A Survey on Robust Wireless JPEG 2000 Images and Video Transmission Systems

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***Abstract*—This paper proposes a survey of robust wireless JPEG 2000 images and video transmission systems. The performance of the presented systems is discussed and compared both in terms of time consumption and in terms of robustness against transmission errors. Some opened tracks are then discuss with a special emphasis on efficient scalable wireless JPEG 2000 image and video transmission schemes.**

Keywords- motion JPEG 2000; wireless network; video streaming; Reed-Solomon codes, Forward Error Correction.

I. INTRODUCTION

Nowadays, more and more multimedia applications integrate wireless transmission functionalities. Wireless networks are suitable for those types of applications, due to their ease of deployment and because they yield tremendous advantages in terms of mobility of User Equipment (UE). However, wireless networks are subject to a high level of transmission errors because they rely on radio waves whose characteristics are highly dependent of the transmission environment.

In wireless video transmission applications like the one considered in this paper and presented in Figure 1, effective data protection is a crucial issue.

JPEG 2000, the newest image representation standard, addresses this issue firstly by including predefined error resilient tools in his core encoding system (part 1) and going straightforward by defining in its 11th part called wireless JPEG 2000 (JPWL) a set of error resilient techniques to improve the transmission of JPEG 2000 codestreams over error-prone wireless channel

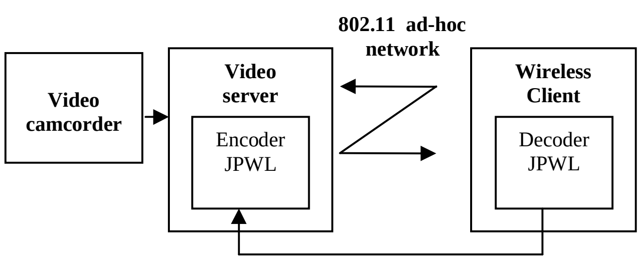

Fig. 1. Wireless video streaming system

II. OVERVIEW OF JPEG 2000 AND WIRELESS JPEG 2000

A. JPEG 2000

JPEG 2000 is the newest image compression standard completing the existing JPEG standard [1].

The interest for JPEG 2000 is growing since the Digital Cinema Initiatives (DCI) has selected JPEG 2000 for future distribution of motion pictures.

Its main characteristics are: lossy or lossless compression modes; resolution, quality and spatial scalability; transmission and progressive image reconstruction; error resilience for low bit rate mobile applications; Region Of Interest (ROI) functionality, etc.

Part 1 of the standard defines different tools allowing the decoder to detect errors in the transmitted codestream, to select the erroneous part of the code and to synchronise the decoder in order to avoid decoder crash. Even if those tools give a certain level of protection from transmission errors, they become ineffective when the transmission channel experiment high bit error rate. Wireless JPEG 2000 (JPEG 2000 11th part) addressed this issue by defining techniques to make JPEG 2000 codestream more resilient to transmissions errors in wireless systems.

B. Wireless JPEG 2000 (JPWL)

Wireless JPEG (JPWL) specifies error resilience tools such as Forward Error correction (FEC), interleaving, unequal error protection.

In this paper we present a wireless JPEG 2000 video streaming system based on the recommendations of JPWL final draft [2].

In [3], the description of the JPWL system is presented and the performance of its Error Protection Block (EPB) is evaluated. A fully JPEG 2000 Part 1 compliant backward compatible error protection scheme is proposed in [4]. A memoryless Binary Symmetric Channel (BSC) is used for simulations both in [4] and [3]. However, as packets errors mainly occur in bursts, the channel model considered in those works is not realistic. Moreover JPEG 2000 codestreams interleaving is not considered in [4].

In this paper we address the problem of robust and efficient JPEG 2000 images and video transmission over wireless networks. The paper is organized as follows: In section II, we

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present a state of art of wireless JPEG 2000 multimedia communication systems along with the challenges to overcome in terms of codestreams protection against transmission errors. In section III, we provide an overview of channel coding techniques for efficient JPEG 2000 based multimedia networking. Finally section IV, provides discussions and prospective issues for future distribution of motion JPEG 2000 images and video over wireless networks.

III. Wireless JPEG 2000 multimedia communication system and its challenges

In high error rate environments such as wireless channels, data protection is mandatory for efficient transmission of images and video. In this context, Wireless JPEG 2000 the 11th part of JPEG 2000 [2] uses different techniques such as data interleaving, Forward Error Correction (FEC) with Reed-Solomon (RS) codes etc. in order to enhance the protection of JPEG 2000 codestreams against transmission errors.

In wireless multimedia system such as the one considered in this paper (see Figure 1), a straightforward FEC methodology is applying FEC uniformly over the entire stream (Equal Error Correction - EEP). However, for hierarchical codes such as JPEG 2000, Unequal Error

Protection (UEP) which assigns different FEC to different portion of codestream has been considered as a suitable protection scheme.

Since wireless channels' characteristics depend on the transmission environment, the packet loss rate in the system also changes dynamically. Thus a priori FEC rate allocation schemes such as the one proposed in [5] are less efficient. Two families of data protection schemes address this issue by taking the wireless channel characteristics into account in order to dynamically assign the FEC rate for JPEG 2000 based images/video. The first family is based on a dynamic layer-oriented unequal error protection methodology whereas the second relies on a dynamic packet-oriented unequal error protection methodology. Hence, in the first case, powerful RS codes are assigned to most important layers and less robust codes are used for the protection of less important layers. It is worth noting that in this case, all the JPEG 2000 packets belonging to the same layer are protected with the same selected RS code. Examples of layer-oriented FEC rate allocation schemes are available in [6] and [7]. On the other side, in packet-oriented FEC rate allocation schemes such as the one presented in [7], RS codes are assigned by decreasing order of packets importance. In [7], we demonstrate that the proposed optimal packet-oriented FEC rate allocation is more efficient than the layer-oriented FEC rate allocation scheme presented in [6] and [7]. However, layer-based FEC rate allocation schemes have low complexity while packet-oriented FEC allocation methodologies are complex especially when the number of packets in the codestream is high. In this case, packet oriented FEC schemes are unpractical for highly time-constrained images/video streaming applications. In this case switching to a layer oriented FEC rate allocation scheme is more interesting.

The smart FEC rate allocation scheme proposed in [9] address this issue by allowing switching from a packet oriented FEC scheme to a layer oriented scheme such as the ones proposed in [10].

In section III.A we present the packet oriented system proposed in [7] to address the issue of robust JPEG 2000 images and video transmission over wireless network. Then in section III.B the layer-oriented scheme proposed in [10] is described. Finally, in section III.C we present the system proposed in [9] to unify packet and layer based scheme.

A. Optimal Packet-oriented FEC rate allocation scheme for robust Wireless JPEG 2000 based multimedia transmission

The functionalities of the proposed JPWL packet-oriented system are presented in Figure 2 The aim of this system is to efficiently transmit a Motion JPEG 2000 (MJ2) video sequence through MANET channel traces.

The system is described as follows:

The input of the JPWL codec is a Motion JPEG 2000 (MJ2) file. The JPEG 2000 codestreams included in the MJ2 file are extracted and indexed.

These indexed codestreams are transmitted to the JPWL encoder ([2] presents a more accurate description of the used JPWL encoder) which applies FEC at the specified rate and adds the JPWL markers in order to make the codestream compliant to Wireless JPEG 2000 standard. At this stage, frames are still JPEG 2000 part 1 compliant, which means that any JPEG 2000 decoder is able to decode them.

To increase JPWL frames robustness, an interleaving mechanism is processed before each frame transmission through the error-prone channel. This is a recommended mechanism for transmission over wireless channel where errors occur in burst (contiguous long sequence of errors). Thanks to interleaving the correlation between error sequences is reduced.

The interleaving step is followed by RTP packetization. In this process, JPEG 2000 codestream data and other types of data are integrated into RTP packets as described in [11].

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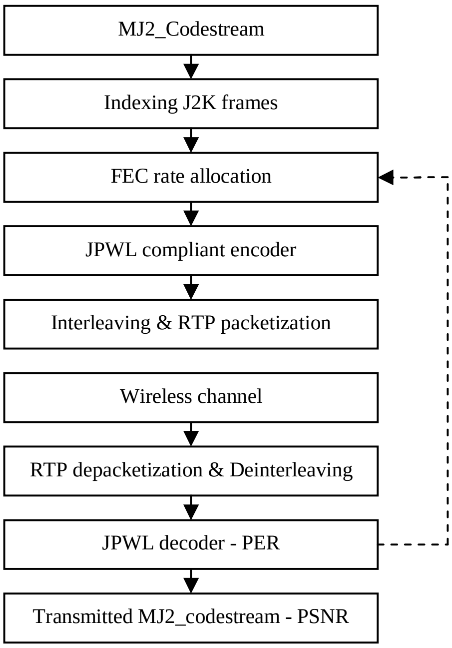

Fig. 2. JPWL based system functionalities

RTP packets are then transmitted through the wireless channel which is modelled in this work by a Gilbert channel model. At the decoder side, after depacketization, the JPWL decoder corrects and decodes the received JPWL codestreams and rebuilds the JPEG 2000 frames. At this stage, parameters such as Packet Error Rate (PER) are extracted, increasing the knowledge of the channel state. The decoder sends extracted parameters back to the JPWL encoder via the Up link. The last process of the transmission chain is the comparison between the transmitted and the decoded image/video. Figure 3 presents JPEG 2000 codestreams transmission through the JPWL packet-oriented FEC system

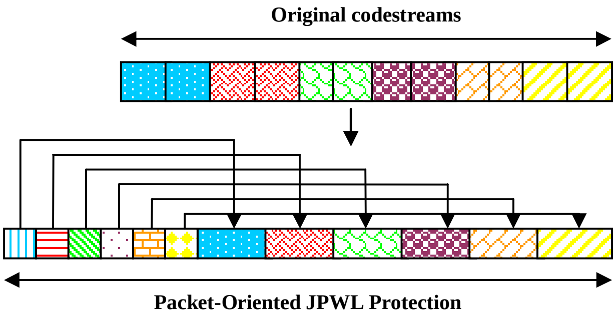

Fig. 3. JPEG 2000 codestreams transmission through the JPWL packet-oriented FEC system

B. Optimal Layer-oriented FEC rate allocation scheme for robust Wireless JPEG 2000 based multimedia transmission

Unlike the system described in [7], where the FEC rate allocation scheme is packet oriented, in the current system we consider a layer oriented FEC rate allocation scheme. In other words the difference between both systems is the FEC rate allocation module. Actually, in the packet oriented scheme the redundancy is added by taking the packets importance into account (see Figure 3) while in the layer oriented scheme we rely on layers importance to allocate the adequate RS codes (see Figure 4).

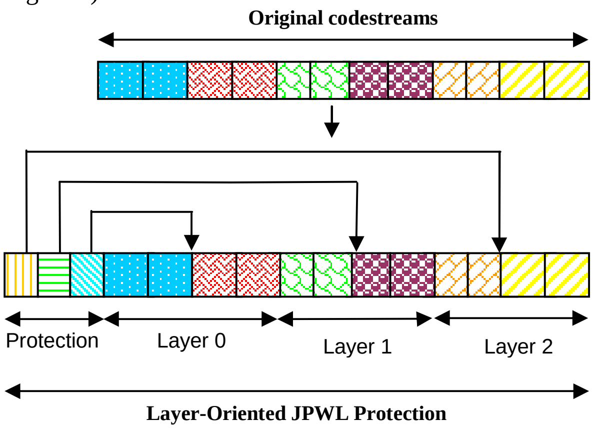

Fig. 4. A JPEG 2000 codestreams transmission through the JPWL layer-oriented FEC system

C. Smart combined Packet/layer based FEC rate allocation scheme for robust Wireless JPEG 2000 based multimedia transmission

The functionalities of the proposed smart JPWL based system are presented in Figure 5.

In this system, indexed JPEG 2000 codestreams are transmitted to the smart FEC rate allocation module. If the number of data packets available in the codestreams is low (typically under the defined smart threshold), the smart module uses the optimal packet-oriented FEC rate allocation methodology presented in [7] whereas it switches to the dynamic layer-oriented FEC rate allocation methodology presented in [10] when the number of data packets is high. Ones the protection rate determined, the codestreams are transmitted to the JPWL encoder which applies FEC at the specified rate and adds the JPWL markers in order to make the codestream compliant to Wireless JPEG 2000 standard. Hence, Figures 3 and 4 correspond to the JPWL protection where redundant data are added to original codestreams. If the JPEG 2000 Frame which is being processed is constituted by less than a defined threshold (*smart_thresh*) , then the smart FEC rate allocation scheme emulates a scenario similar to the one presented in Figure 3 (packet-oriented FEC rate allocation). Otherwise, it emulates the scenario of Figure 4 (dynamic layer-oriented FEC rate allocation). Protected data are then interleaved and transmitted.

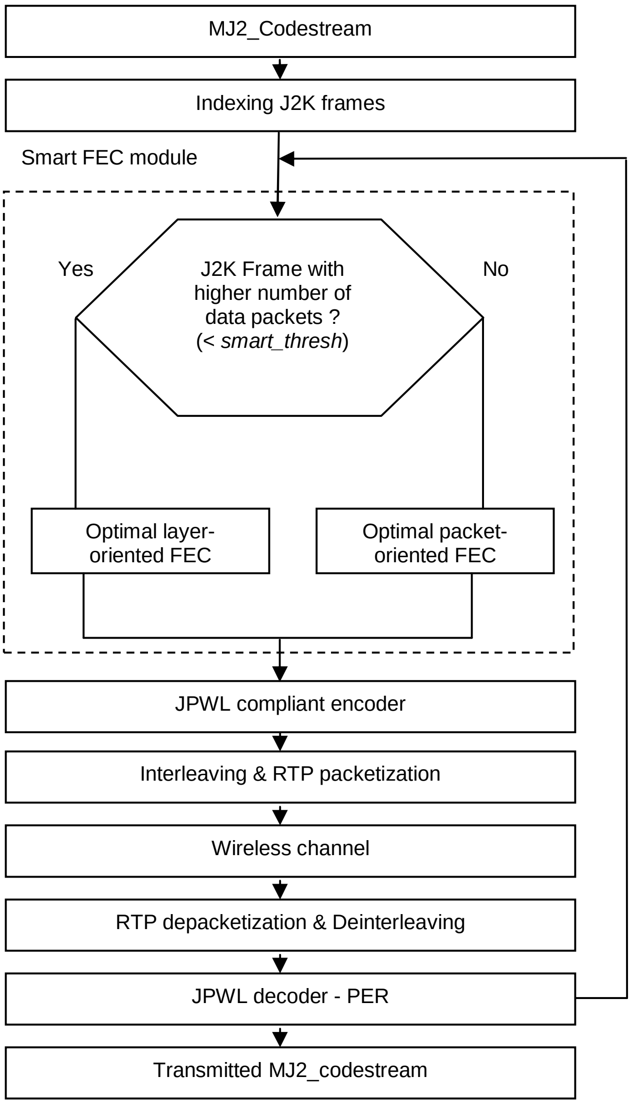

Fig. 5. JPEG 2000 transmission over the smart JPWL system

The interest of the smart FEC rate allocation scheme is to allow switching from the scenario presented in Figure 3 to the scenario described in Figure 4, reducing by this way the complexity of the FEC rate allocation process. Hence, in case of highly layered images/video streaming, the time needed to select the suited FEC rate is significantly reduced. In the following section we present the packet-oriented and layer-oriented algorithm considered in this paper.

IV. RESULTS

A. Performance of layer based FEC scheme in terms of time consumption

In Figure 6 the run time of the proposed layer based FEC rate allocation scheme is plotted versus the number of data packets available in the JPEG 2000 codestreams. This curve is compared to the one achieved using the optimal packet oriented FEC rate allocation scheme [7]. These results are achieved using an Intel core Duo CPU 2.9 Ghz Workstation.

As packet-oriented and layer oriented schemes are linked by the number of layers available in each image, we vary this parameter in order to derive some comparable results. In the considered scenario, the number of available resolution and component of JPEG 2000 frames are fixed (resolution = 10 and component = 1) because these parameters do not impact the time-performance of layer oriented FEC rate allocation schemes. In Figure 6 each packet (i) corresponds to a specific JPEG 2000 frame (with a specific quality layer).

In this scenario, the available bandwidth in the system is set to 18 Mbits/s ($B_{av} = 18\ Mbits/s$). It is worth noting that in practice few existing JPEG 2000 codecs allow high quality scalability and to our knowledge, none of them can handle more than 50 quality layers. Hence, the considered scenario allows generalization to future high quality layer scalable FEC rate allocation systems.

In Figure 6 we notice that both layer and packet oriented scheme have a run time linearly increasing with the number of packets available in the codestreams. However, the optimal layer based FEC scheme is significantly less time consuming than the packet based FEC scheme. For codestreams containing less than 1000 packets (quality layers $\leq$ 10) the packet oriented FEC scheme is 3 times more time consuming than our optimal layer based FEC scheme. For JPEG 2000 codestreams, whose number of packets is between 1000 and 5000 (quality layers between 10 and 50) the packet oriented scheme is up to 5 times the run time of the layer based FEC scheme. Since existing JPEG 2000 codecs handle less than 50 quality layers, our proposed optimal layer based scheme is a good candidate for real-time JPEG 2000 codestreams over wireless channel as its yields low time consumption.

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The proposed optimal layer based scheme, due to its low time consumption, could be viewed as a good candidate for future high quality layer scalable wireless JPEG 2000 based images and video streaming applications.

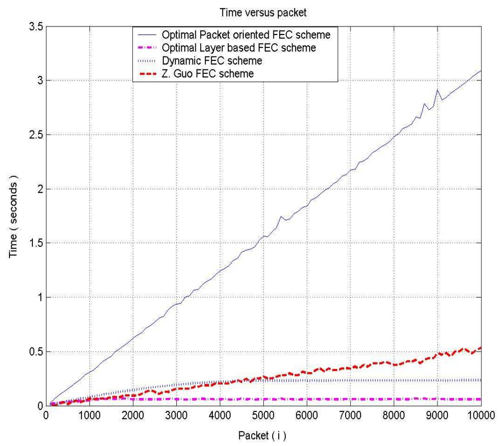

Fig.6 Time versus packets: Fixed image resolution (R=10) –Varying quality layers (0 to 100) – One component (C =1)

Although the layer based scheme achieves good performances in terms of time consumption in comparison to packet oriented FEC rate allocation schemes, the last ones present better performance in terms of visualization quality especially for highly noisy channels. In the following section we demonstrate the effectiveness of the optimal layer based FEC scheme thanks to a client/server application of Motion JPEG 2000 video streaming over real ad-hoc network traces.

B. Packet-oriented and Layer-oriented FEC rate allocation for Motion JPEG 2000 video streaming over real ad-hoc network traces

In this section we present the results achieved while streaming Motion JPEG 2000 based video over real ad-hoc network channel traces [13][13] and we demonstrate that the proposed optimal layer based scheme outperforms existing layer oriented FEC schemes even if for highly noisy channel it is less efficient than packet oriented FEC scheme. The comparison is handled both in terms of Structural Similarity (SSIM) [14] and in terms of successful decoding rate. We derive the Mean SSIM metric of the Motion JPEG 2000 video sequence by averaging the SSIM metrics of the JPEG 2000 images contained on the considered video sequence. It is worth noting that each SSIM measure derived is associated to a successful decoding rate metric which corresponds to decoder crash avoidance on the basis of 1000 transmission trials.

The considered wireless channel traces are available in [13] and the video sequence used is *speedway.mj2* [12] containing 200 JPEG 2000 frames generated with an overall compression ratio of 20 for the base layer, 10 for the second layer and 5 for the third layer. Figure 7 presents the successful decoding rate of the motion JPEG 2000 video sequence *speedway.mj2* [12] transmission over real ad-hoc network channel traces [13]. We observe that for highly noisy channels ($C/N \leq 15\,dB$), the proposed optimal layer outperforms other layer based FEC schemes but is less efficient than the packet oriented scheme. For noisy channel ($15\,dB \leq C/N \leq 18\,dB$), we notice that all layer based UEP schemes exhibit similar performances in terms of successful decoding rate.

For low noisy channel ($C/N \geq 18\,dB$) all the FEC schemes yield the same improvement in terms of successful decoding rate.

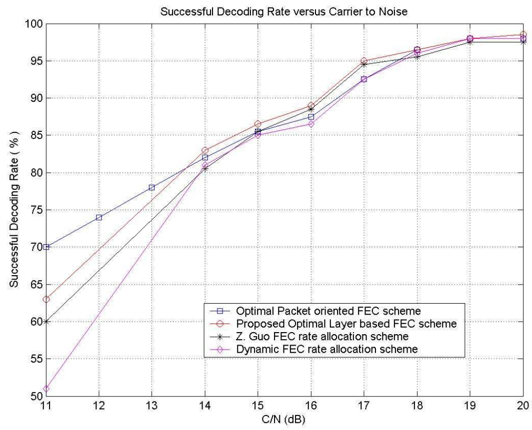

Fig.7 Successful decoding rate versus Carrier to Noise Ratio

In Figure 8 we show that our proposed optimal layer based FEC rate allocation scheme still outperforms other layer based schemes in terms of Mean SSIM. This is due to the fact that the base layer which is the most important part of the codestreams is highly protected in our proposed scheme, in comparison to other layer based schemes, guaranteeing this way a good quality for the visualization.

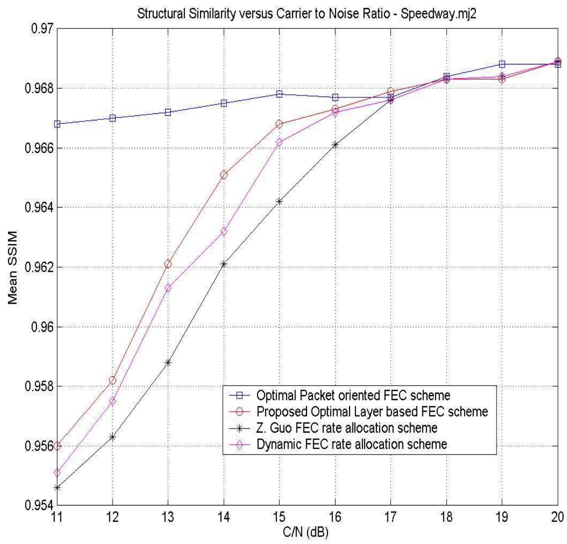

Fig.8 Mean Structural Similarity versus Carrier to Noise Ratio

V. Conclusion and Open Issue : Scalable JPEG 2000 Transmission

Many problems are still to be addressed in the framework of JPEG 2000 codestreams transmission over wireless networks. Image scalability based on dynamic available bandwidth estimation is one of those problems. In the literature, proposed image scalable systems have been implemented using a fixed available bandwidth in their considered scenarios [15], [16]. This assumption is no longer true in wireless systems because they rely on radio waves whose characteristics depend on the transmission environment. Moreover, few of the proposed systems addressed simultaneously the bandwidth estimation problem and the issue of smoothness for JPEG 2000 codestreams scalability. In [17], we addresses both issues by proposing a scalable and non aggressive wireless JPEG 2000 image and video transmission algorithm based on a dynamic bandwidth estimation tool.

The main limitation of the scalable system proposed in [17] is that it handles only one wireless client. However, this limitation could be overcome by generalizing the proposed algorithm to multiple wireless clients' scenario. We propose a framework for this generalization which opens the path for efficient wireless JPEG 2000 codestreams transmission in Next Generation Networks which are characterize by the cohabitation of multiples wireless devices having different standards requirements and different capacities.

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