EVALUATING THE ROBUSTNESS OF COMMERCIAL VIDEO CODECS ON WIRELESS NETWORKS

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Abstract

Currently, the research and development of multimedia networking systems is getting an great impulse due to the demand of applications and services from the entertainment and audio-visual industry. Both, networks and media coding systems are tightly coupled with this kind of applications. In particular, we are working with video transmission over wireless networks, where the poor quality of transport service of these networks becomes the task of sending video a very exciting challenge. In this paper, we will study the robustness of commercial implementations of the most popular video coding techniques (i.e.: MPEG-4, H.263 and MJPEG) when video is sent across a wireless ad-hoc network. We will analyze the impact on the reconstructed video quality of the behaviour of wireless network. Experimental results show that those video codecs that do not employ temporal redundancy (MJPEG) reduction are significantly more robust that the others. However, MJPEG offers very poor video quality when it works at low to very-low bit rates. Finally, H.263 video codec offers the best results in terms of robustness, but if video quality is the main target, then MPEG-4 (DivX) would be the best candidate.

Key Words
Video Coding, Wireless Networks, Robust Video Transmission, Performance Evaluation.

1. Introduction

The coding and transmission of compressed video streams over existing and future communications networks with non-guaranteed QoS presents many exciting challenges. Media-based error recovery techniques are necessary for a wide range of applications/environments: interactive video over the internet, personal video communications over wireless networks, and digital video broadcasting over satellite and cable networks, to name just a few. This kind of techniques has recently received a lot of attention from researchers in academia and industry.

In a noisy or packet lossy environment, as wireless ad-hoc networks [1], video error resilience techniques are necessary due to the nature of compressed video bit streams. For example, standard-based compressed video bitstreams employ Variable Length Codes (VLCs) as means of entropy coding. A single bit error present in VLC coded video data can lead to a loss of synchronization between the encoder and decoder, resulting in the loss of many video blocks. Multiple bit errors, which are usually due to burst channel errors [2] or to packet loss [3,4], may lead to the loss of partial or complete video frames, causing error propagation in the temporal dimension. This propagation is a direct result of motion compensation, which is usually used to reduce video temporal redundancies.

In such network environments, video codecs should be able to protect the video compressed stream before transmission and conceal network errors during the decoding process. The ability to efficiently perform these tasks determines the robustness degree of a video codec. This performance metric needs to be taken into account for choosing/designing video coding systems specially suited for wireless multimedia applications.

In this paper, we analyze the behaviour of several commercial video codecs. In particular, we will study their robustness when transmitting a compressed video stream through a wireless channel. The obtained results will allow us to determine the importance of the robustness behavior with respect to compression rate and video quality when delivering video over error-prone networks.

The organization of this paper is the following: In section 2 we will present proposed wireless channel model. In sections 3 and 4 we describe the simulation framework for evaluating the robustness of video codecs and the evaluation results. Finally, in section 5, some conclusions are drawn.

2. Wireless channel model

The wireless data channel is modelled using Log-normal Shadowing model [5]. This model is an evolution of the Log-distance path loss model takes into consideration that the surrounding environmental arrangement may be very

different given two different locations with the same transmitter-receiver distance. Seminal work by Cox, Murray and Norris [6] have measured the path loss PL(d) at any value d, to be random and distributed log-normally about the mean distance-dependent value. That is:

$$PL(d)[dB] = \overline{PL}(d) + X_\sigma = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right) + X_\sigma \quad (1)$$

The power measured at the receiver is calculated as:

$$P_r(d)[dBm] = P_t[dBm] - PL(d)[dB] \quad (2)$$

where X_σ is a zero-mean Gaussian distributed random variable (in dB) with standard deviation σ. Since PL(d) is a random variable with a normal distribution in dB about the distance-dependent mean, so is Pr(d), and the Q-function can be used to determine the probability that the received signal level will exceed a given value γ can be calculated from the cumulative density function:

$$\Pr[P_r(d) > \gamma] = Q\left(\frac{\gamma - \overline{P_r(d)}}{\sigma}\right) \quad (3)$$

So, we adopted four parameters to describe a channel model, respectively: node's distance d, a path loss exponent n, the standard deviation σ of the Gaussian distribution and the γ factor. From these parameters, the two basic characterizing values are d and γ. The first one is related to the path distance, and the second one identifies the threshold power level that determines if packets will be received or not. In the evaluation section we will propose different channel models varying these parameters in order to represent typical in-building propagation scenarios.
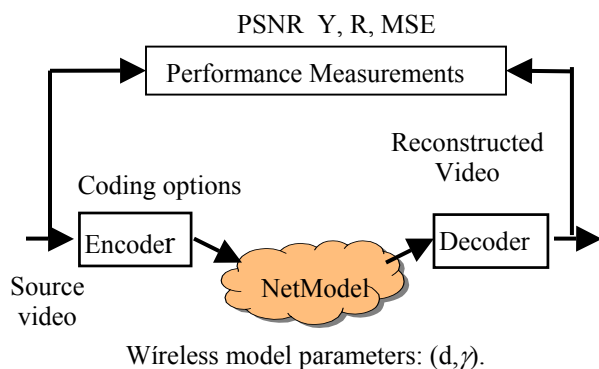

Fig. 1. Evaluation framework for testing video codec resilience

3. Evaluation framework

In order to study the robustness of whatever video codec we have designed the framework shown in Fig. 1. As it can be seen, we can take any input video sequence to encode it with the desired coding options.

Then, the resulting compressed bitstream is decomposed in packets. The wireless network model will decide which packets are going to be lost. At the receiving side, the received packets will be used to reconstruct the video bitstream that will be supplied to the decoder. The decoder will output the reconstructed video after the encoding-transmission-decoding process. Then, we will be able to compare and measure the degradation of video quality due to the wireless channel packet loss.

Several software tools were developed under Microsoft Visual C++ 6.0 using the corresponding multimedia APIs for managing AVI streams and video compression manager.

3.1 Choosing input video sequences

For the evaluation of video codecs analyze their behaviour using as input some well-known test video sequences: Carphone, Coastguard and News. These sequences have different video properties with respect to image details and motion degree.

3.2 Selecting coding options

We have chosen three different and representative commercial codecs. They are the following:

1. DivX. AngelPotion V1-702
2. H.263. Intel I.263 Video Driver V2.55.016
3. MJPEG[1]: Codec de LEAD, versión 1.0.0.11

H.263 [7] is generally used in videoconference applications where very low bit rates are demanded for typically coding slow motion video. Also, this codec is very popular because takes part of H.32x ITU standards.

The DivX codec, MPEG4 [8] based, is also a very popular codec, but its main application is oriented to medium-high video quality coding applications (i.e.: TV broadcast, streaming video, HDTV coding, etc.).

Finally, an MJPEG [9] codec has been chosen as a reference, so we would see the robustness behaviour of video codecs that only exploit spatial redundancy.

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[1] We have tested several JPEG2000 codecs (as Morgan Multimedia, Image Power) for this work, unfortunately, those codecs do not tolerate data losses.

However, this kind of codecs offers low performance levels in terms of rate/distortion metric.

All the above codecs have several configuration parameters. In order, to reduce the number of simulation experiments, we have selected the best parameter set for each codec in order to achieve the best performance results. The only parameters we will modify are related with the bitrate adjustment.

The Intel H.263 codec has been configured with the following coding options:

- Advanced Prediction. For processors without MMX technology, this option uses faster compression options (no effect for processors with MMX).
- Deblocking Filter. Provide subjective improvement by reducing blocking artefacts. However, it slightly blurs the image frame.
- Unrestricted Motion Vector. Useful for high motion sequences, in particular, those with high motion level.
- Bitrate is adjusted with quality and bitrate parameters.

The parameters selected for the MJPEG codec are the proprietary LEAD Compression format and never interleave. Bitrate is adjusted through the quality parameter. For the DivX codec we have selected the following settings:

- Keyframe every 8 seconds: we can select the key frame interval.
- Quality 100%: we can choose a relative quality, inside the ranges due to the others parameters.
- The bitrate is adjusted changing the bitrate parameter.

3.3 Performance Metrics

We will use the Peak Signal-to-Noise Ratio (PSNR) of the luminance colour component (PSNR_Y) for objective quality comparisons.

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \qquad (4)$$

For the robustness evaluation we will define our own metric, we call it R, and is defined as an average value of robustness under different network scenarios.

$$R = \frac{r_{(2,7)} + r_{(2.6,7)} + r_{(3,7)}}{3} \qquad (5)$$

where

$$r_{(d,\gamma)} = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{Q_{[orig]}^i}{Q_{[d,\gamma]}^i}\right) \ / \ 0 < r_{(d,\gamma)} \le 1 \qquad (6)$$

being

$r_{(d,\gamma)}$: Robustness with wireless channel model [d, γ].

N: Number of frames.

$Q_{(d,\gamma)}^i$: MSE of the frame "i" with a channel [d, γ]

Q_{orig}^i: MSE of frame "i" with a error-free channel.

3.4 Evaluating the proposed codecs

We use Carphone as a reference sequence to define three bitrates corresponding with three compression levels: High, medium, and low. The keyframe interval for DivX and H.263 codecs was fixed to 25.

Table I shows the results for Carphone sequence, for the rest of video sequences the corresponding codec parameters were adjusted to achieve similar bitrates.

TABLE I
FIXING BITRATE AND QUALITY LEVELS FOR CARPHONE VIDEO SEQUENCE

Codec	Kbps(PSNRY)
DivX-High	63 (36.78)
DivX-Medium	196 (40.91)
DivX-Low	534 (44.76)
H.263-High	63 (35.70)
H.263-Medium	196 (39.60)
H.263-Low	535 (42.52)
MJPEG-Medium	204 (33.57)
M-JPEG-Low	532 (38.78)

Also, in figure 2, we can see the differences in terms of video quality by using the luminance PSNR (PSNR_Y) metric.

It can be seeing that in all sequences, at the same compression rate, DivX gets the best quality results. The next in the list is H.263 and finally MJPEG, as expected

4. Simulation results

We want analyze the impact of packet loss in a wireless channel, and the robustness of each codec under different wireless channel model parameters. First, we analyze the impact of the packet size in the robustness. Then, fixing packet size, we analyze the codec behaviour and, finally, we analyze the impact of the keyframe interval.

4.1 Impact of Packet Size

As we can see at Figure 3, the packet size has an important influence in the robustness of the video sequence when using the proposed wireless channel model. In general terms, the robustness of video transmission increases when packet size also increases, independently of the target compression rate.

This is due to distribution of lost packets in the proposed wireless channel model. As it can be seen, the probability of loose one packet increases when packets become shorter. For packet sizes greater than 2048 bytes, the robustness is very similar. That is due to the frame size and the packetization scheme. When the frame fits in one packet, increasing the packet size do not affect to the robustness.

4.2 Evaluating Robustness of Selected Codecs

As expected, the MJPEG codec has the highest robustness with the analyzed channel model, due to the independence between consecutive frames at encoding time (only spatial redundancy is exploited in the video source sequence). With this codec, when one packet is lost, the error produced at the decoding side will only affect to the frame associated with this packet. No error propagation will take place with these kind of video codecs, so by definition they will be more robust than the others. We can see this behaviour in Fig. 4. However, at similar compression rates, this codec have the poorest quality. So, if we have limitations in terms of available bandwidth, this kind of video codecs, being more robust to channel errors, will no be the most adequate candidates.
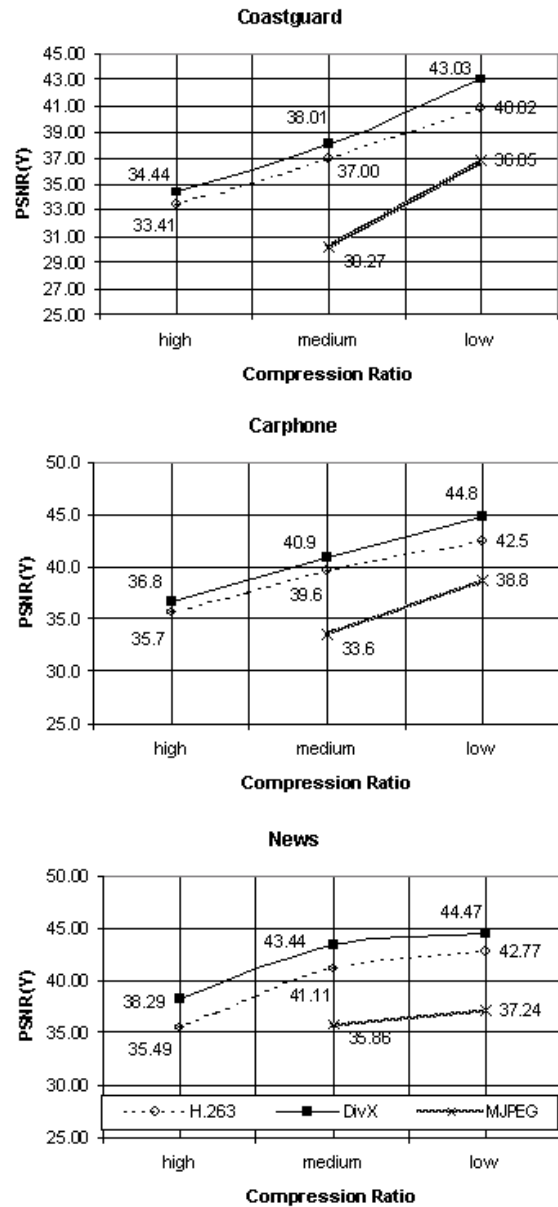
Fig. 2. Comparing the quality of proposed video codecs for Carphone, Coastguard, and News video sequences at different bitrates.
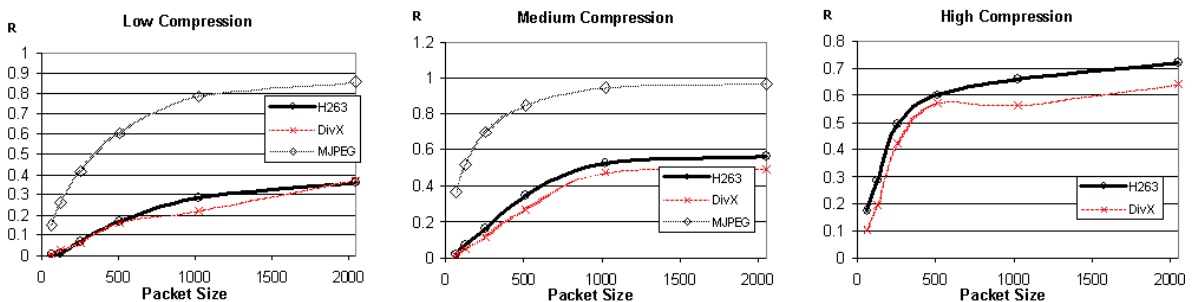
Fig. 3. Impact of the packet size on the video robustness at different compression rates (Carphone sequence).

Analyzing those codecs, we can see that H.263 is the more robust one, especially at high and medium compression rates. This fact may be mainly due to the design decisions taken in the H.263 codec, being more important to increase the robustness than put more efforts to obtain high quality video streams. Notice that H.263 codec is intended for videoconferencing applications, where is more important get very low bitrates, low coding latencies and video resilience. However, DivX is more appropriate for other kind of applications where the final video quality is the more important performance metric. Although DivX is the worst codec in terms of robustness, it offers high quality video coding streams that in some cases obtain similar robustness levels than H.263 at medium compression rates.

For that reason and, in order to use a common packet size for many transmission protocols, we will fix the packet size to 512 bytes.

4.3 Impact of Keyframe Interval

Now, we are going to evaluate the impact of the keyframe interval parameter on the final video robustness. The expected behaviour of this parameter is an increase of the video robustness as the keyframe interval becomes shorter, being closer to the MJPEG behaviour (keyframe interval is 1).

We can see this effect in Fig. 5, where the robustness metric is computed for the three video sequences with 25, 50 and 100, keyframe interval values. The results show that increasing the keyframe interval becomes H.263 and DivX codecs less robust, because the errors are propagated across longer GOPs.

The obtained results show a very similar behavior at low compression rates. However, as compression rate increases the H.263 codec gains in robustness, being significantly superior at high compression rates.

5. Conclusions

We have evaluated the robustness of three commercial video codecs by using a simulation framework where video coded streams are sent over a wireless channel model, in order to test their ability to recover from errors.
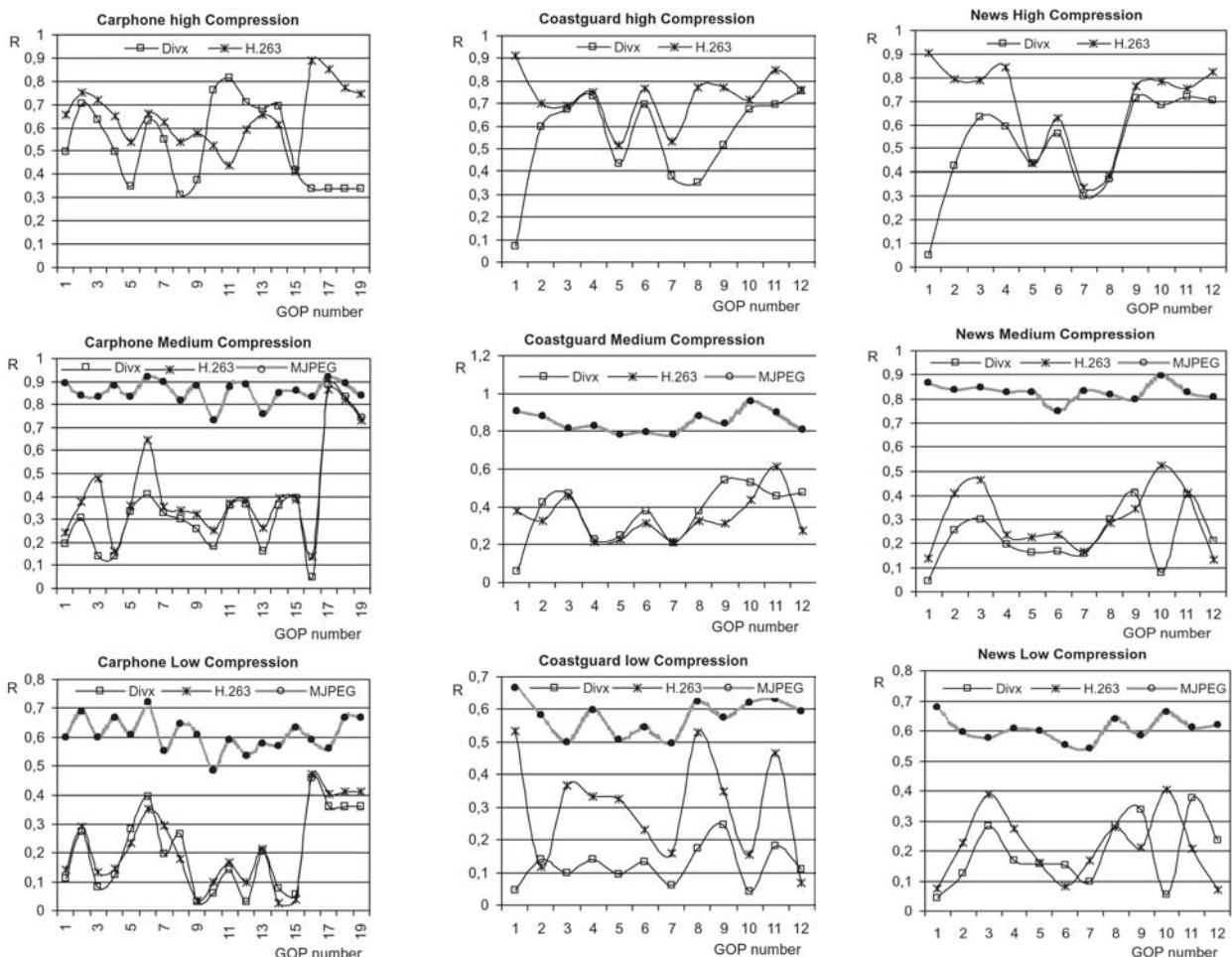

Fig. 4. Robustness behavior of video codecs using the three video sequences with a 512 bytes packet size at different compression rates.
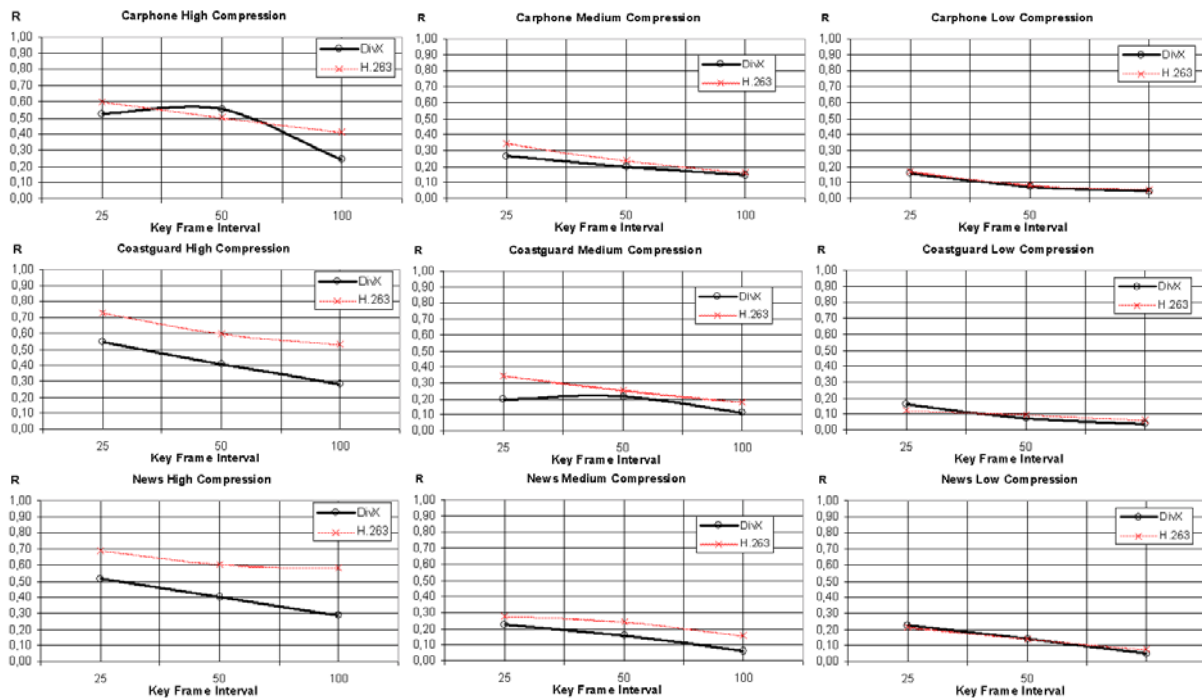
Fig. 5. Robustness behavior of video codecs at different compression rates, varying the keyframe

In our experiments we show that H.263 video codec gets, in general, the best robustness at high and medium video compression rates, especially with low-motion video sequences. When working at low compression rates, both codecs have a similar behaviour but, due to the better quality of DivX, this codec would be the most appropriate if applications require good video quality.

Finally, it is seem clear that, for all the video codecs tested on our proposed framework, and independently of motion degree of video sequences, is convenient to adjust the keyframe interval as low as possible in order to avoid error propagation

6. Acknowledgement

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