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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.

Table of Contents

1. Introduction

In 2007, the Digital Video Broadcasting (DVB) consortium published a technical specification [ETSI-TS-102-034v1.3.1] 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-102-034v1.3.1] 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. In 2008, DVB updated the specification in a new revision that has been published as a DVB Bluebook [DVB-A086r7] and serves as draft ETSI TS-102-034v1.4.1 until the final ETSI publication (expected in early 2009). Among others, some updates and modifications to the AL-FEC protocol have been made.

The DVB 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 the DVB 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 not modified in any way during the FEC encoding process.

The normative DVB AL-FEC protocol considers protection of single-sequence source RTP flows only. The source can be any type of media such as audio, video, text or application. However, in the AL-FEC protocol, the source stream can only be an MPEG-2 transport stream. The FEC data at each layer are generated based on some configuration information, which also determines the exact associations and relationships between the source and repair packets. This document shows how this configuration may be communicated out-of-band in the 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 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. The performance of these FEC codes has been examined in detail in [DVB-A115].

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. Due to interleaving, this FEC is effective against bursty packet losses up to burst sizes of length L.

The DVB AL-FEC protocol requires the D x L block of the source packets protected by the 1-D interleaved FEC code to be wholly contained within a single source block of the Raptor code, if both

FEC layers are used.

Originally, the DVB AL-FEC protocol had adopted the 1-D interleaved FEC payload format from [SMPTE2022-1] in [ETSI-TS-102-034v1.3.1]. However, some incompatibilities with RTP [RFC3550] have been discovered in this specification. These issues have all been addressed in [I-D.ietf-fecframe-interleaved-fec-scheme] (For details, refer to Section 1 of [I-D.ietf-fecframe-interleaved-fec-scheme]). Some of the changes required by [I-D.ietf-fecframe-interleaved-fec-scheme] are, however, not backward compatible with the existing implementations that were based on [SMPTE2022-1].

In a recent liaison from IETF AVT WG to DVB IPI, it has been recommended that DVB IPI defines a new RTP profile for the AL-FEC protocol since in the new profile, several of the issues could easily be addressed without jeopardizing the compliance to RTP [RFC3550].

At the writing of this document, it was not clear whether or not a new RTP profile would be defined for the AL-FEC protocol. DVB attempted to address some of the issues in the updated specification [DVB-A086r7], however, there are still outstanding issues. Note that [DVB-A086r7] does not obsolete [ETSI-TS-102-034v1.3.1] but DVB will exclusively use [DVB-A086r7] for any future revisions of the DVB IPTV Handbook.

The following is a list of the exceptions that MUST be considered by an implementation adopting [I-D.ietf-fecframe-interleaved-fec-scheme] to be in compliant with the AL-FEC protocol as specified in [DVB-A086r7].

o SSRC
  In the DVB AL-FEC protocol, the SSRC fields of the FEC packets MUST be set to 0.

  This requirement conflicts with RTP [RFC3550]. Unless signaled otherwise, RTP uses random SSRC values with collision detection. An explicit SSRC signaling mechanism is currently defined in [I-D.ietf-mmusic-sdp-source-attributes]. It is RECOMMENDED that the DVB AL-FEC protocol uses this mechanism for explicit SSRC signaling.

o CSRC
  The DVB AL-FEC protocol does not support the protection of the CSRC entries in the source packets. Thus, the source stream MUST NOT have any CSRC entries in its packets and the CC fields of the source RTP packets MUST be zero.

Note that if there are no RTP mixers used in a system running the DVB AL-FEC protocol, the CC field of the source RTP packets will be 0 and this is no longer an issue. Thus, if defined, the new RTP profile for the AL-FEC protocol SHOULD forbid the use of any RTP mixers.

- o Timestamp
  In the DVB AL-FEC protocol, the timestamp fields of the FEC packets SHALL be ignored by the receivers.

- o Payload Type
  In the DVB AL-FEC protocol, the PT fields of the FEC packets MUST be set to 96.

  A static payload type assignment for the base-layer FEC packets is outside the scope of [I-D.ietf-fecframe-interleaved-fec-scheme]. If defined, the new RTP profile for the AL-FEC protocol MAY assign 96 as the payload type for the base-layer FEC packets.

In implementations that are based on [I-D.ietf-fecframe-interleaved-fec-scheme] and are willing to be in compliant with the AL-FEC protocol as specified in [ETSI-TS-102-034v1.3.1], all these exceptions MUST be considered as well, however, in this case, the sender does not have to select a random initial sequence number for the FEC stream as suggested by [RFC3550].

Note that neither [ETSI-TS-102-034v1.3.1] nor [DVB-A086r7] implements the 1-D interleaved parity code as specified in [I-D.ietf-fecframe-interleaved-fec-scheme]. Thus, the payload format registered in [I-D.ietf-fecframe-interleaved-fec-scheme] MUST NOT be used by the implementations that are compliant with the [ETSI-TS-102-034v1.3.1] or [DVB-A086r7] specification.

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 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.ietf-fecframe-raptor]. The RTP payload format for Raptor FEC is specified in [I-D.watson-fecframe-rtp-raptor].

It is important to note that the DVB AL-FEC protocol in the latest specification [DVB-A086r7] allows only RTP-over-UDP encapsulation for the enhancement-layer FEC stream. The initial specification

[ETSI-TS-102-034v1.3.1] exclusively permits UDP-only encapsulation for the enhancement-layer FEC stream.

When SDP is used for signaling, the transport protocol identifier permits to distinguish whether an RTP-over-UDP or UDP-only encapsulation is used. In case of any other signaling framework, the differentiation of the protocol for the enhancement-layer stream is achieved either explicitly through a protocol identifier or implicitly by the version number of the DVB IPTV Handbook. If none of the above signaling is provided, the receiver shall concur from the packet size of the repair packets if RTP-over-UDP or UDP-only encapsulation is used.

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-102-034v1.3.1] and [DVB-A086r7].

4. Session Description Protocol (SDP) Signaling

This section provides an SDP [RFC4566] example for [DVB-A086r7]. The example uses the FEC grouping semantics [RFC4756].

In the 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 code as well as another FEC repair stream (mid:R2) that is produced by the Raptor FEC code. 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 source, base-layer FEC and enhancement-layer FEC streams are all encapsulated in RTP.

Due to the exceptions described in Section 3.1, a [DVB-A086r7]-compliant implementation MUST NOT use the RTP payload format defined in [I-D.ietf-fecframe-interleaved-fec-scheme]. Instead, it may use the payload format that has been registered by DVB IPI for [ETSI-TS-102-034v1.3.1].

```
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 96
c=IN IP4 224.1.2.1/127
a=rtpmap:96 vnd.dvb.iptv.alfec-base/90000
a=mid:R1
m=application 30000 RTP/AVP 111
c=IN IP4 224.1.2.2/127
a=rtpmap:111 vnd.dvb.iptv.alfec-enhancement/90000
a=mid:R2
```

Note that in the example above, the payload type has been chosen as 96 for the base-layer FEC stream and there is no "a=fmtp:" line to specify the format parameters. Due to the lack of the format parameters, it is not possible to learn the FEC parameters from the SDP description. This severely limits the ability of using multiple FEC streams that are generated with different settings.

5. Security Considerations

There are no security considerations in this document.

6. IANA Considerations

There are no IANA considerations in this document.

7. Acknowledgments

This document is based on [ETSI-TS-102-034v1.3.1] and [DVB-A086r7]. Thus, the authors would like to thank the editors of [ETSI-TS-102-034v1.3.1] and [DVB-A086r7].

8. References

8.1. Normative References

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8.2. Informative References

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