WHITE PAPER

Video-Aware Link Adaption

Enhances real-time video over LTE

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Contents

1 Executive Summary

The demand for wireless data is growing rapidly, with a substantial component of this growth due to the proliferation of multimedia traffic (and in particular video applications) delivered to smartphones over Wi-Fi® and cellular data networks. Real-time video is expected to become a bigger component of the overall multimedia traffic as LTE begins to enable the use of video conferencing over cellular networks. This growth will outpace the capacity of wireless networks and will necessitate the use of more 'out-of-the-box' approaches to managing the data onslaught. In particular, cross-layer optimization of the wireless networks to exploit the unique nature of video traffic as well as optimization of the video applications for transport over today's congested wireless networks can deliver substantial gains in both network efficiency and user perceived Quality of Experience (QoE).

Figure 1 shows several ways in which the performance of video delivery may be enhanced through cross-layer optimization, making the underlying networks aware of the applications they are supporting and making the applications aware of the networks on which they are running.

In this paper, InterDigital presents two cross-layer approaches to video performance optimization over LTE networks that leverage the structure of real-time video in performing link-adaptation in the MAC/PHY layers at the basestation (Class 3). These approaches include adaptation of Hybrid-ARQ (HARQ) retransmission as well as multi-user scheduling to improve overall user QoE and network efficiency. These techniques may provide very meaningful improvements in the end user's perceived QoE (more than 4dB PSNR) while requiring minimal changes to the network.

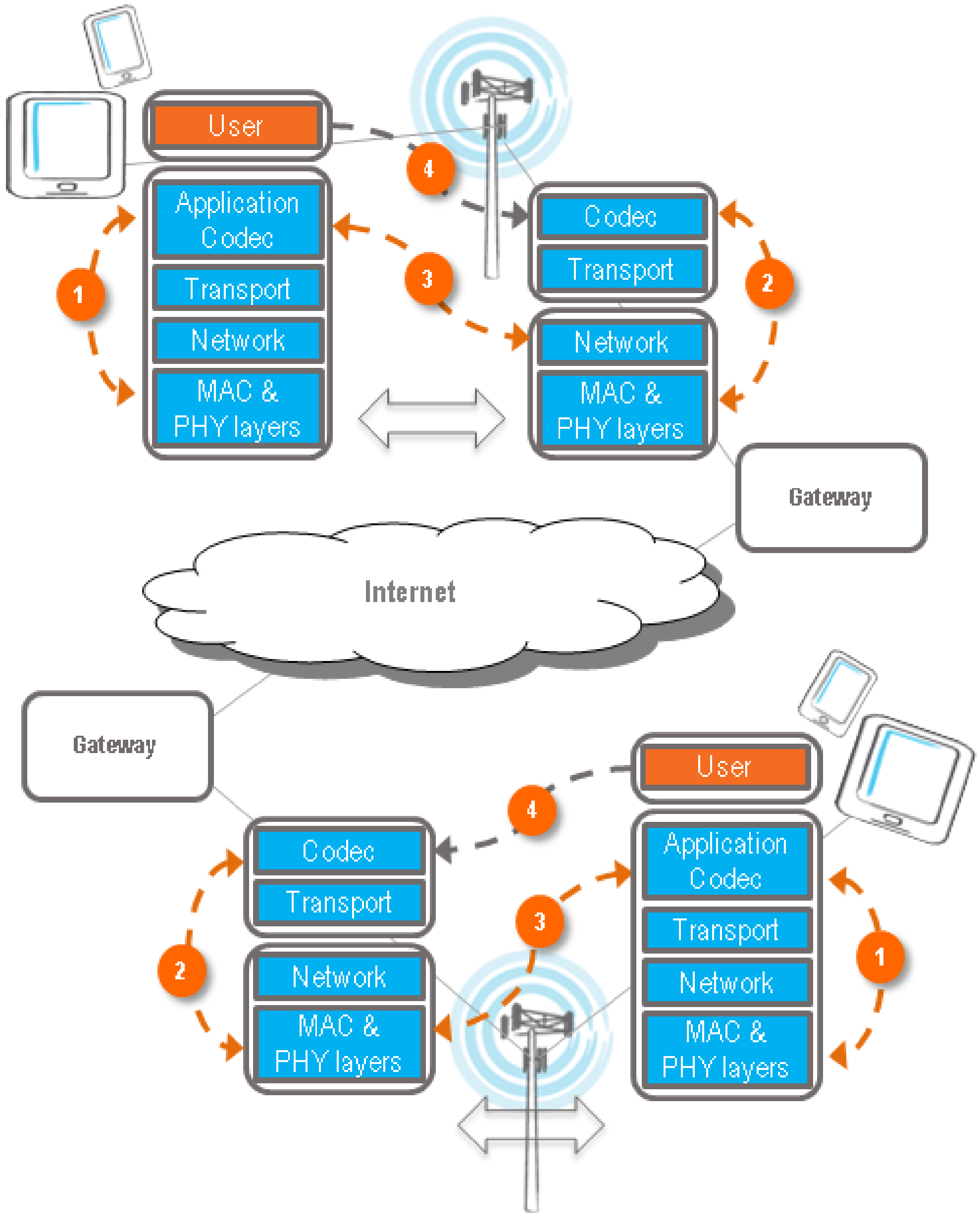

Figure 1: Different classes of cross-layer approaches to enhance video performance over wireless networks including: (Classes 1 & 2) joint optimization of the video application with the MAC/PHY at the subscriber terminal and basestation respectively, (Class 3) joint optimization of the video application in the UE and the MAC/PHY in the wireless network, and (Class 4) optimizing the video application in the network based on the state of the user.

2 InterDigital's Solution

2.1 Adaptation of Hybrid-ARQ for Enhanced QoE

In order for LTE systems to provide robust and spectrally-efficient service over dynamic wireless channels, a fast form of automatic repeat request (ARQ) is used, known as Hybrid-ARQ (HARQ). HARQ provides fast physical layer retransmissions based on feedback from the receiver and employs incremental Turbo coding redundancy and soft combining. HARQ along with adaptive modulation and coding, and fast multi-user scheduling, are the primary tools used by LTE to adapt communications links to the varying nature of the wireless propagation channel.

In a typical LTE system the maximum number of HARQ retransmissions is set to a constant number (typically 4) and is used for the entire communication with no consideration to the type or importance of the data being instantaneously communicated. The HARQ controller is optimized for transmission of uniform transport block priority.

In performing adaptation of HARQ for enhanced QoE, the HARQ controller is aware of the video encoder. All video applications generate packets which, if lost, produce a variable impact on the users perceived QoE. Video packets may be prioritized based on the potential impact to QoE their loss would induce. As such, the HARQ controller can take advantage of knowing the instantaneous packet priority to change its parameters and improve the overall video experience.

Video quality of experience is primarily influenced by the video encoding rate and the packet loss pattern in relation to the video encoding characteristics and the video content. The classification of video packets into priority groups is performed by estimating the impact lost frames would have on video quality, which depends on the coding structure and/or the video content.

For example, hierarchical P video coding (Figure 2) allows subdividing the video frames into temporal layers, according to their frame reference, and associating these layers with different priority groups. A different technique uses repetitive Instantaneous Decoder Refresh (IDR) frames to recover from error propagation. The number of frames since last IDR frame provides a good guide for setting the frame priority.

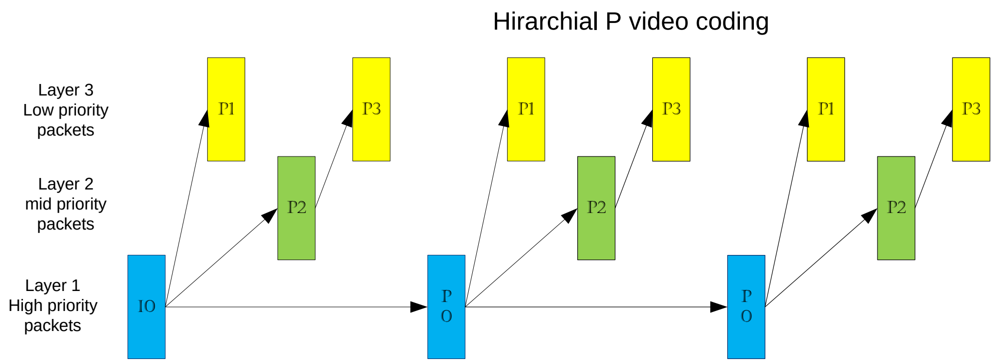

Figure 1 : Hierarchical P video coding frame priority guidelines.

The concept for communicating the video packet priorities from the video application to the HARQ controller is performed by splitting the video stream into multiple sub-streams according to the packet priority. The video streams are mapped to several LTE EPS bearers (Logical channels) with assigned QoS and priority. The MAC layer identifies the associated MAC SDU to Logical channel id and sets the appropriate maximum number of HARQ retransmissions to support the level of video packet importance generated by the video encoder.

Performance evaluation of video-aware HARQ is based on a multi-user LTE system simulation and indicates that video-aware HARQ achieves an average (Peak Signal to Noise Ratio) PSNR gain over all users of ~1dB for the football sequence (Figure 3) and 0.8dB for the Foreman sequence and up to 4dB for certain users.

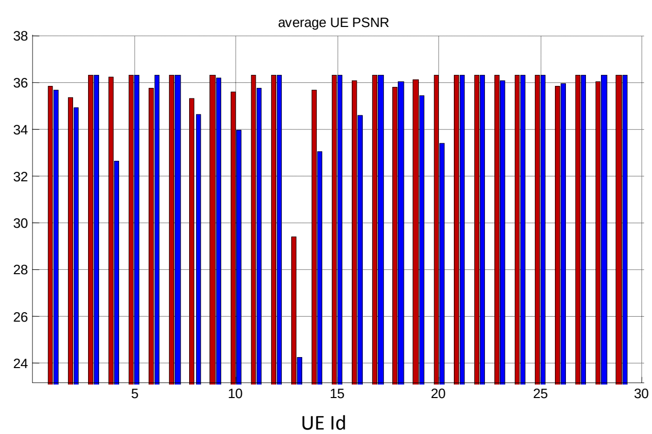

Figure 3: Objective Video Quality Measure (PSNR) per user [dB] (Fixed HARQ – Blue; Adaptive HARQ – Red)

2.2 Adaptation of Multi-User Scheduling for Improved QoE

The classical scheduling algorithm for multiple users competing for the same cellular resources is the proportional fairness algorithm, which maximizes the total throughput while offering certain fairness among different users. Specifically, in proportional fair scheduling, the user with the largest ratio of instantaneous data rate to historical data rate is scheduled. Proportional fairness has proven to be very successful for traditional data communications over cellular networks – a case in point is its adoption by CDMA2000 1x EV-DO Rev. A.

However, video traffic is different from the data carried in traditional cellular networks in that, as was described in Section 2, all video packets are not equally important. For example, in Figure 2, if a packet is lost at Layer 1, this packet and all the other packets afterwards will be affected. However, if a packet is lost at Layer 2, only this packet and one additional packet will be affected. As a result, Layer 1 packets are much more important to the video quality than Layer 2 packets. This unique characteristic of video traffic calls for new approaches to multi-user scheduling.

InterDigital has developed a video-aware multi-user scheduling algorithm that performs prioritization of packets based on their importance to video quality. The video traffic is split into multiple streams, and each is mapped to a separate logical channel. The scheduler prioritizes video packets by differentiating traffic from different logical channels. InterDigital compares the performance of the video-aware scheduling algorithm and the proportional fairness algorithm. The results for a heavily loaded (>65%) LTE system are shown in Figure 4. On average, the video quality is improved by approximately 3dB. In addition, with the video-aware scheduling algorithm, the quality of the video is more equitable among different users. For lighter system loading, the performance gains are smaller but still significant.

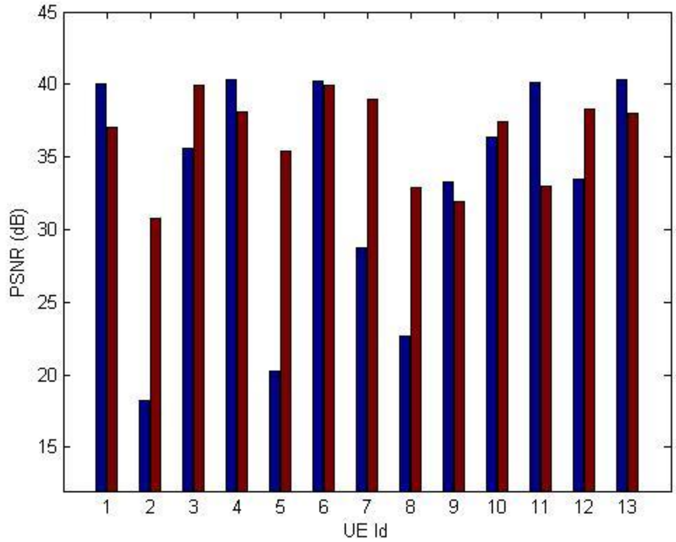

Figure 4: PSNR per UE (Proportional fairness scheduling – Blue; Video-aware scheduling – Red)

2.3 Standardization Impact

The full performance benefit of the two InterDigital technologies described above can be obtained with minimal standardization changes. One such change is to increase the number of QoS differentiation levels for video packets in the LTE system. This change is essential for video traffic that traverses networks operated by different operators.

In addition, without any standardization changes, much of the performance benefit still can be obtained. Within an operator's network, proprietary solutions, such as increasing the number of QoS differentiation levels for video packets, can be used.

3 Conclusions

InterDigital's cross-layer video performance optimizations for wireless networks can provide substantial improvements to both network efficiency and to the end user's quality of experience. In particular, the link adaptation technologies presented in this paper provide a marked improvement in the objective quality metrics that directly relate with the QoE observed by the end user. Specifically, both adaptation of the Hybrid-ARQ function and video adaptive multi-user scheduling can each provide a 1dB average improvement in PSNR and peak gains of more than 4dB. The technologies presented in this paper may be used to help reduce the burden on LTE networks as the demand for wireless video continues to grow.

About InterDigital®

InterDigital develops fundamental wireless technologies that are at the core of mobile devices, networks, and services worldwide. As a long-standing contributor to the evolution of the wireless industry, we solve many of the industry's most critical and complex technical challenges years ahead of market deployment. Our advanced solutions support more efficient wireless networks, a richer multimedia experience, and new mobile broadband capabilities. Accordingly, we have established licenses and strategic relationships with many of the world's leading wireless companies.

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