       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), RFC4326.

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

Table of Contents

1. Introduction

   This document describes three Header Extensions that may be used
   with both 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 [ID-S2-REQ].
   The important characteristics of this encapsulation are described in
   an Appendix to this document. GSE maintains a design philosophy that
   presents a common network interface to that of ULE and uses a
   similar construction for SubNetwork Data Unit (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 receivers that are not addressed by
   the NPA, since these receivers may 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.

   An appendix includes a summary of key design issues and
   considerations based on 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 [ETSI-S2]: The data field part of a Baseband frame
   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 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].

   Encapsulator: A network device 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 [ETSI-S2]. A stream of BBFrames identified by a
   common Input Stream Identifier, and which does not use the MPEG-2 TS
   format. 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].

   MAC: Medium Access Control [IEEE-802.3]. A link layer protocol
   defined by the IEEE 802.3 standard (or by Ethernet v2).

   MPEG-2: A set of standards specified by the Motion Picture Experts
   Group (MPEG), and standardized by the International Standards
   Organisation (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 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 per-SNDU
   CRC, has different header flags, and utilises 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
   optimisation 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
   Next-Header Extension.

   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).

   A Receiver MUST check the validity of the Length value prior to
   processing the payload. A valid Length contains 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)                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
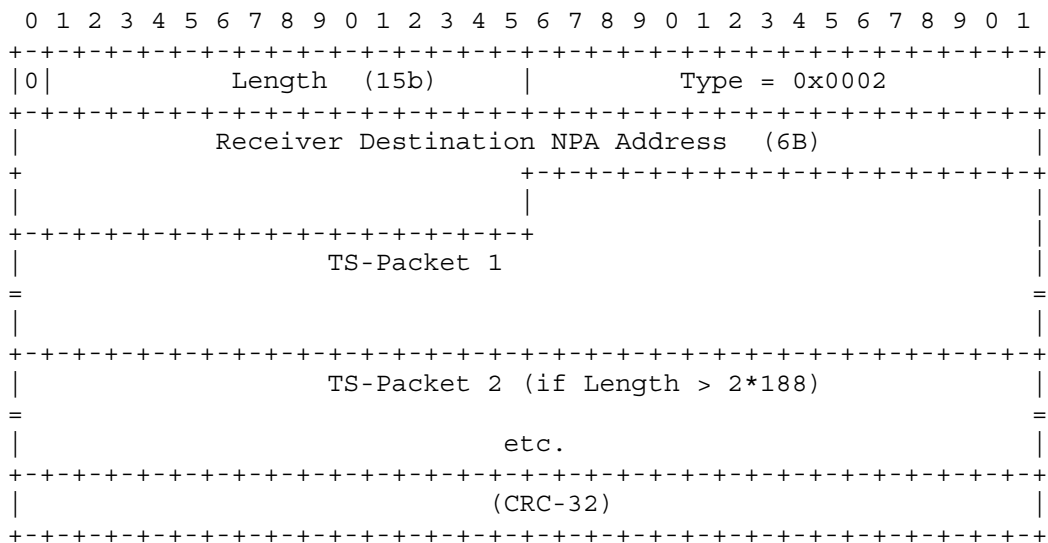
Figure 1: ULE/SNDU Format for a TS-Packet Payload (D=0)

Figure 1 illustrates the format of this Extension Header for ULE
with a value D=0, which indicates the presence of a 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.                             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
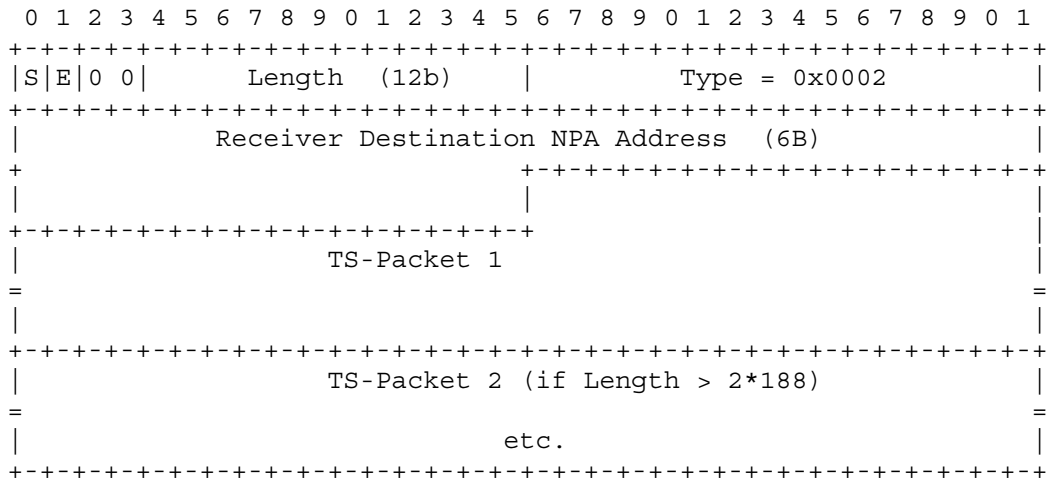
Figure 2: GSE/SNDU Format for a TS-Packet Payload (LT=00)

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

In ULE, a value of D=1, is also permitted and indicates the absence
of a 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)                          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
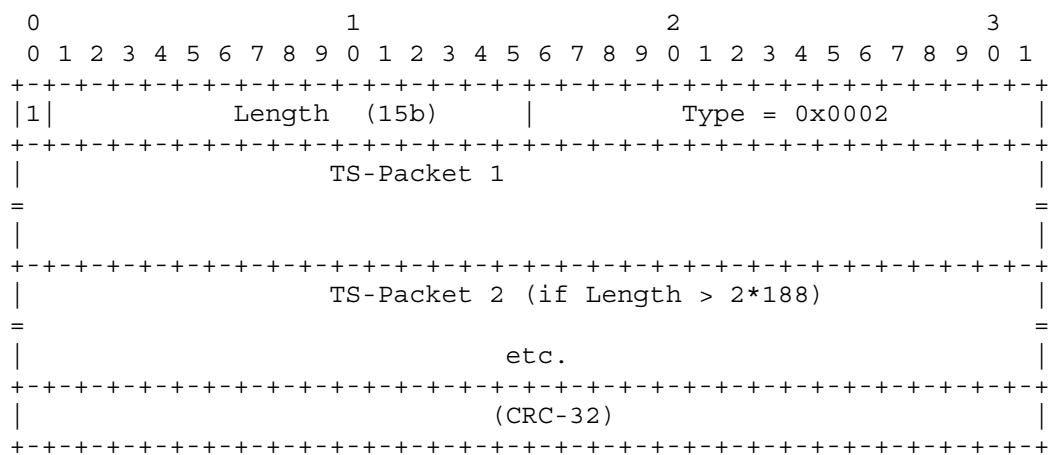
Figure 3: ULE/SNDU Format for a TS-Packet Payload (D=1)

This 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.

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 that a poorly configured Encapsulator could lead to a Multiplex carrying multiple (possibly conflicting) sets of TS Logical Channels and SI information encapsulated at different levels or with different NPA addresses. The need for consistency in the use of PIDs and the related SI information is described in [RFCxARx].

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 as PDU-Length in the following diagrams). 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 figure). 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
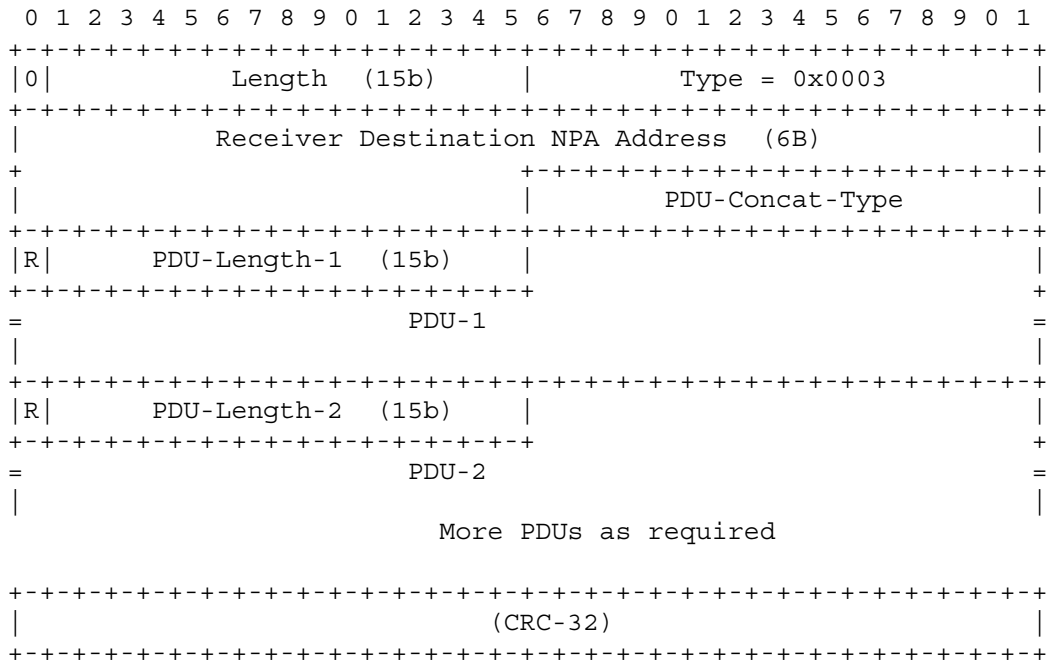forwarded with each PDU, if required by the forwarding interface.

```
      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-Length-1  (15b)      |                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
     =                           PDU-1                               =
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |R|      PDU-Length-2  (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-Length-1  (15b)      |                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
     =                           PDU-1                               =
     |                                                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |R|      PDU-Length-2  (15b)      |                               |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
     =                           PDU-2                               =
     |                                                               |
                         More PDUs as required


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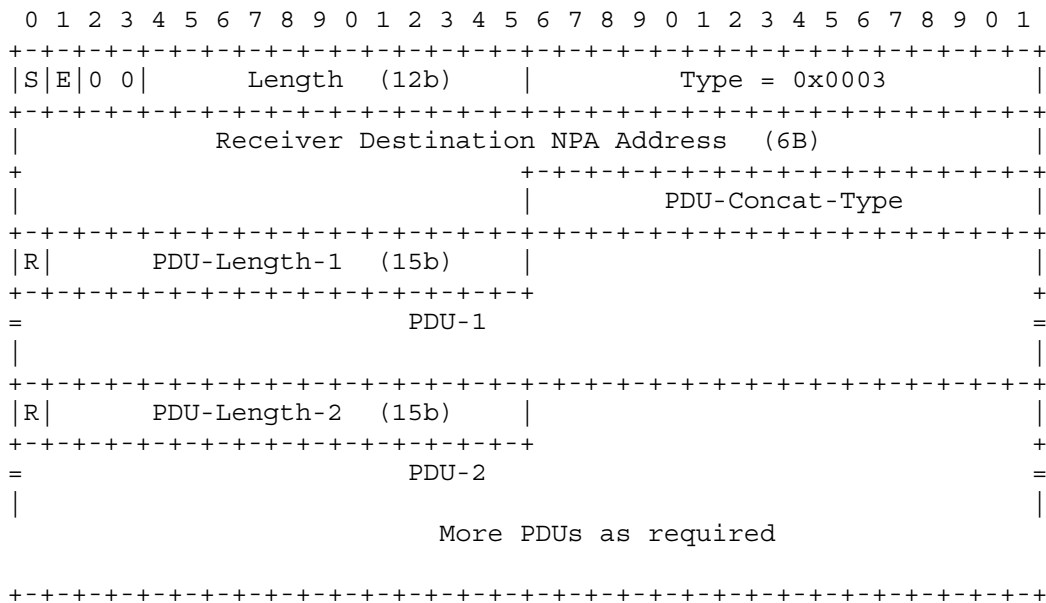
  Figure 5: GSE/SNDU Format for a PDU-Concat Payload (LT=00)_

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 a NPA/MAC address
is in use [RFC4326]. A similar format is supported in GSE (using the
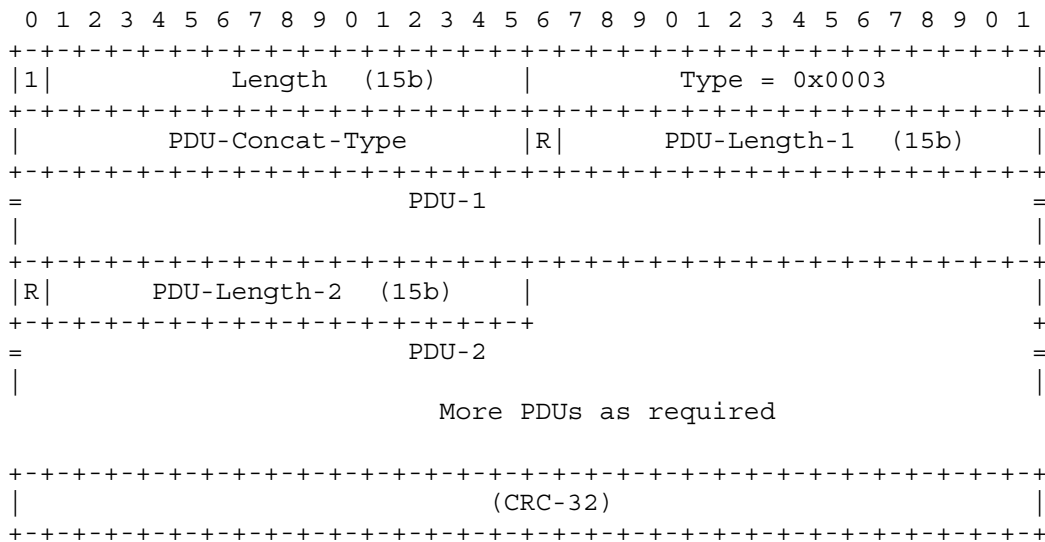LT field).

```
    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-Length-1  (15b)    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   =                             PDU-1                             =
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |R|     PDU-Length-2  (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 Next-Header Extension
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 synchronised 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      |        time stamp HI          |
+---------------+---------------+---------------+---------------+
|         time stamp LO         |             Type              |
+---------------+---------------+---------------+---------------+
```
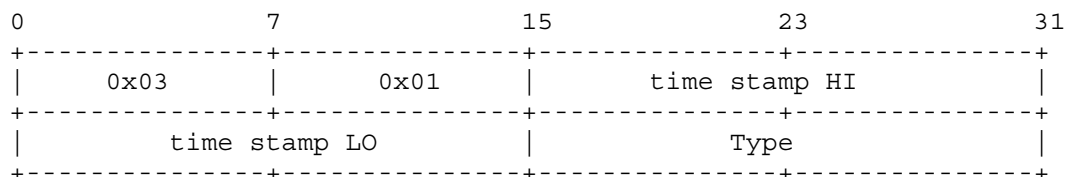
       Figure 7 The format of the 32-bit Timestamp Extension Header

The extension carries a 32-bit value (time stamp HI plus time stamp
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 may use an arbitrary (and varying) value
to pad the unused least-significant bits.

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 Optional Extension Header timestamp
when the PDU is decapsulated. 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

   This document requires IANA involvement for the assignment of 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 format for a HLEN value of 0x3.

5. Acknowledgements

   The author gratefully acknowledges the inputs, comments and
   assistance offered by the members of the DVB-GBS ad hoc group on
   DVB-S2 encapsulation, in particular contributions on DVB-S2
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   Juan Cantillo provided a significant contribution to the informative
   annexe. The authors thank Christian Praehauser for his insight and
   contribution on header extension processing issues.

6. Security Considerations

   This document does not raise new security concerns.

   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 [ID-Sec-Req].

7. References

7.1 Normative References

   [RFC2119] Bradner, S., "Key Words for Use in RFCs to Indicate
   Requirement Levels", BCP 14, RFC 2119, 1997.

   [RFC4326] Fairhurst, G. and B. Collini-Nocker, "Unidirectional
   Lightweight Encapsulation (ULE) for transmission of IP datagrams
   over an MPEG-2 Transport Stream", RFC 4326, December 2005.

   [GSE] "Generic Stream Encapsulation", DVB Document A116, DVB
   Technical Module (GBS Group), May 2007.

7.2 Informative References

   [ETSI-S2] EN 302 307, "Digital Video Broadcasting (DVB); Second
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8. Authors' Addresses

   Godred Fairhurst
   Department of Engineering
   University of Aberdeen
   Aberdeen, AB24 3UE
   UK
   Email: gorry@erg.abdn.ac.uk
   Web: http://www.erg.abdn.ac.uk/users/Gorry

   Bernhard Collini-Nocker
   Department of Computer Sciences
   University of Salzburg
   Jakob Haringer Str. 2
   5020 Salzburg
   Austria

   EMail: bnocker@cosy.sbg.ac.at
   Web: http://www.cosy.sbg.ac.at/

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APPENDIX: 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 Streams (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 (e.g. TS or GSE). Each stream represents
   an independent link with independent address resolution [RFCxARx].

   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 SNDUs is provided by a CRC-32 in the last fragment for
   the corresponding PDU.

[RFC EDITOR NOTE:
This section must be deleted prior to publication]

DOCUMENT HISTORY

Individual Draft 00
This draft complements a study item in the DVB-GBS in this area to
define a Generic Stream Encapsulation (GSE). Comments relating to
this document will be gratefully received by the author(s) and may
also be sent to ip-dvb mailing list at: ip-dvb@erg.abdn.ac.uk

Individual Draft 01
Co-Author Added.
This draft updates the language and format.
This draft fixes problems with the concatenation mode, and defines a
new header format that restricts the use of the Type field so that
all concatenated PDUs MUST have the same Type.

Future versions of this draft may define additional Extension
Headers, proposals and ideas are welcome via the IETF ipdvb mailing
list. Possible extensions include those for encapsulation FEC, Link
parameter negotiation (e.g. for header compression), and support for
ATM/ULE.

Working Group Draft 00
Fixed editorial mistakes from Christian Praehauser and ID style for
WG adoption.

Working Group Draft 01
Corrected contact info for Bernhard.
Added TimeStamp Options
Corrected NITS in draft

Working Group Draft 01
Amended diagrams and text to follow tentative IANA assignments for
the codepoints.

Working Group Draft 01
Ammended text to follow IANA assignments for the codepoints.
Added issues raised at ipdvb meeting by C Praehauser.
Revised annexe with text from GSE Spec, J Cantillo, et al.
Revised wording to clarify corner cases.
Removed references to documents not in public domain.
Updated conventions and abbreviations for consistency.
Updated text referencing ULE.

Working Group Draft 02

Added rules for Types of PDUs in PDU-Concat.
Added appendix on DVB 2 nd generation.
Added new text on timers to control concat (from list).

Working Group Draft 03

Added a table to the start of the method defining recommended.
Fixed NiTs.

Working Group Draft 04 Draft
Editorial changes to prepare the document for WGLC.
Updated IANA section to comply with RFC4326 IANA Guidelines.

Reduced Security considerations section by reference to other
documents that give a fuller discussion.

There were no intentional changes to the protocol specification.

[END of RFC EDITOR NOTE]