Optimization of the Headers in DVB-S2 for Conveying IP Packets over GSE

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Abstract. Convergence has become a key idea in communications over the past few years and IP has become the key 'convergence layer'. GSE (Generic Stream Encapsulation) enables the carriage of IP packets directly over DVB-S2 networks in a very efficient way, and it is considered to be used in the future access encapsulation. Thinking that these future services will be all-IP, this paper is intended to explain how the header of the BBFRAME (Base-Band Frame) of the DVB-S2 can be optimized until be completely removed in future broadcast satellite networks which will use IP/GSE/DVB-S2 only stack. This reduction is intended to separate the physical layer and link layer functionalities provided both by DVB-S2 and to simplify and ease the understanding of the DVB-S2 protocol.

Keywords: DVB-S2, GSE, BBFRAME, IP, optimization, convergence.

1 Introduction

In the future, networks may be founded on the development of an all-IP communication and service infrastructure that will gradually converge the current Internet, mobile, fixed and broadcasting networks. This IP convergence implies the carriage of different types of traffic such as voice, video, data, and images over a single network.

Satellite networks have been massively used for TV broadcasting and currently also follow this all-IP trend since satellite-delivered IP services are growing in every region of the world, not just those with limited telecom infrastructure. There are several factors involved in the growth of broadband satellite IP services: the performance (many satellite operators and hardware providers have integrated advanced IP networking capabilities into their offerings), the reduced cost (both for equipment and bandwidth), the success of multi-site applications based in open standards, but the arrival of a return link by satellite (DVB-RCS) has been the main factor and has been a milestone in these kind of networks.

DVB-S2 is designed as the successor for the popular DVB-S digital television broadcast standard and was ratified in 2005. It provides several functionalities of

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physical layer such as modulation and synchronization and also of link layer such as coding, multiplexing and concatenation. The main objective of this paper is to separate these functionalities and simplify and ease the understanding of the protocol just as providing a first step of a future all internet protocols (user plan, control plan and management plan) over GSE only for the DVB-S2 protocol.

Next sections are organized as follows. In sections 2 and 3 an overview of the DVB-S2 system and GSE encapsulation is presented. Section 4 analyses the reduction of the BBHEADER of the DVB-S2 and in section 5 the reduction of the header in terms of gain efficiency is presented. The final conclusions are drawn in section 6.

2 DVB-S2 Overview

DVB-S2 [2] is a digital satellite transmission system developed by the DVB Project from 2003 as the successor of the world-wide known DVB-S standard. This architecture is designed and optimized for broadcast satellite applications such as digital television, content distribution and data transmission.

DVB-S2 implements the most recent developments in modulation and channel coding, with the use of QPSK, 8-PSK, 16-APSK, 32-APSK and especially, the use of concatenated Bose-Chaudhuri-Hocquenghem (BCH) and Low Density Parity Check (LDPC) codes. DVB-S2 makes use of 28 combinations of modulation format and coding scheme (MODCOD) to deliver performance that approaches the theoretical limit for such systems. Together, these can guarantee a low packet error ratio across a wide range of Signal to Noise plus Interference Ratio (SNIR), from -2.3 dB (QPSK) to 16 dB (32APSK). In addition, DVB-S2 provides functionalities of link layer such as fragmentation, multiplexing, assembling and concatenation and of physical layer as synchronization and modulation. The functional diagram block of DVB-S2 is shown in figure 1.

The processing of packets arriving at the DVB-S2 gateway can be summarized below:

1) Input streams (Generic Streams or Transport Streams) arrive at the Mode Adaptation block and each block input data is sliced into a constant DATAFIELD (DFL) in case of CCM mode or in a variable DATAFIELD in case of VCM/ACM mode. After that, a 80-bits BBHEADER is appended. For the VCM/ACM mode, the maximum length of each DATAFIELD is determined by the field MODCOD between different values (11 values for normal FECFRAME n_{ldpc} = 64800 bits, 10 values for short FECFRAME n_{ldpc} = 16200 bits and 3 values for very short FECFRAME n_{ldpc} = 4096) according to the protection required for each of them.
2) The Stream Adaptation block fills any unused bits in the DATAFIELD with padding (all zero bits) and generates a BBFRAME (Base-band Frame).
3) A block code is applied to each BBFRAME to form the FECFRAME, which can have 4096, 16200 or 64800 bits depending on the field TYPE of the PLHEADER. This code is a combination of BCH binary block code and a Low-Density Parity Check (LDPC) code, adding redundancy from 1/4 to 9/10.

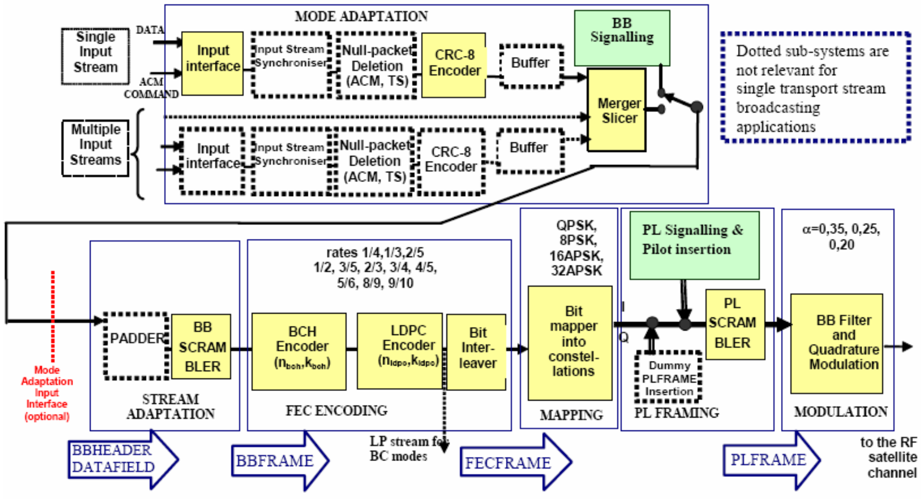


Fig. 1. Functional block diagram of the DVB-S2 system [2]

4) The encoded bits of the FECFRAME are interleaved, mapped to modulation symbols, using either QPSK (parallelism level $\eta_{MOD} = 2$), 8PSK ($\eta_{MOD} = 3$), 16APSK ($\eta_{MOD} = 4$) or 32APSK ($\eta_{MOD} = 5$) to form the XFECFRAME and finally randomized. Then it is sliced into an integer number S of slots of 90 symbols each and embedded in a PLFRAME (Physical Layer Frame), which is prefixed by the SOF (Start of Frame) and the MODCOD. Each PLFRAME length is variable and depends on the chosen constellation. The size of one PLFRAME can be calculated by dividing the total number of bits of the XFECFRAME by the parallelism level (η_{MOD}) and adding the 90 symbols of the PLHEADER.
5) After randomization, the signals shall be square root raised cosine filtered and modulated. The roll-off factor shall be α = 0,35, 0,25 or 0,20, depending on the service requirements.

DVB technology, based on the MPEG-2 system standard, has been increasingly successful in providing IP services and several encapsulation protocols have been proposed, such as MPE (Multi Protocol Encapsulation) [7], ULE (Unidirectional Lightweight Encapsulation) [9] or GSE (Generic Stream Encapsulation) [3], [4]. Although they have been analyzed in the literature [11], [12] and are commonly accepted as the standard ways to carry IP datagrams over existing DVB satellites, Generic Stream Encapsulation (GSE) is known to be a more efficient way to transport IP packets over DVB-S2 and the objective in the next future is to replace the current MPEG2-TS data encapsulation by the GSE direct encapsulation. Figure 2 shows this possible evolution of the protocol stacks from IP/MPE/MPEG2/DVB-S to IP/GSE/DVB-S2.

3 DVB-GSE Overview

DVB Generic Stream Encapsulation (DVB-GSE) comes up to provide a mean of carrying IP based content on DVB-S2 physical layers. Conceptually, it is at the same level in DVB systems as the Transport Stream, offering several functionalities such as concatenation and multiplexing also provided by DVB-S2. All DVB second-generation physical layer standards (e.g. DVB-S2, DVB-T2, etc…) will be "multi-mode", offering the option of using either the traditional MPEG Transport Stream or

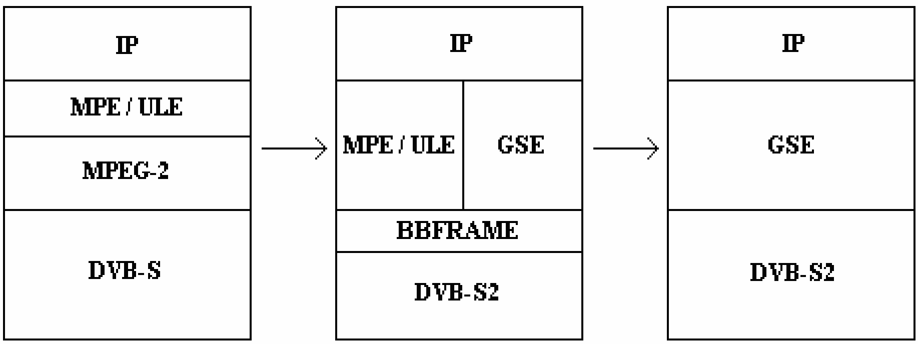


Fig. 2. Evolution of the protocol stacks over DVB

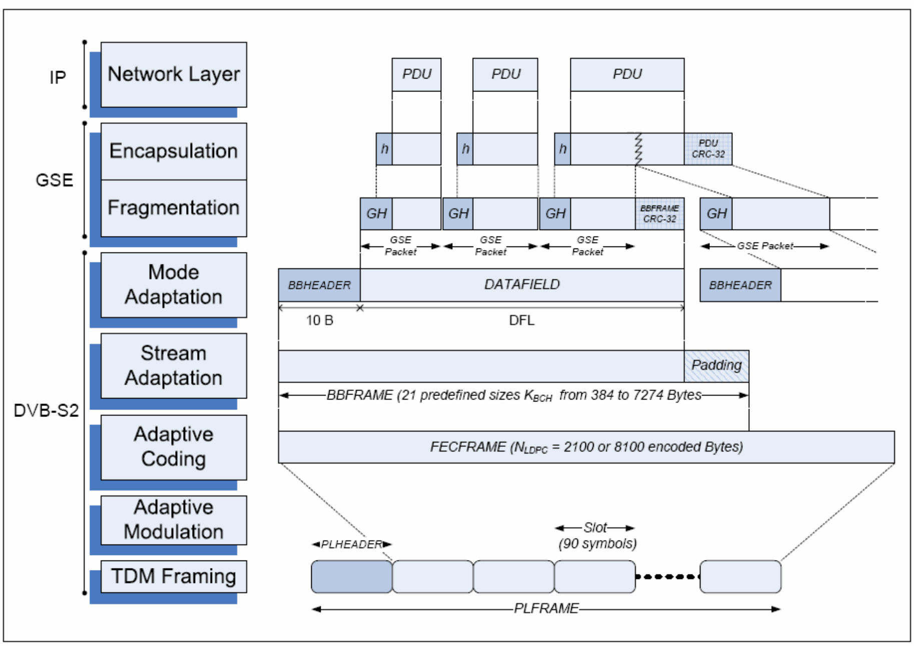


Fig. 3. GSE encapsulation within DVB protocol stack

DVB-GSE. As the network of the future is founded on the development of a converged all-IP communication, the MPEG Transport Stream are going to be replaced likely by the DVB-GSE since the latter is optimized for IP packets, IP-multicast and IPv6 transport (and optionally higher protocols such as MPLS or VLAN). Figure 2 shows a scheme of the evolution protocol stacks over DVB. The tendency is conveying IP packets over GSE (IP/GSE/DVB-S2) for the forward link.

The GSE operation within DVB-S2 protocol stack is depicted in figure 3. An encapsulated PDU (typically IP), prefixed by any optional extension ("h") headers added by the encapsulator, forms the payload of one or more GSE Packets. Each GSE Packet also includes a GSE header ("GH") that contains the length, protocol type and label field (when present). The stream of GSE Packets is placed in the DATAFIELD of a BBFRAME. The sender normally selects the MODCOD (and hence the BBFRAME size) to achieve the QEF (Quasi Error Free) target.

4 DVB-S2 BBHEADER Reduction

As shown in figure 1 and figure 3, after the Mode Adaptation block, a fixed length Base-Band Header (BBHEADER) of 80 bits is inserted in front of the DATA FIELD by the Stream Adaptation block, describing its format. This header adds an overhead to the BBFRAME depending on the LDPC Code and the length of the FECFRAME (normal, short or very short).

All these overhead can be reduced in case of using GSE only. The simplification of the header which is going to be carried out is independent of the protocol encapsulated in GSE (IPv4, IPv6, MPEG2-TS, MPLS…). Next it is presented each field of the BBHEADER, what is used for, its value in case of using GSE and why it does not apply.

1) TS/GS field (2 bits): Transport Stream Input or Generic Stream Input (packetized or continuous). The different values of this field are shown in table 1. With only GSE encapsulation this field should be set to a unique value and therefore can be removed.

Table 1. TS/GS field

TS/GS
11 = Transport 00 = Generic Packetized 01 = Generic Continuous 10 = Reserved

2) SIS/MIS field (1 bit): Single Input Stream (value '1') or Multiple Input Stream (value '0'). The link layer function associated to this field is multiplexing since in DVB-S2 multiple streams may be multiplexed at the transmitter. Generic Stream Encapsulation shall be carried out separately for the incoming data of each generic stream. Each stream is identified by a specific Input Stream Identifier (ISI). Its value is present in the BBHEADER (in the second byte of the MATYPE field) in case of multiple input streams.

The ISI of each (generic or transport) stream in DVB-S2 is signalled in the S2 satellite delivery system descriptor describing the stream. This descriptor is located in the Network Information Table (NIT). This multiplexing function can be resolved by upper layers, and so this field can be removed.

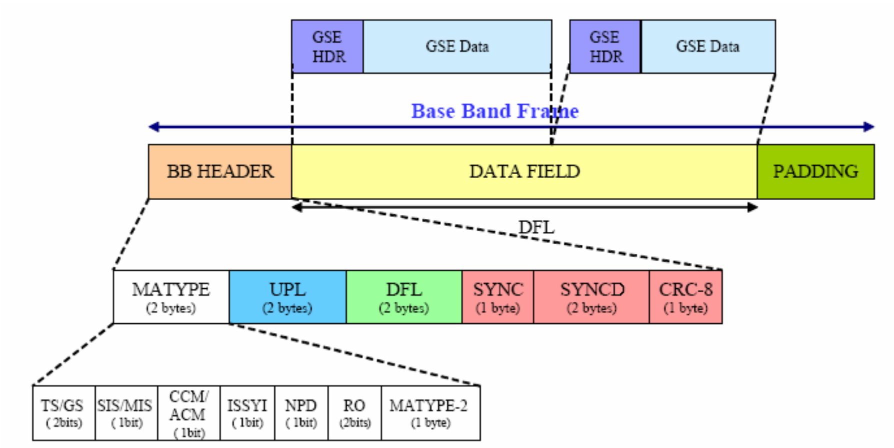


Fig. 4. DVB-S2 BBFRAME format [2]

3) CCM/ACM field (1 bit): Constant Coding and Modulation (CCM, value '1') or Adaptive Coding and Modulation (VCM is signalled as ACM, value '0'). This field could be removed due to the fact that CCM can be considered a particular type of ACM. In fact, the field MODCOD (5 bits) which is part of the PLHEADER of the PLFRAME defines 29 different types of combinations of modulations and coding (28 types and the DUMMY FRAME insertion) and there are 3 possibilities left. We propose to use one of them (29_D, 30_D or 31_D) to signal the CCM mode, or even better, set it by the configuration at the beginning.

4) ISSYI label (1 bit): Input Stream Synchronization Indicator. The function associated with this label allows guaranteeing a constant-bit-rate and is used only for packetized input stream (Transport Stream or Generic Packetized Stream). In case of DVB-S2 encapsulating GSE packets, this field must be always set to 0 (inactive) since GSE is not packetized stream and therefore can be removed. ([2], Annex D.2).

5) NPD field (1 bit): Null-Packet Deletion. The associated function aims at identifying and removing MPEG null-packets because the Transport Stream rules require that the bit rates at the output of the MUX and the input of the DEMUX are constant in time, and the end-to-end delay is also constant. In order to fulfil such requirements in an ACM environment, the null-packet deletion function shall be activated [2]. This field must be set to 0 (inactive) in GSE/DVB-S2 and therefore is not relevant for GSE packets.

6) RO field (2 bits): transmission of the roll-off factor (α). The roll-off factor is a measure of the excess bandwidth of the Base-Band filter (BB Filter) and it varies between 0 (the roll-off zone becomes infinitesimally narrow) and 1 (the non-zero portion of the spectrum is a pure raised cosine). It can take three different values (0.35, 0.25 or 0.20) [2] and it determines the symbol rate.

The roll-off factor does not need to be retransmitted every BBFRAME as once the transmitter and the receiver know the roll-off factor, they can determine the symbol rate. In fact, in the 'Satellite_Delivery_System_Descriptor' [6], the roll-off factor is transmitted together with several parameters such as orbital position or polarization, so this descriptor can be used for this purpose and then these two bits can be removed of the BBHEADER.

7) MATYPE-2 field (8 bits): if SIS/MIS = Multiple Input Stream, this field is used to send the Input Stream identifier (ISI), if not it is reserved. This field can be removed on the same reason than the SIS/MIS field.

8) UPL field (16 bits): User Packet Length in bits, in the range 0 to 65535. The link layer function associated to this field is concatenation. In case of MPEG Transport Stream, this field has to be set to $188x8_D$. For Generic Continuous Streams this field must contain the unique value 0000_{HEX} and can be removed because it is a unique value and this function is already done at GSE level.

9) DFL field (16 bits): Data Field Length in bits. This length can be easily calculated at the physical layer thanks to the 'GSE_Length' field inside the GSE header as shown in figure 5. For a particular MODCOD, the length of the BBFRAME is known and unique. The point here is to calculate how many bits DFL has and how many are padding. In DVB-S2, a Base Band frame always starts with the header of the first GSE packet because there is no fragmentation at the Mode Adaptation level (the fragmentation is just before this, GSE packets are not fragmented between Base Band frames).

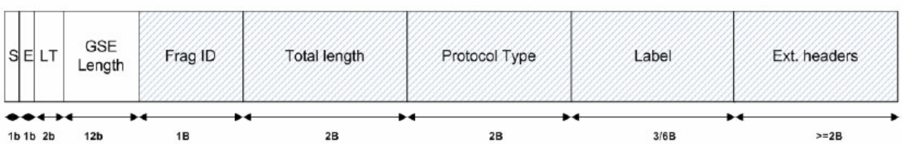


Fig. 5. GSE Header (GH) format [3]

The GSE Length field (fourth field) in the GSE Header indicates the length of the packet after it, so it is easy to calculate the length of the first part of the BBFRAME (16 bits + 'GSE_Length' bits). After that, it should be determined if the next part of the BBFRAME is padding or is another GSE packet (because the padding is provided at GSE level). This is also easy because the padding frame has the first 4 bits of the GSE Header equal to 0000. If the next four bits after the first GSE packet are equal to 0000, the rest of the bits until K_{bch} must be padding and equal to 0. If it is not, it is not a padding frame, and the size will be given by the field 'GSE_Length' as the previous one and so on [3].

10) SYNC field (8 bits): copy of the User packet Sync-byte. In case of MPEG Transport Stream this field has to be set to 47_{HEX}. For Continuous Generic Streams:

SYNC = 00_{HEX} [8]. This field can be removed from the BBHEADER because the synchronization of the packets inside a BBFRAME is already done at the GSE level, since all BBFRAMEs starts with the beginning of a GSE packet.

11) SYNCD field (16 bits): is defined only for packetized Transport and gives the distance in bits from the beginning of the DATA FIELD and the first User Packet (UP) from this frame (first bit of the CRC-8). This field is not defined for Generic Streams and therefore can be removed. Moreover in case of using GSE encapsulation, each PLFRAME must start with the beginning of one GSE packet, so the synchronization at this level is already done and this SYNCD field is redundant.

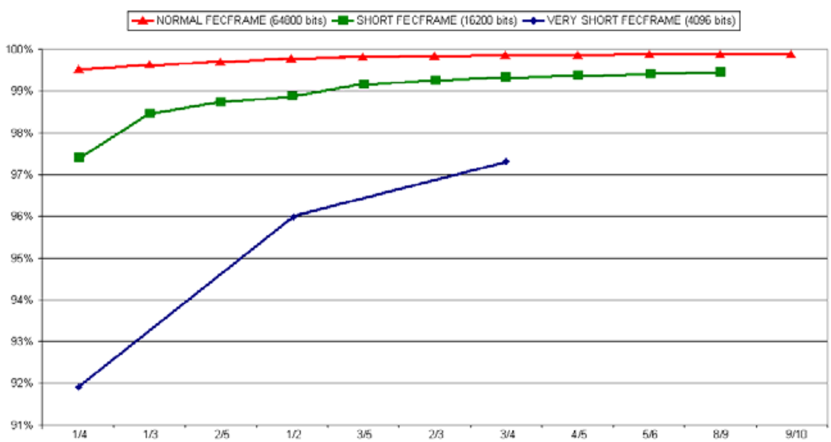
12) CRC-8 field (8 bits): error detection code applied to the first 72 bits of the BBHEADER. Obviously this field can be removed as the header has been removed.

5 Results in Terms of Efficiency for the Optimization of the BBHEADER

This reduction can be measured in terms of efficiency by dividing DFL (Data Field Length = K_{bch} - 80 bits of the header) by the K_{bch} (length of the BBFRAME) as shown:

$$\eta = \frac{k_{bch} - 80}{k_{bch}} = \frac{DFL}{k_{bch}}$$

The figure 6 shows a graphic with the different efficiencies of the BBFRAME depending on the LDPC code and the type of FECFRAME (very short, short or normal) before the reduction.



NORMAL	99,500%	99,626%	99,689%	99,752%	99,793%	99,814%	99,835%	99,845%	99,851%	99,861%	99,863%
SHORT	97,396%	98,471%	98,733%	98,862%	99,162%	99,240%	99,317%	99,356%	99,392%	99,438%	
VERY SHORT	91,944%			95,984%			97,333%				

Fig. 6. BBFRAME Efficiency for each LDPC code (DFL/K_{bch})

For the very short FECFRAME (n_{ldpc} = 4096 bits) the efficiency of the BBFRAME varies between 91,9% (code rate 1/4) and 97,3% (code rate 3/4), for the short FECFRAME (n_{ldpc} = 16200 bits), the efficiency of the BBFRAME varies between 97,39% (code rate 1/4) and 99,43% (code rate 8/9) and for the normal FECFRAME (n_{ldpc} = 64800 bits), between 99,5% (code rate 1/4) and 99,8% (code rate 9/10). So the maximum efficiency loss introduced by the BBHEADER is 8,1% (very short FECFRAME with code rate 1/4) and these losses can be reduced to 0% with the solution provided in this paper.

6 Future Work and Conclusions

The reduction of the BBHEADER explained in the paper makes possible to remove double behaviours such as multiplexing or concatenation also provided by GSE encapsulation just as simplify and ease the understanding of the DVB-S2 protocol giving a clear functional separation between functions of physical layer and functions belonging to the link layer. Therefore, DVB-S2 would be in charge of the physical layer functions such as modulation, coding and synchronization, and GSE of the link layer functionalities such as concatenation and multiplexing.

Although the performance is not the goal of this paper, this reduction also achieves an obvious improvement of the processing at the receiver and the increase of the capacity of 80 bits per BBFRAME. This improvement increases the bit-rate between 0,14% and 8,06% depending on the code and the modulation.

A future step is to understand the synchronization at the satellite terminal (RCST) and study the possibility of inserting MPEG2 packets (which carry the Network Clock Reference) inside GSE packets by the scheduler. As it is known, these NCR packets have to be inserted inside certain GSE packets known in advance, and this can create a cross-layer problem which has to be resolved. The addressing and signalling have also to be carefully studied in these systems since currently MPEG2-TS is used instead of GSE to transport the information tables.

The reduction of the GSE header is another point which could be taken into account since, for example, the 'Total_Length' field is only used for providing information to the RCST to keep memory in the reception buffers.

Finally, all these improvements could be studied in standards such as DVB-T2, DVB-C2 and DVB-SH.

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