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DVB Application-Layer Hybrid FEC Protection
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Abstract

This document describes the Application-layer Forward Error Correction (FEC) protocol that was developed by the Digital Video Broadcasting (DVB) consortium for the protection of media streams over IP networks. The DVB AL-FEC protocol uses two layers for FEC protection. The first (base) layer is based on the 1-D interleaved parity code. The second (enhancement) layer is based on the Raptor code. By offering a layered approach, the DVB AL-FEC offers a good

protection against both bursty and random packet losses at a cost of decent complexity. The 1-D interleaved parity code and Raptor code have already been specified in separate documents and the current document normatively references these specifications.

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1. Introduction

In 2007, the Digital Video Broadcasting (DVB) consortium published a technical specification [ETSI-TS-102-034] through European Telecommunications Standards Institute (ETSI). This specification covers several areas related to the transmission of MPEG2 transport stream-based services over IP networks.

The Annex E of [ETSI-TS-102-034] defines an optional protocol for Application-layer Forward Error Correction (AL-FEC) to protect the streaming media for DVB-IP services carried over RTP [RFC3550] transport. The AL-FEC protocol uses two layers for protection: a base layer that is produced by the 1-D interleaved parity code, and an enhancement layer that is produced by the Raptor code. Whenever a receiver supports AL-FEC protocol, the decoding support for the base-layer FEC is mandatory while the decoding support for the enhancement-layer FEC is optional. Both the interleaved parity code and the Raptor code are systematic FEC codes, meaning that source packets are always sent as part of the transport.

This document briefly explains the DVB AL-FEC protocol by providing references to the two FEC codes used as part of the AL-FEC protocol. This document considers protection of single-sequence RTP flows only. The DVB AL-FEC protocol can protect any type of source media such as audio, video, text or application. The FEC data at each layer is generated based on some configuration information, which also determines the exact associations and relationships between the source and repair packets. This document shows this configuration may be communicated out-of-band in Session Description Protocol (SDP) [RFC4566].

In DVB AL-FEC, the source packets are carried in the source RTP stream and the generated FEC repair packets at each layer are carried in separate 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 may be discarded. However, if there are missing source packets, the repair packets can be used to recover the missing information.

The block diagram of the encoder side for the systematic DVB AL-FEC protection is sketched in Figure 1. Here, the source packets are fed into the parity encoder to produce the parity repair packets. The source packets may also be fed to the Raptor encoder to produce the Raptor repair packets. Source packets as well as the repair packets are then sent to the receiver(s) over an IP network.

```
                              +--------------+
   +--+  +--+  +--+  +--+ --> |  Systematic  | -> +--+  +--+  +--+  +--+
   +--+  +--+  +--+  +--+     |FEC Protection|    +--+  +--+  +--+  +--+
                              +--------------+
                              |    Parity    | -> +==+  +==+  +==+
                              |    Encoder   |    +==+  +==+  +==+
                              +--------------+
                              |    Raptor    | -> +~~+  +~~+
                              |    Encoder   |    +~~+  +~~+
                              +--------------+

   Source Packet: +--+
                  +--+

   Base-layer Repair Packet: +==+
                             +==+

   Enhancement-layer Repair Packet: +~~+
                                    +~~+
```

Figure 1: Block diagram for the DVB AL-FEC encoder

The block diagram of the decoder side for the systematic DVB AL-FEC protection is sketched in Figure 2. This is a Minimum Performance Decoder since the receiver only supports decoding the base-layer repair packets. If there is a loss among the source packets, the parity decoder attempts to recover the missing source packets by using the base-layer repair packets.

```
                              +--------------+
   +--+   X     X    +--+ --> |  Systematic  | -> +--+  +--+  +--+  +--+
   +--+              +--+     |FEC Protection|    +--+  +--+  +--+  +--+
                              +--------------+
         +==+  +==+  +==+ --> |    Parity    |
         +==+  +==+  +==+     |    Decoder   |
                              +--------------+

   Lost Packet: X
```

Figure 2: Block diagram for the DVB AL-FEC minimum performance decoder

On the other hand, if the receiver supports decoding both the base-layer and enhancement-layer repair packets, a combined (hybrid) decoding approach is employed to improve the recovery rate of the lost packets. In this case, the decoder is called an Enhanced Decoder. Section 3.3 outlines the procedures for hybrid decoding.

```
                              +--------------+
   +--+   X     X     X   --> |  Systematic  | -> +--+  +--+  +--+  +--+
   +--+                       |FEC Protection|    +--+  +--+  +--+  +--+
                              +--------------+
         +==+  +==+  +==+ --> |    Parity    |
         +==+  +==+  +==+     |    Decoder   |
                              +--------------+
               +~~+  +~~+ --> |    Raptor    |
               +~~+  +~~+     |    Decoder   |
                              +--------------+

   Lost Packet: X
```

Figure 3: Block diagram for the DVB AL-FEC enhanced decoder

2. 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].

3. DVB AL-FEC Specification

The DVB AL-FEC protocol comprises two layers of FEC protection: 1-D interleaved parity FEC for the base layer and Raptor FEC for the enhancement layer.

3.1. Base-Layer FEC

The 1-D interleaved parity FEC uses the exclusive OR (XOR) operation to generate the repair symbols. In a group of D x L source packets, the XOR operation is applied to the group of the source packets whose sequence numbers are L apart from each other to generate L repair packets. When used in combination with the enhancement layer, the D x L block of the source packets protected by one or more FEC packets SHALL be wholly contained within a single source block of the Raptor code. Further details of the 1-D interleaved parity code are provided in [I-D.begen-fecframe-interleaved-fec-scheme].

3.2. Enhancement-Layer FEC

The Raptor code is a fountain code where as many encoding symbols as needed can be generated by the encoder on-the-fly from a source data. Due to the fountain property of the Raptor code, multiple enhancement layers may also be specified, if needed.

The details of the Raptor code are provided in [I-D.watson-fecframe-raptor]. The performances of both the 1-D interleaved parity code and Raptor code have been examined in detail in [DVB-A115].

3.3. Hybrid Decoding Procedures

The receivers that support receiving and decoding both the base and enhancement-layer FEC perform hybrid decoding to improve the repair performance. The following steps may be followed to perform hybrid decoding:

1. Base-layer (Parity) Decoding: In this step, the repair packets that are encoded by the parity encoder are processed as usual to repair as many missing source packets as possible.

2. Enhancement-layer (Raptor) Decoding: If there are still missing source packets after the first step, the repair packets that are Raptor encoded are processed with the source packets already received and the source packets that are recovered in the first step.

3. Hybrid Decoding: If there are still missing source packets after the second step, the unprocessed base-layer (parity) repair packets are converted to a form in which they can be added to the Raptor decoding process. With this additional information, Raptor decoding may potentially recover any remaining missing source packet.

The procedure that should be followed to benefit from the base-layer repair packets in the Raptor decoding process is explained in detail in Section E.5.2 of [ETSI-TS-102-034].

4. Session Description Protocol (SDP) Signaling

This section provides an SDP [RFC4566] example. This example uses the FEC grouping semantics [RFC4756].

In this example, we have one source video stream (mid:S1), one FEC repair stream (mid:R1) that is produced by the 1-D interleaved parity FEC scheme as well as another FEC repair stream (mid:R2) that is produced by the Raptor FEC scheme. We form one FEC group with the "a=group:FEC S1 R1 R2" line. The source and repair streams are sent to the same port on different multicast groups. The repair window is set to 200 ms.

Editor's note: The payload-format-specific parameters have not been

defined for Raptor FEC yet. Once they are defined, the "a=fmtp" for the second repair stream will be updated accordingly.

```
v=0
o=ali 1122334455 1122334466 IN IP4 fec.example.com
s=DVB AL-FEC Example
t=0 0
a=group:FEC S1 R1 R2
m=video 30000 RTP/AVP 100
c=IN IP4 224.1.1.1/127
a=rtpmap:100 MP2T/90000
a=mid:S1
m=application 30000 RTP/AVP 110
c=IN IP4 224.1.2.1/127
a=rtpmap:110 1d-interleaved-parityfec/90000
a=fmtp:110 L:5; D:10; repair-window: 200000
a=mid:R1
m=application 30000 RTP/AVP 111
c=IN IP4 224.1.3.1/127
a=rtpmap:111 raptor-fec/90000
a=fmtp:111 ss-fssi=qwe123; repair-window: 200000
a=mid:R2
```

5. Status of DVB AL-FEC Specification

At the time of writing this document, there were scheduled updates in the DVB AL-FEC specification. Some parts of these updates will be based on the [I-D.begen-fecframe-interleaved-fec-scheme] and [I-D.watson-fecframe-raptor]. Further updates (if necessary) in the AL-FEC specification may be published by DVB.

6. Security Considerations

The are no security considerations in this document.

7. IANA Considerations

The are no IANA considerations in this document.

8. Acknowledgments

This document is based on [ETSI-TS-102-034]. Thus, the authors would like to thank the editors of [ETSI-TS-102-034].

9. References

9.1. Normative References

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9.2. Informative References

[ETSI-TS-102-034]
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