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Forward Error Correction Grouping Semantics in the Session Description Protocol

Abstract

This document defines the semantics for grouping the associated source and FEC-based (Forward Error Correction) repair flows in the Session Description Protocol (SDP). The semantics defined in this document are to be used with the SDP Grouping Framework (RFC 5888). These semantics allow the description of grouping relationships between the source and repair flows when one or more source and/or repair flows are associated in the same group, and they provide support for additive repair flows. SSRC-level (Synchronization Source) grouping semantics are also defined in this document for Real-time Transport Protocol (RTP) streams using SSRC multiplexing.

Status of This Memo

This is an Internet Standards Track document.

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Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at http://www.rfc-editor.org/info/rfc5956.

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1. Introduction

Any application that needs a reliable transmission over an unreliable packet network has to cope with packet losses. Forward Error Correction (FEC) is an effective approach that improves the reliability of the transmission, particularly in multicast and broadcast applications where the feedback from the receiver(s) is potentially limited.

In a nutshell, FEC groups source packets into blocks and applies protection to generate a desired number of repair packets. These repair packets may be sent on demand or independently of any receiver feedback. The choice depends on the FEC scheme, the packet loss characteristics of the underlying network, the transport scheme (e.g., unicast, multicast, and broadcast), and the application. At the receiver side, lost packets can be recovered by erasure decoding, provided that a sufficient number of source and repair packets have been received.

For example, one of the most basic FEC schemes is the parity codes, where an exclusive OR (XOR) operation is applied to a group of packets (i.e., source block) to generate a single repair packet. At the receiver side, this scheme provides a full recovery if only one packet is lost within the source block and the repair packet is received. There are various other ways of generating repair packets, possibly with different loss-recovery capabilities.

The FEC Framework [FEC-FRAMEWK] outlines a general framework for using FEC codes in multimedia applications that stream audio, video, or other types of multimedia content. The FEC Framework specification states that source and repair packets must be carried in different streams, which are referred to as the source and repair flows, respectively. At the receiver side, the receivers should know which flows are the source flows and which ones are the repair flows. The receivers should also know the exact association of the source and repair flows so that they can use the correct data to repair the original content in case there is a packet loss. SDP [RFC4566] uses [RFC5888] and this RFC for this purpose.

In order to provide applications more flexibility, the FEC Framework [FEC-FRAMEWK] allows a source flow to be protected by multiple FEC schemes, each of which requires an instance of the FEC Framework. Thus, multiple instances of the FEC Framework may exist at the sender and the receiver(s). Furthermore, within a single FEC Framework instance, multiple source flows may be grouped and protected by one or more repair flows.

The FEC Framework requires the source and repair packets to be carried in different streams. When the Real-time Transport Protocol (RTP) [RFC3550] is used to carry the source and repair streams, the FEC Framework recommends that each stream be carried in its own RTP session. This provides flexibility in using FEC in a backward-compatible manner. However, in some scenarios, it may be desirable for a single RTP session to carry multiple RTP streams via Synchronization Source (SSRC) multiplexing in order to reduce the port usage. For such scenarios, appropriate grouping semantics are also required.

A basic example scenario is shown in Figure 1. Here, the source flow S1 is protected by the repair flow R1. Also, the source flows S1 and S2 are grouped and protected together by the repair flow R2.

```
               SOURCE FLOWS             | FEC FRAMEWORK INSTANCE #1
             | S1: Source Flow |--------| R1: Repair Flow
         +---|
         |   | S2: Source Flow
         |
         +______________________________| FEC FRAMEWORK INSTANCE #2
                                        | R2: Repair Flow
```

Figure 1: Example scenario with two FEC Framework instances where R1 protects S1 and R2 protects the group of S1 and S2

Grouping source flows before applying FEC protection may allow us to achieve a better coding performance. As a typical scenario, suppose that source flows S1 and S2 in Figure 1 correspond to the base and enhancement layers in a layered video content, respectively. The repair flow R2 protects the combination of the base and enhancement layers for the receivers that receive both layers, whereas the repair flow R1 protects the base layer only, for the receivers that want the base layer only or that receive both layers but prefer FEC protection for the base layer only due to a bandwidth or any other limitation.

The grouping semantics defined in this document offer the flexibility to determine how source streams are grouped together prior to applying FEC protection. However, not all FEC schemes may support the full range of the possible scenarios (e.g., when the source streams carry different top-level media types such as audio and video).

Using multiple FEC Framework instances for a single source flow provides flexibility to the receivers. An example scenario is sketched in Figure 2. Different instances may offer repair flows that are generated by different FEC schemes, and receivers choose to receive the appropriate repair flow(s) that they can support and decode. Alternatively, different instances (whether or not they use the same FEC scheme) may use larger and smaller source block sizes, which accommodate the receivers that have looser and tighter latency requirements, respectively. In addition, different instances may also provide FEC protection at different redundancy levels. This is particularly useful in multicast scenarios where different receivers may experience different packet loss rates and each receiver can choose the repair flow that is tailored to its needs.

```
        SOURCE FLOWS              | FEC FRAMEWORK INSTANCE #1
        S3: Source Flow |---------| R3: Repair Flow
                        |
                        |---------| FEC FRAMEWORK INSTANCE #2
                                  | R4: Repair Flow
```

Figure 2: Example scenario with two FEC Framework instances, each with a single repair flow protecting the same source flow S3

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. Requirements and Changes from RFC 4756

3.1. FEC Grouping Requirements

As illustrated in the introduction and based on the FEC Framework [FEC-FRAMEWK], the SDP grouping semantics for FEC must support the ability to indicate that:

1. A given source flow is protected by multiple different FEC schemes.

2. Multiple repair flows are associated with a given FEC scheme.

3. Multiple source flows are grouped prior to applying FEC protection.

4. One or more repair flows protect a group of source flows.

3.2. Source and Repair Flow Associations

The FEC grouping semantics defined in this document and the SDP "group" attribute defined in [RFC5888] are used to associate source and repair flows. This document also specifies how the "group" attribute is used to group multiple repair flows with one or more source flows.

Note that [RFC5888] obsoleted [RFC3388] to allow an "m" line identified by its "mid" attribute to appear in more than one "a=group" line using the same semantics. With this change and the definitions contained in this document of the FEC grouping semantics, a sender can indicate the specific associations between the source and repair flows, and a receiver can determine which repair flow(s) protect which source flow(s).

This document defines the FEC grouping semantics and obsoletes [RFC4756]. Implementations compliant with this document MUST use the semantics introduced in Sections 4.1 and 4.3. In addition to complying with the requirements defined in Sections 4.1 and 4.3, implementations are RECOMMENDED to support the "FEC" semantics specified in Section 4.4 for backward-compatibility reasons in scenarios described in Section 4.5.

3.3. Support for Additivity

The FEC Framework [FEC-FRAMEWK] describes support for additive repair flows. Additivity among the repair flows means that multiple repair flows may be decoded jointly to improve the recovery chances of the missing packets in a single or the same set of source flows. Additive repair flows can be generated by the same FEC scheme or different FEC schemes.

For example, in Figure 3, the repair flows R5 and R6 may be additive within the FEC Framework instance #1. Alternatively, all three repair flows R5, R6, and R7 could be additive, too.

```
        SOURCE FLOWS              | FEC FRAMEWORK INSTANCE #1
        S4: Source Flow |---------| R5: Repair Flow
                        |         | R6: Repair Flow
                        |
                        |---------| FEC FRAMEWORK INSTANCE #2
                                  | R7: Repair Flow
```

Figure 3: Example scenario with two FEC Framework instances where two repair flows in the first instance and a single repair flow in the second instance protect the same source flow S4

This document defines the mechanisms to support additive repair flows that were not included in [RFC4756].

4. FEC Grouping

4.1. "FEC-FR" Grouping Semantics

Each "a=group" line is used to indicate an association relationship between the source and repair flows. The flows included in one "a=group" line are called an FEC group. If there is more than one repair flow included in an FEC group, these repair flows MUST be considered to be additive. Repair flows that are not additive MUST be indicated in separate FEC groups. However, if two (or more) repair flows are additive in an FEC group, it does not necessarily mean that these repair flows will also be additive in any other FEC group. Generally, in order to express multiple relations between the source and repair flows, each source and repair flow MAY appear in more than one FEC group.

Using the framework in [RFC5888], this document defines "FEC-FR" as the grouping semantics to indicate support for the FEC Framework features.

The "a=group:FEC-FR" semantics MUST be used to associate the source and repair flows except when the source and repair flows are specified in the same media description, i.e., in the same "m" line (see Section 4.3). Note that additivity is not necessarily a transitive relationship. Thus, each set of additive repair flows MUST be stated explicitly in SDP, as illustrated in the example below.

4.2. SDP Example

For the scenario sketched in Figure 1, we need to write the following SDP:

```
        v=0
        o=ali 1122334455 1122334466 IN IP4 fec.example.com
        s=FEC Grouping Semantics
        t=0 0
        a=group:FEC-FR S1 R1
        a=group:FEC-FR S1 S2 R2
        m=video 30000 RTP/AVP 100
        c=IN IP4 233.252.0.1/127
        a=rtpmap:100 MP2T/90000
        a=mid:S1
        m=video 30000 RTP/AVP 101
        c=IN IP4 233.252.0.2/127
        a=rtpmap:101 MP2T/90000
        a=mid:S2
        m=application 30000 RTP/AVP 110
        c=IN IP4 233.252.0.3/127
        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 233.252.0.4/127
        a=rtpmap:111 1d-interleaved-parityfec/90000
        a=fmtp:111 L=10; D=10; repair-window=400000
        a=mid:R2
```

In this example, the source and repair flows are carried in their own RTP sessions, and the grouping is achieved through the "a=group:FEC-FR" lines.

For the additivity example, let us consider the scenario sketched in Figure 3. Suppose that repair flows R5 and R6 are additive but repair flow R7 is not additive with any of the other repair flows. In this case, we must write

```
        a=group:FEC-FR S4 R5 R6
        a=group:FEC-FR S4 R7
```

If none of the repair flows is additive, we must write

```
        a=group:FEC-FR S4 R5
        a=group:FEC-FR S4 R6
        a=group:FEC-FR S4 R7
```

4.3. FEC Grouping for SSRC-Multiplexed RTP Streams

[RFC5576] defines an SDP media-level attribute, called "ssrc-group", for grouping the RTP streams that are SSRC multiplexed and carried in the same RTP session. The grouping is based on the Synchronization Source (SSRC) identifiers. Since SSRC-multiplexed RTP streams are defined in the same "m" line, the "group" attribute cannot be used.

This section specifies how FEC is applied to source and repair flows for SSRC-multiplexed streams using the "ssrc-group" attribute [RFC5576]. This section also specifies how the additivity of the repair flows is expressed for the SSRC-multiplexed streams.

The semantics of "FEC-FR" for the "ssrc-group" attribute are the same as those defined for the "group" attribute, except that the SSRC identifiers are used to designate the FEC grouping associations: a=ssrc-group:FEC-FR *(SP ssrc-id) [RFC5576].

The SSRC identifiers for the RTP streams that are carried in the same RTP session MUST be unique per [RFC3550]. However, the SSRC identifiers are not guaranteed to be unique among different RTP sessions. Thus, the "ssrc-group" attribute MUST only be used at the media level [RFC5576].

Let us consider the following scenario where there are two source flows (e.g., one video and one audio) and a single repair flow that protects only one of the source flows (e.g., video). Suppose that all these flows are separate RTP streams that are SSRC multiplexed in the same RTP session.

```
               SOURCE FLOWS             | FEC FRAMEWORK INSTANCE #1
               S5: Source Flow |--------| R8: Repair Flow
               S6: Source Flow
```

Figure 4: Example scenario with one FEC Framework instance where a single repair flow protects only one of the source flows

The following SDP describes the scenario sketched in Figure 4.

```
        v=0
        o=ali 1122334455 1122334466 IN IP4 fec.example.com
        s=FEC Grouping Semantics for SSRC Multiplexing
        t=0 0
        m=video 30000 RTP/AVP 100 101 110
        c=IN IP4 233.252.0.1/127
        a=rtpmap:100 JPEG/90000
        a=rtpmap:101 L16/32000/2
        a=rtpmap:110 1d-interleaved-parityfec/90000
        a=fmtp:110 L=5; D=10; repair-window=200000
        a=ssrc:1000 cname:fec@example.com
        a=ssrc:1010 cname:fec@example.com
        a=ssrc:2110 cname:fec@example.com
        a=ssrc-group:FEC-FR 1000 2110
        a=mid:Group1
```

Note that in actual use, SSRC values, which are random 32-bit numbers, may be much larger than the ones shown in this example. Also, note that before receiving an RTP packet for each stream, the receiver cannot know which SSRC identifier is associated with which payload type.

The additivity of the repair flows is handled in the same way as described in Section 4.2. In other words, the repair flows that are included in an "a=ssrc-group" line MUST be additive. Repair flows that are not additive MUST be indicated in separate "a=ssrc-group" lines.

4.4. "FEC" Grouping Semantics

This document deprecates the usage of the "FEC" semantics. Sessions negotiated between two endpoints implementing this specification MUST use the "FEC-FR" semantics and not the "FEC" semantics. Section 4.5 details how an implementation supporting this specification detects peers that do not support this specification (based on their SDP answer to the initial offer). When this occurs, the offering implementation SHOULD initiate a new offer using the "FEC" semantics as defined in this section.

The "FEC" grouping semantics had been originally introduced in [RFC4756]. The "FEC" semantics used the "a=group" line from [RFC3388] to form an FEC group to indicate the association relationship between the source and repair flows.

In the "FEC" semantics, a source or repair flow can only appear in a single "a=group:FEC" line. Thus, all the source and repair flows that are somehow related to each other have to be listed in the same "a=group:FEC" line. For example, for the scenario sketched in

Figure 1, we have to write "a=group:FEC S1 S2 R1 R2" regardless of which repair flows protect which particular source flows. Similarly, for the scenario sketched in Figure 3, we have to write "a=group:FEC S4 R5 R6 R7" regardless of which repair flows are additive. However, the interpretation of these lines would be ambiguous.

In certain simple scenarios, such as where there is one source flow and one repair flow, these limitations may not be a concern. In Offer/Answer model scenarios, when the "FEC-FR" semantics are not understood by the answerer, the "FEC" semantics can be offered, as long as the "FEC" semantics provide an exact association among the source and repair flows and do not create any ambiguity. See Section 4.5 for details.

4.5. SDP Offer/Answer Model and RFC 4756 Backward-Compatibility Considerations

When offering FEC grouping using SDP in an Offer/Answer model [RFC3264], the following considerations apply.

A node that is receiving an offer from a sender may or may not understand line grouping. It is also possible that the node understands line grouping but it does not understand the "FEC-FR" semantics. From the viewpoint of the sender of the offer, these cases are indistinguishable.

Implementations are RECOMMENDED to support the "FEC" semantics specified in Section 4.4 for backward-compatibility reasons. If the sender of the offer supports the "FEC" semantics, it SHOULD fall back to using the "FEC" semantics when the "FEC-FR" semantics are not understood by the node.

When a node is offered a session with the "FEC-FR" grouping semantics, but it does not support line grouping or the FEC grouping semantics, as per [RFC5888], the node responds to the offer with one of the following:

o An answer that ignores the grouping attribute.

  In this case, if the original sender of the offer

  * supports the "FEC" semantics described in Section 4.4, it MUST first check whether or not using the "FEC" semantics will create any ambiguity. If using the "FEC" semantics still provides an exact association among the source and repair flows, the sender SHOULD send a new offer using the "FEC" semantics. However, if an exact association cannot be described, it MUST send a new offer without FEC.

  - does not support the "FEC" semantics described in Section 4.4, it MUST send a new offer without FEC.

- A refusal to the request (e.g., 488 Not Acceptable Here or 606 Not Acceptable in SIP).

  In this case, if the original sender of the offer

  - supports the "FEC" semantics and still wishes to establish the session, it MUST first check whether or not using the "FEC" semantics will create any ambiguity. If using the "FEC" semantics still provides an exact association among the source and repair flows, the sender SHOULD send a new offer using the "FEC" semantics. However, if an exact association cannot be described, it SHOULD send a new offer without FEC.

  - does not support the "FEC" semantics described in Section 4.4, it SHOULD send a new offer without FEC.

In both cases described above, when the sender of the offer sends a new offer with the "FEC" semantics, and the node understands it, the session will be established, and the rules pertaining to the "FEC" semantics will apply.

As specified in [RFC5888], if the node does not understand the "FEC" semantics, it responds to the offer with either (1) an answer that ignores the grouping attribute or (2) a refusal to the request. In the first case, the sender must send a new offer without FEC. In the second case, if the sender still wishes to establish the session, it should retry the request with an offer without FEC.

5. Security Considerations

There is a weak threat for the receiver that the FEC grouping can be modified to indicate FEC relationships that do not exist. Such attacks may result in failure of FEC to protect, and/or to mishandle, other media payload streams. The receiver SHOULD do an integrity check on SDP and follow the security considerations of SDP [RFC4566] to trust only SDP from trusted sources.

6. IANA Considerations

This document registers the following semantics with IANA in the "Semantics for the "group" SDP Attribute" registry under SDP Parameters:

Semantics	Token	Reference
Forward Error Correction (Deprecated)	FEC	[RFC5956]
Forward Error Correction FR	FEC-FR	[RFC5956]

This document also registers the following semantics with IANA in the "Semantics for the "ssrc-group" SDP Attribute" registry under SDP Parameters:

Token	Semantics	Reference
FEC-FR	Forward Error Correction FR	[RFC5956]

7. Acknowledgments

Some parts of this document are based on [RFC4756]. Thus, the author would like to thank those who contributed to [RFC4756]. Also, thanks to Jonathan Lennox, who has contributed to Section 4.3; and Jean-Francois Mule, who has reviewed this document in great detail and suggested text edits.

8. References

8.1. Normative References

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8.2. Informative References

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