

Internet Engineering Task Force (IETF)
Request for Comments: 6683
Category: Informational
ISSN: 2070-1721

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August 2012

Guidelines for Implementing Digital Video Broadcasting - IPTV (DVB-IPTV)
Application-Layer Hybrid Forward Error Correction (FEC) Protection

Abstract

Annex E of the Digital Video Broadcasting - IPTV (DVB-IPTV) technical specification defines an optional Application-Layer Forward Error Correction (AL-FEC) protocol to protect the streaming media transported using RTP. The DVB-IPTV 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-IPTV AL-FEC protocol offers good protection against both bursty and random packet losses at a cost of decent complexity. This document describes how one can implement the DVB-IPTV AL-FEC protocol by using the 1-D interleaved parity code and Raptor code that have already been specified in separate documents.

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Table of Contents

- 1. Introduction 2
- 2. DVB-IPTV AL-FEC Specification 5
 - 2.1. Base-Layer FEC 5
 - 2.2. Enhancement-Layer FEC 7
 - 2.3. Hybrid Decoding Procedures 7
- 3. Session Description Protocol (SDP) Signaling 8
- 4. Security Considerations 9
- 5. Acknowledgments 9
- 6. References 10
 - 6.1. Normative References 10
 - 6.2. Informative References 10

1. Introduction

In 2007, the IP Infrastructure (IPI) Technical Module (TM) of the Digital Video Broadcasting (DVB) consortium published a technical specification [ETSI-TS-102-034v1.3.1] through the European Telecommunications Standards Institute (ETSI). [ETSI-TS-102-034v1.3.1] covers several areas related to the transmission of MPEG2 transport stream-based services over IP networks.

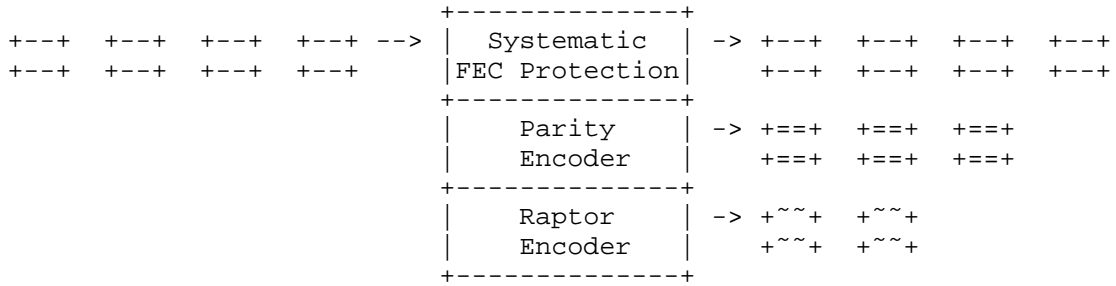
Annex E of [ETSI-TS-102-034v1.3.1] defines an optional protocol for Application-Layer Forward Error Correction (AL-FEC) to protect the streaming media for DVB-IP services transported using RTP [RFC3550]. In 2009, DVB updated the specification in a new revision that is available as [ETSI-TS-102-034v1.4.1]. Among others, some updates and modifications to the AL-FEC protocol have been made. This document describes how one can implement the DVB-IPTV AL-FEC protocol by using the 1-D interleaved parity code [RFC6015] and Raptor code specifications [RFC6681] [RFC6682].

The DVB-IPTV AL-FEC protocol uses two layers for protection: a base layer that is produced by the 1-D interleaved parity code (also simply referred to as "parity code" in the remainder of this document), and an enhancement layer that is produced by the Raptor code. Whenever a receiver supports the DVB-IPTV 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 DVB-IPTV AL-FEC protocol considers protection of single-sequence source RTP flows only. 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-IPTV 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-IPTV AL-FEC protection is described 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.



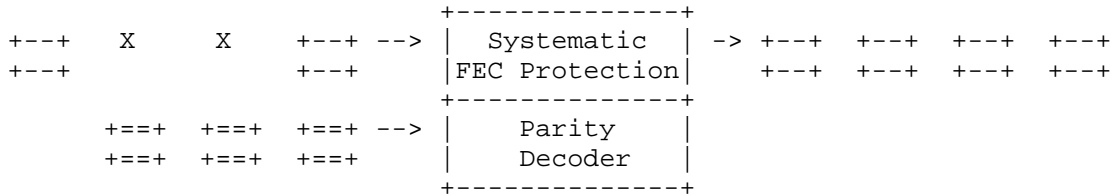
Source Packet: +---+
 +---+

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

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

Figure 1: Block Diagram for the DVB-IPTV AL-FEC Encoder

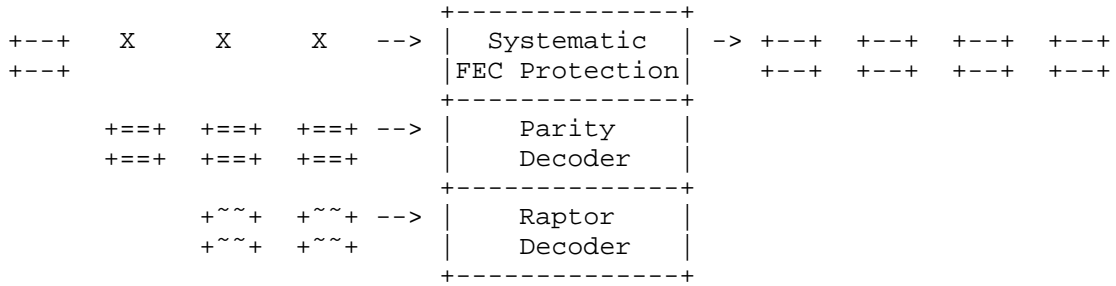
The block diagram of the decoder side for the systematic DVB-IPTV AL-FEC protection is described in Figure 2. This is a minimum performance decoder since the receiver only supports decoding the base-layer repair packets. If there is a loss among the source packets, the parity decoder attempts to recover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



Lost Packet: X

Figure 2: Block Diagram for the DVB-IPTV 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 2.3 outlines the procedures for hybrid decoding.



Lost Packet: X

Figure 3: Block Diagram for the DVB-IPTV AL-FEC Enhanced Decoder

2. DVB-IPTV AL-FEC Specification

The DVB-IPTV 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].

2.1. 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 each group of D source packets whose sequence numbers are L apart from each other to generate a total of L repair packets. Due to interleaving, this FEC is effective against bursty packet losses up to burst sizes of length L.

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

Originally, the DVB-IPTV 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 [RFC6015] (for details, refer to Section 1 of [RFC6015]). Some of the changes required by [RFC6015] are, however, not backward compatible with the existing implementations that were based on [SMPTE2022-1].

In a recent liaison statement from the IETF AVT WG to DVB TM-IPI, it has been recommended that DVB TM-IPI define 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 TM-IPI attempted to address some of the issues in the updated specification [ETSI-TS-102-034v1.4.1]; however, there are still outstanding issues.

The following is a list of the exceptions that need to be considered by an implementation adopting [RFC6015] to be compliant with the DVB-IPTV AL-FEC protocol as specified in [ETSI-TS-102-034v1.4.1].

- o SSRC (synchronization source)

The DVB-IPTV AL-FEC protocol requires that the SSRC fields of the FEC packets be set to zero.

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 [RFC5576] and can be used for this purpose.

- o CSRC (contributing source)

The DVB-IPTV AL-FEC protocol does not support the protection of the CSRC entries in the source packets. Thus, in an implementation compliant to DVB-IPTV AL-FEC protocol, the source stream must not have any CSRC entries in its packets, and subsequently the CC fields of the source RTP packets will be zero.

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

- o Timestamp

In the DVB-IPTV AL-FEC protocol, the timestamp fields of the FEC packets are ignored by the receivers.

- o Payload Type

The DVB-IPTV AL-FEC protocol sets the PT fields of the FEC packets to 96.

A static payload type assignment for the base-layer FEC packets is outside the scope of [RFC6015]. If defined, the new RTP profile for the DVB-IPTV AL-FEC protocol may assign 96 as the payload type for the base-layer FEC packets.

In implementations that are based on [RFC6015] and are willing to be compliant with the DVB-IPTV 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 [ETSI-TS-102-034v1.4.1] implements the 1-D interleaved parity code as specified in [RFC6015]. Thus, the payload format registered in [RFC6015] must not be used by the implementations that are compliant with the [ETSI-TS-102-034v1.3.1] or [ETSI-TS-102-034v1.4.1] specification.

2.2. 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 [RFC6681]. The FEC scheme for the enhancement layer SHALL be the Raptor FEC scheme for a Single Sequenced Flow with FEC encoding ID 5. The RTP payload format for Raptor FEC is specified in [RFC6682].

It is important to note that the DVB-IPTV AL-FEC protocol in the latest specification [ETSI-TS-102-034v1.4.1] allows both UDP-only and RTP-over-UDP encapsulations 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 indicates 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.

2.3. 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 Annex E.5.2 of [ETSI-TS-102-034v1.4.1].

3. Session Description Protocol (SDP) Signaling

This section provides an SDP [RFC4566] example for [ETSI-TS-102-034v1.4.1]. The example uses the FEC grouping semantics [RFC5956].

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-FR 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 2.1, a [ETSI-TS-102-034v1.4.1]-compliant implementation must not use the RTP payload format defined in [RFC6015]. Instead, it may use the payload format that has been registered by DVB TM-IPI for [ETSI-TS-102-034v1.3.1].


```
v=0
o=ali 1122334455 1122334466 IN IP4 fec.example.com
s=DVB-IPTV AL-FEC Example
t=0 0
a=group:FEC-FR S1 R1 R2
m=video 30000 RTP/AVP 100
c=IN IP4 233.252.0.1/127
a=rtpmap:100 MP2T/90000
a=mid:S1
m=application 30000 RTP/AVP 96
c=IN IP4 233.252.0.2/127
a=rtpmap:96 vnd.dvb.iptv.alfec-base/90000
a=mid:R1
m=application 30000 RTP/AVP 111
c=IN IP4 233.252.0.3/127
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 for "vnd.dvb.iptv.alfec-base", it is not possible to learn the FEC parameters from the SDP description.

4. Security Considerations

This specification adds no new security considerations to the DVB-IPTV AL-FEC protocol.

5. Acknowledgments

This document is based on [ETSI-TS-102-034v1.3.1] and [ETSI-TS-102-034v1.4.1]. Thus, the authors would like to thank the editors of [ETSI-TS-102-034v1.3.1] and [ETSI-TS-102-034v1.4.1]. The authors also would like to thank those who reviewed earlier versions of this document.

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