UNEQUAL ERROR PROTECTION OF H.264/AVC VIDEO TRANSMITTED OVER WIRELESS NETWORK

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ABSTRACT. This work focus on the problem linked to the transmission of real time video over packet wireless network. Our objective is to define mechanism able to insuring a quality of video in spite to the problems of packet losses and transmission delays characterizing this type of network. The proposed mechanism is based Forward Error Correction (FEC) compatible with the H.264/AVC standard. This mechanism relies on a rate-distortion algorithm controlling the channel rates under a global rate constraint given by the network. This optimization takes into account the type of packet and his length; the tool of data portioning is used in our proposition. This mechanism leading to an unequal error protection of different units of coded sequence. A Reed-Solomon channel coding in application layer is adapted to unequal protected data. The experimentation results indicate the efficiency of our proposition compared to the equal error protection.

Keywords : real time video, H.264/AVC, data partitioning, packet wireless network, unequal error protection, reed-solomon, joint source channel coding, packet losses

INTRODUCTION

The growing popularity of wireless network encourages the development of new applications, which may also exhibit new usage characteristics. Real-time video applications, for example, have quality-of-service (QoS) requirements and impose strict end-to-end delay constraints those may be difficult to fulfill in a wireless channel. In addition, video packets are generally with different importance. These special features typically require application layer by using source encoder. To satisfy the requirements of such applications, many CoDec have been developed to make the video stream more robust against transmission errors, more compressed but with reduced computational complexity. In this work, we have used the H.264/AVC (Schwarz, et al., 2007) video coding design which demonstrates a superb adaptability in video communications. Such design makes a distinction between a Video Coding Layer (VCL) and a Network Abstraction Layer (NAL) (Yip et al., 2005), the output of the encoding process is VCL data which are mapped to NAL units prior to transmission. Each NAL units (NALU) makes up a packet where it contains some number of bytes including a header and a payload. The header specifies the type of each NALU and the payload contains related data. In VCL, picture frames are divided into MBs. An integer number of MBs are further grouped to form a slice which can be encoded to fit the size of one or more separate NALU that can independently decodable.

This paper is mainly motivated by Antonios Argyriou et al. (2009). We propose a Joint Source channel coding scheme based Reed-Solomon FEC compatible with the H.264/AVC standard. This proposal relies on a rate-distorstion algorithm controlling the channel rates under a global rate constraint given by the network. Data partitioning tool (DP) is used to make difference between video packets as presented in many existing methods (Argyriou et al., 2009; Stockhammer et al., 2004) to permit the use of unequal error protection (UEP) which make the third class of (Khalek et al., 2012). We take into account the packet size to allocate bandwidth to different video packets without exceeding the channel capacity. Channel coding in application layer using Shortened Reed Solomon codes is applied to the video bitstream taking into account the packet priority. This combination is Joint Source Channel Coding (JSCC) scheme. The performance of the proposed JSCC unequal error control is demonstrated over wireless network by performing simulations under several channel conditions. Simulations are compared with an equal error protection (EEP) scheme.

The rest of this paper is organized as follows: section 2 gives a detailed description of the proposed JSCC video transmission. In section 3 we report on performances of our application, using parameters like image quality, bit error rate(BER), packet loss rate (PLR) and PSNR (Peak Signal-to-Noise Ratio). Finally, a conclusion and further works are provided in section 4.

SYSTEM OVERVIEW

In this section, we develop our joint protection design, which use an unequal error protection at the application layer. Consider the single-transmit single-receiver in an IEEE 802.11e wireless channel. Figure 1 illustrates the layer structure system on both the transmitter and the receiver side, from the transmitter side in the upper part of the figure to the receiver side in the lower part. The system input is a digital video content that has been compressed using the most recent H.264/AVC compression standard. We have used a simple H.264/AVC NALUs packetization scheme that put exactly one NALU in one RTP packet. The packetization rules for this mode are indeed very simple: put a NALU into the payload of an RTP packet, set the RTP header values as defined in the RTP specification (Mihaela et al., 2005). Then, the RTP packet will be send to the lower layers. H.264/AVC introduces the concept of parameter sets, which contain information that can be used to decode a large number of encoded video sequences.

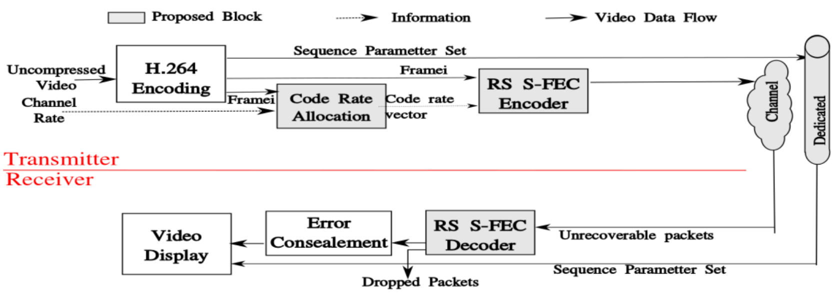

Figure 1. The Proposed Cross Layer Architecture

In the proposal, we consider that the sequence parameter set is transmitted out of band and error free because its integrity is a critical constraint in the source decoding. The not VCL units can be transmitted without channel coding for carrying enhancement information which are not necessary for source decoding. The remaining VCL units are protected using an optimal JSSC scheme where a variable code rate is calculated for each NALU in one frame. The code rate selection is warranted by a rate allocation algorithm (Argyriou et al., 2009) described in Section 2.1; which uses both type and size of NALU as constraints. Source packets are then sent to the application layer FEC Reed Solomon (RS) encoder which generates (n-m) additional packets for m input source ones. At the receiver's side, the NALUs are extracted from the RTP packets. The frames that have even single bit errors cannot be sent to the application layer source decoder. In such a case, the erroneous packets will be passed to the FEC decoder process which tries to recover them instead of passing the unreliable decoded packets to the source decoder.

JSCC Rate Allocation algorithm

The first important feature of this work is that the source rate does not change across the transmission. By using this idea, a considerable reduction in the processing requirement can be achieved at the encoder. The incoming compressed bitstream is first encoded at the application layer. This is accomplished using H.264/AVC standard that includes the data partitioning mode. As a result, each source frame is encoded as a sequence of 3N NALUs, where N is the frame slice number. The JSCC algorithm (Mohamed et al., 2009) calculates the optimal channel code rate for each partition and adapts the bit rate to the capacity of the given line. So, this algorithm is responsible for optimally allocating the available channel rate between the source and FEC with respect to their importance to minimize the video distortion at the decoder side.

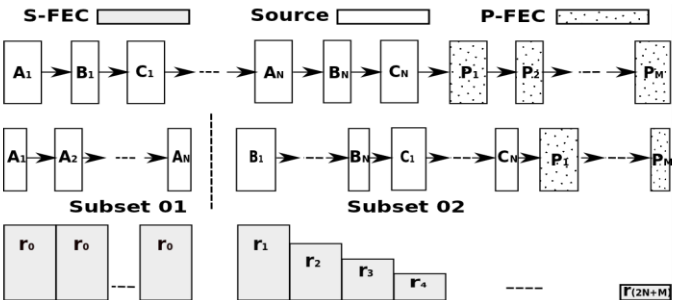

Figure 2. Frames NALUs's Clasification

Here, source packet consists of a SVC NAL unit portrayed as a row in Figure 2. This figure shows all the source packets included for transmission in one frame which are ordered according to their subjective importance (type and size) and divided in two subsets. The first one contains the A partitions which have a same code rate r_0 . The second one is the concatenation of three subsets, which are B partitions, C partitions and parity packets respectively; where the partitions of each subset are listed in descending order of size. Therefore, we need to sort the corresponding code rate vector $\left(r_{1,}...,r_{(2N+M)}\right)$ starting by an initial one. Figure 2 illustrates this correspondence, and it depicts the percentage of bandwidth allocated to the source and channel coding respectively. The dark areas correspond to the additional percentage of the bandwidth that is used for channel coding. The bigger part of the bandwidth is needed for the first subset channel coding where all NALUs have the same percentage of parity bits. However, the percentage vector of the second subset is proportional to partitions size. The complete JSCC allocation algorithm is described in (Mohamed et al., 2009).

Unequal Error Protection (UEP) at Application Layer

The single NAL unit packet defined here must contain only one NAL unit, of the types defined in (Mihaela et al., 2005). This means that neither an aggregation packet nor a fragmentation unit can be used within a single NAL unit packet. A NAL unit stream composed by decapsulating single NAL unit packets in RTP sequence number order must conform to the NAL unit decoding order. It should be noted that, the NAL unit header is designed to conserve as the payload header of an RTP payload format. In the application layer we implement unequal FEC mechanism based on shortened code. We utilize RS codes since it has good error correction properties and is widely used in FEC schemes. The fundamental concept of erasure code is described in (Hafner et al., 2005). In general a (n, m) RS code contains m source blocks and (n-m) parity blocks. The key idea behind erasure codes is that any subset of m encoded blocks suffices to reconstruct the source data knowing that his correction capacity is (n + m)/2. In the current implementation, we use systematic codes where the rest m of the n+m encoded blocks are identical to the m source packets. Each NAL unit packet is RS encoded using the remaining rate ri from the channel allocation where ri is the ith NALU of the picture as presented in 3(b). Basically, a RS(50/ri; 50) shortened Reed-Solomon code, defined in Galoi Field, G(256) is used, while a RS(18; 12) shortened RS code is used for RTP header. Therefore, any RS block can correct up to 50/2ri bytes errors. As long as the number of lost blocks is less than the corrector capacity, all original video blocks can be decoded successfully. When the loss exceeds the FEC correction limit, only the received video packets are put into the decoded video files which will contain mostly the A partitions since they are the most protected by the UEP scheme unlike the B and C partitions. In such a case, the last problem that the decoder has to cope with is the recovery of the B and C partitions which are poorly protected by our technique. This function is warranted using the H.264/AVC error concealment tool (Xu et al., 2004) which can recreate the B and C partitions using the most protected partitions.

EXPERIMENTAL RESULTS

Simulation Model

To illustrate the effectiveness of our proposed unequal error protection scheme, we have performed experiments on two video sequences ***Tree*** and ***Mobile calendar*** (QCIF format), encoded using the JM10.0 standard. Since an encoded picture in a QCIF video sequence includes 99 MBs, we set the number of MB per slice at 33 to obtain pictures encoded in 3 slices each. We also chose the extended profile which allows us to encode each slice into 3 NALUs using the data partitioning mode. Therefore, each picture is encoded in 9 NALUs. Note that the initial rate vector is set to [k/85, k/80, k/75, k/70, k/65, k/60, k/55, k/50], and Symbol Size=50. The compared EEP method, using RS code, is fixed channel coding rate as follow:

$$r_{moy} = \frac{\frac{1}{N}\sum_n Rs(n)}{R_c} \quad (1)$$

where R_c is the channel rate and $R_s(n)$ is the number of bits in the n^{th} picture.

Simulation Results and Discussion

In this section, the simulation results for two video transmission techniques are evaluated; UEP and EEP FEC coding. We quantify the performance of our method by calculating the Bit Error Rate (BER) at the output of channel decoder using both protection techniques EEP and UEP. This is one of the most important parameters of this study since it can quantify the coding efficiency. Video sequences are compressed using H.264/AVC encoder in DP mode. The video encoded stream is protected by a rate compatible punctured RS codes depending on the UEP and EEP scheme. Therefore, to compare effectiveness of the two correctors we add a noise to the both encoded sequences and analyze the bit error rate results in both cases, before and after channel decoding. In each group of experiments, we change the Signal Noise Ratio (SNR) from 3 to 10 in step size of 0.5. In both cases, the BER is improved through the correction. Indeed, the errors before channel decoding can't be fully corrected. The obtained results show that the error rates in both cases are almost identical; the two correctors have almost the same performance with a small advantage to the EEP scheme. However, it is worth noting that the EEP has an advantage over UEP regarding computational complexity. It requires less computation to allocate equal code rates to all NALUs, and its performance is slightly better than UEP against the bit error rate. On the other side, its major problem is that it can't take into account the video stream semantic and it is not able to effectively compensate the loss of high priority packets. In this case, the UEP corrector can be more useful because of its high performance against the peak-signal-to-noise ratio (PSNR) and visual quality, which will be shown later.

Packet Loss Rate

Now let's evaluate the effect of EEP and UEP on packet loss rate of the three partitions. This factor is defined as a ratio of the number of lost packets to the total number of transmitted packets. Note that a packet is considered lost if at least one bit is erroneous. This parameter has an immediate effect on the multimedia transmission quality (voice and video) and an indirect effect on data transfer applications which use typically TCP. Figure 3 shows the comparison results of the three partitions A, B and C respectively under different channel SNR, decoded using EEP and UEP schemes. Each result is obtained as the average of 10 runs.

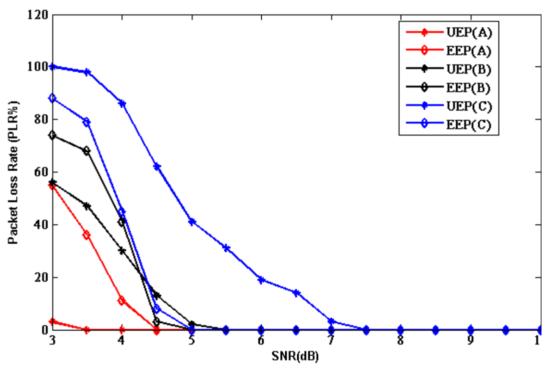

Figure 3. Loss rate of partitions under EEP and UEP schemes, using test sequence Mobile calendar

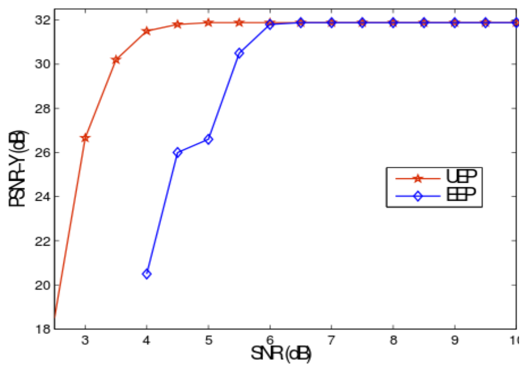

Figure 4. Comparison of reconstructed quality with different SNR

In all observed cases, the packet loss rate decreases when SNR increases. Thus, asymptotically, we can see that the FEC using the UEP have an unequal protection capability of the three types of NAL units. In Figure 3(red), the UEP provides enhanced protection of partition A compared with the second technique whatever the value of the SNR, unlike partitions C, which are more protected by EEP than UEP (Figure 3(bleu)). Partitions B are better protected by the UEP between 0 and 4.5dB (Figure 3(black)), 4.5dB above, the protection offered by the UEP decreases and gives lower quality compared to the EEP. In Figure 3(black), the UEP scheme yields a better protection to large NALUs than small ones which make their recovery more efficient when the channel is too noisy. However, when the channel become less noisy, the average code rate of EEP scheme can recover both large and small NALUs. On the other hand, small packets suffer neglect by the unequal error protection which gives rise to their losses. This explains why the EEP is more effective at high SNR region and UEP gives minimal PLR values at low SNR.

Peak-Signal-to-Noise Ratio (PSNR)

To see the impact of our technique to the reconstructed quality, we can calculate the PSNR of received video sequences compared to the original sequences in both scenarios (UEP and EEP). The comparison results of the two schemes with different channel SNR is shown in Figure 4. Typical values for the PSNR in lossy image and video compression are between 30 and 35 dB, where higher is better. Acceptable values for wireless transmission quality loss are considered to be about 20 dB to 25 dB. It can be seen clearly from figure 4 that compared with the fixed channel coding rate scheme, our proposed one can achieve a higher reconstructed quality of 32db at the receiver side. It can recover most of A partitions which makes the concealment of partitions B and C more efficient by the source decoder.

CONCLUSION AND FUTURE WORKS

In this paper, we propose a joint source channel coding approach to H.264/AVC video transmission over wireless networks. We employ both data partitioning mode and error concealment of the H.264/AVC extended profile. The second tool is used for most of the modern video decoders due to its efficiency. The proposed scheme is based on an unequal error protection using ReedSolomon codes. The UEP scheme was designed based on the type of NALUs and their size to allocate jointly the channel code rate.

Our proposal has proven effective over the equal error protection against the PSNR and visual quality by using strong protection to the packets of type A. We plan to integrate FEC in MAC layer using an RS code; the unrecoverable packets will be passed to the Application FEC decoder process which tries to recover them. We are also planning to compensate the Application Forward Error Correction by a low-overhead ARQ. When an uncorrectable error is detected, a selective ARQ system requests retransmission only for the uncorrectable A packets which reduces the frequencies of retransmission as well. This combination can provide higher reliability than an FEC system alone and higher throughput than the system with ARQ only. Last but not least, an optimization of the code rate allocation algorithm could reduce the computational complexity which can save energy consumption.

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