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Foreword

This Technical Specification (TS) has been produced by Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECTrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI).

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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Founded in September 1993, the DVB Project is a market-led consortium of public and private sector organizations in the television industry. Its aim is to establish the framework for the introduction of MPEG-2 based digital television services. Now comprising over 200 organizations from more than 25 countries around the world, DVB fosters market-led systems, which meet the real needs, and economic circumstances, of the consumer electronics and the broadcast industry.

1 Scope

The present document includes the definition of the Generic Stream Encapsulation (GSE) protocol, which allows for efficient encapsulation of IP and other network layer packets over a "generic" physical layer. Such a "generic" physical layer is intended as a transport mode that carries a sequence of data bits or data packets, possibly organized in frames, but with no specific timing constraints.

The first generation of DVB standards only supported data transport using the MPEG format (see ISO/IEC 13818-1 [2]), with a Transport Stream packet multiplex (MPEG-TS). Multi Protocol Encapsulation (EN 301 192 [3]) is the DVB standard for encapsulation of audio/video and other content on MPEG-TS packets. The second generation of DVB standards features backwards compatibility modes for carrying MPEG-TS as well as generic modes for carrying arbitrary packets of variable length. These are referred to as Generic Streams (GS).

The GSE protocol has been devised as an adaptation layer to provide network layer packet encapsulation and fragmentation functions over Generic Stream. GSE provides efficient encapsulation of IP datagrams over variable length Layer 2 packets, which are then directly scheduled on the physical layer into Base Band frames.

GSE maximizes efficiency of IP datagrams transport reducing overhead by a factor 2 to 3 with respect to MPE over MPEG-TS. This is achieved without any compromise of the functionalities provided by the protocol, due to the variable length Layer 2 packet size, suited to IP traffic characteristics. For example in an interactive DVB-S2 system, the overhead is reduced on average from about 10 % for MPE/MPEG-TS to 2 % to 3 % for GSE. Hence yielding an overall throughput gain of about 5 % to 15 %, the actual benefit is of course dependent on the concrete system and traffic characteristics.

In addition to the overhead reduction, GSE provides a more efficient system operation for interactive systems that utilize advanced physical layer techniques such as for instance Adaptive Coding and Modulation (ACM). The inherent channel rate variability experienced in ACM systems makes the Generic Stream format more suited than the Transport Stream. GSE provides a flexible fragmentation and encapsulation method, which permits use of a smart scheduler to optimize system performance, either by increasing the total throughput and/or by improving the average packet end-to-end delay. In addition, GSE flexibility leads to a reduction in packet loss under fading variations, allowing the scheduler at the transmitter to dynamically change transmission parameters (for example modulation format, coding rate) for a particular network layer packet.

GSE also provides additional features that increase the protocol flexibility and applicability. Some key GSE functions/characteristics are:

- 1) Support for multi-protocol encapsulation (IPv4, IPv6, MPEG, ATM, Ethernet, 802.1pQ VLANs, etc.).
- 2) Transparency to network layer functions, including IP encryption and IP header compression.
- 3) Support of several addressing modes: In addition to the 6-byte MAC address (including multicast and unicast), it supports a MAC addressless mode, and an optional 3-byte address mode.
- 4) A mechanism for fragmenting IP datagrams or other network layer packets over Base Band frames to support ACM/VCM.
- 5) Support for hardware filtering.
- 6) Extensibility: additional link protocols can be included through specific protocol type values (e.g. Layer 2 security, IP Header Compression, etc.).
- 7) Low complexity.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

- [1] ETSI EN 302 307: "Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications".
- [2] ISO/IEC 13818 (parts 1 and 2): "Information technology - Generic coding of moving pictures and associated audio information".
- [3] ETSI EN 301 192: "Digital Video Broadcasting (DVB); DVB specification for data broadcasting".
- [4] IETF RFC 4326: "Unidirectional Lightweight Encapsulation (ULE) for Transmission of IP Datagrams over an MPEG-2 Transport Stream (TS)".
- [5] IETF RFC 3819: "Advice for Internet Subnetwork Designers".
- [6] IETF RFC 3309: "Stream Control Transmission Protocol (SCTP) Checksum Change".
- [7] IETF RFC 1112: "Host extensions for IP multicasting".
- [8] IETF RFC 2464: "Transmission of IPv6 Packets over Ethernet Networks".
- [9] draft-ietf-ipdvb-ule-ext-04.txt: "Extension Formats for Unidirectional Lightweight Encapsulation (ULE) and the Generic Stream Encapsulation (GSE)".

2.2 Informative references

- [10] ETSI TR 101 162: "Digital Video Broadcasting (DVB); Allocation of Service Information (SI) codes for DVB systems".

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACM	Adaptive Coding and Modulation
ATM	Asynchronous Transfer Mode
BB	Base Band
CRC	Cyclic Redundancy Check
DVB	Digital Video Broadcast
E	End indicator
EBU	European Broadcasting Union
FragID	Fragmentation Identifier
GS	Generic Stream
GSE	Generic Stream Encapsulation
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPR	Intellectual Property Rights
ISO	International Standard Organization
JTC	Joint Technical Committee
LT	Label Type indicator
MAC	Medium Access Control
MODCOD	MODulation and CODing
MPE	Multi Protocol Encapsulation
MPEG	Moving Pictures Experts Group
MPLS	Multiple Protocol Label Switching
NPA	Network Point of Attachment
PDU	Protocol Data Unit
QoS	Quality of Service
RCS	Return Channel System
RFC	Request For Comment (IETF standard)
S	Start indicator
SI	Service Information
TS	Transport Stream
ULE	Unidirectional Lightweight Encapsulation
VCI	Virtual Channel Identifier
VLAN	Virtual LAN
VPI	Virtual Path Identifier
VCM	Variable Coding and Modulation

4 Generic Stream Encapsulation (GSE) Protocol

4.1 GSE Principles

Figure 1 illustrates GSE operation. IP datagrams, Ethernet Frames, or other network layer packets, herein named Protocol Data Units (PDUs), that are scheduled for transmission, are encapsulated in one or more GSE Packets. The encapsulation process delineates the start and end of each network-layer PDU, adds control information such as the network protocol type and address label, and provides an overall integrity check when needed.

The PDU may be encapsulated in a single GSE Packet or sliced into PDU fragments and encapsulated in several GSE Packets. GSE Packets have in general variable length, in order to match the input IP traffic with minimum overhead.

GSE Packets may be sent in different Base Band frames, not necessarily consecutive or with the same transmission parameters (modulation format, coding rate). Moreover, no constraint on the GSE Packet position within the frame is assumed. However, GSE Packets shall not be reordered between encapsulator and de-encapsulator. In general, a Base Band frame may multiplex more than a single GSE Packet. Base Band frames may have fixed or variable length.

GSE does not include a mechanism for integrity check of single GSE Packets. A CRC-32 is only appended to the last PDU fragment of a fragmented PDU to verify the correctness of the reassembly operation. GSE relies on the physical layer being able to ensure the required error detection and/or correction probability (see [5] for best current practices in IP networks). The present approach is independent of the specific physical layer provided that this meets the required level for error detection capability.

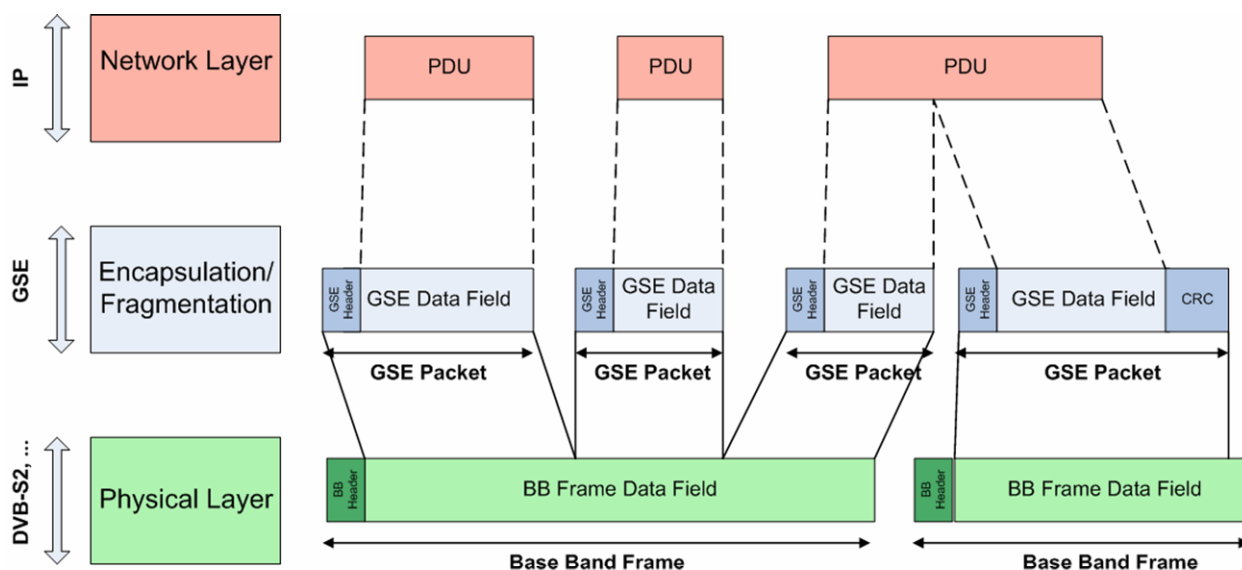


Figure 1: GSE encapsulation within DVB protocol stack

In a system where ACM is utilized, transmission parameters typically change dynamically on a frame-by-frame basis. A receiver will generally successfully decode only a subset of the transmitted frames, i.e. only the ones whose transmission parameters are compatible with the receiver's current channel conditions. GSE does not require that Base Band frames include a payload unit start indicator signalling the position of the first GSE packet in the frame. GSE requires that a Base Band frame always starts with the GSE Header of the first GSE Packet. GSE Packet fragmentation between Base Band Frames is therefore not allowed.

GSE Packets, including fragments of the same encapsulated PDU, can be scheduled without any restriction (on the frame transmission parameter, on the frame position within the sequence of frames or on the GSE Packet position within the frame) in the Base Band frames. Transmission of fragments shall be in-sequence, preserving the transmit order. The GSE reassembly mechanisms support reconstructing the original PDU regardless of the position of GSE Packets in the transmitted frames.

Optimal efficiency of GSE over a physical layer with ACM requires the encapsulator/scheduler to have a-priori knowledge of the Base Band frame lengths (either fixed or variable). Then utilization of the DataField of a Base Band Frame can be optimized through PDU fragmentation. GSE can fragment PDUs into fragments of arbitrary size. Additional information on processing at the encapsulator and on the interface with the modulator is included in annex B.

4.1.1 PDU Fragmentation and Reassembly

The basic GSE Header comprises protocol fields to perform fragmentation and encapsulation. The fragmentation/reassembly process utilizes a Fragmentation Identifier (Frag ID) label. The Frag ID field is present in the GSE Header of each GSE Packet that carries a PDU fragment, and indicates the PDU to which a fragment belongs. This mechanism supports reassembly of GSE Packets that are interleaved but carry fragments of different PDUs either addressed to the same or different receivers. An integrity check trailer with a CRC32 is appended to the final (end) fragment to detect reassembly errors.

The maximum number of PDU fragments that can be simultaneously present on each GS stream is $N=256$. When the forward channel is considered, a single point-to-multipoint data stream shared between receiver terminals shall be assumed. On the other hand, in the case of the return channel, where multipoint-to-point connectivity is in place, a number of point-to-point data streams between each transmitter and the receiver terminal shall be assumed. When the sender has completed transmission of a given PDU, the associated Frag ID value is freed and can be used to fragment another PDU. The number of 256 Frag IDs is considered to exceed the needs of current systems and is foreseen to be adequate for next generation systems as well. Therefore, receivers may limit the number of buffers used to less than 256, depending on the system and on the application (see annex A).

The header of each GSE Packet carries a one bit Start Indicator (S bit) in the most-significant bit. An S bit with a value of "1" indicates the start of a PDU after the GSE Header. Additionally the GSE Header has an End Indicator (E bit) as the second-most-significant bit in the header. An E bit with a value of "1" indicates the end of a PDU within the GSE Packet data field. In case both S and E bit have the value "1" the GSE Packet shall carry a complete PDU. The maximum GSE Packet length is 4KB, this length is carried in the right-most 12 bits of the first two bytes in the GSE Header. A PDU that cannot be carried in a single GSE Packet needs to be fragmented.

4.1.2 Network Protocol Identification

The GSE Header includes a 2 byte Protocol Type/Extension field that indicates the type of protocol carried by the PDU. The Protocol Type field is given in the GSE Header for each complete PDU or the first fragment of an encapsulated PDU and uses the method defined in the Unidirectional Lightweight Encapsulation (ULE) protocol [4]. Extension headers may therefore be defined as in ULE. This approach allows efficient support for a number of PDU formats, including IPv4, IPv6, Ethernet, MPLS, arp, 802.1pQ, etc., and permits inclusion of new protocol types. Moreover, it provides a format for Layer 2 security mechanisms, providing functions such as encryption, identity hiding, and authentication methods, without modification of the GSE Header structure.

4.1.3 Addressing and Hardware Filtering

GSE supports four addressing formats. The default method uses a 6-byte Label (e.g. a IEEE MAC address). It also introduces a 3-byte Label to save overhead in specific cases (see clause 5) and a format with no Label in the GSE Header, either for broadcasting services or for networks, where IP address (or other network layer addressing) processing is implemented. In order to reduce MAC signalling within one single Base Band frame a fourth option (called label re-use) allows to reuse the Label of the previous GSE Packet for subsequent GSE Packets in a given Base Band frame to the same destination address.

To indicate the used format, the GSE Header contains a Label Type Indicator (LT) field of length 2 bits. The value of the Label Type Indicator indicates whether the Label has a length of 6 bytes, or of 3 bytes, or no label is present or label re-use is active. When a Label is present, the receiver shall check the Label and discard any GSE Packet, whose label does not match one configured at the receiver. The GSE Length field in the GSE Header permits the receiver to discard the remainder of a Packet that is not forwarded, by pointing to the start of the following GSE Packet. When the LT value indicates broadcast operation (or IP header processing), all receivers shall process the GSE Packet. Finally, in the case of Label re-use, a receiver shall process a GSE Packet, if and only if the address of the last previously provided GSE Packet matched a receiver address. Label re-use is restricted within the same Base Band frame.

4.1.4 Locating GSE Streams

The receiver terminal shall determine when GSE protocol is applied to a certain received information stream. In the specific case of DVB-S2 for instance, this information is carried in the SYNC field of the Base Band frame header (see [1]).

Depending on the physical layer standard, multiple streams may be multiplexed at the transmitter and simultaneously received at the terminal side. Each stream shall be considered as a separate logical channel. Therefore, GS encapsulation, including fragmentation, shall be carried out separately for the incoming data of each generic stream. The scope of the Frag ID label is per Generic Stream.

4.1.5 Transporting Signalling Information

The stream used for the signalling information may be a Transport Stream (see clause 6). As an alternative, a single Generic Stream may also be used, for which signalling will be defined in the future.

4.2 GSE Packet Format

4.2.1 Specification

A Generic Stream consists of a sequence of possibly variable length Base Band frames. GSE Packets are multiplexed and allocated in Base Band Frames as defined in table 1. Encapsulated PDUs, or fragments of a PDU (see clause 4.3), are transported in GSE Packets. Padding (when needed) is added after the last GSE Packet in a Base Band frame. When information on the actual data occupation of the Base Band frame (for example in DVB-S2 through the Data Field Length) is not provided as signalling information in the Base Band Header, the Receiver shall recognize the presence of padding through detection of a specific combination of the Start Indicator, End Indicator and Label Type indicator bits (see table 2). The Receiver shall discard any GSE packet subsequent to detection of this combination, which shall never be used for any GSE Header.

Table 1: Syntax for Base Band Frame structure

Syntax	Number of bits	Mnemonic
Frame() {		
for (j=0; j<N1; j++) {		
GSE_Packet()		
}		

Each GSE Packet is composed of a GSE Header followed by a GSE Payload, where the (fragment of the) encapsulated PDU is located. The GSE Header is composed of the fields shown in figure 2. The unshaded fields are always present, while the shaded fields may be omitted depending on the preceding control fields in the first 4 bits of the GSE Header. The presence of possible Extension Headers is determined by the Protocol Type value. The minimum GSE Header length is therefore 2 bytes.

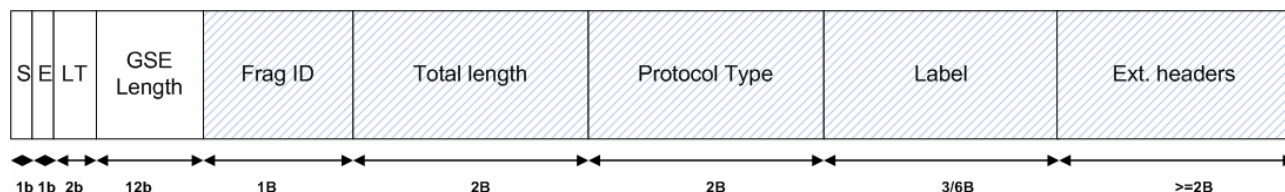


Figure 2: GSE Header format

The syntax and semantics of the GSE Packet are defined in table 2.

Table 2: Syntax for GSE Packet structure

Syntax	Number of bits	Mnemonic
GSE_Packet() {		
Start_Indicator	1	bslbf
End_Indicator	1	bslbf
Label_Type_Indicator	2	bslbf
if (Start_Indicator=="0") and (End_Indicator=="0") and (Label_type_Indicator=="00") {		
Padding_bits	4	bslbf
for (i=0; i<N1; i++) {		
Padding_bytes	8	bslbf
}		
} else {		
GSE_Length	12	Uimsbf
If (Start_Indicator=="0") or (End_Indicator=="0") {		
Frag_ID	8	Uimsbf
}		
If (Start_Indicator=="1") and (End_Indicator=="0") {		
Total_Length	16	Uimsbf
}		
If (Start_Indicator=="1") {		
Protocol_Type	16	Uimsbf
if (Label_Type_Indicator=="00") {		

Syntax	Number of bits	Mnemonic
6_byte_Label	48	Bslbf
} else if (Label_Type_Indicator=="01") {		
3_byte_Label	24	Bslbf
}		
if (Protocol_Type < 1536) {		
for(i=0;i<N2;i++) {		
Extension_Header_byte	8	Bslbf
}		
}		
}		
for(i=0;i<N3;i++) {		
PDU_data_byte	8	Bslbf
}		
If (Start_Indicator=="0") and ("End_Indicator=="1") {		
CRC_32	32	Rpchof
}		
}		
}		

The semantics of GSE Packet are as follows:

Start_Indicator: A value of "1" indicates that this GSE Packet contains the start of the encapsulated PDU. A value of "0" indicates that the start of the PDU is not present in this GSE Packet. For padding, the Start_Indicator shall be set to "0".

End_Indicator: A value of "1" indicates that this GSE Packet contains the end of the encapsulated PDU. A value of "0" indicates that the end of the PDU is not present in this GSE Packet. For padding, the End_Indicator shall be set to "0".

Label_Type_Indicator: This is a 2-bit field. For padding, the Label_Type_Indicator shall be set to "00". Otherwise, if the Start_Indicator is set to "0", the Label_Type_Indicator is reserved and shall be set to "11". The values of the Label_Type_Indicator have the semantics included in table 3. Definition of labels and addressing modes is included in clause 5.

Table 3: Label Type Indicator semantics

Value	Meaning
"00"	Indicates that a 6 byte Label is present and shall be used for filtering.
"01"	Indicates that a 3 byte Label is present and shall be used for filtering.
"10"	Broadcast. No label field is present. All receivers shall process this GSE Packet. This combination shall be used also in non broadcast systems when no filtering is applied at Layer 2, but IP header processing is utilized [4].
"11"	Label re-use. No label field is present. All receivers shall reuse the label that was present in the previous GSE Packet of the same Base Band frame. This method is used for transmitting a sequence of GSE Packets with the same label without repeating the label field. This value shall not be used for the first GSE Packet in the frame.

Padding_bits: Shall be set to "0".

NOTE 1: N1 is the number of bytes until the end of the Base Band frame.

Padding_bytes: Should be set to "0". When used for padding, the Start_Indicator, End_Indicator, and Label_Type_Indicator shall be all set to "0"/"00".

GSE_Length: This 12-bit field indicates the length, in bytes, of the GSE Packet counted from the byte following this GSE Length field. The GSE Length field allows for a length of up to 4 096 bytes for a GSE Packet. The GSE Length field points to the start of the following GSE Packet, or to the end of the Data Field or start of the padding field if the GSE packet is the last in the frame.

Frag_ID: This is present when a PDU fragment is included in the GSE Packet, while it is not present if Start_Indicator and End_Indicator are both set to "1". All GSE Packets containing PDU fragments belonging to the same PDU shall contain the same Frag ID. The selected Frag ID shall not be re-used on the link until the last fragment of the PDU has been transmitted. (see clause 4.3).

Total_Length: This field is present in the GSE Header carrying the first fragment of a fragmented PDU. The 16-bit field carries the value of the total length, defined as the length, in bytes, of the Protocol Type, Label (6 byte Label or 3 byte Label), Extension Headers, and the full PDU. The receiver shall perform a total length check after reassembly. It may also use the total length information for pre-allocation of buffer space. Although the length of a single GSE Packet is limited to almost 4 096 bytes, larger PDUs are supported through fragmentation, up to a total length of 65 536 bytes.

Protocol_Type: This 16-bit field indicates the type of payload carried in the PDU, or the presence of a Next-Header. The set of values that may be assigned to this field is divided into two ranges, similar to the allocation of Ethernet and shall follow the rules described in [4]. The two ranges are:

Type 1: Next-Header Type field

The first range of the Type space corresponds to the range of values 0 to 1535 decimal. These values may be used to identify link-specific protocols and/or to indicate the presence of Extension Headers that carry additional optional protocol fields (e.g. a bridging encapsulation). The range is sub-divided into values less than 256 and greater than 256, depending on the type of extension. The use of these values is co-ordinated by an IANA registry [4].

Type 2: EtherType compatible Type Fields

The second range of the Type space corresponds to the values between 0x600 (1536 decimal) and 0xFFFF. This set of type assignments follow DIX/IEEE assignments (but exclude use of this field as a frame length indicator). All assignments in this space shall use the values defined for EtherType, the following two Type values are used as examples (taken from the IEEE EtherTypes registry):

EXAMPLE:

0x0800: IPv4 Payload

0x86DD: IPv6 Payload

6_byte_Label: This 48-bit field contains the 6-byte label used for addressing (see clause 5).

3_byte_Label: This 24-bit field contains the 3-byte label used for addressing (see clause 5).

NOTE 2: N2 is the length in bytes of the extension headers as defined in [4].

Extension_Header_byte: These optional bytes may be used to carry one or more extension header(s). The extension header format is defined by the ULE specification [4].

NOTE 3: N3 is the length of the encapsulated PDU or PDU fragment in bytes.

PDU_data_byte: These bytes contain the PDU data.

CRC_32: This field is only present in a GSE Packet that carries the last PDU fragment. This field shall be set as defined in clause 4.2.3.

4.2.2 CRC-32 Trailer

When a receiver reassembles a fragmented PDU with fragments scattered over multiple frames, there is a non-negligible probability that a fragment may be missing. The error detection capability of GSE shall therefore be sufficiently strong to detect a wrong reassembly with a high probability. This is achieved in GSE through the computation of a CRC-32 at PDU level for every fragmented PDU.

Each GSE Packet where the S-bit value is "0" and E-bit value is "1" shall carry a 32-bit CRC field in the last four bytes of the GSE Packet. This position eases CRC computation by hardware. The CRC-32 polynomial below shall be used. This is a 32 bit value calculated according to the generator polynomial represented 0x104C11DB7 in hexadecimal:

$$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x^1 + x^0.$$

The Encapsulator initializes the CRC-32 accumulator register to the value 0xFFFF FFFF. It then accumulates a transmit value for the CRC32 that includes all bytes of the PDU payload, of the Total Length, of the Protocol Type, of the Label (when present) and possible Extension headers fields, and places this in the CRC Field. In GSE, the bytes are processed in order of increasing position. This use resembles, but is different to that in SCTP [6].

In the reassembly state the Receiver performs an integrity check by independently calculating the same CRC value of all reassembled PDU with the addition of the above mentioned fields, and comparing this with the transmitted value in the last GSE Packet trailer. PDUs that do not have a valid CRC, are discarded, causing the Receiver to enter the Idle State.

In figure 3 an example study case is shown, where a PDU is divided in three fragments, which are transmitted in three GSE Packets. The shaded fields in figure 3 are the ones that contribute to the CRC calculation: the bytes over which the CRC is to be calculated shall be starting from the Total Length field, omitting all subsequent GSE Packet Headers of the same Frag ID up to, but not including the CRC field.

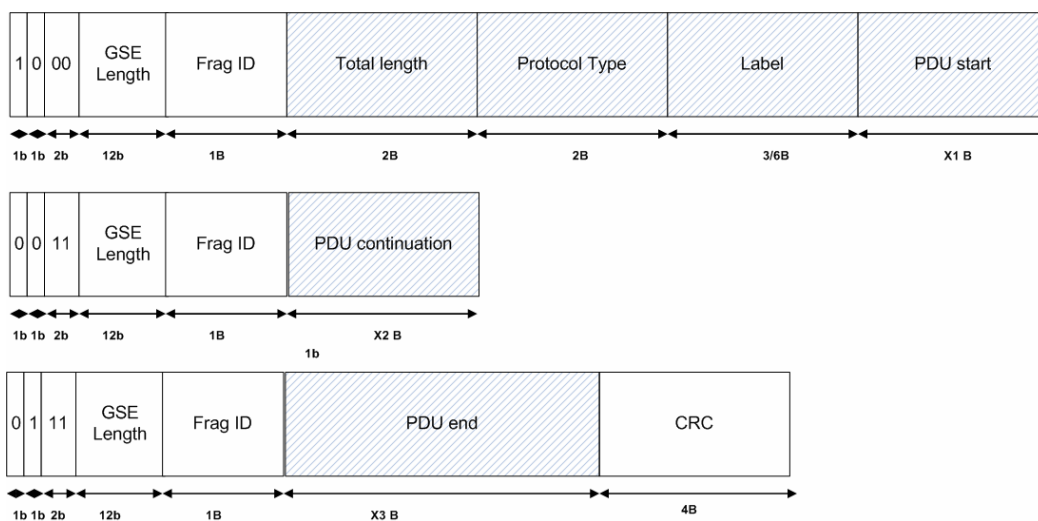


Figure 3: CRC calculation example

This description may be suited for hardware implementation, but the present document does not imply any specific implementation. Software-based table-lookup or hardware-assisted software-based implementations are also possible.

The sole purpose of this CRC is to protect a fragmented PDU (header, and payload) from undetected reassembly errors and/or errors that may be introduced by unexpected software/hardware operation while the encapsulated PDU fragments are in transit across the underlying subnetwork and during processing at the Encapsulator and/or the Receiver. It may also detect the presence of uncorrected errors from the physical link (however, as previously mentioned, it is assumed that sufficient physical layer error detection capabilities are present).

4.3 PDU Fragmentation

GSE Packets with data from the same PDU shall have the same Frag ID and shall be transmitted in order. However, they may not be transmitted consecutively, but may be interleaved with GSE Packets carrying full PDUs or fragments with a different Frag ID. Reassembled PDUs will be delivered to higher layers in the order of the reception of the last fragment of the PDUs.

The following rules shall apply:

- 1) All GSE Packets carrying data of the same PDU shall have the same Frag ID.
- 2) The first GSE Packet with a given Frag ID shall have S equal "1" and E bit equal "0".
- 3) The GSE Packets carrying PDU fragments, which are neither the first nor the last PDU fragment, shall have S equal "0" and E bit equal "0".
- 4) The last GSE Packet with a given Frag ID shall have S equal "0" and E bit equal "1".
- 5) Whilst a PDU is still incomplete, its Frag ID shall not be reused within a period of 256 BB frames.

- 6) All GSE Packets with the same Frag ID shall be transmitted in order.
- 7) The Label shall only be used in the first GSE Packet.

Whenever fragmentation is to be applied, the GSE Encapsulator takes the first $X1$ bytes of the PDU and:

- forms a GSE Packet with S bit set to value "1", E bit set to value "0";
- sets the GSE Length Field to the calculated number of bytes including the length of the PDU data $X1$ (see figure 3), the length of the Frag ID field, the Total length field, the Protocol Type field, the Label field (if present) and any Extension Header. The GSE Payload carries the first part of the encapsulated PDU with length $X1$ bytes. The derived GSE length shall not exceed the remaining free space in the current Base Band frame Data Field;
- sets Frag ID to a free value;
- sets the Total Length field to the calculated number of bytes including the length of the unfragmented PDU, of the Protocol Type field, of the Label field (if present), and of any extension header;
- adds an appropriate Protocol Type field;
- adds the Label Field, when applicable;
- inserts $X1$ (see figure 3) bytes from the PDU data in the GSE Payload; and
- then places this GSE Packet into the current frame as first GSE packet or after any other GSE Packet already present in the frame.

When the PDU is divided into more than two fragments, the GSE Encapsulator takes the following $X2$ (see figure 3) PDU data and:

- forms a GSE Packet with S bit value set to "0" and the E bit value set to "0";
- sets the GSE Length Field in the GSE Header to the calculated number of bytes including the length of the PDU data $X2$ (see figure 3) and of the Frag ID field. The derived GSE length shall not exceed the remaining free space in the current Base Band frame Data Field;
- sets the Frag ID to the same value as for the previous fragments of this PDU;
- inserts $X2$ (see figure 3) bytes from the PDU in the GSE Payload; and
- then places this GSE Packet into the selected frame (depending on the scheduler policy) as first GSE packet or after any other GSE Packet already present in the frame. The same operation is repeated for all the PDU fragments, except the last.

Finally, the GSE Encapsulator takes the remaining $X3$ (see figure 3) PDU data and:

- forms a GSE Packet with S bit value set to "0" and the E bit value set to "1";
- sets the GSE Length Field in the GSE Header to the calculated number of bytes including the length of the PDU data $X3$, of the Frag ID field and the size of the CRC-32. The derived GSE length shall not exceed the remaining free space in the current Base Band frame Data Field;
- sets the Frag ID to the same value as for the previous fragments of this PDU;
- inserts the remaining $X3$ (see figure 3) PDU data in the GSE Payload and appends the CRC-32; and
- then places this GSE Packet into the selected Base Band frame (depending on the scheduler policy) as first GSE Packet or after any other GSE Packet already present in the frame.

5 Labels: Addresses and Binding

The GSE Label Field is optional. Depending on the Label Type Indicator of the GSE Header, the Label field can have a length of 6 byte, 3 byte or be omitted.

This field shall be carried (i.e. Label Type Indicator set to "00" or "01") for IP unicast packets destined to routers using shared links (i.e., where the same link connects multiple Receivers). A sender may omit this field (Label Type Indicator set to "10") for an IP unicast packet and/or multicast packets delivered to Receivers that are able to utilize a discriminator field (e.g. the IPv4/IPv6 destination address, or a bridged MAC destination address) of the encapsulated protocol, which could be interpreted as a Layer 2 address.

When the GSE Header Label Type Indicator is set to "00", a 6 byte Label (e.g. a Network Point of Attachment NPA field) directly follows the Protocol Type Field of the GSE Header.

When the GSE Header Label Type Indicator is set to "01", a 3 byte Label (e.g. a Network Point of Attachment NPA field) directly follows the Protocol Type Field of the GSE Header. Receiver processing of GSE Packets with 3-byte labels is optional.

In the default addressing mode, Labels will correspond to NPA destination addresses that are 6 byte numbers, normally expressed in hexadecimal. Labels can be used to identify those Receiver(s) in the network that should process a specific GSE Packet. The 3 byte Label can be used as an alternative addressing, for instance in DVB-RCS networks where the 3 byte label can represent the 1-byte group ID and 2 byte logon ID.

The value 0x00:00:00:00:00:00, shall not be used as a Label in a GSE Packet. The least significant bit of the first byte of the Label is set to "1" for multicast frames, and the remaining bytes specify the link layer multicast address. The specific value 0xFF:FF:FF:FF:FF:FF is the link broadcast address, indicating that the reassembled (if fragmented) PDU is to be delivered to all Receivers.

IPv4 packets carrying an IPv4 subnetwork broadcast address need to be delivered to all systems with the same network prefix. When a GSE 6 byte Label is present (Label Type Indicator set to "00") the 6 byte Label shall be set to the NPA link broadcast address (0xFF:FF:FF:FF:FF:FF). When the PDU is an IP multicast packet and a GSE 6 byte Label is present (Label Type Indicator set to "00"), the IP group destination address of the multicast packet shall be mapped to the multicast GSE Label (following the method used to generate a destination MAC address in Ethernet). The method for mapping IPv4 multicast addresses is specified in [7]. The method for mapping IPv6 multicast addresses is specified in [8].

If several consecutive PDUs are sent to the same destination, label re-use can be utilized to save overhead. In this case, the Label field of all concatenated GSE Packets except the first one can be omitted and the Label Type Indicator is set to "11". The first of the concatenated GSE Packets shall contain a 3 byte Label or a 6 byte Label (Label Type Indicator is set to "00" or "01"). A receiver which receives a GSE Packet in label re-use mode assumes that the label of the previously received GSE Packet is still valid. Label re-use is allowed in the case of GSE Packets transmitted within the same Base Band frame.

In GSE the simultaneous use of several 6-byte and one 3-byte addresses is supported. For each address a binding mechanism needs to be devised.

A terminal shall use the following bindings:

- All terminals with a unicast MAC address, shall use their MAC hardware address as 6-byte address; this binding shall be valid for all terminal types (e.g. S2-receive-only, DVB-RCS, terrestrial return link, etc.)
- Terminals shall use mechanism for IP to MAC mapping described in [7] and [8] for IPV4 and IPV6 multicast addresses when signalled in the forward link (see clause 6).

A terminal may also support further addressing modes, for instance:

- Terminals may use the mechanism described in [4] for no-address mode.
- DVB-RCS terminals may bind their group/logon-ID to the 3-byte address if this mapping is signalled in the forward link (see clause 6).

- Other 3 byte label bindings are possible:
 - ATM: binding to VCI/VPI (see clause 6).
 - VLAN extension (3 byte MAC address as VLAN ID for simple cases, implicit binding with dedicated group marker, e.g. 0xFFFF) (see clause 6).

6 GSE SI specifications

For signalling on an MPEG-TS the presence of a GSE stream, an IP/MAC `generic_stream_location_descriptor` as defined in clause 8.4.5.15 of EN 301 192 [3] shall be carried in an IP/MAC Notification Table (also see [3]).

The selector bytes in the IP/MAC `generic_stream_location_descriptor` shall be used to convey the following `generic_stream_binding_info`.

Table 4: Syntax for `generic_stream_binding_info`

Syntax	Number of bits	Mnemonic
<code>generic_stream_binding_info () {</code>		
<code>rfc_multicast_binding</code>	1	bslbf
<code>dvb-rcs_group_logon_id_binding</code>	1	bslbf
<code>atm_pvc_binding</code>	1	bslbf
<code>vlan_extension_binding</code>	1	bslbf
Reserved	12	bslbf
<code>}</code>		

rfc_multicast_binding: The service shall set this flag to "1" if it uses the IP to MAC mapping as described in [7] for IPv4 multicast addresses and [8] for IPv6 multicast addresses. If this flag is set to "0", the mapping of IP addresses to MAC addresses for multicast addresses is done outside the scope of the present document.

dvb_rcs_group_logon_id_binding: The service shall set this flag to "1" if the interactive terminal has to bind to its `groupid/logon_id` as a `3_byte_label`.

atm_pvc_binding: The service shall set this flag to "1" if VPI/VCI is translated in a `3_byte_label`.

vlan_extension_binding: The service shall set this flag to "1" if `vlan_id` is translated in a `3_byte_label`.

Annex A (normative): Receiver Processing

A Receiver tunes to a specific Generic Continuous Stream and sets a receive filter to accept all frames for that specific stream. These frames are reassembled to form a stream of GSE Packets. A single Receiver may be able to receive multiple Generic Streams. In each case, reassembly shall be performed independently for each Generic Stream and for each fragmented PDU. To perform this reassembly, the Receiver may use a buffer to hold the partially assembled PDU. Implementations may choose to use other data structures, but shall provide equivalent operations.

As a minimum, the receiver shall implement one reassembly buffer for each address that it binds to. An advanced network supporting QoS mechanisms may use different Frag IDs per address to allow for interleaving PDU fragments to the same address. Therefore, in this kind of networks, a receiver may need to be able to handle per Generic Stream a larger number of concurrently fragmented PDUs up to a maximum of 256.

The receiver shall start processing the first GSE Packet which starts directly after the Base Band frame header and then continue with all following GSE Packets. The receiver can determine the start of the next GSE Packet by calculating the length of the current GSE Packet from the GSE Length field in the GSE Header.

NOTE: There may be more than one GSE Packet per Base Band frame.

A.1 Filtering

The receiver shall filter the GSE Packets for certain labelling modes (e.g. 3-byte or 6-byte labels). If the S bit in the GSE Header is set to "1" (one), the receiver shall interpret the label bits. If the GSE Header contains a 6-byte or 3-byte label matching any of the filters, the receiver continues with the processing the packet. Otherwise the receiver shall discard the GSE Packet and continue processing with the next GSE Packet. If the LT-bits are set to "10" (no label present), the receiver shall process the packet regardless of any filters. If the LT field is set to "11" (label re-use mode), the receiver shall check if the previous GSE Packet in the frame was destined for the receiver. If so, the receiver processes the packet, otherwise the receiver shall discard the GSE Packet. The use of a LT value of "11" after a previous LT value of "10" (no label) is illegal.

If the S and E bits are both set to "1", the GSE Packet contains a single PDU. The receiver reads the GSE Length field and can process the packet (see clause A.3), otherwise the GSE Packet is subject to reassembly processing (see clause A.2).

A.2 Reassembly

If the S bit is set to "1" and the E bit is set to "0", the GSE Packet contains the first fragment of a PDU with the given Frag ID. Prior to entering the reassembly process for this Frag ID, the receiver shall:

- check whether the ID is already in use, i.e. the receiver has fragments for that Frag ID in a reassembly buffer. If the Frag ID is already in use, the receiver shall first discard the already buffered fragments corresponding to this Frag ID;
- enter the reassembly process for the given Frag ID and start reassembly of a new PDU. The required buffer space can be derived from the Total Length field.

When the S bit is set to "0", the GSE Packet contains a continuation or end fragment. If the receiver has a buffer in the re-assembly state for the Frag ID corresponding to that in the GSE Header, it continues with processing. Otherwise, the GSE Packet shall be discarded.

If the S bit is set to "0" and the E bit is set to "0", the GSE Packet contains a continuation fragment of a PDU with the Frag ID corresponding to that in the GSE Header. It shall add the fragment to the re-assembly buffer. The receiver may check the size of the fragment to ensure that the total reassembled length does not exceed the size of Total Length (if it does, the receiver shall discard the already buffered fragments corresponding to this Frag ID and abort the reassembly).

If the S bit is set to "0" and the E bit is set to "1", the GSE Packet contains the last fragment of a PDU with the Frag ID given in the GSE Header. The receiver shall add the fragment to the re-assembly buffer for this Frag ID. The receiver shall verify if the number of received bytes, including the length of the unfragmented PDU, of the Protocol Type field, of the Label field (if present), and of any extension header, corresponds to the Total Length field value in the first GSE Packet for this PDU. If the length of the re-assembled PDU plus the additional above listed fields does not match the Total Length, the receiver shall discard the PDU. Finally the receiver shall check the CRC (last 4 bytes of the current GSE Packet) against the CRC of the current PDU buffer. If the CRC does not match, the receiver shall discard the current PDU buffer. This error event should be recorded as a PDU CRC error. If the CRC matches, the encapsulated PDU has been correctly received and the PDU shall be processed (see clause A.3). The receiver shall then free this Frag ID to allow for re-use of the same Frag ID by following PDUs.

If a PDU belonging to a given Frag ID cannot be re-assembled within 255 consecutive frames, the receiver shall discard the buffer and free the Frag ID. This error event should be recorded as a PDU reassembly time-out error.

A.3 Protocol Type and Next Header Processing

After receiving a valid and complete PDU, the receiver starts processing by inspecting the Type field. A set of header types are described in [4] and [9], other types may be specified in the Next Header Registry.

A Type field value less than 256 indicates a Mandatory Extension Header. The receiver shall perform the processing for the specified Type field value. Further extension headers may follow this extension header. All unimplemented values cause the received data to be discarded, and processing continues with the next GSE packet. This error event should be recorded as a PDU extension header error.

A Type field value between 256 and 1 535 indicates an Optional Extension Header. If implemented, the receiver performs the processing for the specified Type field value, otherwise it discards the next header field, and continues processing by inspecting the next Type value. Further extension headers may follow this extension header.

The PDU payload shall then be passed to the next protocol layer. A PDU with a Type field value greater than 1 536 which is not supported by a receiver may be discarded. This error event should be recorded as a PDU type error.

A.4 Label re-use

If the first GSE packet in the Base Band frame has the Label Type Indicator set to "11", the Receiver shall discard the GSE packet and process the following GSE packet, until it detects a GSE Packet whose Label Type Indicator is not set to "11".

A.5 Padding

When receiving a GSE Header, where the Start Indicator and the End Indicator are set to "0", and the Label Type Indicator is set to "00", padding is detected and the Receiver shall discard all the following bytes until the end of the Base Band frame.

Annex B (informative): Encapsulator Processing

B.1 Encapsulator/Scheduler Functions

Figure B.1 shows a block diagram highlighting the key functions related to the scheduling and encapsulation process, which take place at the transmitter. This high-level representation is not intended to specify a GSE encapsulation implementation, but rather to exemplify the main functional elements and their interrelations.

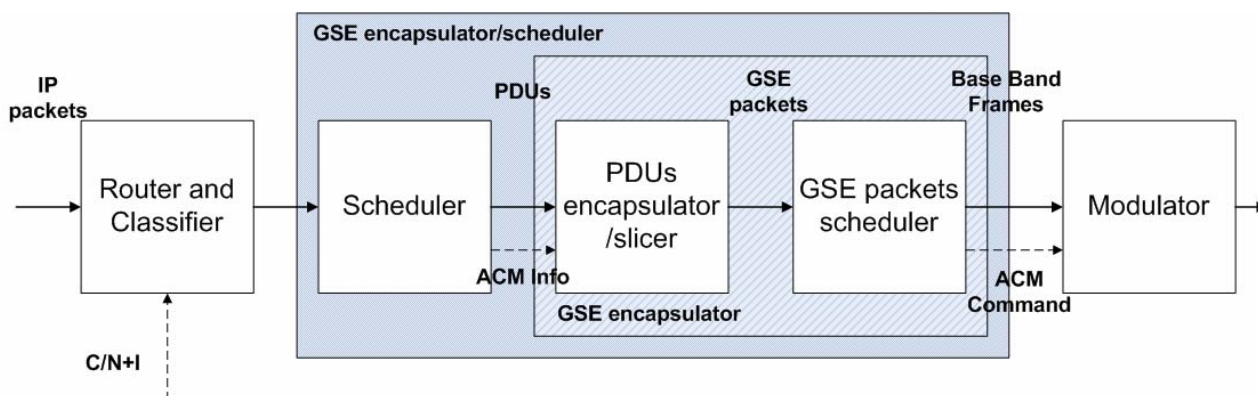


Figure B.1: Encapsulator/scheduler block diagram

First, the un-shaded blocks are discussed. The second step will analyze the shaded blocks, which are an aggregation of the elementary plain blocks, analyzing how additional interrelations and joint operation can bring significant benefits in terms of system efficiency.

Incoming IP or other network layer packets are processed and routed into different buffers depending on their destination and QoS requirements/priority. When an ACM system is considered, the channel quality of the destination terminal shall also be taken into account. Following such classification, the scheduler selects packets to be transmitted, based on a specific scheduling policy, which in general aims at maximizing capacity while guaranteeing achievement of individual QoS targets.

The PDU's, output from the scheduler, will be fragmented and encapsulated (including the addition of any required extension headers) to form GSE Packets (PDU encapsulator/slicer), and further allocated into Base Band frames (GSE Packets scheduler). The generated Base Band frames are then sent to the modulator, together with an indication of the corresponding transmission parameters (coding rate, modulation format) if ACM is utilized.

A design that fully exploits the Base Band frame payload minimizing padding overhead is possible when knowledge of the frame length is used for ad-hoc fragmentation of the incoming encapsulated PDU's (see figure 1). In this case, there is a relation between the function of PDU encapsulation and fragmentation and the GSE Packet allocation into the Base Band frame; a feedback from the GSE Packet scheduler to the PDU encapsulator may be required. Therefore the two functions may be thought of as being jointly performed by a single and more complex block, named here GSE encapsulator.

When ACM is utilized, each receiver will in general only decode a part of the transmitted data stream, and in particular only the frames transmitted with modulation and coding parameters fitting the receiver terminal channel quality. This is the reason why it is necessary for the scheduling of GSE Packets into frames to take into account the ACM information related to the terminal to which a particular PDU was addressed.

A scheduler in the GSE encapsulator, which performs smart placement of GSE Packets in the Base Band frames, allows for optimizing system efficiency. The rationale is exemplified in figures B.2 and B.3, where a study case is proposed. In figure B.2, PDU1, PDU2 and PDU3 form a sequence of PDUs, pre-scheduled by the outer scheduler. The term MODCOD indicates the modulation format and coding rate associated to a given PDU. This assumes that the efficiency of MODCOD2 is higher than the one of MODCOD1, i.e. MODCOD1 corresponds to a more robust transmission. The PDUs are encapsulated and scheduled into Base Band Frames by the GSE encapsulator.

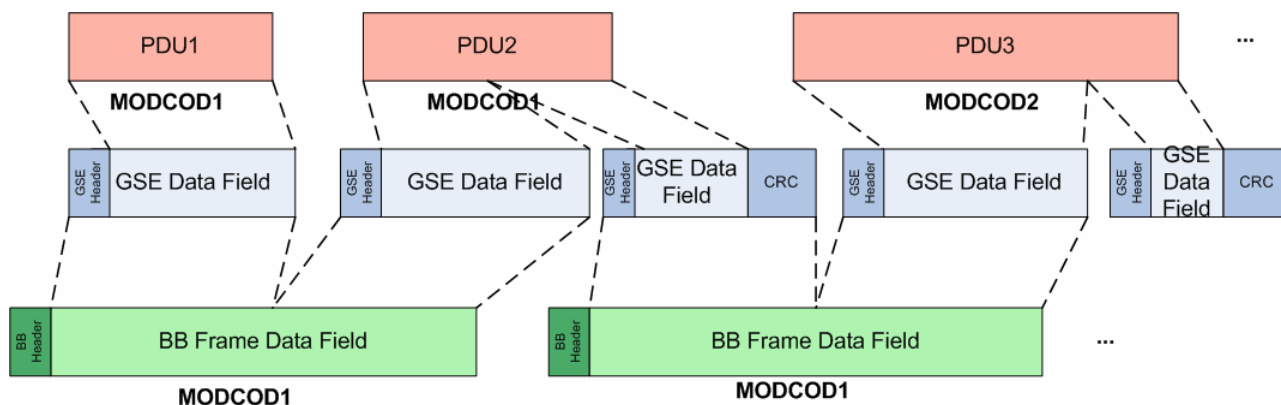


Figure B.2: Disjoint encapsulation/scheduling

When a PDU is fragmented, for example to optimally fill the Base Band Frame Data Field, as in the case for the PDU2 in the above example, the remaining PDU fragment is encapsulated in an independent GSE Packet, which shall be transmitted in one of the following Base Band Frames. However, if no smart scheduling strategy is utilized, the generated GSE Packet will be scheduled for a Base Band Frame, together with other pre-scheduled encapsulated PDUs. Since the transmission parameters are constant for the same frame, the encapsulator shall "downgrade" to MODCOD 1 the fragment of the following PDU required to fill the frame. This implies a degradation of the instantaneous channel capacity with respect to the achievable one, due to the disjoint scheduling and encapsulation process. Figure B.3 shows how a joint operation of scheduling and encapsulation can eliminate link efficiency losses and can achieve a better system efficiency.

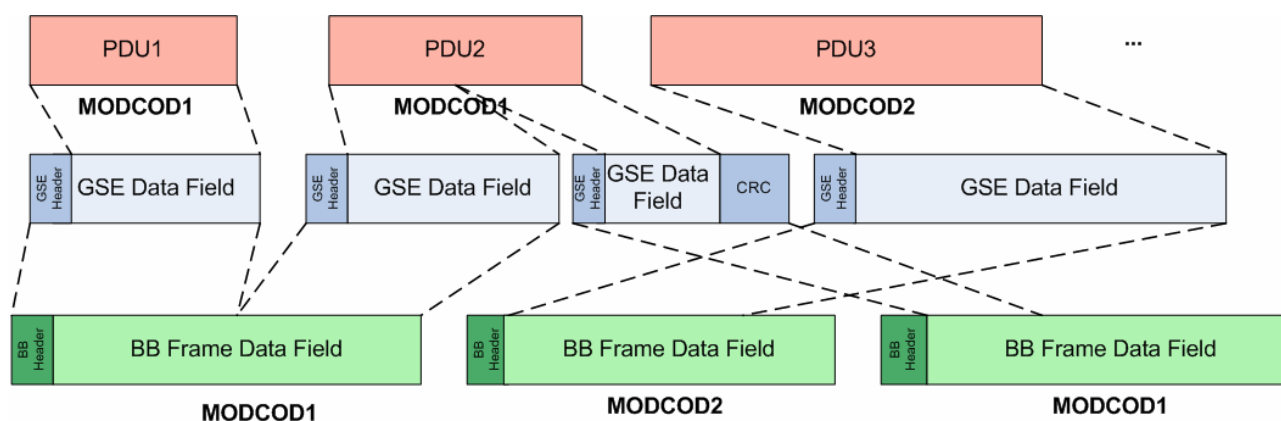


Figure B.3: Joint scheduling/encapsulation

The issue of distributing scheduling functions between the outer scheduler and the inner GSE Packets scheduler is not addressed in the present document. It is dependent both on the selected scheduling routine and on implementation issues. However, GSE allows for a fully flexible scheduling of encapsulated PDU and PDU fragments into the Base Band Frames, provided that GSE Packets including fragments of the same PDU are transmitted in order. With a joint optimized operation of scheduler and encapsulation, the overall system efficiency can be optimized.

B.2 Use of the Label Type Indicator

The Label Type Indicator allows an Encapsulator to notify the receivers about the format of the NPA address that it should use for filtering of received GSE Packets. The presence of a Label Type Indicator in each GSE Packet for a series of GSE Packets destined for the same NPA address is redundant, and may be optimized by using the LT value of "11". An Encapsulator shall use the Label Type value of "11" only within the scope of one single frame, and never for the first GSE packet of a frame. This rule prevents ambiguities in the case of frame loss.

Annex C (informative): GSE Packet Format Examples

The following figures show example study cases of GSE Packet format.

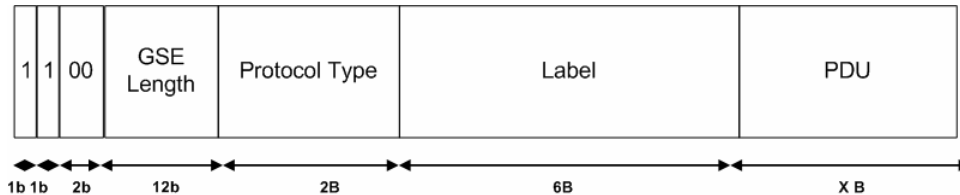


Figure C.1: GSE Packet carrying a full, unfragmented PDU with a 6 byte NPA Address

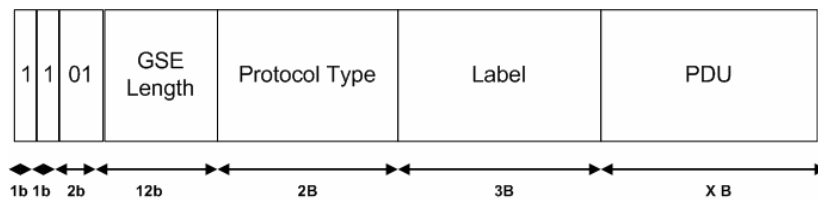


Figure C.2: GSE Packet carrying a full, unfragmented PDU with a 3 byte NPA Address

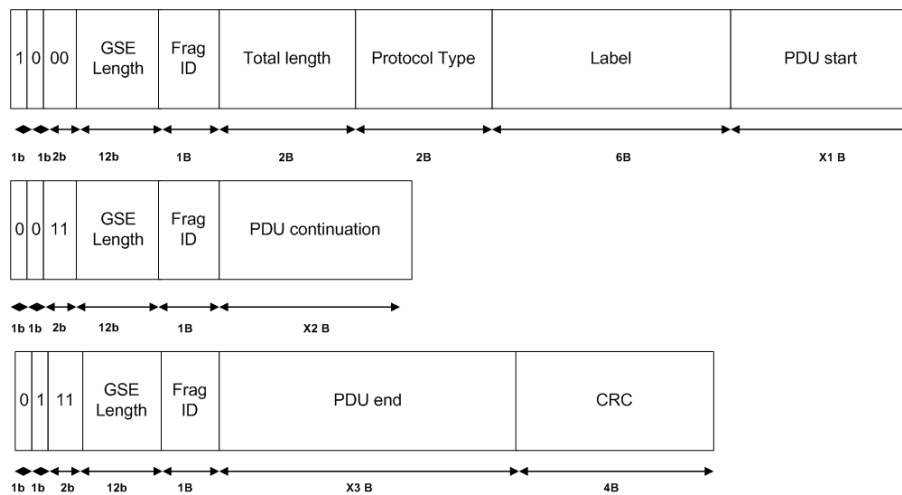


Figure C.3: A sequence of GSE Packets carrying the start, continuation and end of a PDU

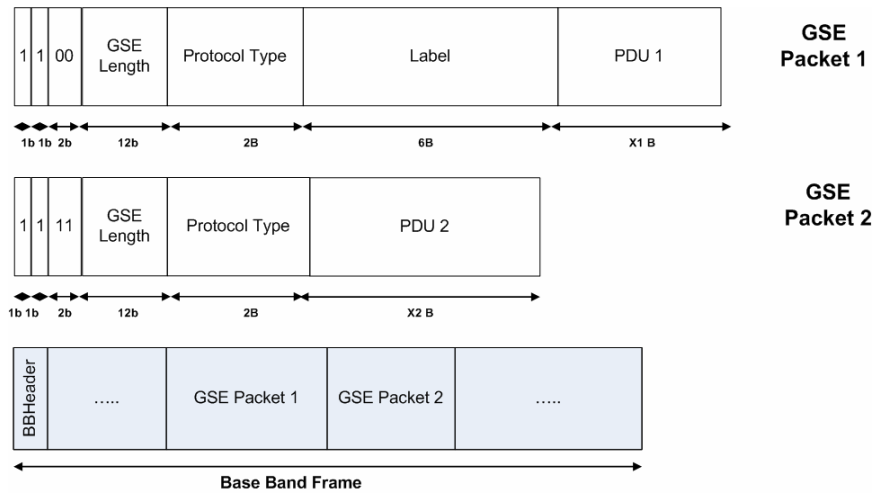


Figure C.4: Concatenated GSE Packets: GSE Packet formats and allocation in a Base Band Frame

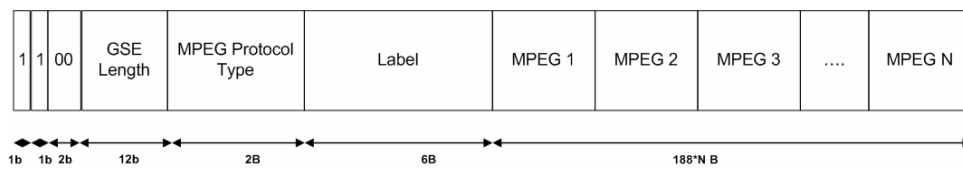


Figure C.5: GSE encapsulation of MPEG signalling packets [9]

Annex D (informative): Bibliography

- ETSI EN 301 790: "Digital Video Broadcasting (DVB); Interaction channel for satellite distribution systems".
- ETSI EN 300 468: "Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems".

History

Document history		
V1.1.1	October 2007	Publication