Release 7). Although originally designed for mobile networks, IMS has been considered as core component for NGN fixed networks, as shown in Fig. 1. This vision is supported by the standardisation bodies 3GPP, ETSI TISPAN and 3GPP2/LTE [2]. Towards this end a number of new capabilities have been considered for the IMS Release 7.

The 3GPP Release 7 architecture comprises of three planes:

1. Application Plane: It includes the following subsystems:
    - Application Servers (ASs) are located in either in the home network or in an external third-party network to which the home operator has a service agreement and provide value-added multimedia services on the top of IMS.
    - Home Subscriber Server (HSS) is the main database for all subscriber and service-related data, such as user identities, registration information, access parameters and self-triggering information.
    - Subscription Locator Function (SLF) is responsible for finding the appropriate HSS that holds the subscriber data for a given identity (if multiple HSS are deployed) on behalf of I-CSCF, S-CSCF and the AS.
2. Signaling Plane: It provides the call signaling informs the transport plane about the media path and generates the billing information. It consists of the following subsystems:
    - Proxy Call/Session Control Function P-CSCF acts as an outbound/inbound SIP proxy server that forwards session requests in the appropriate direction (towards IMS network or terminal). It establishes secure associations with the terminal, authenticates the user, verifies SIP requests and generates charging information towards a charging collection node.
    - Interrogating (I-CSCF) retrieves user location information, through HSS, and routes the SIP request to the appropriate destination, which typically is an S-CSCF server.
    - Serving CSCF (S-CSCF) is the central node of the signaling plane that acts as a SIP server as well as a SIP registrar. Particularly, it performs session control and maintains binding between user location and the user's SIP address of record (Public User ID). S-CSCF maintains a Diameter interface with HSS for authentication purpose.
    - Resource and Admission Control Subsystem: It comprises the following functionalities
        - RACS Functionalities include service based local policy control
        - Policy Decision Function (PDF): It takes a service level policy request from the application layer and translates it into QoS parameters.
        - Network Attachment Subsystem (NASS) functionalities provide the following: dynamic provision of IP addresses through DHCP, user authentication, authorization of network access, location management to support emergency services and CPE configuration.
    - Breakout Gateway Control Function (BGCF) is responsible for choosing where a breakout to the circuit-switched domain occurs.
    - Media Resource Function (MRF) provides a source of media in the home network. It is divided into the signaling plane node called the Media Resource Function Controller (MRFC) and the media plane node for media processing called the Media Resource Function Processor (MRFP).
    - Interconnect Border Control Function (BCF) has been introduced by TISPAN to interconnect different networks. It includes functionalities such as NAT and firewall functions, signaling policy, IPv4 to IPv6 conversion.
3. User Plane: The user plane includes an IPv6 core network that can be accessed by the mobile user over cellular, WiFi and broadband networks. It is designed to allow QoS guaranteed IP multimedia services that may be server based or peer-to peer.

2.1 Media Resource Function overview

In the context of this paper, the MRF has the capability to adapt the QoS of the video stream upon a request from the mobile user. As part of the IMS platform [3] the MRF provides additional media resources complementary or fundamental for the services and

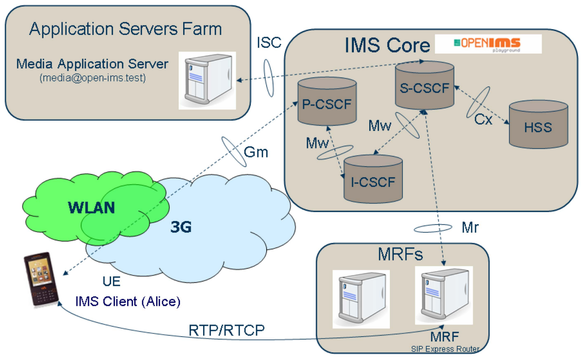

Figure 2: IMS Testbed

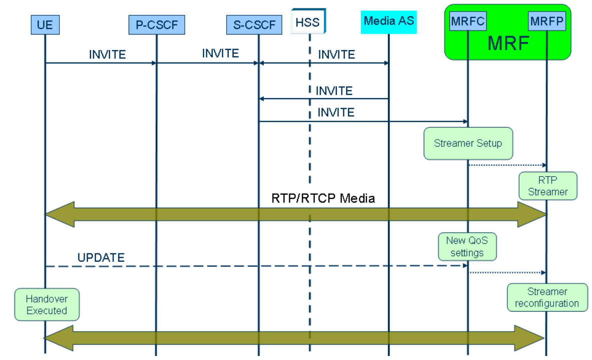

Figure 3: Application setup and handover signaling diagram

Table 1: Overall Latency for session establishment

Access network	Registration (s)	Video Setup (s)
3G	0.624	1.435
WLAN	0.371	0.968

Table 2: Handoff delay

Procedure	Signaling Delay (s)	Handoff delay (s)
3G→WLAN	1.623	0.632
WLAN→3G	0.517	1.104

at the same time it contains the functionality to manipulate multimedia streams. Furthermore, if the MRF is instructed by the AS, it sets ups the service and establishes RTP streams to the user. As described in the above section, MRF is involved in both session establishment and media flow control, through its two separate functional parts. The MRFC acts as a SIP B2BUA and at the same time it manages the features and controls the media streams resources of the MRFP. In addition, MRFP handles media streams either by processing them (audio transcoding and analysis), or by mixing incoming streams. The most important, in the context of this study, role of MRFP is that it can provide a set of codecs and transcoders to resize and manipulate audio and video. Specifically, the MRFP is comprised of three types:

- packet distributor - responsible for media distribution
- media player - supports applications such as conferencing and transcoding as well as, real-time audio and video mixing
- media bridge - is involved in applications such as network announcements, while it provides audio playback and collects and plays DTMF (Dual-tone multi-frequency).

3. QOS ADAPTATION IN HETEROGENEOUS NETWORKS

3.1 State of the Art

As the users may handoff across networks with constrains, packet losses and jitter may increase. These two factors may impact the perceived video quality in terms of blockiness and jerkiness [4]. For this reason, video adaptation can be performed on the fly (real-time) in order to lower the video transmitted rate [5].

Adaptation techniques become extremely important in such a heterogeneous environment so that quality management and provision to multimedia traffic over the error-prone channels of the heterogeneous systems can satisfy the demands of various network users. Various algorithms have been proposed for video adaptation [6]: adapting the quantization step-size (coarser quantizer leads to decreasing the bit rate at the expense of increasing the coding distortion and vice versa), using a layer-video codec and adding/dropping layers according to the available bandwidth, using a transcoding mechanisms in order to adapt the video semantics to the constraints imposed by the network.

3.2 QoS adaptation in the context of IMS

In the context of this study the QoS adaptation is performed at the MRF node of the IMS. More specifically, the user registers to IMS and the AS in order to request a video stream. The AS will contact the HSS in order to be informed about the user profile and the charging policy. The AS will consider this information in order to select the quality parameters of the video stream and inform the appropriate MRF. The MRF will establish the communication link with the user and according to the received information from the AS, will setup the video stream. In the case of a vertical handover to another access network, the user prior to handover issues an UPDATE message to the AS informing it about the type of the network that the user is going to be handed off. The AS will repeat the above procedure and will notify the MRF about the new QoS parameters of the video stream.

Since a handoff from WLAN to 3G is usually associated with more restricted throughput in terms of available bandwidth, the video rate needs to be reduced and be adapted to the new conditions. A controlled QoS adaptation by the system will decrease the probability of losing important information due to congestion in 3G that would increase the distortion of the received video. This video Rate-Distortion adaptation is performed in MRF according to the information that MRF receives form the AS.

4. SYSTEM MODEL

4.1 Overview

This section describes the experimental setup with the two access networks, 3G and WLAN, the IMS core platform and the video application user, as shown in Fig. 2. In particularly, the IMS platform is based on the FhG FOKUSs Open-IMS Core [7] implementation that provides core network infrastructure, service access and testing capabilities. In addition, Ericsson's Service Development Studio (SDS) [8] has been used for the development of SIP based Media Application Server and IMS Client. SDS is a development environment based on the Eclipse platform. It provides end-to-end support for the design, coding, and testing of Value Added Services that leverage the capabilities of the IMS. SDS includes Application Programming Interfaces (APIs) designed to hide network and terminal complexity from the developer. Moreover, SDS provides end-to-end support for design, coding, and testing emulation of deployment environments both for the terminal side and the server side (Session Initiation Protocol Application Server (SIP AS)). In the context of this work the Media AS is programmed to accept INVITE messages, process them and trigger the appropriate MRF. Moreover, the developed IMS client is capable of initiating a video session and recieving live video streaming from the specified MRF. The IMS client is running on a laptop that has two wireless interfaces, one for 3G/UMTS access and one 802.11b WLAN access.

During the service setup procedure, the IMS client initiates a SIP session by sending an INVITE message which includes its media capabilities (video/audio codec, desired level of quality, etc.) to the IMS core. Upon the reception of the INVITE message, the S-CSCF interacts with the HSS through the DIAMETER protocol [9] in order to check the Initial Filter Criteria (IFC) of the client. If the IFC are fulfilled, then the INVITE message is forwarded to the appropriate Media AS. The AS evaluates the Session Description Protocol (SDP) content of the INVITE message, defines the parameters of the video streaming (codec, bitrate, etc.) and triggers the suitable MRF through a new INVITE message.

When a vertical handover occurs the IMS client is responsible of informing the corresponding AS via an UPDATE message that the access network has changed. Upon reception of this UPDATE message the AS instructs the MRF to update the video streaming parameters according to the new conditions. Fig. 3 illustrates the signaling interaction between MT, the xCSF and the MRF.

4.2 Performance evaluation

The performance evaluation of IMS system during vertical handoffs and the video perceived quality adaptation framework has been tested under real network conditions. The focus is on the signaling delay that is introduced during the handover and the QoS adaptation of the ongoing video stream that is handled by MRF. Moreover, perceived video quality achieved by adapting the bit rate of the stream when network conditions change during handoffs is compared against the perceived video QoS when no bit rate adaptation is performed.

The throughput of the 3G network is measured on average 1Mbps throughout the experiments, while 802.11b is configured to allow 11Mbps throughput. An additional five wireless nodes are also using the 802.11b transmission channel, transmitting CBR background traffic of 500kbits/s. The video stream is encoded as H.264/AVC provided by [10]. In addition, a Dummynet router [11] is implemented in the testbed in order to control network path conditions.

In Table 1 the overoll latency introduced during the registration procedure of a new client and the video session setup in both 3G and WLAN is summarized. The latency is defined as the time from sending the initial REGISTER message to getting 200 OK from the IMS core (Registration) and from sending the INVITE message to getting the first RTP packet. Moreover, Table 2 shows the measured delay of the handover procedure and the SIP signaling delay for the session update.

The measured delay and latency are unacceptable for real-time appplications, therefore more suitable handover procedures need to be investigated. In particular, handover delay can be further reduced by considering more intelligent vertical handover schemes that include context transfer capabilities [12] and 802.21 Media Independent Handover (MIH) framework [13], which are the subject for future work.

5. CONCLUSIONS

This paper presents a performance evaluation of a multimedia QoS adaptation framework across heterogeneous wireless access networks using the IMS platform. The MRF functionality in the IMS architecture has been described and its role on QoS adaptation during vertical handoffs is analyzed. A real network environment comprising 3G and WLAN access technologies is used to demonstrate the level of adaptation as well as signaling overhead during vertical handoffs.

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