FEC Framework
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Raptor FEC Schemes for FECFRAME
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Abstract

This document describes Fully-Specified Forward Error Correction (FEC) Schemes for the Raptor and RaptorQ codes and their application to reliable delivery of media streams in the context of FEC Framework. The Raptor and RaptorQ codes are systematic codes, where a number of repair symbols are generated from a set of source symbols and sent in one or more repair flows in addition to the source symbols that are sent to the receiver(s) within a source flow. The Raptor and RaptorQ codes offer close to optimal protection against arbitrary packet losses at a low computational complexity. Six FEC Schemes are defined, two for protection of arbitrary packet flows, two that are optimised for small source blocks and another two for protection of a single flow that already contains a sequence number. Repair data may be sent over arbitrary datagram transport (e.g. UDP) or using RTP.

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1. Introduction

The FEC Framework [RFC6363] describes a framework for the application of Forward Error Correction to arbitrary packet flows. Modeled after the FEC Building Block developed by the IETF Reliable Multicast Transport working group [RFC5052], the FEC Framework defines the concept of FEC Schemes which provide specific Forward Error Correction schemes. This document describes six FEC Schemes which make use of the Raptor and RaptorQ FEC codes as defined in [RFC5053] and [RFC6330].

The FEC protection mechanism is independent of the type of the source data, which can be an arbitrary sequence of packets, including for example audio or video data. In general, the operation of the protection mechanism is as follows:

- o The sender determines a set of source packets (a source block) to be protected together based on the FEC Framework Configuration Information.
- o The sender arranges the source packets into a set of source symbols, each of which is the same size.
- o The sender applies the Raptor/RaptorQ protection operation on the source symbols to generate the required number of repair symbols.
- o The sender packetizes the repair symbols and sends the repair packet(s) along with the source packets to the receiver(s).

Per the FEC Framework requirements, the sender MUST transmit the source and repair packets in different source and repair flows, or in the case RTP transport is used for repair packets, in different RTP streams. At the receiver side, if all of the source packets are successfully received, there is no need for FEC recovery and the repair packets are discarded. However, if there are missing source packets, the repair packets can be used to recover the missing information.

The operation of the FEC mechanism requires that the receiver can identify the relationships between received source packets and repair packets and in particular which source packets are missing. In many cases, data already exists in the source packets which can be used to refer to source packets and to identify which packets are missing. In this case we assume it is possible to derive a "sequence number" directly or indirectly from the source packets and this sequence number can be used within the FEC Scheme. This case is referred to as a "single sequenced flow". In this case the FEC Source Payload ID defined in [RFC6363] is empty and the source packets are not modified

by the application of FEC, with obvious backwards compatibility advantages.

Otherwise, it is necessary to add data to the source packets for FEC purposes in the form of a non-empty FEC Source Payload ID. This case if referred to as the "arbitrary packet flow" case. Accordingly, this document defines six FEC Schemes, two for the case of a single sequenced flow and four for the case of arbitrary packet flows.

2. Document Outline

This document is organised as follows:

o Section 5 defines general procedures applicable to the use of the Raptor and RaptorQ codes in the context of the FEC Framework.

o Section 6defines an FEC Scheme for the case of arbitrary source flows and follows the format defined for FEC Schemes in [RFC6363]. When used with Raptor codes, this scheme is equivalent to that defined in [MBMSTS].

o Section 7 defines an FEC Scheme similar to that defined in Section 6but with optimisations for the case where only limited source block sizes are required. When used with Raptor codes, this scheme is equivalent to that defined in [dvbts] for arbitrary packet flows.

o Section 8 defines an FEC Scheme for the case of a single flow which is already provided with a source packet sequence number. When used with Raptor codes, this scheme is equivalent to that defined in [dvbts] for the case of a single sequenced flow.

3. Requirements Notation

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 [RFC2119].

4. Definitions and Abbreviations

The definitions, notations and abbreviations commonly used in this document are summarized in this section.

4.1. Definitions

This document uses the following definitions. For further definitions that apply to FEC Framework in general, see [RFC6363].

Symbol: A unit of data. Its size, in octets, is referred to as the symbol size.

FEC Framework Configuration Information: Information that controls the operation of the FEC Framework. Each FEC Framework instance has its own configuration information.

4.2. Abbreviations

This document uses the following abbreviations. For further abbreviations that apply to FEC Framework in general, see [RFC6363].

FSSI: FEC-Scheme-Specific Information.

SS-FSSI: Sender-Side FEC-Scheme-Specific Information.

RS-FSSI: Receiver-Side FEC-Scheme-Specific Information.

ADUI: Application Data Unit Information.

5. General procedures for Raptor FEC Schemes

This section specifies general procedures which apply to all Raptor and RaptorQ FEC Schemes, specifically the construction of source symbols from a set of source transport payloads. As described in [RFC6363] for each Application Data Unit (ADU) in a source block, the FEC Scheme is provided with:

- o A description of the source data flow with which the ADU is associated and an integer identifier associated with that flow.
- o The ADU itself.
- o The length of the ADU.

For each ADU, we define the Application Data Unit Information (ADUI) as follows:

Let

- n be the number of ADUs in the source block.

- T be the source symbol size in octets. Note: this information is provided by the FEC Scheme as defined below.

- i the index to the (i+1)-th ADU to be added to the source block, 0 <= i < n.

- R[i] denote the number of octets in the (i+1)-th ADU.

- l[i] be a length indication associated with the i-th ADU - the nature of the length indication is defined by the FEC Scheme.

- L[i] denote two octets representing the value of l[i] in network byte order (high order octet first) of the i-th ADU.

- f[i] denote the integer identifier associated with the source data flow from which the i-th ADU was taken.

- F[i] denote a single octet representing the value of f[i].

- s[i] be the smallest integer such that s[i]*T >= (l[i]+3). Note s[i] is the length of SPI[i] in units of symbols of size T octets.

- P[i] denote s[i]*T-(l[i]+3) zero octets. Note: P[i] are padding octets to align the start of each UDP packet with the start of a symbol.

- ADUI[i] be the concatenation of F[i] ,L[i], R[i] and P[i].

Then, a source data block is constructed by concatenating ADUI[i] for i = 0, 1, 2, ... n-1. The source data block size, S, is then given by sum {s[i]*T, i=0, ..., n-1}. Symbols are allocated integer Encoding Symbol IDs consecutively starting from zero within the source block. Each ADU is associated with the Encoding Symbol ID of the first symbol containing SPI for that packet. Thus, the Encoding Symbol ID value associated with the j-th source packet, ESI[j], is given by ESI[j] = 0, for j=0 and ESI[j] = sum{s[i], i=0,...,(j-1)}, for 0 < j < n.

Source blocks are identified by integer Source Block Numbers. This specification does not specify how Source Block Numbers are allocated to source blocks. The Source FEC Packet Identification Information consists of the identity of the source block and the Encoding Symbol ID associated with the packet.

6. Raptor FEC Schemes for arbitrary packet flows

6.1. Introduction

This section specifies an FEC Scheme for the application of the Raptor and RaptorQ codes to arbitrary packet flows. This scheme is recommended in scenarios where maximal generality is required.

When used with Raptor codes, this scheme is equivalent to that specified in [MBMSTS].

6.2. Formats and Codes

6.2.1. FEC Framework Configuration Information

6.2.1.1. FEC Scheme ID

The value of the FEC Scheme ID for the fully-specified FEC scheme defined in this section is XXX when [RFC5053] is used and YYY when [RFC6330] is used, as assigned by IANA.

6.2.1.2. Scheme-Specific Elements

The scheme-specific elements of the FEC Framework Configuration information for this scheme are as follows:

Maximum Source Block Length Name: "Kmax", Value range: A decimal non-negative integer less than 8192 (for Raptor) or 56403 (for RaptorQ), in units of symbols

Encoding Symbol Size Name: "T", Value range: A decimal non-negative integer less than 65536, in units of octets

Payload ID Format Name: "P", Value range: "A" or "B"

An encoding format for The Maximum Source Block Length and Encoding Symbol Size is defined below.

```
                        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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |       Symbol Size (T)         |Max. Source Block Length (Kmax)|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |P|  Reserved   |
   +-+-+-+-+-+-+-+-+
```

Figure 1: FEC Scheme Specific Information

The P bit shall be set to zero to indicate Format A or to one to indicate Format B. The last octet of the above encoding may be omitted, in which case Format A shall be assumed.

The Payload ID Format identifier defines which of the Source FEC Payload ID and Repair FEC Payload ID formats defined below shall be used. Payload ID Format B SHALL NOT be used when[RFC5053] is used.

6.2.2. Source FEC Payload ID

This scheme makes use of an Explicit Source FEC Payload ID, which is appended to the end of the source packets. Two formats are defined for the Source FEC Payload ID, format A and format B. The format that is used is signaled as part of the FEC Framework Configuration Information.

The Source FEC Payload ID for format A is provided in Figure 2.

.

```
                        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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Source Block Number (SBN)   |   Encoding Symbol ID (ESI)    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Source FEC Payload ID - Format A

Source Block Number (SBN), (16 bits): An integer identifier for the source block that the source data within the packet relates to.

Encoding Symbol ID (ESI), (16 bits): The starting symbol index of the source packet in the source block.

The Source FEC Payload ID for format B is provided in Figure 3.

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      SBN      |            Encoding Symbol ID (ESI)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: Source FEC Payload ID - Format B

Source Block Number (SBN), (8 bits): An integer identifier for the source block that the source data within the packet relates to.

Encoding Symbol ID (ESI), (24 bits): The starting symbol index of the source packet in the source block.

6.2.3. Repair FEC Payload ID

Two formats for the Repair FEC Payload ID, Format A and Format B are defined below.

The Repair FEC Payload ID for format A is provided in Figure 4.

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Source Block Number (SBN)   |   Encoding Symbol ID (ESI)    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Source Block Length (SBL)   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Repair FEC Payload ID - Format A

Source Block Number (SBN), (16 bits) An integer identifier for the source block that the repair symbols within the packet relate to. For format A, it is of size 16 bits.

Encoding Symbol ID (ESI), (16 bits) Integer identifier for the encoding symbols within the packet.

Source Block Length (SBL), (16 bits) The number of source symbols in the source block.

The Repair FEC Payload ID for format B is provided in Figure 5.

```
                        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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      SBN      |            Encoding Symbol ID (ESI)           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Source Block Length (SBL)   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Repair FEC Payload ID - Format B

Source Block Number (SBN), (8 bits) An integer identifier for the source block that the repair symbols within the packet relate to. For format A, it is of size 16 bits.

Encoding Symbol ID (ESI), (24 bits) Integer identifier for the encoding symbols within the packet.

Source Block Length (SBL), (16 bits) The number of source symbols in the source block.

The interpretation of the Source Block Number, Encoding Symbol Identifier and Source Block Length is defined by the FEC Code Specification.

6.3. Procedures

6.3.1. Source symbol construction

This FEC Scheme uses the procedures defined in Section 5 to construct a set of source symbols to which the FEC code can be applied. The sender MUST allocate Source Block Numbers to source blocks sequentially, wrapping around to zero after Source Block Number 65535 (Format A) or 255 (Format B).

During the construction of the source block:

o the length indication, l[i], included in the Source Packet Information for each packet shall be the transport payload length.

o the value of s[i] in the construction of the Source Packet Information for each packet shall be the smallest integer such that s[i]*T >= (l[i]+3).

6.3.2. Repair packet construction

The ESI value placed into a repair packet is calculated as specified in Section 5.3.2 of [RFC5053] when Raptor as defined in [RFC5053] is used and as specified in Section 4.4.2 of [RFC6330] when RaptorQ as

defined in [RFC6330] is used, where K=SBL.

6.4. FEC Code Specification

The Raptor FEC encoder defined in [RFC5053] or [RFC6330] SHALL be used. The source symbols passed to the Raptor FEC encoder SHALL consist of the source symbols constructed according to Section 6.3.1. Thus the value of the parameter K used by the FEC encoder (equal to the Source Block Length) may vary amongst the blocks of the stream but SHALL NOT exceed the Maximum Source Block Length signaled in the FEC Scheme-specific information. The symbol size, T, to be used for source block construction and the repair symbol construction is equal to the Encoding Symbol Size signaled in the FEC Scheme Specific Information.

7. Optimised Raptor FEC Scheme for arbitrary packet flows

7.1. Introduction

This section specifies a slightly modified version of the FEC Scheme specified in Section 6 which is applicable to scenarios in which only relatively small block sizes will be used. These modifications admit substantial optimisations to both sender and receiver implementations.

In outline, the modifications are:

- All source blocks within a stream are encoded using the same source block size. Code shortening is used to encode blocks of different sizes. This is achieved by padding every block to the required size using zero symbols before encoding. The zero symbols are then discarded after decoding. The source block size to be used for a stream is signaled in the Maximum Source Block Size field of the scheme-specific information. This allows for efficient parallel encoding of multiple streams. Note that the padding operation is equivalent to the padding operation in [RFC6330] with K' the specified single source block size and K the actual source block size K.

- The possible choices of the source block size for a stream is restricted to a small specified set of sizes. This allows explicit operation sequences for encoding and decoding the restricted set of source block sizes to be pre-calculated and embedded in software or hardware.

When the Raptor FEC encoder as defined in [RFC5053] is used, this scheme is equivalent to that specified in [dvbts] for arbitrary

packet flows.

7.2. Formats and Codes

7.2.1. FEC Framework Configuration Information

7.2.1.1. FEC Scheme ID

The value of the FEC Scheme ID for the fully-specified FEC scheme defined in this section is XXX when [RFC5053] is used and YYY when [RFC6330] is used, as assigned by IANA.

7.2.1.2. FEC Scheme specific information

See . (Section 6.2.1.2)

7.2.2. Source FEC Payload ID

See . (Section 6.2.2)

7.2.3. Repair FEC Payload ID

SeeSection 6.2.3

7.3. Procedures

7.3.1. Source symbol construction

See Section 6.3.1

7.3.2. Repair packet construction

The number of repair symbols contained within a repair packet is computed from the packet length. The ESI value placed into a repair packet is calculated as X + MSBL - SBL, where X would be the ESI value of the repair packet if the ESI were calculated as specified in Section 5.3.2 of [RFC5053] when Raptor as defined in[RFC5053] is used and as specified in Section 4.4.2 of [RFC6330] when RaptorQ as defined in [RFC6330] is used, where K=SBL. The value of SBL SHALL be at most the value of MSBL.

7.4. FEC Code Specification

The Raptor FEC encoder defined in [RFC5053] or [RFC6330] SHALL be used. The source symbols passed to the Raptor FEC encoder SHALL consist of the source symbols constructed according to Section 6.3.1 extended with zero or more padding symbols such that the total number of symbols in the source block is equal to the Maximum Source Block

Length signaled in the FEC Scheme Specific Information. Thus the value of the parameter K used by the FEC encoded is equal to the Maximum Source Block Length for all blocks of the stream. Padding symbols shall consist entirely of octets set to the value zero. The symbol size, T, to be used for source block construction and the repair symbol construction is equal to the Encoding Symbol Size signaled in the FEC Scheme Specific Information.

When [RFC5053] is used, the parameter T SHALL be set such that the number of source symbols in any source block is at most 8192. The Maximum Source Block Length parameter - and hence the number of symbols used in the FEC Encoding and Decoding operations - SHALL be set to one of the following values:

101, 120, 148, 164, 212, 237, 297, 371, 450, 560, 680, 842, 1031, 1139, 1281

When [RFC6330] is used, the parameter T SHALL be set such that the number of source symbols in any source block is less than 56403. The Maximum Source Block Length parameter SHALL be set to one of the supported values for K' defined in Section 5.6 of [RFC6330].

8. Raptor FEC Scheme for a single sequenced flow

8.1. Formats and codes

8.1.1. FEC Framework Configuration Information

8.1.1.1. FEC Scheme ID

The value of the FEC Scheme ID for the fully-specified FEC scheme defined in this section is XXX when [RFC5053] is used and YYY when [RFC6330] is used, as assigned by IANA.

8.1.1.2. Scheme-specific elements

See Section 6.2.1.2

8.1.2. Source FEC Payload ID

The Source FEC Payload ID field is not used by this FEC Scheme. Source packets are not modified by this FEC Scheme.

8.1.3. Repair FEC Payload ID

Two formats for the Repair FEC Payload ID are defined, Format A and Format B.

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Initial Sequence Number    |      Encoding Symbol ID       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Source Block Length      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 6: Repair FEC Payload ID - Format A

Initial Sequence Number (Flow i ISN) - 16 bits This field specifies the lowest 16 bits of the sequence number of the first packet to be included in this sub-block. If the sequence numbers are shorter than 16 bits then the received Sequence Number SHALL be logically padded with zero bits to become 16 bits in length respectively.

Encoding Symbol ID (ESI) - 16 bits This field indicates which repair symbols are contained within this repair packet. The ESI provided is the ESI of the first repair symbol in the packet.

Source Block Length (SBL) - 16 bits This field specifies the length of the source block in symbols.

```
                     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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Initial Sequence Number    |      Source Block Length      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Encoding Symbol ID           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Repair FEC Payload ID - Format B

Initial Sequence Number (Flow i ISN) - 16 bits This field specifies the lowest 16 bits of the sequence number of the first packet to be included in this sub-block. If the sequence numbers are shorter than 16 bits then the received Sequence Number SHALL be logically padded with zero bits to become 16 bits in length respectively.

Source Block Length (SBL) - 16 bits This field specifies the length of the source block in symbols.

Encoding Symbol ID (ESI) - 24 bits This field indicates which repair symbols are contained within this repair packet. The ESI provided is the ESI of the first repair symbol in the packet.

8.2. Procedures

8.2.1. Source symbol construction

This FEC Scheme uses the procedures defined in Section 5 to construct a set of source symbols to which the FEC code can be applied. The sender MUST allocate Source Block Numbers to source blocks sequentially, wrapping around to zero after Source Block Number 65535 in the case Format A is used for FEC Payload IDs and 255 in the case Format B is used for FEC Payload IDs.

During the construction of the source block:

- o the length indication, l[i], included in the Source Packet Information for each packet shall be dependent on the protocol carried within the transport payload. Rules for RTP are specified below.

- o the value of s[i] in the construction of the Source Packet Information for each packet shall be the smallest integer such that s[i]*T >= (l[i]+3)

8.2.2. Derivation of Source FEC Packet Identification Information

The Source FEC Packet Identification Information for a source packet is derived from the sequence number of the packet and information received in any repair FEC packet belonging to this Source Block. Source blocks are identified by the sequence number of the first source packet in the block. This information is signaled in all repair FEC packets associated with the source block in the Initial Sequence Number field.

The length of the Source Packet Information (in octets) for source packets within a source block is equal to length of the payload containing encoding symbols of the repair packets (i.e. not including the Repair FEC Payload ID) for that block, which MUST be the same for all repair packets. The Application Data Unit Information Length (ADUIL) in symbols is equal to this length divided by the Encoding Symbol Size (which is signaled in the FEC Framework Configuration Information). The set of source packets which are included in the source block is determined from the Initial Sequence Number (ISN) and Source Block Length (SBL) as follows:

Let,

- o I be the Initial Sequence Number of the source block

o LP be the Source Packet Information Length in symbols

o LB be the Source Block Length in symbols

Then, source packets with sequence numbers from I to I +LB/LP-1 inclusive are included in the source block.

Note that if no FEC repair packets are received then no FEC decoding is possible and it is unnecessary for the receiver to identify the Source FEC Packet Identification Information for the source packets.

The Encoding Symbol ID for a packet is derived from the following information:

o The sequence number, Ns, of the packet

o The Source Packet Information Length for the source block, LP

o The Initial Sequence Number of the source block, I

Then the Encoding Symbol ID for packet with sequence number Ns is determined by the following formula:

ESI = (Ns - I) * LP

Note that all repair packet associated to a given Source Block MUST contain the same Source Block Length and Initial Sequence Number.

Note also that the source packet flow processed by the FEC encoder MUST have consecutive sequence numbers. In case the incoming source packet flow has a gap in the sequence numbers then implementors SHOULD insert an ADU in the source block that complies to the format of the source packet flow, but is ignored at the application with high probability. For additional guidelines refer to [RFC6363], Section 10.2, paragraph 5.

8.2.3. Repair packet construction

See Section 7.3.2

8.2.4. Procedures for RTP source flows

In the specific case of RTP source packet flows, then the RTP Sequence Number field SHALL be used as the sequence number in the procedures described above. The length indication included in the Application Data Unit Information SHALL be the RTP payload length plus the length of the CSRCs, if any, the RTP Header Extension, if present, and the RTP padding octets, if any. Note that this length

is always equal to the UDP payload length of the packet minus 12.

8.3. FEC Code Specification

See Section 7.4

9. Security Considerations

For the general security considerations related to the use of FEC, refer to [RFC6363]. No security considerations specific to this document have been identified.

10. Session Description Protocol (SDP) Signaling

This section provides an SDP [RFC4566] example. The syntax follows the definition in [RFC6364] .Assume we have one source video stream (mid:S1) and one FEC repair stream (mid:R1). We form one FEC group with the "a=group:FEC-FR S1 R1" line. The source and repair streams are sent to the same port on different multicast groups. The repair window is set to 200 ms.

```
v=0
o=ali 1122334455 1122334466 IN IP4 fec.example.com
s=Raptor FEC Example
t=0 0
a=group:FEC-FR S1 R1
m=video 30000 RTP/AVP 100
c=IN IP4 233.252.0.1/127
a=rtpmap:100 MP2T/90000
a=fec-source-flow: id=0
a=mid:S1
m=application 30000 UDP/FEC
c=IN IP4 233.252.0.2/127
a=fec-repair-flow: encoding-id=6; fssi=Kmax:8192,T:128,P:A
a=repair-window:200ms
a=mid:R1
```

11. Congestion Control Considerations

For the general congestion control considerations related to the use of FEC, refer to [RFC6363].

12. IANA Considerations

12.1. Registration of FEC Scheme IDs

The value of FEC Scheme IDs is subject to IANA registration. For general guidelines on IANA considerations as they apply to this document, refer to [RFC6363].

This document registers three values in the FEC Framework (FECFRAME) FEC Encoding IDs registry as follows:

- 1 for the Raptor FEC Scheme for Arbitrary Packet Flows (Section 6 using Raptor [RFC5053].
- 2 for the Raptor FEC Scheme for Arbitrary Packet Flows (Section 6 using RaptorQ [RFC6330].
- 3 for the Optimised Raptor FEC Scheme for Arbitrary Packet Flows (Section 7) using Raptor [RFC5053].
- 4 for the Optimised Raptor FEC Scheme for Arbitrary Packet Flows (Section 7) using RaptorQ [RFC6330].
- 5 for the Raptor FEC Scheme for a single sequence flow (Section 8) using Raptor [RFC5053].
- 6 for the Raptor FEC Scheme for a single sequence flow (Section 8) using RaptorQ [RFC6330].

13. Acknowledgements

Thanks are due to Ali C. Begen for thorough review of earlier draft versions of this document.

14. References

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