Real Time PQoS Enhancement of IP Multimedia Services Over Fading and Noisy DVB-T Channel

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Abstract. This paper presents the implementation and testing of a complete transmission and control chain of a DVB-T network architecture featuring QoS capabilities, by enhancing in real time the PQoS degradation, resulting from a fading/noisy downlink DVB-T channel.

Keywords. Perceived Quality of Service (PQoS), DVB-T, Quality Improvement

I. INTRODUCTION

The development of Digital Video Broadcasting – Terrestrial (DVB-T) standard during the last years, has already driven to the implementation of many commercial DVB-T networks over Western Europe. Moreover, a digital terrestrial television broadcaster is not restricted to offer only TV services, but also to provide to consumers IP-based multimedia services, exploiting the feature of DVB-T to encapsulate IP packets into the transport stream using the Multiprotocol Encapsulation Protocol [1].

Based on the above feature, DVB-T can be used as a means of computer system broadband networking, using a suitable technology (i.e. GPRS, PSTN) as return channel. In such DVB-T networks, it is possible the provision of multimedia services, which are primarily designed and implemented for IP networks. Thus, video on demand services or streaming applications can be adapted and transmitted via DVB-T networks, simultaneously with the standard TV services.

The extension of IP applications to DVB-T networks has as result the adaptation of IP network topics to DVB-T, such as Quality of Service (QoS) issues of the offering IP services. Moreover, regarding multimedia services, the concept of the Perceived Quality of Service (PQoS) is introduced, which is defined as the collective effect of service performance that indicates the degree of user satisfaction [2].

A possible commercial scenario of PQoS concept is an implementation, in which a user requests an IP multimedia service at a desired PQoS level through a DVB-T network (where the selection of the PQoS level is based on criteria such as the service availability, the type of the user subscription or the user terminal). Normally the delivered PQoS level of the video content will be equal to the requested one, but this is not what happens in reality, where fading or noisy parameters may appear in the downlink DVB channel, having as result the PQoS degradation of the end user.

The IST Athena project aims at proposing the proper actions to be taken concerning the Digital Switchover (DSO) in UHF band (i.e. the transition form traditional analogue television broadcasting to digital TV). Athena project will explore and validate, in a city, the deployment/realisation of the digital switchover issue through the design, implementation and evaluation of an infrastructure, which uses a regenerative DVB-T stream for the interconnection of distribution nodes, enabling access to IP services, and digital TV programmes. In such configuration, all kind of citizens/providers are co-equal users of the same infrastructure via which they access (or provide) IP services. Such implementation can be used and exploited as common infrastructure by 3G and B3G operators and broadcasters having independent business plans and different users/clients. Thus, project is oriented to the active users/citizens that can provide and manipulate their own services to the entire IP backbone (i.e. spin-off businessman, off line IP television multicasters, etc.). The use of regenerative DVB-T configurations in conjunction with intermediate distribution nodes (cell main nodes - CMNs) that utilize broadband uplinks, constitutes a broadband access infrastructure capable to accommodate the active users/citizens.

This paper presents the implementation and testing of a complete transmission and feedback loop chain of a DVB-T network architecture capable of eliminating in real time the video impairments resulting from a fading/noisy downlink DVB-T channel.

This rest of the paper is organized as follows: Section II describes the proposed network architecture and introduces basic parts and components. Also the description of the network functionality under real channel impairments is included. Section III describes the PQoS measurement algorithm. In section IV performance measurements of a small scale prototype are presented, showing the PQoS improvement of a multimedia service, over a fading and noisy DVB-T channel. Finally, section IV concludes the paper.

II. OVERALL SYSTEM AND NETWORK ARCHITECTURE

The overall system and network architecture that has been implemented for the needs of this paper is depicted in figure 1.

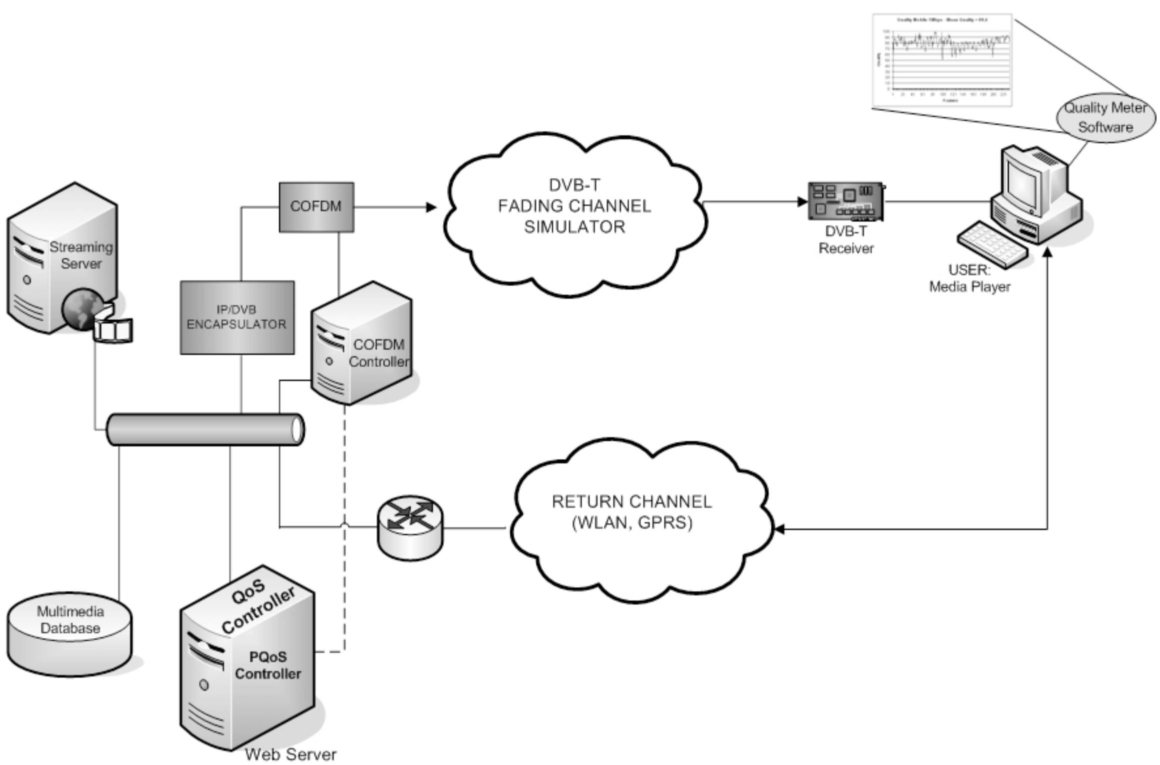

Figure 1. The overall system and network architecture.

The core of the proposed DVB-T network consists mainly of an IP to DVB gateway, which performs special fragmentation and adaptation operations in order to encapsulate IP datagrams into MPEG-2 transport packets. The gateway also serves as a multiplexer, which accepts digital video programs as inputs and multiplexes them in real time with the IP traffic in order to produce a constant bit rate DVB bouquet at a rate up to 32 Mbps. This final multiplexed stream is fed into a DVB-T modulator, which performs a 2-layer error correction before modulating the baseband signal in 16-QAM utilizing the COFDM scheme (8k mode). Finally the COFDM signal is up-converted in order to occupy a 8 MHz channel in the UHF band.

At the end user side, the DVB signal is received by a standard UHF antenna and is fed into a DVB-T receiver module, which performs the receiving, decoding and demultiplexing processes. According to these, the IP datagrams are extracted from the DVB transport stream and are sent up to the TCP/IP layer, in order to initiate the delivered multimedia service.

The digital video broadcasting deals is suitable for unidirectional distribution of multimedia content. Typical IP-based applications require bi-directional exchange of data, making necessary the existence of a return channel. In the proposed architecture a WLAN 802.11b technology was used for uplink purposes, but instead of this other technologies, such as GPRS, can also be used.

According to figure 1, the service provider hosts a Web server, a Streaming Video Server, a Multimedia Database (MDB) and a QoS Controller (QoSC). The user authentication process takes place at the web server by the appropriate login name and password. After a successful login, the user selects the PQoS level, at which he desires to access multimedia content. Browsing among various thematic categories, the user selects and requests a specific video file. The request is examined by QoS controller (QoSC), which advices the Multimedia Database (MDB), in order to determine the parameters of the specific media file, at which the selected PQoS level will be achieved. The MDB stores essential information regarding the mapping of the PQoS level to encoding parameters, such as bit rate value, resolution and frame rate. This mapping has been done off line in previous phases and multimedia files have been stored at different bit rates, corresponding to different quality levels.

The updated (with specifically defined video clip parameters) request of the media file is forwarded by the QoSC to a Streaming Server (where the media files are located). Finally the streaming process is initiated using the RTSP application protocol [3] via the DVB-T downlink channel. An IP/DVB Encapsulator is an important link of the transmission chain, where the IP packets are encapsulated into the MPEG-2 transport stream.

At the reception area, there are several test points located at properly selected sites, where the PQoS is measured in real time by a Quality Meter Software (QMS) [4]. When the quality of the received multimedia content is above a reference threshold, then no actions are anticipated. In the case that the perceived quality, as measured by the QMS, drops below the threshold for a specific period of time, a feedback alarm is send back to PQoSC via the return channel. The reference threshold (R_T) and the time (T_B) have been calculated a-priory during an off line procedure. For this reason various PQoS drops resulting from different fading profiles were used in order to estimate the integer mean values of R_T and T_B. Figure 2 depicts a representative set from these experimental measurements for a MPEG-4 test signal with CIF resolution at 400kbps. According to the whole offline procedure the R_T value has been specified equal to 65 (in a 0 to 100 quality scale) and the T_B value has been set equal to 5 seconds.

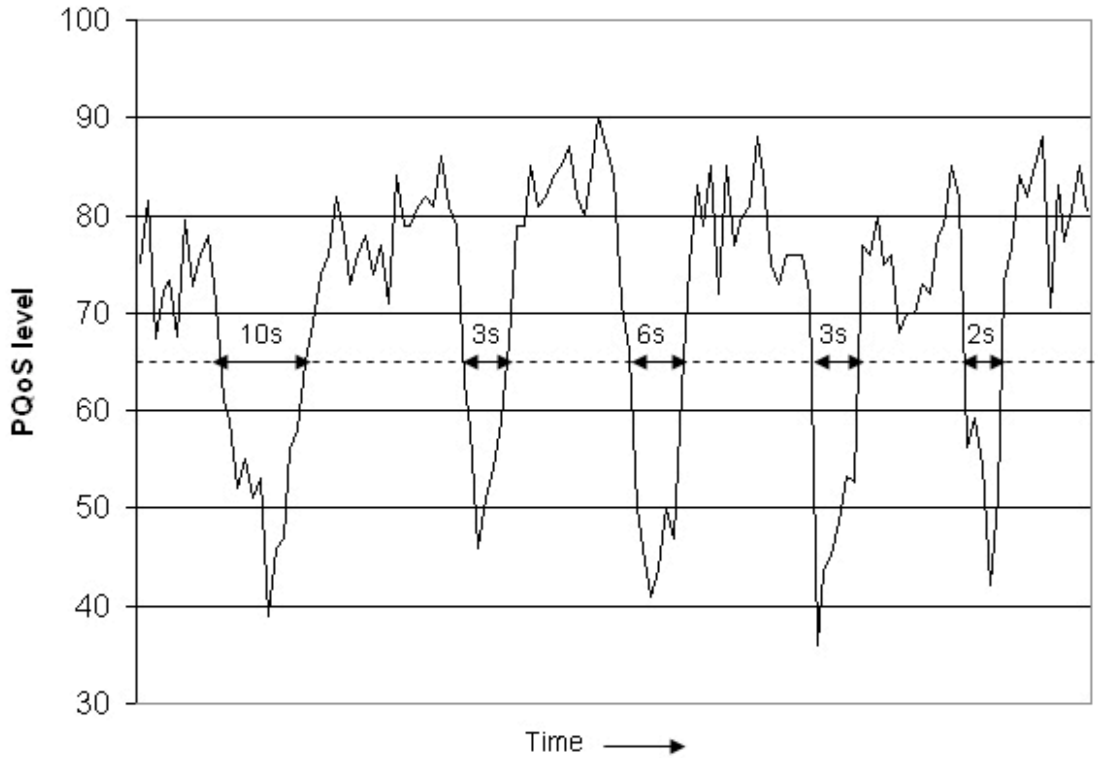

Figure 2. Determination of R_T and T_B values

The PQoSC collects and statistically processes the feedbacks that arrive from different test points within a period of 30 seconds. In this way, the PQoSC monitors the average quality level that the end users practically receive. In case that more than the 50% of the test points have sent feedback alarms in the time window of 30 seconds, indicating that the quality level is below R_T, then the PQoSC forwards a signal to COFDM Controller, which changes the DVB-T Code Rate transmission parameter to a more error resilient state.

Typical values of code rate are 1/2, 2/3, 3/4, 5/6, and 7/8. The higher the ratio is, the more efficient the available bandwidth is used. This means that more useful bit rate is available for the MPEG-2 transport stream. However, lower rates ensure a more robust and error-tolerant transmission as the error correction capability of the receiver is increased.

After each code-rate update procedure, the system remains at this state for a time window of 5 minutes. Afterwards, the PQoSC continues to monitor the quality that the end users receive by processing the test-point feedback alarms every 30 seconds. In case that the new alarm arrivals does not correspond at least to the 50% of the test points, then it returns the code rate value to the previous state. Otherwise, a new update procedure is initiated again in order to improve the user-experienced quality level.

III. THE PQOS MEASUREMENT

The algorithm, on which is based the PQoS estimation of the QMS at the test point equipment, has its basis in MPEG coding procedure, where the high compression results in loss of high frequency Discrete Cosine Transformation (DCT) coefficients, resulting into luminance and amplitude discontinuities between adjacent DCT blocks (8x8 pixels). Generally, the differences between adjacent pixels are reduced by the encoding process, which causes generally blurring of the encoded frame. Exception is the pairs of adjacent pixels across the border of DCT blocks and macro-blocks. After the encoding process, the average amplitude differences of some pairs show a particular pattern in comparison with the original video clip.

The average amplitude luminance $L(x, y)_{average}$ for each border pixel is computed using the luminance values L(x, y) of the surrounding K x K pixels [5] (where K is equal to 2, which results in taking in consideration the values of the first pixel neighbors only):

$$L(x, y)_{average} = \frac{1}{KxK} \sum_{i=-K/2}^{K/2} \sum_{j=-K/2}^{K/2} L(x+i, y+j) \quad (1)$$

Based on this simple objective metric, the PQoS level is measured objectively in real time by the QMS. In the next section the performance measurements of the aforementioned network architecture will be presented.

IV. PERFORMANCE MEASUREMENTS

In order to test the proposed platform under real operation conditions, a small scale prototype was implemented with one test point terminal. Channel impairments were introduced into the downlink DVB-T channel by a TV test Transmitter featuring fading channel simulation. For the test procedure of this paper, a Rice DVB-T channel profile was selected, in order to introduce impairments and distortions in the delivered video clip.

Rice fading is caused by Doppler-shifted echoes with a Gaussian distribution, but in addition there is always a direct path from the sender to the receiver. This path in mobile reception can only be influenced by the Doppler Effect. Except from the direct path, many echoes arrive from different directions, so the angle that is used for the calculation of the Doppler shift is not constant in mobile reception.

For the test measurements of this paper, the RF level was set 20 dB above the DVB-T receiver threshold. The fading parameters for the Rice channel were 20 km/h constant speed, Doppler Frequency 11.16 Hz and Frequency Ratio 1.0 dB.

Moreover, white noise was added in the previous fading channel profile, making the signal reception even weaker.

The test scenario was the following: The user requests a media file at a specific PQoS level. During the streaming process at a random time point, fading effect with Power Ratio 10 dB and white noise with CNR 15dB are introduced in the downlink DVB-T channel, having as result the degradation of the delivered PQoS. The drop of the digital video quality below R_T=65 for more than T_B=5 seconds is measured in real time by the QMS, which results in sending an alarm feedback to the QoSC, indicating that the PQoS level has dropped to critical level. Then the QoSC initiates the procedure to change the code rate value in order to strengthen the robustness of the DVB-T signal.

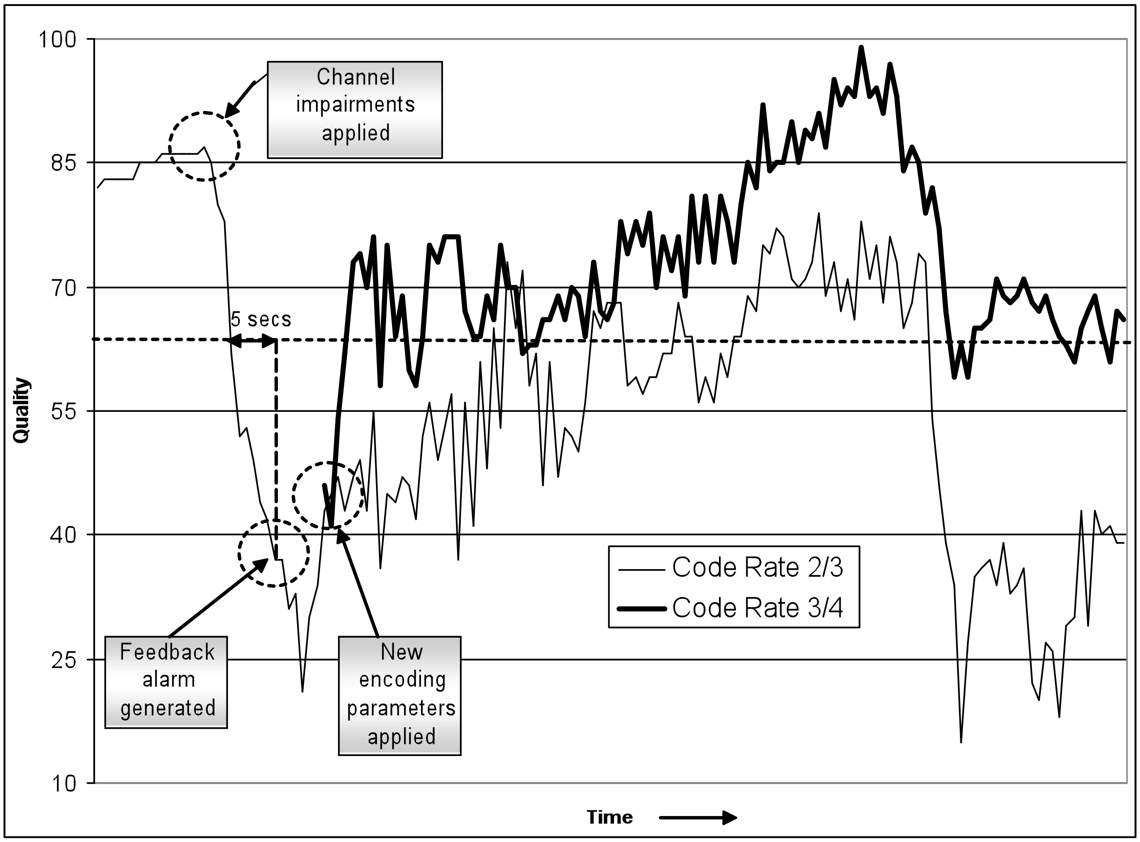

Figure 3. PQoS Measurements over fading and noisy DVB-T channel, with and without feedback implementation.

Figure 3 depicts the PQoS measurements for a MPEG-4 video clip with CIF resolution at 384 kbps, containing scenes of various temporal and spatial activity levels.

Streaming process initiates normally at the test point terminal, until time point 1, where channel impairments are introduced. This results in significant PQoS degradation below the reference level of 65 (dashed line). According to the proposed network architecture, an alarm feedback by the end user is initiated at point 2 (when the T_B=5sec period has passed) and eventually the QoSC upgrades the code rate value from 2/3 to 3/4 with scope to ensure a more robust and error-tolerant transmission. This update affects the end user PQoS level from point 3 (bold line) of the figure and over, where the improvement of the experienced quality level is approximately 20% in comparison with the case that the code rate would remain the same (normal line). The period between time point 1 and 2 corresponds to the time that the feedback generation takes and the overall system needs in order to stabilize on the new encoding parameters.

Although the proposed architecture has been implementing in a small scale prototype, where the change of encoding parameters was concentrated on one test point only, it can be easily applied, and adapted in already developed DVB-T networks, combining more test points. The implementation of the proposed concept will result in a DVB-T network featuring QoS capabilities for the offered multimedia IP-based services.

IV. CONCLUSIONS

This paper illustrated the implementation and testing of a complete transmission and control chain DVB-T network architecture, featuring QoS capabilities. A QoS feedback notification was implemented in order to improve delivered PQoS level, when channel impairments affect the quality of the end user service. A small scale, but fully operational prototype was implemented and tested in order to demonstrate the performance and verify the proper operation of the proposed concept.

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