On the Performance and Efficiency of Generic Stream Encapsulation Combined with LDPC Coding for the Terrestrial DVB Systems

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***Abstract*—Generic Stream Encapsulation (GSE) provides a simple and efficient method to encapsulate network layer packets to a format suitable for the physical layer. The performance of GSE is considered in this paper through overhead calculations and simulations over four physical layer configurations. The results are compared to the results of Multi-Protocol Encapsulation (MPE) with Transport Stream multiplex. The combined effect of encapsulation and forward error correction is taken into account also.**

Keywords—**Channel modeling & simulation, DVB, Mobile TV**

I. INTRODUCTION

Digital Video Broadcasting for Terrestrial networks (DVB-T) has been a great success that enabled switch off of analogue TV networks in Europe. DVB-T2 (second generation terrestrial) is designed to meet the challenges facing the industry as it seeks to exploit commercial opportunities that will follow analogue switch off, providing advanced techniques that will enable new services, e.g. HDTV (high-definition TV). The DVB-T2 standardization is under progress [1]. Publication of a DVB-T2 ETSI (European Telecommunications Standards Institute) standard is planned to the end of 2008.

To maintain maximum compatibility with the family of DVB standards, the assumption is that the LDPC (Low Density Parity Check) forward error correction code from DVB-S2 [2] (second generation satellite) will be used [1]. Also, it is expected that the packet structure, including baseband frames, will be preserved.

The first generation of DVB standards support the MPEG format with a Transport Stream packet multiplex (MPEG-TS) for data transport. Internet Protocol (IP) packets are encapsulated into MPE (Multi-Protocol Encapsulation) sections that are transported in constant length MPEG-TS packets [3]. Figure 2 depicts the MPE encapsulation method in DVB-H (handheld).

The second generation of DVB standards introduce generic modes for carrying arbitrary packets of variable lengths, i.e. Generic Streams (GS) [4]. The use of both Transport Stream and Generic Stream are defined in the commercial requirements [1] for DVB-T2.

The Generic Stream Encapsulation (GSE) protocol functions as an adaptation layer to provide efficient encapsulation and fragmentation of IP and other network layer packets, named Protocol Data Units (PDU), over a “generic” physical layer [4]. Such a “generic” physical layer carries a sequence of data bits or data packets without specific timing constraints. PDUs are encapsulated into one or more GSE packets (Figure 1), which vary by length in order to maximize the efficiency of IP packets transport with minimum overhead. GSE packets are transported in BaseBand (BB) frames (L1). In S2 they have the length of the data part of one LDPC code word. The LDPC code in DVB-S2 [2] has a constant code word length of 16200 or 64800 bits, whereas the amount of data and redundancy bits are varied to achieve different code rates.

In the next sections the performance of the combination of GSE transported in baseband frames, protected by the DVB-S2 LDPC code, with other transmission parameters taken from the DVB-T specification is compared to standard DVB-T and DVB-H implementations for IP transmission. In addition, the performance of a DVB-T system, where channel coding consisting of concatenated convolutional and Reed-Solomon RS(204,188) codes are replaced by LDPC, is analyzed. Similar approach has been used in [5], in which convolutional and Reed-Solomon codes are replaced with the turbo code. Here, replacement is LDPC, since it is currently used, for example, in DVB-S2. Thus, the following options have been considered in this paper:

- IP/GSE/BB over DVB-T with LDPC
- IP/MPE/TS/BB over DVB-T with LDPC
- IP/MPE/TS over DVB-T
- IP/MPE-FEC/TS over DVB-H

II. PROTOCOL OVERHEAD CALCULATIONS

In this section the relative protocol overhead from the link layer and physical layer protocol headers are calculated. The relative protocol overhead is calculated by

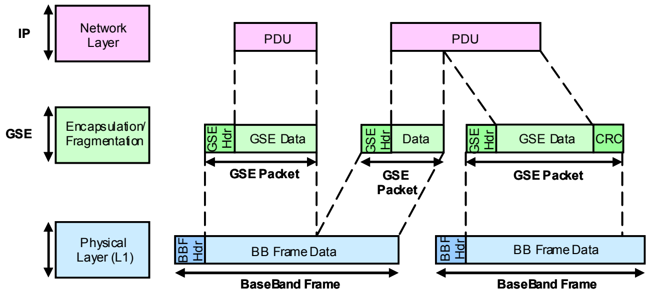

Figure 1. GSE encapsulation within DVB protocol stack [4]

$$o = \frac{ip + g_h + b_h}{ip} - 1, \tag{1}$$

where ip denotes total amount of IP packet data, g_h denotes the link layer overhead, i.e. GSE or MPE header length (incl. GSE fragmentation headers) and b_h denotes physical layer overhead, i.e. baseband frame header lengths (10B) and/or TS headers (4-5B). The length of the GSE header was 7 bytes, including a 3 byte label, and the length of a GSE fragmentation header was 3 bytes.

Figure 3 and Figure 4 show the overhead for GSE/BB, MPE/TS and MPE/TS/BB. In addition an option of encapsulating MPE section into baseband frames (MPE/BB) is considered. This will probably not be supported by the DVB-T2 specification but including this option enables a fair comparison between the first and second generation link layer encapsulation methods.

The results show that GSE/BB always introduces less protocol overhead than MPE/TS/BB. Figure 3 demonstrates that the differences between GSE/BB and MPE/BB are small, especially with the short LDPC block, i.e. L1 packet length 405-1800 bytes. Figure 4 demonstrates that the difference in protocol overhead is greatest with short IP packets.

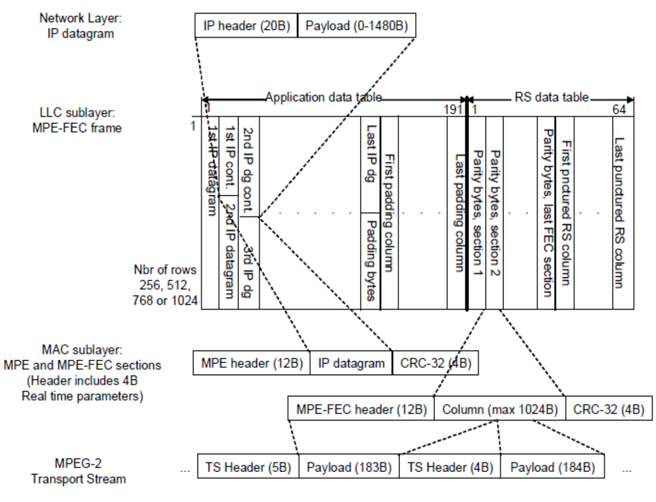

Figure 2. MPE encapsulation in DVB-H

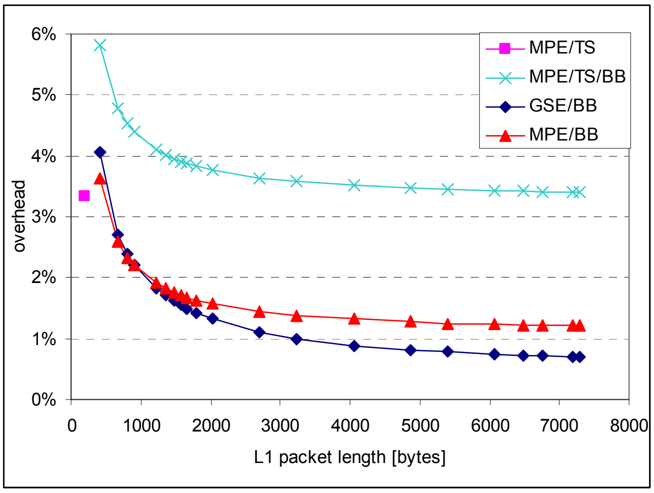

Figure 3. Protocol overhead with IP packet length 1500 bytes.

III. SIMULATIONS

A. Simulator

The simulations were performed with MATLAB. The goal of the simulations is to compare IP packet error ratios and byte error ratios for different encapsulation and error correction combinations. The receiver side of the GSE simulator, i.e. the decapsulator, consists of two functions (Figure 5): baseband frame header removal and GSE packet header removal. The decapsulator takes the byte error trace, in which '0' indicates an erroneous byte and '1' indicates a correct byte, from the LDPC decoder as input.

First the 10 byte BB frame header is removed from the error trace. In the simulations the BB frame header structure is not studied in detail, and therefore possible errors occuring in the BB frame headers are not considered to have an effect of losing whole BB frames.

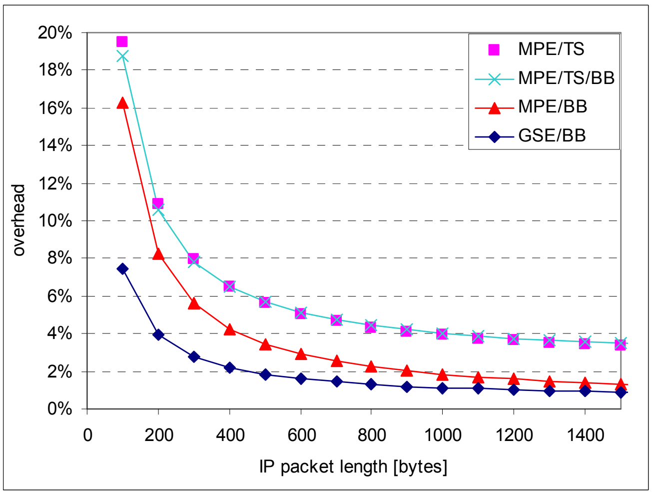

Figure 4. Protocol overhead with BB frame length = 4050 bytes or TS packet length = 188 bytes.

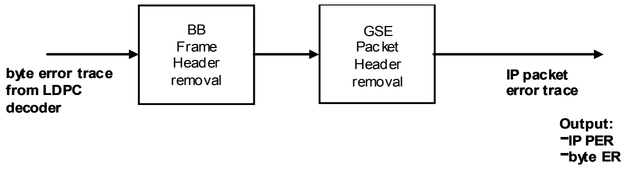

Figure 5. GSE decapsulation

After the removal of the BB frame header follows the GSE packet header removal. In the simulations one GSE packet is composed of the GSE packet header and the payload, i.e. the PDU. Here the PDU is one complete (varying length) IP packet, i.e. one IP packet per one GSE packet. This is contrary to [4], according to which a PDU can be fragmented over several GSE packets. The fragmentation of a PDU would require the use of cyclic redundancy check (CRC) in the GSE packet of the last PDU fragment (Figure 1). This is avoided in the simulations by fragmenting the GSE packets. The GSE packet header consists of different fields as indicated in Figure 6. This is only one example of the GSE packet header. Further details can be found from [4].

The S (Start) and E (End) fields indicate here with one bit value '1' that the IP packet, i.e. the PDU, has a start and an end in this GSE packet. In the simulations this is always the case, contrary to the PDU fragmentation [4], which alters the use of the S and E fields. Also, the LT (Label Type) field is always the same in the simulations. It is chosen to be '01' in value, indicating that the label (Label field) is chosen to be constantly a three byte label to simplify the simulations. There are in fact four different label types that should be used according to different situations [4].

The GSE Length field indicates the joint lengths of the Protocol Type and Label fields and the PDU. And as the lengths of the PDUs vary, so does the value of the GSE Length field. The Protocol Type and Label fields are considered as random data in the simulations, and detailed information of them can be found from [4].

In the simulations, the GSE packet is considered to be lost if an error occurs ('0' in the byte error trace) in the first or second byte of the GSE packet header, i.e. in the S, E, LT or GSE Length fields. Since there is no synchronization field in the GSE packet header, one lost GSE packet in a BB frame would result losing the following GSE packets within that BB frame, as well. The lack of synchronization in GSE results in poor parsing, i.e. finding the GSE packets from the received stream, in case of errors in the header. However, the simulations are simplified so as not to take this cumulative effect into account. Instead, it is assumed that the beginning of every GSE packet is known.

B. Results

Two different channel types were considered in the simulations: COST207 6-tap Typical Urban (TU6) channel [6]

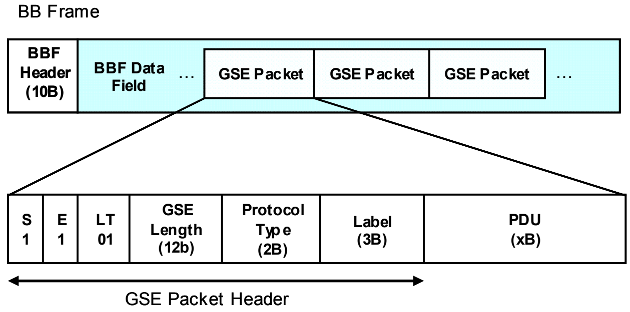

Figure 6. Baseband frame and GSE packets

with 10Hz Doppler frequency to model mobile reception and the Ricean channel model for fixed reception. IP packet error ratios (IP PER) and byte error ratios were studied at a variety of carrier-to-noise-ratios (C/N). The physical layer parameters were 16-QAM modulation with code rate 1/2 (convolutional or LDPC) and 8K OFDM FFT size with guard interval 1/8. For the DVB-H use case the MPE-FEC (Forward Error Correction) code rate 3/4 was used, resulting in an RS(255,191) code.

Figure 7 and Figure 8 contain the IP PER and byte error ratios, respectively, for the mobile channel while Figure 9 and Figure 10 present the IP PER and byte error ratios, respectively, for the fixed channel. The following observations can be made:

- It is seen that both GSE/BB and MPE/TS/BB over DVB-T with LDPC give similar results; the error performance is not related to encapsulation.
- When comparing the performance of channel coding, it is seen that with LDPC error ratios decrease rapidly with growing C/N values. In case of mobile reception, Figure 7 and Figure 8 imply that DVB-T performs better with lower C/N values compared to the results of DVB-T with LDPC. However, time interleaving, which was not performed over DVB-T with LDPC in the simulations, will be used in DVB-T2 and this is expected to result in better performance. Time interleaving is needed in the mobile channel due to error bursts and the effect of it in DVB-H is studied, for example, in [7]. In contrary, DVB-T with LDPC in the Ricean channel gives better results than standard DVB-T even without time interleaving. This shows that in fixed reception time interleaving in not that crucial.
- In a comparison of mobile and fixed reception conditions it is seen that the C/N requirements are higher in the mobile channel to achieve the same error ratio since the mobile channel is more demanding. In the mobile channel (Figure 7) the benefit of the MPE-FEC coding in the DVB-H case can be seen since about 0.5dB less C/N is needed to achieve 1% IP PER compared to the other cases.

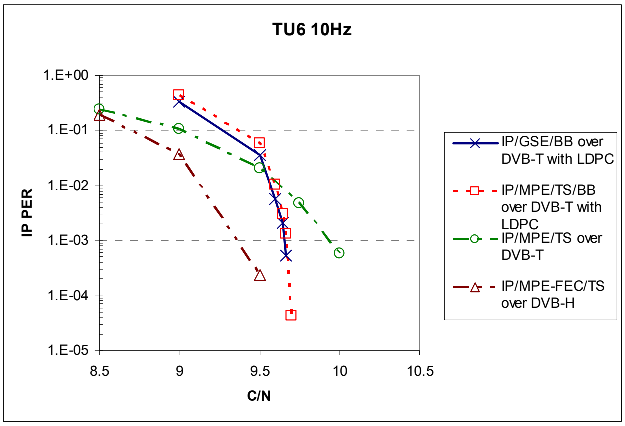

Figure 7. IP packet error ratios in the TU6 10 Hz channel

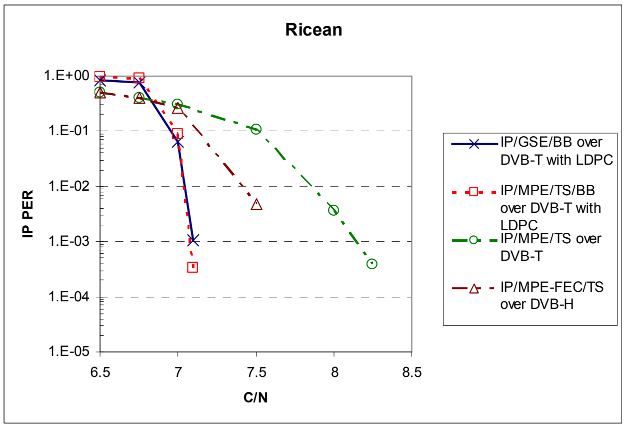

Figure 9. IP packet error ratios in the Ricean channel

Because of the assumption of knowing the beginning of every GSE packet in the simulations and not taking the BBF header errors into account, the results can be considered optimistic for GSE. If the BBF loss and the cumulative effect of GSE packet errors would be taken into account, the error ratio would increase. To avoid the cumulative errors the GSE packet header structure and the GSE packet parsing could be improved. One possibility could be, for example, to add a synchronization field to the header. Another possibility could be to change the GSE packet header fields from [4]. For example, the S and E fields could have been used for other purposes in the simulations, since no PDU fragmentation was performed but complete IP packets were always encapsulated into GSE packets. Also, it could be considered to use protection for the GSE packet header, e.g. CRC, to reduce the possibility of losing whole GSE packets.

If time interleaving would have been performed in the use cases with LDPC, the results would have been different for the TU6 channel. Instead, in the Ricean channel time interleaving would not have such a great effect. In DVB-H, time interleaving is performed over one MPE-FEC frame, which is about 110 ms. In DVB-T2, time interleaving is performed over one LDPC block, which covers three 8K symbols. In time this is about 3 ms. In mobile reception this would not be sufficient but longer time interleaving would be required to battle against burst errors. Due to the physical layer parameters the IP level throughput bit rate is 11.06 Mbps for the terrestrial use cases. After the link layer MPE-FEC, DVB-H has throughput bit rate of 8.29 Mbps. This difference in the bit rates makes the comparison of the results more uneven, still.

As part of the future work the effect of BBF loss and cumulative GSE packet errors on the performance of GSE will be studied thoroughly. The alteration of the GSE packet header structure will be studied. For example, we could see how better parsing by adding a synchronization field to the GSE packet header would affect on the performance without the assumption of knowing the beginnings of the GSE packets beforehand. Also, new simulations will be performed to study the effect of using the same IP level throughput bit rates in comparison of DVB-T/T2 and DVB-H. The effects of time interleaving in DVB-T2 will be an important part of the future work, as well.

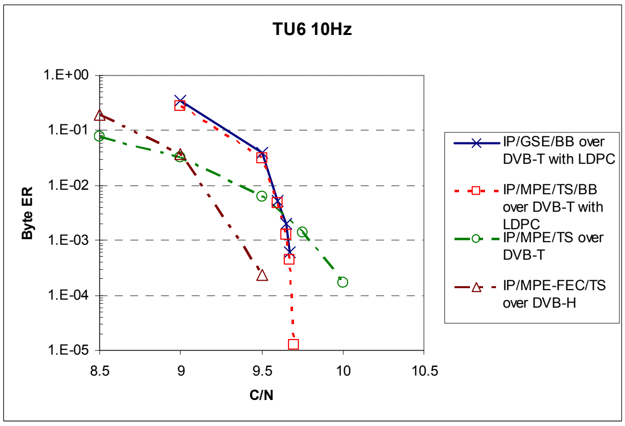

Figure 8. Byte error ratios in the TU6 10 Hz channel

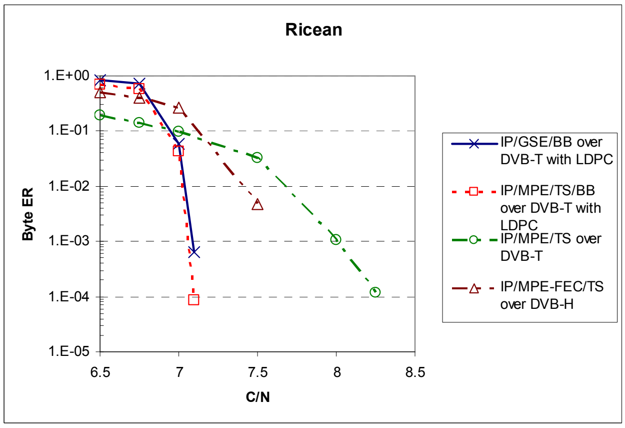

Figure 10. Byte error ratios in the Ricean channel

IV. CONCLUSIONS

In this paper a general idea of Generic Stream Encapsulation is introduced. The performance and efficiency of GSE is analyzed and compared to different cases using MPE (Multi-Protocol Encapsulation). Overhead calculations are presented to show how the use of GSE/BB results in better efficiency compared to MPE/TS/BB when transporting data.

In the simulations a different approach from [4] is used. Here the fragmentation is not performed on the IP packets but on the GSE packets. Simulation results are presented to depict the performance of GSE combined with LDPC coding in fixed and mobile reception scenarios. The performance is compared to DVB-T, DVB-H and modified DVB-T system, where channel coding is replaced by LDPC code. The results imply that the performance is independent of the method of encapsulation. However, positive assumptions for the GSE packet parsing were made in the simulations concluding in optimistic results. Therefore it can be deduced that MPE would perform more efficiently than GSE when comparing the error ratios. Considering the results and assuming that time interleaving would be included, it can be stated that DVB-T with LDPC performs better than standard DVB-T.

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