Performance Evaluation of the MPE-iFEC Sliding RS Encoding for DVB-H Streaming Services

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Abstract—**This article studies the performance of the Sliding RS Encoding (SRSE) in the transmission of streaming services in DVB-H (Digital Video Broadcasting - Transmission System for Handheld Terminals) networks. The SRSE forms part of a set of specifications called MPE-iFEC which has been recently defined in the DVB-SH (Digital Video Broadcasting - Satellite Services to Handheld Devices) standard and is fully compatible with the link layer of DVB-H. MPE-iFEC is capable of encoding information related to different datagram bursts in a jointly manner in order to counteract the long signal blockages expected in satellite reception. This is what is usually referred to as Multi-Burst Encoding (MBE) and provides a protection that extends across several time sliced bursts. MBE can also improve the reception in terrestrial networks such as DVB-H, which relay in the use of MPE-FEC (Multi Protocol Encapsulation - Forward Error Correction) for link layer protection. The SRSE employs the same Reed Solomon (RS) algorithm used in MPE-FEC and a sliding encoding mechanism in order to perform MBE. This paper evaluates the improvements that the use of SRSE can achieve over the legacy MPE-FEC using vehicular urban field measurements in a DVB-H single frequency network. The effect of the different parameters that regulate the operation of the SRSE will be evaluated and the best configurations for its use in DVB-H will be highlighted.**

I. INTRODUCTION

Today is commonly accepted the necessity of broadcast networks in order to offer mobile TV services. These networks are capable of distributing high speed multimedia services around wide extensions without any limitation in the number of users that can receive the service. The European Mobile Digital Terrestrial Television (DTT) standard is known as DVB-H (Digital Video Broadcasting - Handhelds), which is a technological evolution of the Digital Terrestrial Television (Digital Video Broadcasting - Terrestrial) standard, adapted to mobile reception [1]. DVB-H was originally designed to work in the UHF band between 470 and 862 MHz, and is capable of providing a capacity between 5 and 10 Mb/s in an 8 MHz channel. Although DVB-H maintains the physical layer of DVB-T, it adds new link layer elements, making possible a reutilization of the network infrastructure (transmitters, multiplexers etc.). Its main features are a transmission technique called time slicing where data is periodically sent in bursts, and an additional link layer error correction mechanism called MPE-FEC (Multi Protocol Encapsulation - Forward Error Correction) which provides a more robust transmission in the presence of mobility and impulse interference.

The MPE-FEC protection incorporated into the DVB-H standard has been proved not to be very effective in urban and indoor scenarios. MPE-FEC can only correct partial burst losses and is not capable of repairing bursts where all the information is lost. In order to correct complete burst losses it is necessary to encode information from several consecutive bursts in a jointly manner. This technique is usually referred to as Multi Burst Encoding (MBE). MBE has been standardized in DVB-H for the provision of file delivery services by means of AL-FEC (Application Layer - Forward Error Correction) [2]. The use of AL-FEC to improve the reception of DVB-H streaming services has been previously studied in [3], where the idea of delivering streaming content as a succession of time-constrained files is developed.

The new DVB-SH (Digital Video Broadcasting - Satellite Services to Handheld Devices) standard [4] defines a new link layer protection framework called MPE-iFEC. MPE-iFEC was designed to cope with the characteristic impairments of the satellite propagation channel. In satellite transmissions, the signal is usually blocked by buildings and trees, resulting in the presence of long error periods in the received information that can corrupt entire time sliced bursts. However, terrestrial systems as DVB-H can also suffer from shadowing, especially if a low number of transmitters have been deployed. MPE-iFEC is fully compatible with the link layer of DVB-H and thus can be used in DVB-H networks to improve the reception of streaming services. At present, the Sliding Reed Solomon Encoding (SRSE) is the only MPE-iFEC mapping incorporated into the DVB-SH implementation guides [5]. The SRSE is a MPE-iFEC configuration that encodes together information from different bursts by means of a sliding encoding approach. As it employs the same Reed Solomon (255,191) encoding algorithm as MPE-FEC, the SRSE allows the reuse of several components of the MPE-FEC implementation, which facilitates the incorporation of MPE-iFEC into the user terminals. DVB-H networks can be easily updated with MPE-iFEC protection, improving the user experience and extending the service area without the need of new network infrastructure.

The paper is structured as it follows. The limitations of MPE-FEC to achieve good quality reception in the presence of long signal blockages and the necessity of MBE mechanisms are explained in chapter II. Chapter III is dedicated to the description of the SRSE along with all its parameters. In chapter IV the results obtained by SRSE and the comparisons with MPE-FEC are presented to finally end the paper with the conclusions in chapter V.

II. MULTI BURST ENCODING

In DVB-H, the link layer receives the IP information from the upper layers in the form of IP datagram bursts. Every datagram burst is independently encoded by MPE-FEC by means of a Reed Solomon (255,191) encoding algorithm. Each datagram burst will be transmitted in a time sliced burst along with the parity data. A datagram burst will be repaired if enough IP information and parity data are received without errors in the time sliced burst. In DVB-H networks the presence of shadowed areas is quite common, especially if a low number of transmitters have been deployed. When passing through shadowed areas, the received terminal experiments signal outages that can corrupt entire time sliced bursts. In outage situations where the majority of the information within each burst is erroneous, the bursts can not be repaired by MPE-FEC and thus the quality experimented by the user decreases. The operator has to deploy more transmitters to eliminate the shadowed areas and assure the correct reception of DVB-H services.

In order to cope with the error bursts derived from signal blockage, a protection mechanism capable of encoding information from different bursts in a jointly manner is required. In MBE, information from several datagram bursts is interleaved in one or more encoding matrixes, and thanks to the user mobility and the time slicing transmission mode, MBE achieves spatial and time diversity that is proportional to the velocity and shadowing characteristics of the environment. In MBE, complete burst losses can be recovered as long as the encoding matrixes in which the bursts were interleaved can be repaired. Contrary to MPE-FEC, a MBE mechanism is capable of correcting erroneous information of one time sliced burst by using the correct information and parity data from the other time sliced bursts that were interleaved in the same encoding matrixes. The number of bursts along which the MBE spans is usually referred to as interleaving depth. The longer the interleaving depth, the larger the protection offered by MBE. For example, if 10 bursts are encoded together by means of MBE and a code rate of 1/2 is employed, it would be possible to recover the complete loss of 5 time sliced bursts assuming that the rest of IP information and parity data have been received without errors. Also, bigger encoding matrixes have a higher probability of recovering enough correct information and parity data to be succesfully decoded and thus, MBE mechanisms capable of processing larger encoding matrixes achieve better performance.

The protection offered by MBE comes with an increase in the latency of the received information. In order to decode a received datagram burst, the terminal must wait until the arrival of all the IP information and parity data of the encoding matrixes where the datagram burst was interleaved. Although the latency introduced by MBE may not be relevant to the majority of Mobile TV services, it brings along an increase in the zapping time, which can seriously degrade the service quality in streaming services. The zapping time is defined as the portion of time between when the user switches to a new channel and the moment when the content of the new channel is displayed. When MBE is used and the user switches to a new channel, the terminal must buffer all the information of the encoding matrixes where the first burst was encoded. During this time the terminal has no information available for displaying, and the user has no chose but to wait. The zapping time increases along with the interleaving depth, although there are some fast zapping techniques that achieve better zapping times with little or no penalty in the achieved protection.

III. SLIDING RS MECHANISM

The MPE-iFEC Sliding RS Encoding is an encoding scheme that employs a sliding window and a RS coder in order to achieve MBE protection. Portions of information from different bursts are interleaved and coded together in encoding matrixes by means of the same RS coder (255,191) employed by MPE-FEC. Because of this, each encoding matrix can contain an amount of IP information equal to one datagram burst. A sliding window encloses several encoding matrixes, and each time one datagram burst with IP information is received from upper layers, the sliding window advances one encoding matrix forward. The information of the new datagram burst is distributed and placed along the encoding matrixes enclosed by the sliding window. After this mechanism, one of the encoding matrixes will be encoded to generate the parity data which will be sent in a time sliced burst along with one previously received datagram burst. Although a datagram burst will be always sent in a single time sliced burst, the parity data from each encoding matrix can be distributed over several time sliced bursts in an effort to achieve a higher interleaving depth. The encoding operation of the SRSE is shown in Fig. 1.

The decoding operation is basically the reverse of the encoding operation. Each time a time sliced burst is received, the sliding window advances one position and the IP information and parity data are placed in the encoding matrixes enclosed by the sliding window. After this, one encoding matrix is decoded and one datagram burst is passed to the upper layers.

As only one matrix with a similar size to one datagram burst is decoded every time a time sliced burst is received, the SRSE avoids the computational peaks of other mechanisms where bigger matrixes are used. However, its main drawback is precisely the fact that the size of the encoding matrixes is limited to one datagram burst. Because of this, the SRSE achieves less protection than MBE schemes based on algorithms capable of processing bigger encoding matrixes such as Raptor codes.

There are three main parameters that regulate the operation of the SRSE: the encoding parallelization (B), the FEC spreading (S) and the transmission delay (D). The encoding parallelization is the number of encoding matrixes that are enclosed by the sliding window. As one encoding matrix can only contain an amount of IP information equal to one

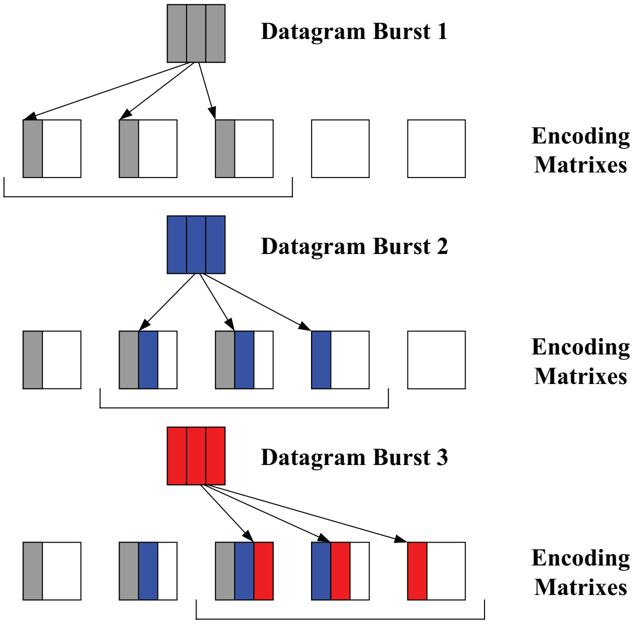

Fig. 1. Operation scheme of the SRSE. It can be seen how the sliding window advances and interleaves the data from different datagram bursts

datagram burst, each one of the encoding matrixes is filled with portions of information from *B* different datagram bursts. Each datagram burst is interleaved in *B* different encoding matrixes with the previous *B*-1 and next *B*-1 datagram bursts. As the *B* parameter is incremented, the interleaving achieved by the SRSE increases, but also does the latency, as the receiver has to wait until the arrival of *B* bursts in order to fill one encoding matrix.

The FEC spreading is the number of time sliced bursts along which the parity data is distributed. Each time sliced burst will carry parity data from *S* encoding matrixes and the parity data generated in one encoding matrix will be transmitted in *S* different time sliced bursts. Similarly to the *B* parameter, greater values of *S* allow better protection but also increment the latency of the system.

The transmission delay refers to the portion of time between when a datagram burst is received from the upper layers and the time when is finally transmitted in a time sliced burst. Instead of transmitting the datagram burst just received from the upper layers, it is possible to store it in order to send it several bursts later. By setting the *D* parameter to an adequate value, it is possible to reduce the zapping time in order to offer a better user experience.

When SRSE is employed, the terminal has to wait until the arrival of all the IP information and parity data of each encoding matrix in order to achieve full protection. Full protection is accomplished when all the IP information and parity data of each encoding matrix is available for decoding. When *D*=0, the parity data generated from one encoding matrix is sent in time sliced bursts subsequent to the bursts carrying the IP information of the same encoding matrix. The terminal has to receive first, the *B* bursts necessary to retrieve all the IP information and then, the *S* bursts necessary to retrieve the parity data. Because of this, the terminal has to wait a total of *B*+*S* bursts to be able to fill one encoding matrix and achieve full protection. However, increasing the *D* value delays the sending of the datagram bursts with respect to the parity, and so, the parity begins to be sent in the same time sliced bursts as the IP information from which it was generated. For example, if *D* is set to a value between *B* and *S*, the terminal has only to wait until the arrival of *B* bursts. This can affect the performance of the mechanism but reduces the latency seen by the receiver and effectively decreases the zapping time. If *D* is increased beyond *B*+*S*, the parity is again not interleaved with the IP information from the same encoding matrixes and the performance increases. However, the end to end latency is incremented along with the memory requirements. In any case, if full protection is desired, the terminals will always have to wait at minimum *B* bursts in order to receive all the information data, no matter the value of *D*. Equations (1) and (2) determine the zapping time needed for full protection.

$$sizing(B,S,D) = B + max(0, S-D) + max(0, D-B) \quad (1)$$

$$ZappingTime = CycleTime \times sizing(B,S,D) \quad (2)$$

As it has been explained, the values of *B* and *S* regulate the interleaving depth of the IP information and parity data respectively. Although many combinations between these two parameters are possible, in [5] it is recommended to set *B* and *S* proportionally to the amount of information and parity present in every time sliced burst. For instance, if *B*+*S* has a value of 6 and a code rate of 1/2 has been configured, both *B* and *S* will be set to 3. If the *B*+*S* value is mantained but the code rate is now changed to 2/3, *B* will be set to 4 and *S* will be set to 2.

IV. RESULTS

The performance of the SRSE has been evaluated by means of DVB-H Transport Stream (TS) packet error traces obtained in the DVB-H test network of the University of Turku (Finland). The network consists on two transmitters at 610 MHz that were configured to operate in single frequency mode. While the network is dimensioned for providing service to pedestrian users, all the traces were taken in vehicular reception conditions. The DVB-H transmission mode employed was: FFT size 8K, Guard Interval (GI) 1/4, modulation 16QAM and coding rate 1/2, which provides a data rate of 10 Mb/s at the physical layer.

The measurement system was formed by two professional receivers with a common external antenna and a GPS receiver that registered synchronized reception information with a sampling interval of 100 ms. 18 traces of 7 minutes each one, were obtained from these measurements. The error traces consist in a stream of characters where a 1 represents one correctly received TS packet and a 0 represents one erroneously received TS packet. The 18 traces cover a wide range of MPE SER (Section Error Rate) values, which represents the percentage

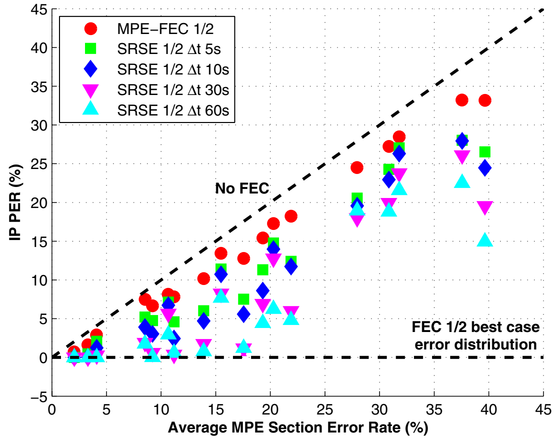

Fig. 2. IP packet error rate vs. average MPE section error rate for all measured trajectories. Streaming service 6 minutes at 256 kbps

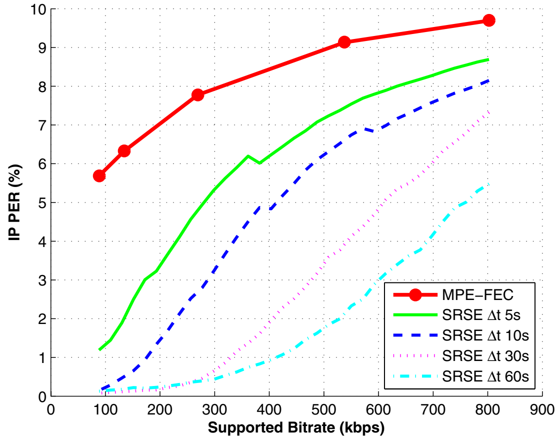

Fig. 4. IP packet error rate vs. bitrate in the trace with a MPE section error rate of 11.3%. The cycle time has been fixed to 0.95 s. Streaming service 6 minutes at 256 kbps

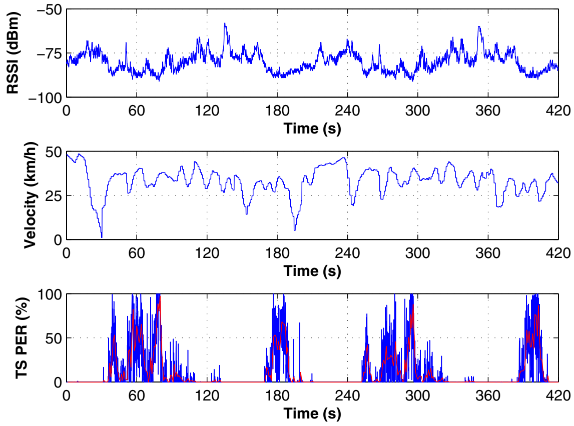

Fig. 3. RSSI, velocity and TS packet error rate measured along the trace with a MPE section error rate of 11.3%

of erroneously received MPE sections. In order to evaluate the performance of link layer protection mechanisms in these traces, the IP PER (IP Packet Error Ratio) parameter has been employed. The IP PER is calculated as the percentage of IP datagrams that were received with errors and could not be repaired by the link layer. Although a bit optimistic, an IP PER value of 5% can be considered as a good quality threshold. The MPE-FEC frame has been configured to 512 rows and the IP datagram size has been fixed to 512 bytes. The B and S parameter values have been set accordingly to the recommendations in [5].

The performance of MPE-FEC and the SRSE in all 18 traces can be seen in Fig. 2. The IP PER as a function of the MPE SER is represented when the two mechanisms are configured with a code rate of 1/2. Also, the curves of a FEC 1/2 configuration in a completely uniform error distribution and a configuration with no FEC at all are also represented. As all the 18 traces have a percentage of errors below the 50%, a code rate of 1/2 should be low enough to repair all the information. On the contrary, if no FEC is applied, it is not possible to correct any error and thus, the IP PER is equal to the MPE SER. In the figure, it can be seen how MPE-FEC achieves the worst performance for all the traces or values of MPE SER. The results obtained by MPE-FEC are very close to the no FEC curve, which denotes that MPE-FEC cannot cope with the errors originated in actual DVB-H networks. As it was expected, the amount of errors in the information decreases with the latency introduced by the SRSE. The improvement of SRSE with respect to MPE-FEC varies from trace to trace because of the fact that it depends not only on the percentage of errors but also on the their distribution. Traces with very long error bursts require extremely long interleaving durations, and therefore, the SRSE can bring little improvement over MPE-FEC with latencies below 60 s. This is the case of the traces with MPE SER values of 28% and 31%. However, in other traces the difference is quite significant; such is the case of the traces with MPE SER values of 39% and 18%, where the SRSE reduces considerably the IP PER.

A trace with a MPE SER of 11.3% is depicted in Fig. 3, where the RSSI (Received Signal Strength Indicator), velocity and TS PER registered in the measurement are represented. The performance that both MPE-FEC and SRSE achieved in this trace is shown in Fig. 4. The cycle time has been fixed to 0.975 s for all the code rates. Therefore the supported bitrate can be obtained by dividing the amount of IP information transmitted in each burst by the cycle time. In the figure, the SRSE considerably outperforms the legacy MPE-FEC even with small latencies. For instance, if the IP PER objective is set to 6%, an SRSE mechanism configured to 5 s of latency, supports twice as bitrate as MPE-FEC. When the SRSE is configured to 30 s, it can support a bitrate more than three times higher. In this trace, the SRSE is able to achieve IP PER values well below the IP PER 5% threshold with only 5 s of latency.

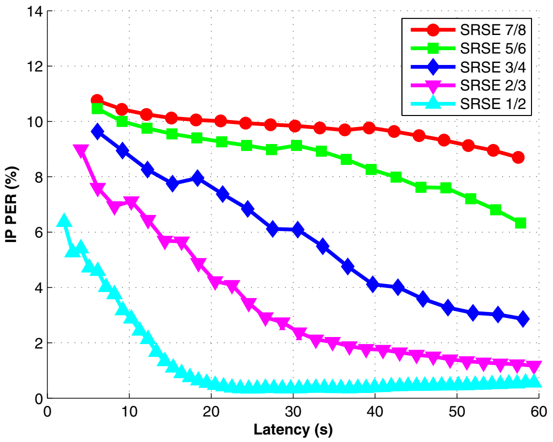

Fig. 5. IP packet error rate over latency in the trace with a MPE section error rate of 11.3%. Streaming service 6 minutes at 256 kb/s

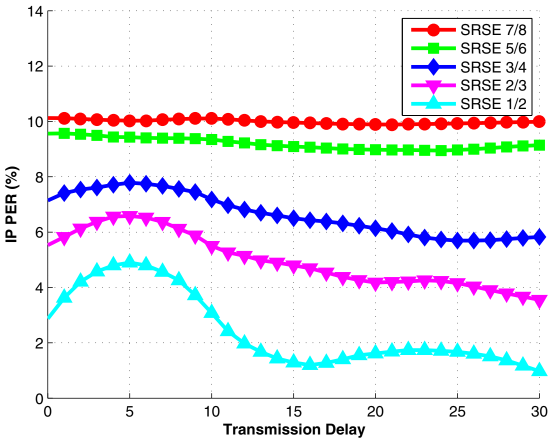

Fig. 6. IP packet error rate over the transmission delay in the trace with a MPE section error rate of 11.3%. *B* and *S* are configured to 5. Streaming service 6 minutes at 256 kb/s

In Fig. 5, the same trace is used to show how the obtained IP PER decreases as the latency of the SRSE is incremented for five different code rates. Thanks to SRSE, the lower code rates reach the IP PER 5% threshold for latencies well below 60 s. Code rates 1/2, 2/3 and 3/4 achieve an IP PER 5% with 5, 19 and 37 seconds of latency respectively. Therefore it is needed to set the code rate according to the latency in order to achieve the desired quality with the available capacity. However, higher code rates failed to reach the threshold even with the maximum allowed latency. If the percentage of errors is higher than the correcting capabilities of the code rate, it is not possible to repair the information regardless of the duration of the interleaving.

In Fig. 6, the effect of the transmission delay parameter has been analyzed on the trace with a MPE SER of 11.3% when the SRSE is configured to B=5 and S=5. As it was previously explained, increasing the D parameter reduces the zapping time at the cost of some performance, and the results of Fig. 6 corroborate this assumption. When D is set below the B+S value, which in this case is 10, the performance degrades with respect to D=0. If the value is set over B+S, the performance actually improves, however, the end to end latency and memory requirements are increased. The worst performance is achieved when D=B=S and all the parity data is sent in the same time sliced bursts as the information data from which it was generated. The effect is less noticeable for the higher code rates as the amount of parity is too small to be affected by interleaving. In the case of the lowest code rate, setting the transmission delay to 5 bursts maintains the IP PER below the 5% threshold, but at the same time, cuts the zapping time in half. This is an example of how an adequate configuration of the transmission delay can seriously improve the service quality experimented by the user.

V. CONCLUSION

A new link layer protection framework called MPE-iFEC has been recently defined in the DVB-SH standard. The SRSE is a MPE-iFEC mapping that employs a sliding encoding mechanism and the same RS (255,191) encoding algorithm as MPE-FEC in order to achieve MBE protection. In this paper, the performance of the SRSE in the transmission of streaming services in DVB-H networks has been evaluated with DVB-H error traces. The results show that although the SRSE was originally designed for satellite transmissions, it can seriously decrease the number of errors in real terrestrial networks. However, as a consequence of the MBE, some latency is introduced in the system, which increments the zapping time and decreases the quality of the service experimented by the user. Thanks to an adequate configuration of the parameters that regulate the SRSE mechanism, the zapping time can be reduced to acceptable levels with little or no penalty in the offered protection.

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