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METHOD FOR UNEQUAL ERROR PROTECTION IN DVB-H FOR MOBILE TELEVISION

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ABSTRACT

This paper introduces a method for unequal error protection (UEP) of media data in a time-sliced DVB-H channel. Media datagrams are assigned priorities using some a-priori knowledge. Datagrams covering a certain period of playback time are first grouped based on the priority assignment. Each group is then protected using Reed–Solomon forward error correction (FEC) codes and packed into multi-protocol encapsulation (MPE) FEC frames as defined by the DVB-H standard. All MPE-FEC frames for a certain period of playback time are then sent back to back without any delay between these MPE-FEC frames. This method of UEP is generic and can be tuned according to the priority assignment algorithm. Simulations using H.264/AVC video were conducted to evaluate the performance of the proposed method. It used a simple priority assignment algorithm. The resulting rate distortion graphs show good performance and an average luma peak signal-to-noise ratio (PSNR) improvement of up to 0.8 dB was achieved.

I. INTRODUCTION

Point-to-multipoint (PTM) wireless data communication using digital television broadcast networks has seen significant scientific interest in recent times. Broadcast networks provide a high bandwidth asymmetric communication link to a large audience. This technology is an excellent alternative for PTM communication when interactivity is not a priority and the target audience is large.

To enable data communication to handheld wireless mobile terminals the Digital Video Broadcasting (DVB) organization has defined a new standard: Digital Video Broadcasting-Handhelds (DVB-H) [1]. DVB-H is very closely based on Digital Video Broadcasting-Terrestrial (DVB-T) [2] and is backward compatible with it. DVB-T was found to be useful for mobile data communications. However, it was found to be insufficient to meet the harsh demands imposed by small handheld, battery-operated devices. Mobile handheld devices have strict power constraints and are more demanding with respect to data robustness when transmitted over highly error-prone radio channels.

To address these drawbacks, the DVB-H working group was formed, and in July 2004, released the final draft of the DVB-H standard. DVB-H uses the same basic concepts of DVB-T but adds additional link-layer features to solve the power constraint and robustness problems. The concept of time-slicing was introduced, reducing the average power consumption of a hand-held mobile terminal by as much as 90-95%. An optional enhancement using Reed-Solomon forward error correction (FEC) codes encapsulated into Multi-protocol encapsulated sections (MPE-FEC) was also introduced to provide added robustness required for hand-held mobile terminals. MPE-FEC improves the carrier-to noise (C/N) and Doppler performance in the DVB-H channel while also providing improved tolerance to impulse interference.

Although MPE-FEC provides the much needed data robustness in wireless channels, under very erroneous conditions it fails. Using a-priori knowledge of the transmitted media and tuning the way MPE-FEC is applied across the media datagrams can provide better robustness.

Unequal error protection (UEP) is such a scheme that uses a-priori knowledge of the media to differentially protect data using FEC. UEP has been used for visual coding in ways which can be coarsely grouped into three classes. The first class uses methods to protect important parts of coded data like headers, motion vectors and DCT coefficients more than other data as in [3]. The second class uses differential protection to layered coding as in [4]. The third class use bias based on the importance of different types of coded pictures in the overall presentation of the video content as in [5]. UEP has also been used for audio where coded frames and coded sample data are unequally protected as in [6].

Although many UEP schemes exist, none deal with a time-sliced DVB-H channel. The UEP scheme in [7] deals with the 3GPP’s multimedia broadcast/multicast service (MBMS) channel which is characteristically different from a DVB-H channel. This paper presents a novel method of UEP in a time sliced DVB-H channel. It uses intelligent manipulation of DVB-H time slicing parameters and smart grouping of datagrams into priorities. The method is validated using simulations that show the comparative performance with and without its use.

The rest of the paper is organised as follows. Section II briefly discusses the causes of wireless channel errors and techniques currently used to provide better reliability in wireless channel. Forward error correcting codes (FEC) are introduced in Section III and Section IV briefly introduces the concept of priorities in multimedia contents. DVB-H with its enhancements is described in Section V. Section VI details the new method for UEP in DVB-H. A simple simulation conducted to verify the use of UEP and its advantages is given in Section VII followed by the conclusions in Section VIII.

II. WIRELESS CHANNEL ERRORS

Erroneous data transmission over current generation networks is considered a part of the system’s normal operation. Depending on the mechanisms and medium of transmission the causes of errors vary. Wireless transmission errors occur due to physical radio channel characteristics like physical barriers in the environment, interference from other

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signals in the transmission area, multi-path propagation errors, and fading errors.

Among methods to provide reliability in wireless channels, two methods stand out. The first of these is protection using forward error correction (FEC) codes. Here additional parity information is added to the actual data which can then be used to correct data errors when they are detected. The second method is to use automatic repeat request (ARQ) techniques. Using this technique, when a receiver encounters a data loss, it requests the sender to resend the lost data. The server upon receiving such a request makes an identical copy of the lost data and resends it to the receiver.

ARQ techniques are effective when there is a feedback channel available. However, ARQ techniques can increase the transmission delay within the system due to request-response turn-around time. Furthermore, in PTM type transmission, using ARQ techniques is a challenge due to the possibility of request implosion at the sender. The implosion problem occurs when channel conditions for many receivers are bad and all these receivers simultaneously send resend-requests to the sender.

Some transmission channels, like DVB by its own, do not have a feedback channel. Furthermore, in a wireless PTM type channel, different receivers can experience different error conditions based on its location, interference from other signals, and due to receiver motion. FEC techniques have an advantage of correcting varying error conditions experienced by different receivers using the same codes for all the receivers. These reasons make FEC a preferred error resiliency mechanism for PTM type communications.

III. FORWARD ERROR CORRECTION

FEC codes transform some number of equal length k symbols into n symbols, where $n > k$, by adding $(n\text{-}k)$ additional symbols, called parity symbols. Ideally, an FEC code can reconstruct any k lost/corrupted symbols of the n symbols. This property is called Maximum Distance Separable (MDS) property and most practical FEC systems are bounded by this property. The Reed-Solomon (RS) FEC code is a good example of an FEC code that follows MDS property and is used by DVB-H.

FEC techniques, in general, can be classified into two types based on how it is applied to the data. The first is called media-unaware FEC. Media-unaware FECs are generic algorithms which work independent of the media it is protecting. While they do provide a good recovery mechanism, their bandwidth efficiency is usually suboptimal. The second technique is called media-aware FEC. It takes advantage of the knowledge about the type of media it is protecting and its importance in the overall quality of the transmitted media. However, media-aware FECs are tailored to specific media formats and incompatibility problems arise quite frequently.

Errors in wireless channels occur as clusters of bursts rather than isolated errors. Under heavy channel error conditions FEC cannot always recover the lost data. To minimize the probability of long burst errors, data interleaving is commonly used. Interleaving transforms long burst errors into smaller burst or isolated errors.

IV. PRIORITY ASSIGNMENT

Different components and data parts of multimedia contents contribute unequally to the perception quality of the multimedia content. For example, audio is considered subjectively more important than video in audio-visual contents like news and documentaries. Delving further into coding specifics, in hybrid video coding algorithms, such as MPEG-1, MPEG-2, MPEG-4 and H.264/AVC, picture frames used for reference (I, P pictures) is more important than picture frame that are not used for reference (B picture for MPEG-X and p non-reference pictures for H.264/AVC). Going even deeper into details of hybrid video coding algorithms, header data, motion vector information, and certain DCT coefficients are considered more important than other coded data. For audio, some audio coding schemes require the presence of codebook information before playback of the content can start, and here the packets carrying the codebook have a higher priority than the content packets.

Based on the importance of components or data-parts of a multimedia presentation (known a-priori), priority assignments can made. For example, audio can be assigned a higher priority than video (content dependent) and in video a reference picture can be allocated higher priority than non-reference picture. Based on these priorities, error resiliency methods such as FEC can be applied unequally: higher priority getting higher protection than lower priority data.

V. DVB-H

Broadcasting of data other than broadband digital television in DVB is called Data casting [8]. Data casting in DVB uses one of the six different profiles, each of them catering to applications with different requirements. These profiles are (a) Data piping (b) Data streaming (c) Multi-Protocol Encapsulation (MPE) (d) Data Carousals (e) Object Carousals and (f) Higher protocols based on asynchronous data streams.

DVB-H is designed to carry Internet Protocol (IP) [9] based data traffic. IP, being an addressable protocol, has special requirement different from what the DVB system was initially designed for. Hence, for seamless integration between the DVB and IP worlds, an intermediary translator capable of understanding both IP and DVB protocols is required. The MPE profile performs this job of protocol translation. Private data Digital Storage Media – Command and Control (DSM-CC) specification is used to encapsulate the OSI layer 3 datagrams into MPE sections. The MPE sections are then mapped onto MPEG-2 system layer transport stream (TS) packets [10].

A. MPE-FEC

MPE-FEC was included in DVB-H to improve the unfavourable carrier-to-noise (C/N) conditions typical of a wireless radio channel. It is an optional multiplexer-layer FEC code based on Reed-Solomon (RS) codes. MPE-FEC is

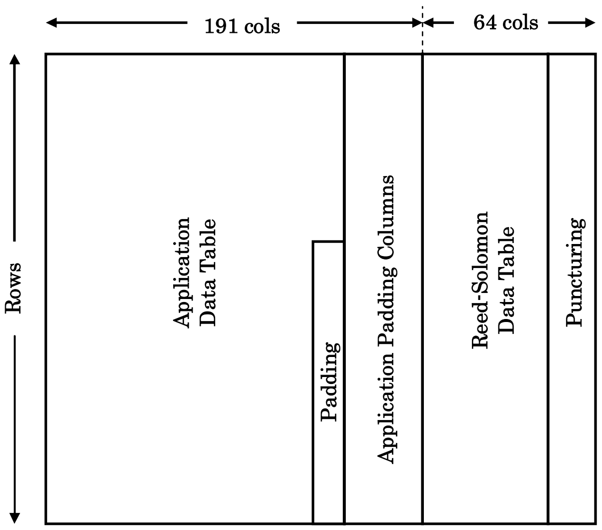

Figure 1: The MPE-FEC matrix structure.

computed over IP packets and encapsulated into MPE sections. MPE-FEC sections are transmitted such that an MPE-FEC ignorant receiver would have no problems receiving just the unprotected data.

To compute MPE-FEC, data (IP packets) are filled into an N x 191 matrix where each cell of the matrix hosts one byte of information and N denotes the number of rows in the matrix. The standard defines the value of N to be one of 256, 512, 768 or 1024. The datagrams are filled into the matrix column-wise. RS codes are computed for each row and concatenated such that the final size of the matrix is of size N x 255. The N x 191 part of the matrix is called the Application data table (ADT) and the next N x 64 part of the matrix is called the RS data table (RSDT). For rate-control and disallowing of IP packet fragmentation between two MPE-FEC frames in the standard, the ADT need not be completely filled. This unfilled part of the ADT is called padding. To control channel code-rate all 64 columns of RSDT need not be transmitted and the un-transmitted RSDT columns is called puncturing. The structure of an MPE-FEC matrix is shown in Figure 1 and further detailed information on the MPE-FEC matrix construction can be obtained from [8].

B. Time-slicing for power saving

Battery-operated mobile devices have a limited source of power. The power consumed in receiving, decoding and demodulating a standard full-bandwidth DVB-T signal would use up substantial amount of battery life in a short time. Time slicing of the MPE-FEC frames is used to solve this problem [11]. The data is received in bursts so that the receiver, utilizing control signals, remains inactive when no bursts are to be received. The bursts are sent at a significantly higher bit-rate compared to bit-rate when conventional bit rate management is used.

Time-slicing in DVB-H uses the delta-t method to signal the start of the next burst. Timing information delivered using delta-t method is relative. In other words, the delta-t time is the difference between the current time and the start of the next burst. The use of delta-t method to signal, removes the need for synchronization between the transmitter and receiver. Its use also provides flexibility since parameters such as burst size, burst duration, burst bandwidth and the off-times can be freely varied. Figure 2 shows two time-sliced bursts and parameters that define time-sliced bursts.

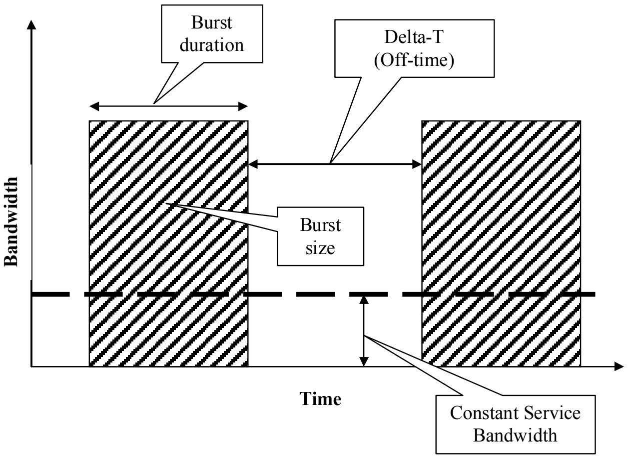

Figure 2: Time-slicing in DVB-H.

VI. METHOD FOR UEP IN DVB-H

A new method for UEP using MPE-FEC and time-slicing is described in this section. In this paper, a service is defined as a multiplex of multimedia packets that are of relevance to a receiver. For example, a multiplex of a video stream, the associated audio stream, and subtitling information relevant to a receiver can be considered to be a service.

The datagrams of a service are assigned priorities either manually or automatically using some a-priori knowledge. Taking a news broadcasting service as an e.g., the audio can have a higher priority than video which in turn has a higher priority than auxiliary media enhancement data like subtitle text. Continuing with the same example, further priority assignment can be made in the video bit stream such that reference picture datagrams such as datagrams of an Intra frame and referenced Inter picture can be assigned higher priority than datagrams of non-referenced Intra pictures. This priority labelling procedure can either be done at the IP Encapsulator or external to it.

The multiplexed media datagrams corresponding to certain duration (either in terms of decoding or output timestamps) are encapsulated into two or more MPE-FEC matrix according to their priority label. These MPE-FEC matrices are referred to as peer MPE-FEC matrices. The number of peer MPE-FEC matrices in a time-sliced burst is equal to the number of unique priority labels assigned to the datagrams. For example, if there are K priority labelled datagrams that can be transmitted in one time-sliced burst and there are P different priorities associated with the media datagrams of the service, then each of the K datagrams will be a part of one of P MPE-FEC peer matrices in the burst.

To construct the peer MPE-FEC matrices in a time-sliced burst, the datagrams are grouped using their priority labels.

The grouping procedure is performed on all the datagrams that go into the time-sliced burst. The grouped datagrams are arranged in ascending order such that the datagrams with the lowest priority comes first in the transmission order and the datagrams with the next higher priority comes next and continuing so forth until the datagram group that has the highest priority comes last in the transmission order. This fact holds true for all time-sliced bursts of a service. For example, K datagrams with L unique priority labels among them where $P = \{p_1, p_2, p_3, \ldots p_L\}$ is the set of L different priority labels, and where the priority ranking is such that $p_L < p_{(L-1)} < \ldots < p_2 < p_1$, then all datagrams are grouped in such a way that all datagrams with a priority label of p_L comes before all datagrams with priority label $p_{(L-1)}$ and continuing similarly until all datagrams with priority p_1 comes last.

The peer MPE-FEC matrices are transmitted back-to-back, i.e. there is no transmission delay or interval between the peer MPE-FEC matrices. One way to implement this is to consider delta-t between peer MPE-FEC matrices being equal to zero. This fact holds true for all time-slices burst of the service. The peer MPE-FEC matrices are arranged in ascending priority order, i.e. the lowest priority MPE-FEC matrix is sent first and the highest priority matrix is sent last. If a receiver starts the reception of the stream in the middle of the period when a certain set of peer MPE-FEC matrices are sent, it is likely that the receiver will receive at least the highest priority MPE-FEC matrix.

The choice of RSDT columns for all the MPE-FEC matrices in all the time-sliced bursts in the service should be such that the average service bit rate when using this method shall not overshoot the maximum allowed service bit rate. The MPE section headers for all sections in the peer MPE-FEC matrices other than the peer MPE-FEC matrix that contains the highest priority datagrams, sets delta-t value in their section headers to zero. Similarly, the MPE section headers of all sections in the peer MPE-FEC matrices set the maximum_burst_duration field as the maximum duration of the peer MPE-FEC matrix reception. The delta-t value in the MPE section headers of MPE-FEC matrix that consists of the datagrams with the highest priority is set to the time when the next time-sliced burst for the service starts. Figure 3 illustrates the method for construction of MPE-FEC matrix in the non UEP case and the UEP case.

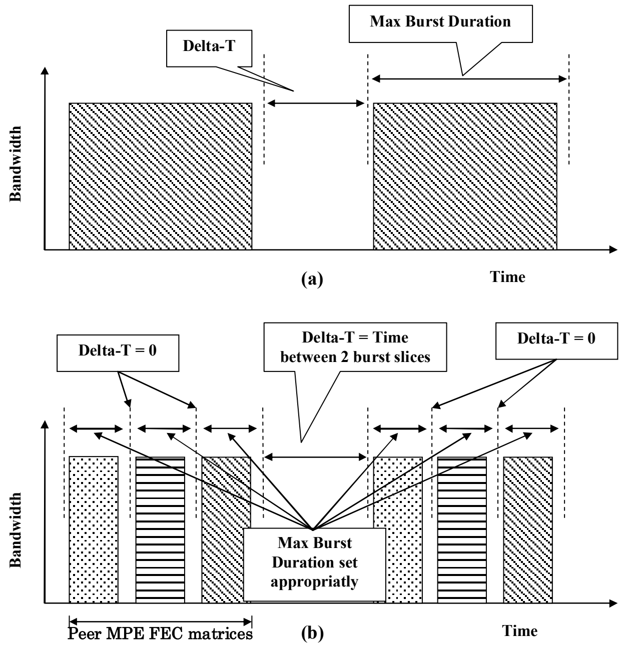

Figure 3: MPE-FEC matrix construction and transmission (a) Without UEP (b) With UEP.

VII. SIMULATIONS

Simulations were conducted to verify the performance of the UEP method described in this paper using a simple priority assignment algorithm. For simplifying simulations, a service consisted of a single H.264/AVC coded video stream.

A. *Simulation environment*

The simulations were carried out for two well known video sequences: Paris and Silent. Since the original lengths of these sequences were short to get any reliable statistics, the sequences were made longer by end to end concatenation. The final length of the video sequences after concatenation was 3000 picture frames. The videos were coded at 15 frames per second using a baseline H.264/AVC encoder. MPEG-2 TS error pattern with an error probability of 0.09 approximating a TU6 channel was created. The number of MPE-FEC rows was set to 512. Two priorities, the highest given to reference pictures (IDR and reference P pictures) and the lowest priority to non-reference p pictures was used. IDR frequency was set to 120 picture frames. The maximum slice-size was set to 1000 bytes and IPV6 was assumed for all simulations.

For PSNR comparison, a simple error-concealment algorithm was used. Lost slices were replaced in the decoder picture buffer (DPB) by a copy of the same slice in the previous picture in presentation order. When an entire picture is lost, a copy of the previous picture in presentation order is used as concealment for the lost picture in DPB.

B. *Simulation method*

For comparative statistics, simulations using UEP and without UEP was carried out. When using the non-UEP mode, 3/4 code-rate was used i.e. 191 ADT columns and 64 RSDT columns. The following algorithm was used iteratively for the entire coded bit stream.

1. Fill an MPE-FEC matrix at 3/4 code-rate. This would give a non-UEP MPE-FEC matrix.
2. In this non-UEP MPE-FEC frame identify the reference and non-reference frames and their respective IP packets.
3. Separate the reference and non-reference IP packets and form two peer MPE-FEC matrices one for the highest priority datagrams and the other for the lowest priority datagrams.
4. Protect each peer matrix with the appropriate RSDT columns. In our case the code rate was set to 95% of 64 columns for priority-1 peer MPE-FEC matrix and

5% of 64 columns to priority-2 MPE-FEC peer matrix.

It should be noted that by using the above algorithm, channel bit rates for both the UEP case and the non-UEP case is held approximately constant with extremely minuscule differences between the two bitrates.

C. *Simulation results and analysis*

The graphs plotted in Figure 4 and Figure 5 show the rate distortion for the two sequences simulated. It shows that the use of UEP using the priority assignment algorithm as discussed in this paper outperforms the non UEP based approach especially at higher bitrates.

The plots can be explained as follows: when UEP is used, the reference frames are better protected than non-reference frames. Therefore, a reference picture loss probability is lesser than the non-reference picture loss probability. When reference pictures are lost, prediction errors cause subsequent pictures in decoding order to be decoded incorrectly. This is the case even if the coded data for the subsequent pictures are received correctly. The duration of this error propagation depends on the Intra picture insertion interval. On the other hand when non-reference pictures are lost, error propagation does not occur as the picture is not used as a reference for any other picture in the coded sequence. This results in only the lost non-reference picture being decoded and presented incorrectly. Perceptually a non-reference picture loss is sensed as a jerk in moving video, while the loss of reference picture is perceived as garbled pictures for as long as the error propagation occurs.

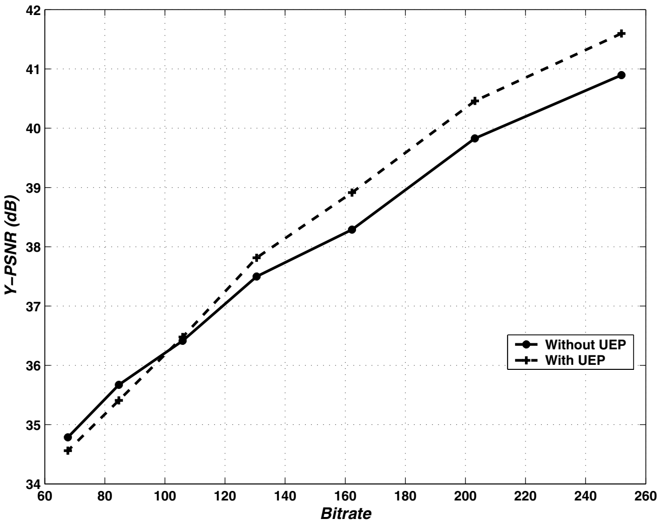

Figure 4: Rate distortion plot for Silent.

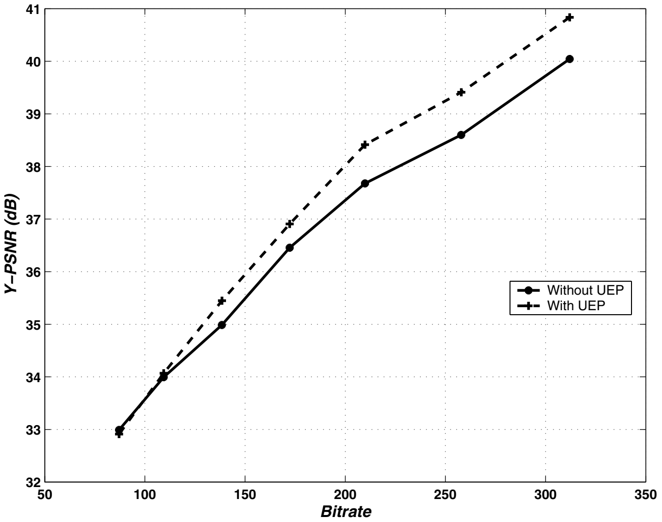

Figure 5: Rate distortion plot for Paris.

VIII. CONCLUSIONS

This paper described a method to provide unequal error protection (UEP) to media data transmitted over a DVB-H channel. The method uses priority labelling and grouping of labelled datagrams to protect data using forward error correction codes packed into multi-protocol encapsulation sections (MPE-FEC). Simulation results using a simple algorithm for priority assignment for an H.264/AVC encoded bit stream show that average luma PSNR improvements of up to 0.8 dB can be achieved. This method of UEP is generic and can be used for any type of media that contains data parts of unequal importance as long as an appropriate priority assignment algorithm is used.

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