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Extension Formats for Unidirectional Lightweight Encapsulation (ULE) and the Generic Stream Encapsulation (GSE)

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Abstract

This document describes a set of Extension Headers for the Unidirectional Lightweight Encapsulation (ULE), RFC 4326.

The Extension Header formats specified in this document define extensions appropriate to both ULE and the Generic Stream Encapsulation (GSE) for the second-generation framing structure defined by the Digital Video Broadcasting (DVB) family of specifications.

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1. Introduction

This document describes three Extension Headers that may be used with both the Unidirectional Lightweight Encapsulation (ULE) [RFC4326] and the Generic Stream Encapsulation (GSE) [GSE]. ULE is defined for links that employ the MPEG-2 Transport Stream, and supports a wide variety of physical-layer bearers [RFC4259].

GSE has been designed for the Generic Mode (also known as the Generic Stream (GS)), offered by second-generation DVB physical layers, and in the first instance for DVB-S2 [ETSI-S2]. The requirements for the Generic Stream are described in [S2-REQ]. The important characteristics of this encapsulation are described in the appendix of this document. GSE maintains a design philosophy that presents a network interface that is common to that presented by ULE and uses a similar construction for SubNetwork Data Units (SNDUs).

The first Extension Header defines a method that allows one or more TS Packets [ISO-MPEG2] to be sent within a ULE SNDU. This method may be used to provide control plane information including the transmission of MPEG-2 Program Specific Information (PSI) for the Multiplex. In GSE, there is no native support for Transport Stream packets and this method is therefore suitable for providing an MPEG-2 control plane.

A second Extension Header allows one or more PDUs to be sent within the same ULE SNDU. This method is designed for cases where a large number of small PDUs are directed to the same Network Point of Attachment (NPA) address. The method may improve transmission efficiency (by removing duplicated MAC layer overhead). It can also reduce processing overhead for a receiver that is not configured to receive the NPA address associated with an SNDU, allowing this receiver to then skip several PDUs in one operation. The method is defined as a generic Extension Header and may be used for IPv4 or IPv6 packets. If, and when, a compression format is defined for ULE or Ethernet, the method may also be used in combination with this method.

A third Extension Header provides an optional TimeStamp value for an SNDU. Examples of the use of this TimeStamp option include monitoring and benchmarking of ULE and GSE links. Receivers that do not wish to decode (or do not support) the TimeStamp extension may discard the extension and process the remaining PDU or Extension Headers.

The appendix includes a summary of key design issues and considerations relating to the GSE Specification defined by the DVB Technical Module [GSE].

2. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

b: bit. For example, one byte consists of 8b.

B: byte. Groups of bytes are represented in Internet byte order.

BBFrame payload: The data field part of a Baseband frame [ETSI-S2] that may be used for the communication of data. Typical BBFrames range in size from 3072 to 58192 bits according to the choice of modulation format and Forward Error Correction (FEC) in use.

DVB: Digital Video Broadcasting. A framework and set of associated standards published by the European Telecommunications Standards Institute (ETSI) for the transmission of video, audio, and data.

E: A one-bit flag field defined in GSE [GSE].

Encapsulator: A network device [RFC4259] that receives PDUs and formats these into Payload Units (known here as SNDUs) for output in DVB-S or the Generic Mode of DVB-S2.

GS: Generic Stream. A stream of BBFrames identified by a common Input Stream Identifier, and which does not use the MPEG-2 TS format [ETSI-S2]. It represents layer 2 of the ISO/OSI reference model.

GSE: Generic Stream Encapsulation [GSE]. A method for encapsulating PDUs to form a Generic Stream, which is sent using a sequence of BBFrames. This encapsulation format shares the same extension format and basic processing rules of ULE and uses a common IANA Registry.

LT: A two-bit flag field defined in GSE [GSE].

MAC: Medium Access Control [IEEE-802.3]. A link-layer protocol defined by the IEEE 802.3 standard.

MPEG-2: A set of standards specified by the Motion Picture Experts Group (MPEG), and standardized by the International Organization for Standardization (ISO/IEC 113818-1) [ISO-MPEG2], and ITU-T (in H.220).

Next-Header: A Type value indicating an Extension Header [RFC4326].

NPA: Network Point of Attachment [RFC4326]. In this document, refers to a destination address (resembling an IEEE MAC address) within the DVB-S/S2 transmission network that is used to identify individual Receivers or groups of Receivers.

PID: Packet Identifier [ISO-MPEG2]. A 13-bit field carried in the header of each TS Packet. This identifies the TS Logical Channel to which a TS Packet belongs [ISO-MPEG2]. The TS Packets that form the parts of a Table Section or other Payload Unit must all carry the same PID value. The all-ones PID value indicates a Null TS Packet introduced to maintain a constant bit rate of a TS Multiplex. There is no required relationship between the PID values used for TS Logical Channels transmitted using different TS Multiplexes.

PDU: Protocol Data Unit [RFC4259]. Examples of a PDU include Ethernet frames, IPv4 or IPv6 datagrams, and other network packets.

PSI: Program Specific Information [ISO-MPEG2].

S: A one-bit flag field defined in [GSE].

SI Table: Service Information Table [ISO-MPEG2]. In this document, this term describes a table that is been defined by another standards body to convey information about the services carried on a DVB Multiplex.

SNDU: SubNetwork Data Unit [RFC4259]. In this document, this is an encapsulated PDU sent using ULE or GSE.

Stream: A logical flow from an Encapsulator to a set of Receivers.

TS: Transport Stream [ISO-MPEG2], a method of transmission at the MPEG-2 level using TS Packets; it represents layer 2 of the ISO/OSI reference model.

ULE: Unidirectional Lightweight Encapsulation (ULE) [RFC4326]. A method that encapsulates PDUs into SNDUs that are sent in a series of TS Packets using a single TS Logical Channel. The encapsulation defines an extension format and an associated IANA Registry.

3. Description of the Method

In ULE, a Type field value that is less than 1536 in decimal indicates an Extension Header. This section describes a set of three extension formats for the ULE encapsulation. [GSE] uses a Type field that adopts the same semantics as specified by RFC 4326. The encapsulation format differs in that GSE does not include a Cyclic Redundancy Check (CRC) for each SNDU, has different header flags, and utilizes a different SNDU length calculation [GSE].

There is a natural ordering of Extension Headers, which is determined by the fields upon which the Extension Header operates. A suitable ordering for many applications is presented in the list below (from first to last header within an SNDU). This does not imply that all types of Extensions should be present in a single SNDU. The presented ordering may serve as a guideline for optimization of Receiver processing.

Fields related to Extension Header	Example Extension Headers
Link framing and transmission	TimeStamp Extension
Entire remaining SNDU Payload	Encryption Extension
Group of encapsulated PDUs	PDU-Concat or TS-Concat
Specific encapsulated PDU	IEEE-defined type Test or MAC bridging Extension

Table 1: Recommended ordering of Extension Headers

3.1. MPEG-2 TS-Concat Extension

The MPEG-2 TS-Concat Extension Header is specified by an IANA-assigned H-Type value of 0x0002 in hexadecimal. This is a Mandatory Extension Header.

The extension is used to transport one or more MPEG-2 TS Packets within a ULE SNDU. The number of TS Packets carried in a specific SNDU is determined from the size of the remainder of the payload following the MPEG-2 TS Extension Header. The number of TS Packets contained in the SNDU is therefore (Length-N-10+D*6) / 188, where N is the number of bytes associated with Extension Headers that precede the MPEG-2 TS-Concat Extension (zero if there are none) and D is the value of the D-bit.

A Receiver MUST check the validity of the Length value prior to processing the payload. A valid Length corresponds to an integral number of TS Packets. An invalid Length (a remainder from the division by 188) MUST result in the discard of all encapsulated TS Packets and SHOULD be recorded as TS-Concat size mismatch error.

```
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0|           Length  (15b)     |         Type = 0x0002         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Receiver Destination NPA Address  (6B)             |
   +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
   |                   TS-Packet 1                                 |
   =                                                               =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   TS-Packet 2 (if Length > 2*188)             |
   =                                                               =
   |                              etc.                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             (CRC-32)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: ULE/SNDU Format for a TS-Packet Payload (D=0)

Figure 1 illustrates the format of this Extension Header for ULE with a value D=0, which indicates the presence of an NPA address [RFC4326]. In this case, the valid payload Length for a ULE SNDU with no other extensions is (Length-10) / 188.

The method used to define the Length in GSE differs to that of ULE. The equivalent case for GSE would result in a payload Length value of (Length-6) / 188 (Figure 2).

```
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |S|E|0 0|      Length  (12b)    |         Type = 0x0002         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Receiver Destination NPA Address  (6B)             |
   +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
   |                   TS-Packet 1                                 |
   =                                                               =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   TS-Packet 2 (if Length > 2*188)             |
   =                                                               =
   |                              etc.                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: GSE/SNDU Format for a TS-Packet Payload (LT=00)

Fragmented GSE SNDUs are protected by a CRC-32 carried in the final fragment. After reassembly, this CRC-32 is removed and the resulting SNDU carries a Total Length field. The fields labeled S and E are defined by [GSE] and contain control flags used by the GSE link layer. The Label Type (LT) field specifies the presence and format of the GSE label. The LT field is only specified for the first fragment (or a non-fragmented) GSE SNDU (i.e., when S=1).

In ULE, a value of D=1 is also permitted and indicates the absence of an NPA address (Figure 3). A similar format is supported in GSE.

```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |1|           Length  (15b)     |         Type = 0x0002         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   TS-Packet 1                                 |
   =                                                               =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                   TS-Packet 2 (if Length > 2*188)             |
   =                                                               =
   |                              etc.                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             (CRC-32)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: ULE/SNDU Format for a TS-Packet Payload (D=1)

The TS-Concat extension may be used to transport one or more MPEG-2 TS Packets of arbitrary content, interpreted according to [ISO-MPEG2]. One expected use is for the transmission of MPEG-2 SI/PSI signalling [RFC4259].

NULL TS Packets [ISO-MPEG2] SHOULD NOT be sent using this encapsulation. To reduce transmission overhead and processing, an Encapsulator SHOULD specify a maximum period of time that it can wait before sending all queued TS Packets. This is known as the TS Packing Threshold. This value MUST be bounded and SHOULD be configurable in the Encapsulator. A larger value can improve efficiency, but incurs higher jitter and could increase the probability of corruption. If additional TS Packets are NOT received within the TS Packing Threshold, the Encapsulator MUST immediately send any queued TS Packets.

The use of this format to transfer MPEG-2 clock references (e.g., a Network Clock Reference, NCR) over ULE/GSE framing raises timing considerations at the encapsulation gateway, including the need to update/modify the timing information prior to transmission by the physical layer. These issues are not considered here, but this operation may be simplified in GSE by ensuring that all SNDUs that carry this Extension Header are placed before other data within the BBFrame DataField [GSE].

This document does not specify how TS Packets are to be handled at the Receiver. However, it notes:

* A Receiver needs to consistently associate all TS Packets in a Stream with one TS Logical Channel (Stream). If an Encapsulator transmits more than one Stream of TS Packets each encapsulated at a different level or with a different NPA address, a Receiver needs to ensure that each is independently demultiplexed as a separate Stream (Section 3.2 [RFC4259]).

* If an Encapsulator transmits service information encapsulated at different levels or with different NPA addresses, the Receivers need to ensure each Stream is related to the corresponding SI table information (if any). A RECOMMENDED way to reduce signaling interactions is to ensure each PID value uniquely identifies a Stream within a TS Multiplex carrying ULE and also any TS Packets encapsulated by a ULE/GSE Stream.

The need for consistency in the use of PIDs and the related service information is described in section 4.2 of [RFC4947].

3.2. PDU-Concat Extension

The PDU-Concat Extension Header is specified by an IANA-assigned H-Type value of 0x0003 in hexadecimal. This is a Mandatory Next-Header Extension. It enables a sequence of (usually short) PDUs to be sent within a single SNDU Payload.

The base header contains the Length of the entire SNDU. This carries the value of the combined length of all PDUs to be encapsulated, including each set of encapsulation headers. The base header MAY be followed by one or more additional Extension Headers that precede the PDU-Concat Extension Header. These Extension Headers (e.g., a TimeStamp Extension) apply to the composite concatenated PDU.

The Extension Header also contains a 16-bit ULE Type field describing the encapsulated PDU, PDU-Concat-Type. Although any Type value specified in the ULE Next-Header Registry (including Extension Header Types) may be assigned to the encapsulated PDU (except the recursive use of a PDU-Concat type), all concatenated PDUs MUST have a common ULE Type (i.e., all concatenated PDUs passed by the network layer must be associated with the same Type value). This simplifies the receiver design, and reduces the transmission overhead for common use cases.

Each PDU is prefixed by its length in bytes (shown in the following diagrams as PDU-x-Length for the xth PDU). Encapsulated PDUs are of arbitrary length (in bytes) and are not necessarily aligned to 16-bit or 32-bit boundaries within the SNDU (as shown in the figures 4, 5, and 6). The most significant bit of the first byte is reserved, R, and this specification requires that this MUST be set to zero. Receivers MUST ignore the value of the R bit. The length of each PDU MUST be less than 32758 bytes, but will generally be much smaller.

When the SNDU header indicates the presence of an SNDU Destination Address field (i.e., D=0 in ULE), a Network Point of Attachment, NPA, field directly follows the fourth byte of the SNDU header. NPA destination addresses are 6 byte numbers, normally expressed in hexadecimal, used to identify the Receiver(s) in a transmission network that should process a received SNDU. When present, the Receiver MUST associate the same specified MAC/NPA address with all PDUs within the SNDU Payload. This MAC/NPA address MUST also be forwarded with each PDU, if required by the forwarding interface.

```
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |0|           Length  (15b)     |         Type = 0x0003         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Receiver Destination NPA Address  (6B)             |
   +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               |        PDU-Concat-Type        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|      PDU-1-Length  (15b)    |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   =                        PDU-1                                  =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|      PDU-2-Length  (15b)    |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   =                        PDU-2                                  =
   |                                                               |
                              More PDUs as required

   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             (CRC-32)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: ULE/SNDU Format for a PDU-Concat Payload (D=0)

```
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |S|E|0 0|      Length  (12b)    |         Type = 0x0003         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            Receiver Destination NPA Address  (6B)             |
   +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               |        PDU-Concat-Type        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|      PDU-1-Length  (15b)    |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   =                        PDU-1                                  =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|      PDU-2-Length  (15b)    |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   =                        PDU-2                                  =
   |                                                               |
                              More PDUs as required

   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: GSE/SNDU Format for a PDU-Concat Payload (LT=00)

When the SNDU header indicates the absence of an SNDU Destination Address field (i.e., D=1 in ULE), all encapsulated PDUs MUST be processed as if they had been received without an NPA address.

The value of D in the ULE header indicates whether an NPA/MAC address is in use [RFC4326]. A similar format is supported in GSE (using the LT field).

```
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |1|           Length  (15b)     |         Type = 0x0003         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |         PDU-Concat-Type       |R|      PDU-1-Length  (15b)    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   =                        PDU-1                                  =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|      PDU-2-Length  (15b)    |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
   =                        PDU-2                                  =
   |                                                               |
                              More PDUs as required

   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             (CRC-32)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: ULE/SNDU Format for a PDU-Concat Payload (D=1)

To reduce transmission overhead and processing, an Encapsulator SHOULD specify a maximum period of time it will wait before sending a Concatenated PDU. This is known as the PDU Packing Threshold. This value MUST be bounded and SHOULD be configurable in the Encapsulator. A larger value can improve efficiency, but incurs higher jitter and could increase the probability of corruption. If additional PDUs are NOT received within the PDU Packing Threshold, the Encapsulator MUST immediately send all queued PDUs.

The Receiver processes this Extension Header by verifying that it supports the specified PDU-Concat Type (unsupported Types MUST be discarded, but the receiver SHOULD record a PDU-Type error [RFC4326]). It then extracts each encapsulated PDU in turn. The Receiver MUST verify the Length of each PDU. It MUST also ensure that the sum of the Lengths of all processed PDUs equals the Length specified in the SNDU base header. A Receiver SHOULD discard the whole SNDU if the total and PDU sizes are not consistent and this event SHOULD be recorded as a PDU-Concat size mismatch error. A receiver MUST NOT forward a partial PDU with an indicated PDU-Length greater than the number of unprocessed bytes remaining in the SNDU payload field.

3.3. TimeStamp Extension

The TimeStamp Extension Header is an Optional Extension Header that permits an Encapsulator to add a TimeStamp field to an SNDU. The TimeStamp Extension Header is specified by the IANA-assigned H-Type value of 257 decimal. This extension is an Optional Extension Header ([RFC4326], Section 5).

This extension is designed to support monitoring and measurement of the performance of a link to indicate the quality of an operational ULE link. This may be useful for GSE links (e.g., where significant complexity exists in the scheduling provided by the lower layers). Possible uses of this extension include:

* Validation of in-sequence ordering per Logical Channel
* Measurement of one-way delay (when synchronized with the sender)
* Measurement of PDU Jitter introduced by the link
* Measurement of PDU loss (with additional information from sender)

Figure 7 shows the format of this extension with a HLEN value of 3 indicating a TimeStamp of length 4B with a Type field (there is no implied byte-alignment).

```
0               7               15              23              31
+---------------+---------------+---------------+---------------+
|     0x03      |      0x01     |        TimeStamp HI           |
+---------------+---------------+---------------+---------------+
|          TimeStamp LO         |            Type               |
+---------------+---------------+---------------+---------------+
```

Figure 7: Format of the 32-bit TimeStamp Extension Header

The extension carries a 32-bit value (TimeStamp HI plus TimeStamp LO). The specified resolution is 1 microsecond. The value therefore indicates the number of 1-microsecond ticks past the hour in Universal Time when the PDU was encapsulated. This value may be earlier than the time of transmission, due for example to Packing, queuing, and other Encapsulator processing. The value is right-justified to the 32-bit field. Systems unable to insert TimeStamps at the specified resolution MUST pad the unused least-significant bits with a value of zero.

The last two bytes carry a 16-bit Type field that indicates the type of payload carried in the SNDU or the presence of a further Next-Header ([RFC4326], Section 4.4).

Receivers MAY process the TimeStamp when the PDU encapsulation is removed. Receivers that do not implement, or do not wish to process, the TimeStamp Extension MAY skip this Extension Header. Receivers MUST continue to process the remainder of the SNDU, forwarding the encapsulated PDU.

4. IANA Considerations

IANA has assigned three new Next-Header Type values from the IANA ULE Next-Header Registry. These options are defined for specific use cases envisaged by GSE, but are compatible with ULE.

The following assignments have been made in this document and registered by IANA:

Type	Name	Reference
2:	TS-Concat	Section 3.1
3:	PDU-Concat	Section 3.2

Type	Name	H-LEN	Reference
257:	TimeStamp	3	Section 3.3

The TS-Concat Extension is a Mandatory next-type Extension Header, specified in Section 3.1 of this document. The value of this next-header is defined by an IANA assigned H-Type value of 0x0002.

The PDU-Concat Extension is a Mandatory next-type Extension Header specified in Section 3.2 of this document. The value of this next-header is defined by an IANA assigned H-Type value of 0x0003.

The TimeStamp Extension is an Optional next-type Extension Header specified in Section 3.3 of this document. The value of this next-header is defined by an IANA assigned H-Type value of 257 decimal. This documents defines the format for an HLEN value of 0x3.

5. Acknowledgments

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Juan Cantillo provided a significant contribution to the informative appendix. The authors thank Christian Praehauser for his insight and contribution on Extension Header processing issues.

6. Security Considerations

Security considerations for ULE are described in [RFC4326], and further information on security aspects of using ULE are described in the security considerations of [RFC4259] and [Sec-Req].

An attacker that is able to inject arbitrary TS Packets in a ULE or GSE Stream may modify layer 2 signalling information transmitted by the MPEG-2 TS-Concat extension. Since this attack requires access to the link and/or layer 2 equipment, such an attack could also directly attack signalling information sent as native TS Packets (not encapsulated by ULE/GSE). Security issues relating to the transmission and interpretation of layer 2 signalling information (including Address Resolution) within a TS Multiplex are described in [RFC4947]. The use of security mechanisms to protect the MPEG-2 signalling information is discussed by [Sec-Req].

7. References

7.1. Normative References

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7.2. Informative References

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Appendix A. The Second-Generation DVB Transmission Specifications

This section provides informative background to the network-layer requirements of the second-generation DVB Transmission Specifications. The second-generation waveforms specified by the Digital Video Broadcasting project offer two main enhancements. First, more efficient physical-layer methods that employ higher-order modulation with stronger FEC and permit adaptive coding and modulation response to changes in traffic and propagation conditions. Second, at the link layer, they offer greater flexibility in framing. Support is provided for a range of stream formats including the classical Transport Stream (TS) [RFC4259]. In addition, a new method called Generic Stream (GS) (or the Generic Mode) is supported. A GS can be packetized or continuous and is intended to provide native transport of other network-layer services. One such method is that provided by the Generic Stream Encapsulation (GSE) [GSE].

For example, the DVB-S2 [ETSI-S2] transmission link sequentially multiplexes a series of baseband frames (BBFrames). Each BBFrame comprises a fixed-size 10B header and a payload. The payload carries a DataField and uses padding to fill any unused space. A stream comprises a sequence of BBFrames associated with an Input Stream Identifier (ISI) that is carried in the header of each BBFrame. The simplest scheme uses a single stream (with just one ISI value), but multiple streams are permitted. The BBFrames forming a stream may be of variable size (selected from a set of allowed sizes), and must use the same stream format (i.e., TS or GSE). Each stream represents an independent link with independent address resolution [RFC4947].

GSE provides functions that are equivalent to those of the Unidirectional Lightweight Encapsulation (ULE) [RFC4326]. It supports the transmission of IP packets and other network-layer protocols. The network-layer interface resembles that of ULE, where it adopts common mechanisms for a Length field, a 16-bit Type field, and support for Extension Headers. As in ULE, GSE permits multiple address formats, indicated by the LT field (functionally equivalent to the D field in ULE). The default addressing mode uses a 6-byte NPA and a suppressed NPA address (functionally equivalent to D=1 in ULE).

GSE also provides more flexible fragmentation at the interface to the physical layer (using the S and E flags). This adapts the SNDUs to a variable-sized link-layer frame, and reflects the more complex requirements in terms of fragmentation and assembly that arise when using point-to-multipoint adaptive physical layers. The integrity of a reassembled SNDU is validated using a CRC-32 in the last fragment for the corresponding PDU.

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