UEP implementation for MPEG-4 video quality improvement on RLC layer of UMTS

B.H. Pathak, G. Childs and M. Ali

An unequal error protection (UEP) scheme is proposed which complies with the UMTS standards defined by 3GPP and is also customised according to the requirements of the video codec (MPEG-4), channel conditions and bandwidth limitations. The results show significant PSNR and frame loss saving improvements.

**Introduction:** Any UEP scheme would normally seek to provide greater error protection to the most important parts of a data stream than is afforded the less important bits. Such schemes often utilise enhanced forward error correction (FEC) or automatic repeat request (ARQ) mechanisms for the most important data.

In 3G mobile networks various levels of FEC are available for the signal and radio access bearers which can be combined in different ways dependent on the data rates being used (3GPP TS 34.108) [1]. However little flexibility in the schemes is available for the data rates above 32 kbit/s required for video transmission.

It is important that any overhead or redundancy be added in a way which does not make the modified video bit-stream incompatible with the standard [2].

Some of the problems arising from FEC implementation can be avoided through the use of the UEP mechanisms provided by the services offered by the RLC (radio link control) layer in the form of the various data transfer modes offered to upper layer protocols. These data transfer services include transparent mode, unacknowledged mode and acknowledged mode [3, 4].

In this Letter, a scheme which utilises the UEP capability provided by the allowed data transfer modes within the RLC layer, coupled with the inter-frame coding structure of MPEG-4, is tested and shown to give improvements in frame loss and PSNR.

**Proposed UEP scheme and model simulation:** The Transparent Mode (TM) data transfer service transmits upper layer PDUs without adding any protocol information, possibly including segmentation/reassembly functionality, while the Acknowledged Mode (AM) service transmits upper layer PDUs and guarantees error-free delivery to the peer entity. This latter mode is implemented through a process of error detection at the receiving peer entity and retransmission of the RLC PDU. The advantage of using a retransmission mechanism at the RLC layer instead of transport layer (TCP) is the size of RLC PDUs, which are significantly smaller than TCP segments [6].

As the MPEG-4 encoded I-frames represent the most important data structure, in the proposed UEP scheme only I-frames are transmitted using the AM RLC mode, while P and B frames are transmitted utilising the TM mode. This results in only a small amount of data having to be retransmitted in bursty error-prone environments.

In the tested scheme, at the application layer the video data is divided into two different bit-streams. Bit-stream-0 contains all I-frames while bit-stream-1 contains the P and B frames. Bit-stream-0 is assigned Type of Service (ToS) ‘Interactive multimedia’ which utilises the RLC AM while bit-stream-1 is assigned ToS ‘Streaming multimedia’ class utilising the RLC TM configuration.

Because all the I-frame data is transmitted utilising the AM service, it is expected that all the I-frame PDUs are received without any errors. Those which are received with errors are retransmitted and thus this ARQ removes all errors in the received I-frame data.

Although the amount of data to be retransmitted over the AM service is typically small, the buffer and delay requirements need careful analysis.

**Simulation model on physical layer:** The Signal Processing Workshop (SPW) tool by CoWare was used to model the environment in which the test MPEG-4 video stream was transmitted over various types of propagation conditions defined by the 3GPP standards [7]. A 64 kbit/s downlink data channel and 2.5 kbit/s control channel were used for this UMTS simulation. These two channels were multiplexed and transmitted over the WCDMA air-interface. It is assumed that throughout the simulation time the received signal-to-noise ratio (SNR) value remains constant and no power control algorithm is implemented.

The typical parameter set for reference RABs (radio access bearer) and SABs (signalling access bearer) and relevant combinations of them are defined in the 3GPP TS 34.108 and are used in this implementation. Performance evaluation of MPEG-4 with reference to these parameters is discussed in [8] in more detail. In this analysis errors occurring in higher layer overheads are ignored and the work concentrates only on errors occurring on video application data.

**Video clips and video quality measurement techniques used:** For evaluation purpose three standard video test sequences were used, these being: Mother-Daughter, Highway and Foreman. Each of these clips is of 650 frames in length of QCIF (176 × 144) resolution and encoded with a standard MPEG-4 codec at 10 fps.

The objective video quality is measured by the peak signal-to-noise ratio (PSNR) as defined by ANSI T1.801.03-1996. Video Quality Metric (VQM) software is used for the measurement of the video quality.

**Propagation conditions:** The typical parameter set for the conformance testing as mentioned in 3GPP TS 25.101 is used for the radio interface configuration as listed in **Table 1**.

**Table 1:** Conformance testing parameter set

<table>
<thead>
<tr>
<th>Interference</th>
<th>−60 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWGN noise</td>
<td>4 × 10^−5 W</td>
</tr>
<tr>
<td>Data rate</td>
<td>64 kbit/s</td>
</tr>
</tbody>
</table>

**Birth-death propagation conditions:** The dynamic propagation condition for the test of the base band performance is a non-fading propagation channel with two taps. The moving propagation condition has two taps, Path1 and Path2 which alternate between ‘birth’ and ‘death’. The positions the paths appear are randomly selected with an equal probability and are explained in more detail in 3GPP TS 25.101. Parameters used for this model are given in **Table 2**.

**Table 2:** Birth-death propagation conditions parameters

<table>
<thead>
<tr>
<th>DPCH power/total power transmitted</th>
<th>−10.25 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_b/N_0 (traffic data channel)</td>
<td>6.53 dB</td>
</tr>
<tr>
<td>BER (bit error rate)</td>
<td>0.001</td>
</tr>
<tr>
<td>BLER (block error rate)</td>
<td>0.12</td>
</tr>
</tbody>
</table>

**Fig. 1 PSNR improvements with UEP implementation**

**Simulation results:** Three different video clips are transmitted over birth-death propagation environments in the UMTS downlink simulation and results with and without UEP implementation are compared. It can be seen from Fig. 1 that several dB of improvement
in the average PSNR value is achieved with the UEP implementation. Similarly the number of frames dropped (Fig. 2) as a result of decoding errors in the codec, shows a marked improvement with implementation of the UEP scheme.

![Frame loss improvements with UEP implementation](image)

**Conclusion:** Simulation results show that implementation of UEP can result in significant improvements of the received video quality. This implementation requires a certain amount of the video clip data to be retransmitted but this is small compared to the total data transmitted and also compares favourably to other proposed retransmission [9, 10]. Results are presented for moving propagation conditions and results for other propagation conditions (static, multipath, moving) will be presented in a more detailed paper.

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B.H. Pathak, G. Childs and M. Ali (Department of Electronic Engineering, School of Technology, Oxford Brookes University, Oxford, OX3 0BP, United Kingdom)

E-mail: bpathak@brookes.ac.uk

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7. 3GPP, TSG Access Network, UE radio transmission and reception (FDD), 3GPP TS 25.101, V6.3.0 (2003–12)