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Error Sensitivity Analysis of DMB Transport Streams

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ABSTRACT In this paper, we examine the sensitivity of the digital multimedia broadcasting (DMB) MPEG-2 transport stream (TS) format to transmission errors. To find the sensitivity of different parts of TS packets to transmission errors, each TS packet is divided into four cells, i.e., the first three cells comprising 48 bytes each and the last cell is of 44 bytes length. Bit errors are then introduced into these different parts of the TS packets. The sensitivity of DMB videos to transmission errors and their locations is assessed in terms of the following measures: 1) Number of decoder crashes; 2) Number of decodable videos; 3) Total number of decodable frames; and 4) Objective perceptual video quality of the decoded videos. The structural similarity index and visual information fidelity criterion are used as objective perceptual quality metrics. Simulations are performed on seven different DMB videos using various bit error rates. The results show that the first cell of the TS packets is highly sensitive to bit errors compared to the subsequent three cells, both in terms of spatial and temporal video quality. Further, the sensitivity decreases from Cell 1 to Cell 4 of a DMB TS packet. The error sensitivity analysis reported in this paper may guide the development of more reliable transmission systems for future DMB systems and services. Specifically, the insights gained from this study may support designing better error control schemes that take the sensitivity of different parts of DMB TS packets into consideration.

INDEX TERMS Digital multimedia broadcasting, transport stream, error sensitivity, objective perceptual video quality, structural similarity index, visual information fidelity.

I. INTRODUCTION

Mobile digital television (TV) broadcasting has become more common due to the increasing number of handheld devices such as smartphones, phablets, and tablets. In view of the advancements in connected automotive and autonomous car technologies, automotive infotainment systems are growing rapidly incorporating mobile or terrestrial multimedia broadcasting services. In this context, the digital multimedia broadcasting (DMB) standard [1], [2] has been widely adopted in South Korea [3] as component of its national IT project, in particular, the terrestrial (T-DMB) version of DMB (see [2] for details on channel allocations). Further, Smart DMB has been introduced in 2013 to run on smartphones. This standard is supported for the South Korean market by Samsung's Galaxy Grand models SHV-E270S/K/L and its successors [4]. Although primarily deployed in South Korea, DMB trails have been pursued in several regions worldwide [3].

Regarding standardization specifications, T-DMB is designed to operate well in vehicles with speeds reaching up to 300 km/h. In practice, on the other hand, a number of temporal and spatial artifacts due to transmission impairments have been observed including frame skips and blocking. In [5], for example, an experimental study on quality of experience (QoE) of DMB services has been reported based on T-DMB videos that were made available from a field test on automotive infotainment systems in a live T-DMB system in South Korea. A subjective test on the collected T-DMB video samples was conducted involving a panel of observers. The subjective test revealed that the full range of quality ratings from excellent to bad can appear in a live T-DMB system when the receiving device is moving with typical speed of a vehicle. This finding warrants to advance error concealment at the receiver or to enhance the transmission system by using more efficient error control coding.

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A. RELATED WORK

In the following, a brief review of work related to physical layer aspects, error control coding techniques, and QoE assessment of DMB systems is provided along with a comparison to digital video broadcasting (DVB) systems.

T-DMB has been competing with the terrestrial DVB (DVB-T) standard. Both standards have similarities in the physical layer, e.g., using orthogonal frequency-division multiplexing (OFDM) while significant differences include the following: (1) Number of subcarriers and carrier separation resulting in different overall bit rates [6], [7]; (2) T-DMB uses differential demodulation while DVB-T uses coherent one-tap equalization which results in different bit error rates (BERs) under mobility conditions [8], [9]; (3) T-DMB uses frequency interleaving together with a very long time-interleaving span while DVB-T does not use time-interleaving. Due to these differences in the physical layer, the coded BER of T-DMB and DVB-T also differs [10]. Further, a comparison of the physical layer performance of T-DMB and DVB-T/H in fast fading channels is given in [11].

In order to provide reliable mobile multimedia, such as terrestrial, satellite, and Smart DMB, with acceptable quality over wireless channels, efficient error control coding is essential to alleviate the impact of severe transmission errors. Designing efficient error control coding depends, among others, on the different levels of importance of the different parts of the multimedia data format for the reconstruction of the multimedia content at the reveiver. As for the considered T-DMB format, it is important to know how transmission errors in different parts of the DMB MPEG-2 TS and corresponding packets affect the resulting video quality. The knowledge of the sensitivity of different parts of the DMB packets will help designing efficient error control coding which in turn improves the quality of DMB services. Additionally, this knowledge may assist the receiver/decoder to better handle erroneous packets in order to improve both temporal and spatial quality of the delivered videos.

Measurement guidelines, e.g., to setup testbeds for hardware testing of digital TV systems or to set these systems to the appropriate operating parameters, can be found in [12]. However, these guidelines do not cover techniques on how to handle erroneous TS packets. Instead, it is assumed that the receiver/decoder simply discards packets containing residual errors, regardless of their impact on the decoding outcome and/or the resulting video quality. As such, more advanced approaches may be advised to better deal with erroneous packets rather than simply discarding them. In addition, unequal error protection codes could be employed taking into account the different levels of error sensitivity of the TS packets in order to improve QoE, particularly, under poor channel conditions. An error sensitivity study of MPEG-2 bitstreams is reported in [13]. In this study, the error sensitivity of different parameters of MPEG-2 bitstreams was investigated in terms of the average peak signal-to-noise ratio (PSNR) due to bit errors in a particular parameter. The sensitivity of MPEG-2 TS is not considered, which limits its applicability to only video bitstreams but does not cover transport streams. However, PSNR does not always correlate well with human perception of video quality [14], [15]. Furthermore, the case of simultaneous multiple parameter errors was not considered. Another error sensitivity/resilience study of MPEG-2 bitstreams is reported in [16] for wireless asynchronous transfer mode (ATM) networks. The MPEG-2 data is first packetized into the ATM adaptation layer (AAL) and further packetized into ATM cells. The error resilience of MPEG-2 bitstreams is investigated in terms of PSNR of the resulting video for different types of ATM cell losses. Due to the further packetization of the MPEG-2 TS, and the insertion of an additional header, the results of this sensitivity study are not valid for the sensitivity of MPEG-2 TS itself. Further, the video format in this study was MPEG-2 Part 2 using the H.262 video compression format [17] while modern broadcasting systems, such as DMB, use the more advanced MPEG-4 Part 10 H.264 video compression format [18]. Several other sensitivity studies have been conducted such as those reported in [19]–[21] but these also focus on MPEG-2 video codec resilience/sensitivity rather than on the actual MPEG-2 TS itself. Similar to [16], these studies consider H.262 rather than H.264.

Regarding performance assessment of digital TV broadcasting systems in terms of QoE or objective perceptual video quality, a large body of literature exists for DVB-T and advanced broadcasting services. A comprehensive coverage of recent research, technologies, and fundamentals of QoE for advanced broadcasting services is provided in the special issue published as [22]. Other works include a study on QoE of digital mobile multimedia services [23] and an experimental study on the impact of Internet Protocol (IP) based service integrity parameters on QoE of DVB [24]. Several studies have been conducted to reveal how display size and impairments such as latency and freezes affect QoE in DVB-T. A novel combination of full reference and no reference video quality models for real-time digital TV quality monitoring has been reported in [25]. On the other hand, DMB has been given little attention when it comes to QoE and objective perceptual quality assessment.

B. CONTRIBUTIONS AND PAPER STRUCTURE

Motivated by all of the above, in this paper, we examine the error sensitivity of different parts of DMB transport streams. In particular, the DMB TS packets are split into four parts, referred to as cells, and errors are introduced into each of these cells. Different metrics are used to analyze the effects of these errors on the quality of the received DMB videos. These metrics include the decoder crash count, number of decodable videos, total number of decodable frames, and objective perceptual video quality. In summary, contributions of this paper include the following:

- DMB TS packet splitting into four cells is proposed as basis for the error sensitivity analysis. Each of these cells is of even length as is the length of a DMB TS packet.

- Error sensitivity of DMB TS packets for different error rates is assessed in terms of decoder crash count, number of decodable videos, and total number of decodable frames to reveal the impact of transmission errors on the temporal video quality.
- Error sensitivity of DMB TS packets for different error rates is assessed in terms of the structural similarity (SSIM) index [15] and visual information fidelity (VIF) criterion [26] to reveal the impact of transmission errors on objective perceptual video quality in the spatial domain.
- Simulation results are provided showing that transmission errors at the beginning of DMB TS packets (Cell 1) degrade the temporal and spatial video quality more compared to errors in the subsequent cells (Cell 2 to 4).

The rest of the paper is organized as follows. Section II describes the packet structure of the DMB TS format. The approach used to analyze the error sensitivity of DMB streams is described in Section III. Section IV provides and discusses the numerical results. Finally, Section V concludes the paper.

II. DMB TRANSPORT STREAM FORMAT

DMB systems use the MPEG-2 TS format [27] with a single program per one MPEG-2 TS. The MPEG-2 TS comprises the following types of packets:

- Program allocation table (PAT) packets: Contain the table of all programs along with packet IDs (PIDs) of the program map table (PMT) packets associated with each of these programs.
- PMT packets: Contain mainly the data associated with a single program, for instance, the PIDs of all the packets associated with that program.
- Object descriptor (OD) packets: Describe all the objects contained in a particular program including audio and video objects.
- Scene descriptor (SD) packets: Contain the description of a video scene.
- Audio packets: Carry the packetized elementary stream (PES) which contains audio in the advanced audio coding (AAC) format [28]. In DMB, audio packets may also contain the program clock reference (PCR).
- Video packets: Contain the video data in H.264/MPEG-4 Part 10 format [18].
- Other packets: Include null packets used to maintain a fixed rate for the transport stream, network information table (NIT) packets containing mainly program specific information (PSI), also called service information (SI) [27], among others.

Fig. 1 shows the structure of a DMB TS packet. Each DMB TS packet contains 188 bytes out of which the first four bytes contain the TS header. The rest of the packet contains an optional adaptation field (AF) and data payload. The header contains information about the packet such as the sync byte that marks the start of a packet and the PID. The adaptation field may contain some additional stream information such as the program clock reference (PCR). The payload part of DMB TS packets may be different for different packet types.

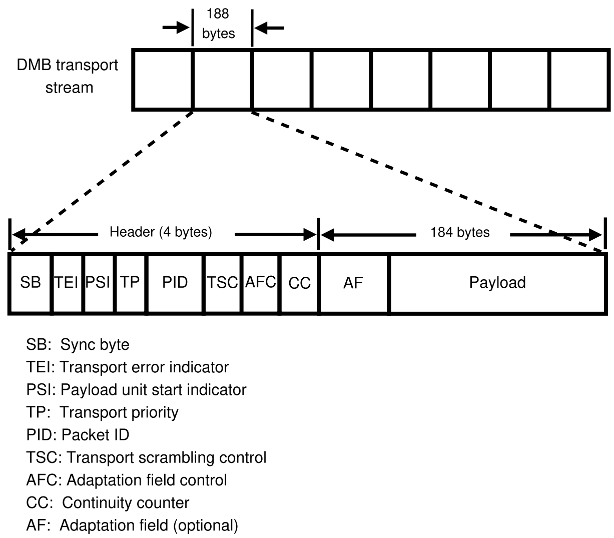


FIGURE 1. DMB TS packet structure [27].

III. ERROR SENSITIVITY OF DMB TRANSPORT STREAMS

In DMB, the packets pass through an error-prone wireless channel which inflicts errors into these packets. In order to cope with such errors, DMB uses Reed-Solomon (RS) codes [29] with a message length of $k = 188$ symbols (bytes) and a codeword length of $n = 204$ symbols (bytes) for forward error correction. This enables the DMB receiver to correct up to eight erroneous bytes per TS packet. However, if the number of errors in any packet is higher than eight bytes, the receiver is unable to correct these errors. As a result, all the packets that have more than eight erroneous bytes are discarded which results in a degraded quality of the reconstructed video. On the other hand, if the receiver attempts to decode the erroneous packets, depending on the amount and location of the transmission errors, there might be a risk of decoding failure and/or more quality degradation due to possible loss of synchronization. However, errors in some parts of a packet may not significantly affect the quality. Therefore, it is important to find out the sensitivity of different parts of DMB TS packets to transmission errors.

In order to analyze the sensitivity of different parts of DMB TS packets for transmission errors, in this paper, each of the TS packets is divided into four parts (referred to as cells). The first three cells are 48 bytes long while the last cell contains 44 bytes as illustrated in Fig. 2. The choice of using four cells rather than splitting a DMB TS packet into the header (4 bytes) and the rest of the packet (184 bytes) is motivated by the fact that some parts of the payload, e.g. PAT and PMT packets, are of same importance as the header. Further, considering the structure of audio and video packets, one may

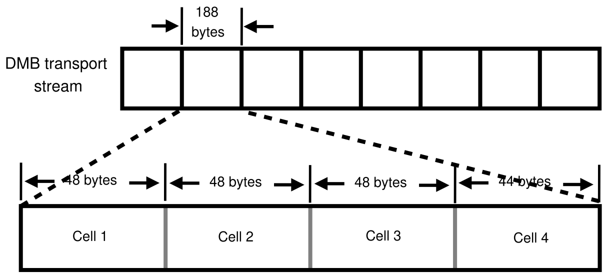


FIGURE 2. DMB TS packet splitting into four cells.

cluster the DMB header (4 bytes), adaptation field, and PES header into one cell followed by a second cell containing the rest of the packet. However, PES header and adaptation field are not present in all packet types and have variable length which motivates to split a DMB TS packet into more than two cells. The suggested four cell structure copes with the variability associated with audio and video packets while being also applicable to other packet types. As such, four cells give sufficient granularity for the sensitivity analysis while keeping analysis complexity within reasonable limits compared to a finer cell structure.

In the subsequent numerical results section, the error sensitivity of these cells is analyzed and discussed in terms of the following metrics:

- Decoder crash count: Counts the number of times that the decoder crashed and hence requires a restart of the decoder.
- Number of decodable videos: Refers to the number of videos that are fully or partially decodable.
- Total number of decodable frames: Quantifies the frame decodability of a video and relates to the temporal quality of the video presentation.
- SSIM index [15]: Uses intensity and contrast measures to predict spatial degradation of structural information in visual stimuli.
- VIF criterion [26]: Uses natural scene statistics and Gaussian scale mixtures to predict objective perceptual quality of a visual stimulus.

IV. NUMERICAL RESULTS

The sensitivity of DMB TS packets to transmission errors has been examined through extensive simulations using a test suite implemented in Matlab and C/C++. Open-source tools such as VLC were also used in the simulations. In the following, the simulation setup used and the results obtained are discussed.

A. SIMULATION SETUP

Seven different DMB video sequences were chosen for the conducted simulations. Due to the scarcity of DMB video sequences in publicly available video databases, the seven sample DMB videos have been obtained from [30]. The selected videos cover a variety of different scenes from people's faces to different landscapes, and from very slow video dynamics with only the camera zooming out to very fast video dynamics. These videos are given in quarter video graphics array (QVGA) resolution of 320×240 pixels, with lengths of 16 to 17 seconds, and were played at the rate of 25 frames per second. In every simulation run, residual bit errors were introduced only into one of the four cells of the respective DMB TS packets either of the same packet type or all types of packets, i.e.,

- Errors in a single cell of video packets
- Errors in a single cell of audio packets
- Errors in a single cell of PMT packets
- Errors in a single cell of SD packets
- Errors in a single cell of other packets
- Errors in a single cell of all the above packet types

In this context, residual bit errors shall refer to those errors that remain undetected by the (204, 188) RS code. Accordingly, simulations were conducted applying successively two different strategies to each of the four cells of the proposed DMB TS four cell structure: 1) Errors were introduced into a single packet type for a single cell while all other packet types and remaining cells were kept error free. In this way, the impact of errors for each individual packet type with respect to each cell is revealed. 2) Errors were introduced in all packet types for a single cell while all remaining cells were kept error free. This second strategy reveals the combined impact of errors in all packet types of each of the four cells. For both strategies, the impact of residual errors on the resulting DMB video stream at the receiver is analyzed using the above described metrics. Several different error rates were used to simulate different channel conditions.

B. NUMBER OF DECODER CRASHES

The decoding information contained in the transport stream after passing through the transmission channel and arriving at the receiver may be corrupted due to residual errors. This corrupted information can cause the decoder to crash. In this case, either the decoder needs to be able to automatically restart itself or the end user may have to reset/restart the decoder/receiver in order to resume the decoding which degrades the overall quality of experience of the end user. As such, it is important to consider the likelihood of decoder crashes as a quality indicator in the presence of residual errors apart from resorting only on visual quality degradation.

Fig. 3 shows the number of times that the decoder crashed during the decoding process, i.e., could not completely decode the video. The related decoder crash count is presented for different residual error rates and accumulated over all seven DMB sample video streams. In particular, using different simulation seeds, Figs. 3(a)-(c) show the results for the cases where the residual errors are present in the different cells of video packets while all other types of packets are error free. The average decoder crash count over all

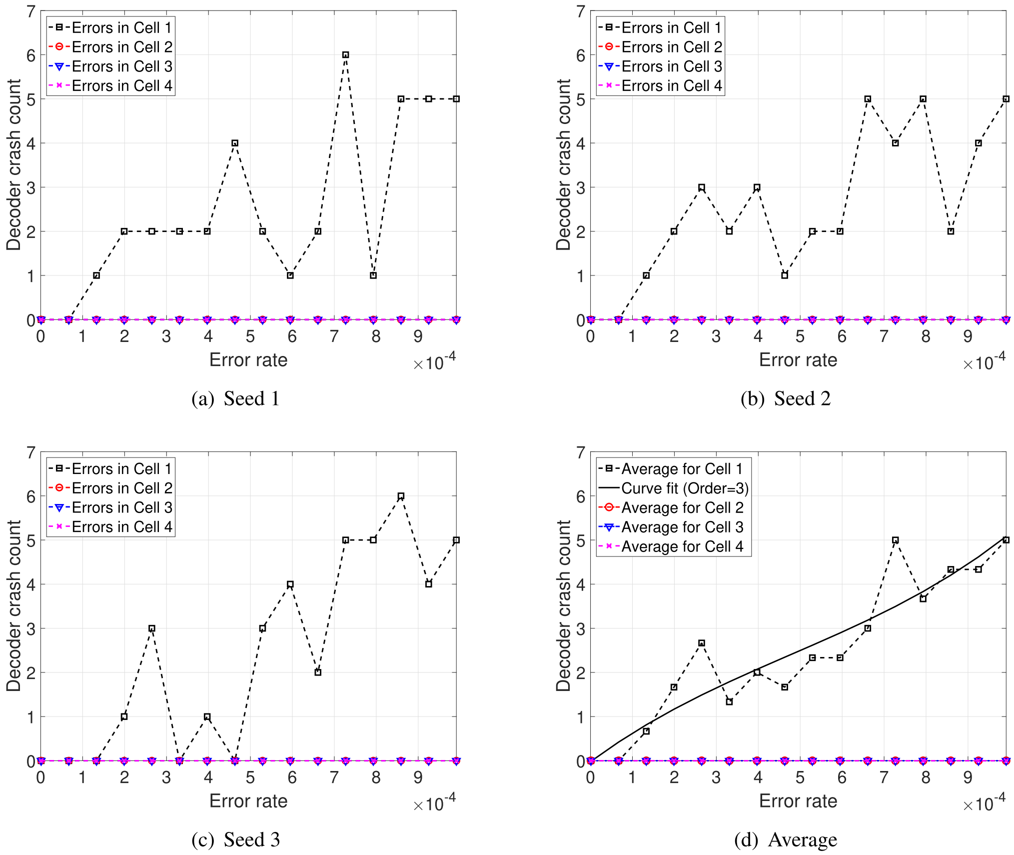


FIGURE 3. Number of times the decoder crashed during decoding for the case that errors are in video packets.

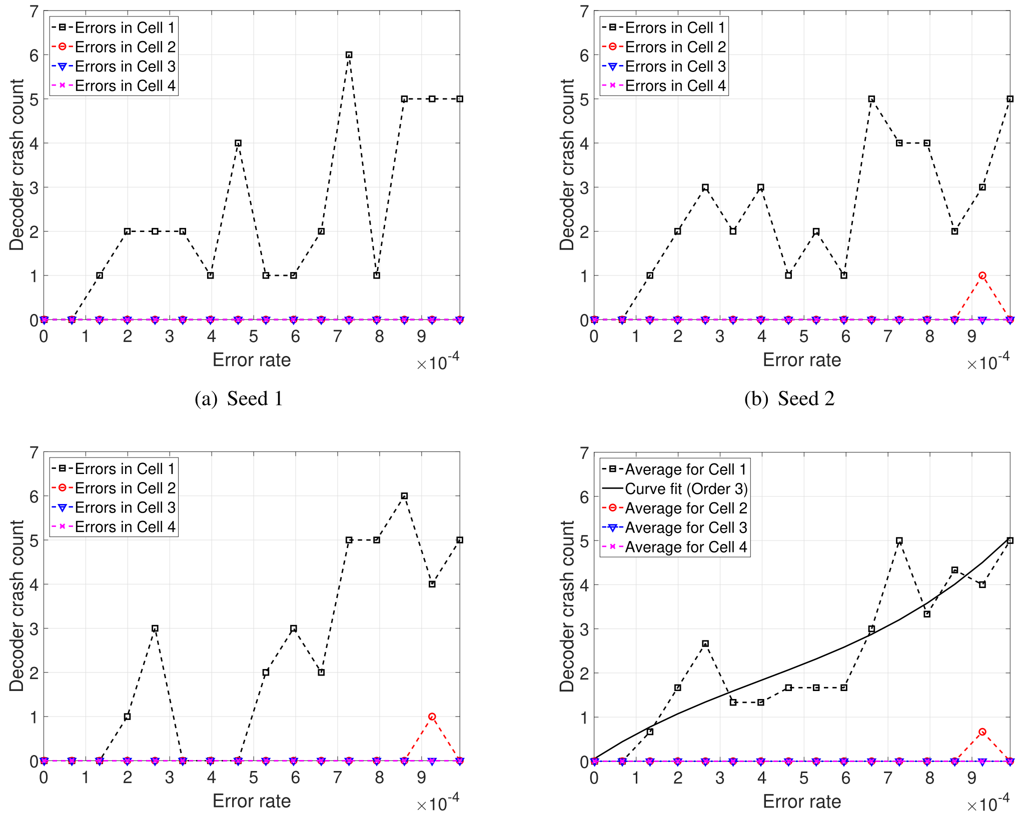
three simulation seeds and related polynomial fit are shown in Fig. 3(d). Clearly, Cell 1 of the video packets is highly sensitive to errors and may cause the decoder to crash during decoding even for small error rates. In contrast, errors in the subsequent cells of video packets beyond Cell 1 have no effect on the decoding process. The reason for the high sensitivity of Cell 1 to errors is that it contains the PES header and DMB TS packet header which carry important decoding information. Errors in the PES header can therefore impair the required decoding information and as a consequence cause the decoder to crash. It should be mentioned that errors in all other types of packets did not result in decoder crashes. Graphical illustrations for these cases are therefore omitted.

Fig. 4(a)-(d) shows the results for three different simulation seeds and average results for the scenarios where all packet types have errors in a single selected cell. Again, errors induced in Cell 1 cause the decoder to crash while none of the subsequent cells is sensitive enough to cause the decoder to crash. A detailed analysis of the different packets revealed that errors causing the decoder crashes were in the video packets while errors in the other types of packets have very little effect on the decoding process. As a result, similar trends as those seen in Fig. 3 are observed in decoder crash count versus error rate with respect to Cell 1.

C. NUMBER OF DECODABLE VIDEOS

In this section, we assess how errors in different packet types affect video decoding. A video is considered as decodable if the decoder is able to fully or partially decode the video. As such, the decodable videos include those for which the decoder was able to decode and play parts of the video with or without crashing. The number of decodable videos obtained from the simulations are shown in Fig. 5 and 6 for different residual error rates.

Fig. 5 depicts the results obtained for the case that errors are present only in one type of packet, i.e. PMT or OD packet, while all other types of packets are error free. Similar as for the decoder crash count, the results for those packet types that have a negligible effect on the number of decodable videos are omitted. Specifically, errors in video packets, regardless of their locations, turned out to have very little impact on video decodability. PMT and OD packets, on the other hand, have higher impact on video decoding. This is because PMT packets contain all the information about a program including the PID's of all associated packets while OD packets have detailed information about all the objects contained in that program and their description (see also Section II). The correctness of this information is essential for fully decoding a video while errors in this information may render the video



(a) Seed 1 (b) Seed 2 (c) Seed 3 (d) Average

FIGURE 4. **Number of times the decoder crashed during decoding for the case that errors are in all packet types.**

undecodable. Given that seven videos have been used in the simulations, it is observed that most of the videos can be partially or fully decoded even for relatively high error rates.

Fig. 6 shows the results of the error sensitivity with respect to a single cell for the case that errors are in all packet types. The results indicate that Cell 2 appears to be the most sensitive to errors while Cell 1 is the second most error sensitive part of a DMB TS when it comes to decodability. Again, most of the videos are decodable even at relatively high error rates.

D. TOTAL NUMBER OF DECODABLE FRAMES

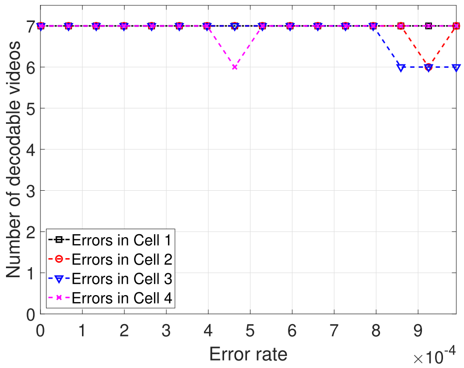
The frame decodability is related to video presentation and playback. The more frame losses occur, the less smooth is the playback and the more freezes happen. Hence, the total number of decodable frames may represent the temporal quality of these videos.

Fig. 7 shows the total number of decodable frames for all videos as a result of errors in only one type of packets. As before, results are provided only for those packet types that have an effect on frame decodability. In particular, errors in audio, PAT, and SD packets do not harm frame decoding while erroneous video, PMT and OD packets can indeed affect the frame decodability. The results for video packets shown in Fig. 7(a) reveal that Cell 1 is highly sensitive to errors, making a large number of frames undecodeable, compared to the same amount of errors in any of the other three cells. Further, Cell 3 of PMT packets is the most sensitive to errors while errors in Cell 2 have the highest impact on OD packets.

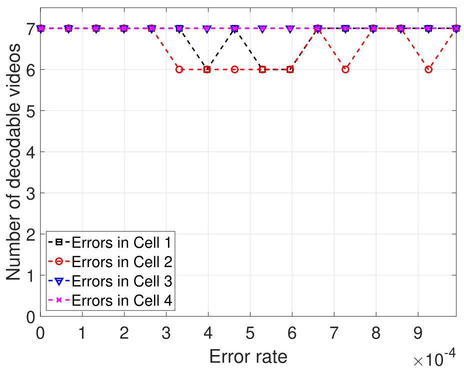
Fig. 8 shows the results for the case that all packet types have errors in a given single cell. In general, moving from Cell 1 to Cell 4, the number of decodable frames tends to increases for any error rate which highlights the highest importance of Cell 1 compared to the other three cells. In view of this finding, it would be beneficial to provide stronger error protection to Cell 1 compared to the remaining three cells as an efficient technique to maintain given levels of temporal video quality.

E. OBJECTIVE PERCEPTUAL VIDEO QUALITY ASSESSMENT

Since a transmission channel inflicts errors into a video stream, some of the video frames may not be decodable at the receiver, resulting in less number of reconstructed frames compared to the number of transmitted video frames. Furthermore, information about the position of the decoded frames with respect to the original timeline in the video stream at the transmitter may also not be available. As such, the decoder may not know exactly when a particular frame is to be played. On the other hand, when computing a full reference video quality metric such as the SSIM index or the VIF criterion,



(a) Errors in PMT packets



(b) Errors in OD packets

FIGURE 5. Number of decodable videos for errors in a single packet type.

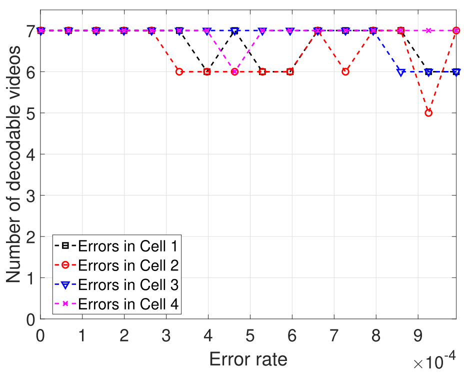
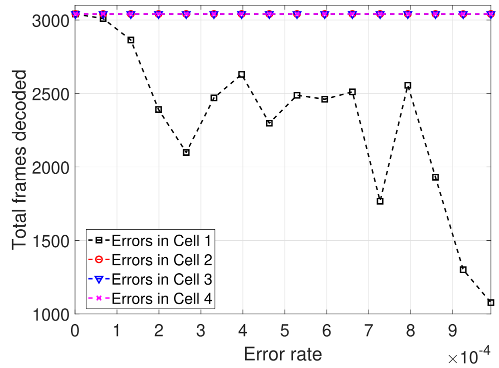
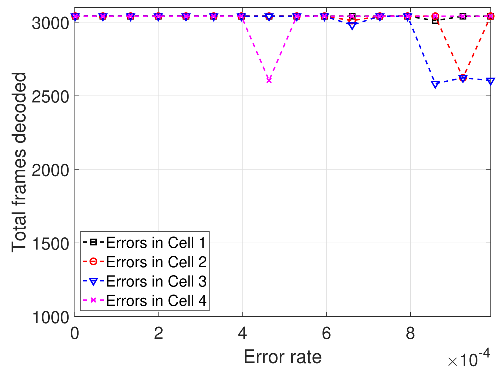


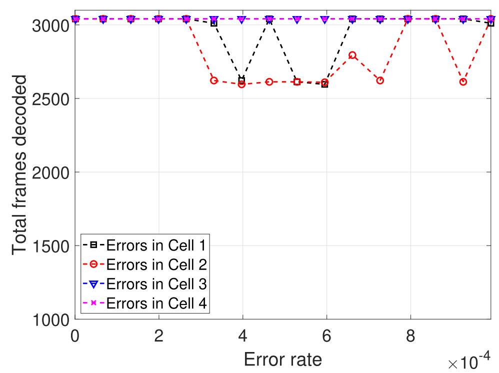
FIGURE 6. Number of decodable videos for errors in all packet types.



(a) Errors in video packets



(b) Errors in PMT packets



(c) Errors in OD packets

FIGURE 7. Total number of decodable frames for errors in a single packet type.

it is required that the reconstructed frames of the decoded video be compared with the same frame of the reference video.

This raises two challenges: 1) Alignment of the reconstructed video frames to the reference video frames. 2) Computation of the quality of the frames that the receiver/decoder was unable to decode. To address the first challenge, we computed the correlation between the reconstructed video frames and the reference video frames using the Pearson correlation coefficient. Every frame of the reconstructed video was placed at the frame location of the reference frame with which it has the highest correlation. The second challenge was addressed by assuming that the DMB receiver has enough memory to hold the last decoded frame on the display screen until the decoder is able to decode and display a subsequent frame. Then, it can always hold this newly decoded frame on the screen until a new decodable frame arrives. Based on this approach, for the reconstructed video, we copied every decoded frame in places of all succeeding frames that were not decodable to fill up the frames until the next decodable frame. In this way, we reconstructed the received video in which the frames are aligned to the

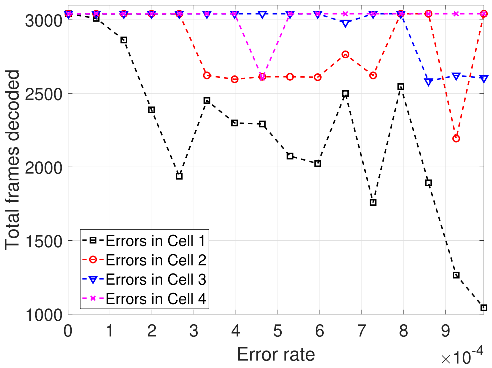
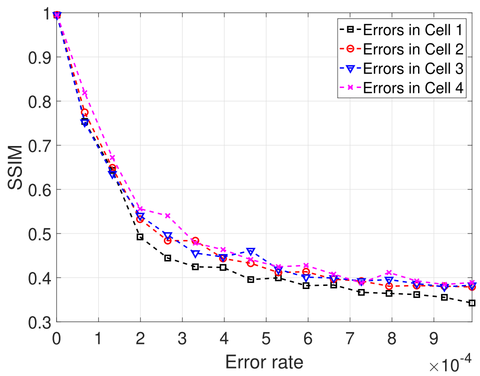
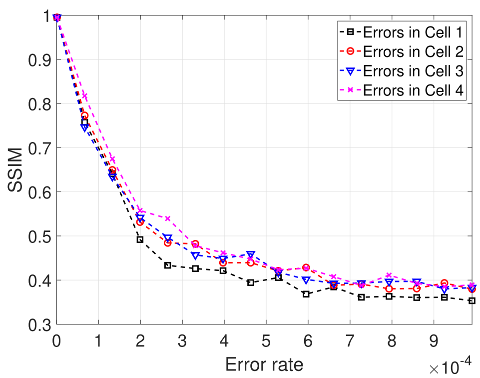


FIGURE 8. Total number of decodable frames for errors in all packet types.

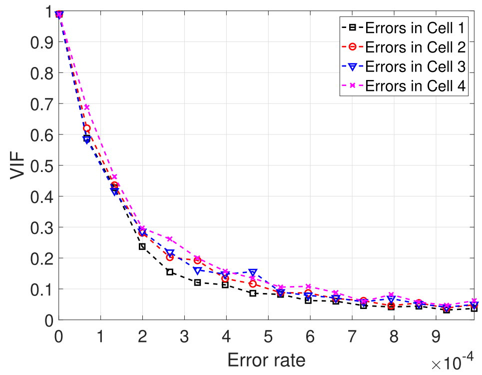


(a) Errors in video packets

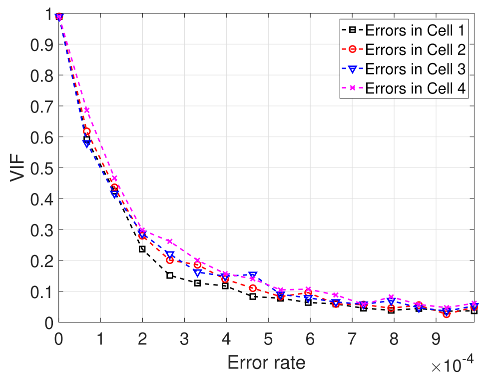


(b) Errors in all types of packets

FIGURE 9. Objective perceptual video quality in terms of the SSIM index.



(a) Errors in video packets



(b) Errors in all types of packets

FIGURE 10. Objective perceptual video quality in terms of the VIF criterion.

frames of the reference video and the reconstructed video has the same length as the references video.

Once the reconstructed videos are brought into alignment with the reference videos, the next step is to quantify the objective perceptual quality of these videos. It has been widely observed that PSNR does not always correlate well with human judgement of image or video quality [14], [15]. Further, when it is applied to videos by simply averaging the PSNR's of the individual frames, the obtained representation of visual quality does not seem to be useful as has been reported in [14]. As PSNR is a fidelity metric that processes the visual content pixel-by-pixel, it does not mimic the behaviour of the human visual system which processes structural information among others. For these reasons, we have used objective perceptual quality metrics, i.e., the SSIM index [15] and the VIF criterion [26]. As SSIM operates only on structural distortions related to the spatial domain, it can be applied to the individual frames of a video and hence be related to the respective sequence of frames composing the video. The VIF criterion approaches visual quality assessment as an information theoretical problem. It measures degradation of visual quality as the result of distortions by calculating the information available in a reference image and the amount of information that is still available in the impaired image. It has been shown that these quality metrics possess better correlation with human perception [14], [15], [26]. Since the values of both of these metrics vary between [0-1], unlike PSNR which can even approach infinity, the averaging of the qualities of a sequence of individual frames is also possible and relevant.

Fig. 9 shows the average SSIM for all the examined DMB videos. It can be seen from this figure that residual errors located in Cell 1 are degrading the objective perceptual video quality more than the same amount of residual errors in the other cells. The visibility of quality degradation is larger,

FIGURE 11. One frame from DMB video sample no. 1, Top-left: errors in Cell 1, top-right: errors in Cell 2, bottom-left: errors in Cell 3, bottom-right: errors in Cell 4 (Error rate = 1.33×10^{-4}).

FIGURE 12. One frame from DMB video sample no. 3, Top-left: errors in Cell 1, top-right: errors in Cell 2, bottom-left: errors in Cell 3, bottom-right: errors in Cell 4 (Error rate = 1.33×10^{-4}).

the earlier errors appear in the considered cell structure from Cell 1 to Cell 4. This characteristic is more pronounced for higher error rates. It was also observed that errors in other types of packets have no considerable effect on visual quality.

Similar trends can be observed for the VIF criterion in Fig. 10. Specifically, it is observed that errors in Cell 1 result in the lowest VIF value compared to the same amount of errors in the subsequent cells for almost all error rates. This characteristic applies in particular to the mid-region of considered error rates.

Finally, in Figs. 11 and 12, we provide two examples of individual frames taken from two different sample videos, to support visual inspection of quality. It can be seen from these figures that errors in Cell 1 cause more visual quality degradation compared to the same amount of errors in Cells 2 and onwards. In Fig. 11, errors in Cell 1 cause clear blocking artifacts while visual quality is much higher and rather similar for the same amount of errors in Cell 2 to Cell 4. Visual inspection of Fig. 12 reveals that the amount of lost information causing black blocks reduces when errors move from Cell 1 to Cell 4 (no black blocks).

V. CONCLUSION

In this paper, we have examined the sensitivity of different parts of DMB TS packets to transmission errors. In particular, residual errors have been introduced into different parts of DMB TS packets and their effect on the decoding and quality of the reconstructed videos have been analyzed. Error sensitivity has been assessed using decoder crash count, number of decodable videos and frames, and objective perceptual video quality. In this way, both temporal and spatial aspects of video quality have been considered.

Simulations were performed on seven DMB video sequences and for various error rates to account for different conditions of the transmission channel. The simulation results have shown that residual errors located at the beginning of a DMB TS packet (Cell 1) degrade the resulting video quality more compared to the quality degradation caused by the same amount of errors in the subsequent parts of a packet (Cell 2 to 4).

The error sensitivity analysis reported in this article may assist to improve existing and to design better transmission systems for future DMB applications. For example, more efficient unequal error protection schemes may be advised to improve overall objective perceptual video quality. Further, the knowledge about error location and its related error sensitivity may assist the decoder deciding on whether to discard or to decode erroneous packets.

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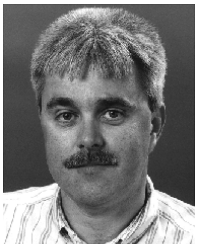

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