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The Layer Refresh Request (LRR) RTCP Feedback Message

Abstract

This memo describes the RTCP Payload-Specific Feedback Message Layer Refresh Request (LRR), which can be used to request a state refresh of one or more substreams of a layered media stream. This document also defines its use with several RTP payloads for scalable media formats.

Status of This Memo

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1. Introduction

This memo describes an RTCP [RFC3550] Payload-Specific Feedback Message [RFC4585] "Layer Refresh Request" (LRR), which is designed to allow a receiver of a layered media stream to request that one or more of its substreams be refreshed. The stream can then be decoded by an endpoint that previously was not receiving those layers, without requiring that the entire stream be refreshed (as it would be if the receiver sent a Full Intra Request (FIR) [RFC5104]; see also [RFC8082]).

The feedback message is applicable to both temporally and spatially scaled streams and to both single-stream and multi-stream scalability modes.

2. Conventions and Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2.1. Terminology

A "layer refresh point" is a point in a scalable stream after which a decoder, which previously had been able to decode only some (possibly none) of the available layers of stream, is able to decode a greater number of the layers.

For spatial (or quality) layers, in normal encoding, a subpicture can depend both on earlier pictures of that spatial layer and also on lower-layer pictures of the current picture. However, a layer refresh typically requires that a spatial-layer picture be encoded in a way that references only the lower-layer subpictures of the current picture, not any earlier pictures of that spatial layer. Additionally, the encoder must promise that no earlier pictures of that spatial layer will be used as reference in the future.

However, even in a layer refresh, layers other than the ones being refreshed may still maintain dependency on earlier content of the stream. This is the difference between a layer refresh and a FIR [RFC5104]. This minimizes the coding overhead of refresh to only those parts of the stream that actually need to be refreshed at any given time.

The spatial-layer refresh of an enhancement layer is shown below. The "<--" indicates a coding dependency.

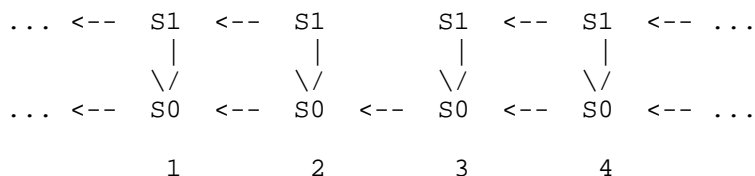


Figure 1: Refresh of a Spatial Enhancement Layer

In Figure 1, frame 3 is a layer refresh point for spatial layer S1; a decoder that had previously only been decoding spatial layer S0 would be able to decode layer S1 starting at frame 3.

The spatial-layer refresh of a base layer is shown below. The "<--" indicates a coding dependency.

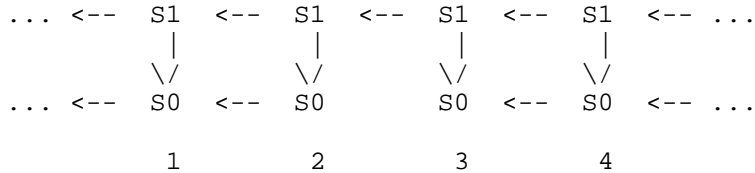


Figure 2: Refresh of a Spatial Base Layer

In Figure 2, frame 3 is a layer refresh point for spatial layer S0; a decoder that had previously not been decoding the stream at all could decode layer S0 starting at frame 3.

For temporal layers, while normal encoding allows frames to depend on earlier frames of the same temporal layer, layer refresh requires that the layer be "temporally nested", i.e., use as reference only earlier frames of a lower temporal layer, not any earlier frames of this temporal layer and promise that no future frames of this temporal layer will reference frames of this temporal layer before the refresh point. In many cases, the temporal structure of the stream will mean that all frames are temporally nested; in this case, decoders will have no need to send LRR messages for the stream.

The temporal layer refresh is shown below. The "<--" indicates a coding dependency.

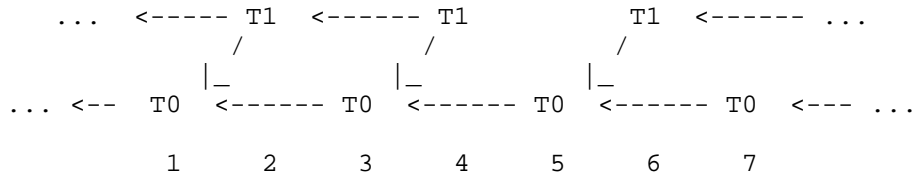


Figure 3: Refresh of a Temporal Layer

In Figure 3, frame 6 is a layer refresh point for temporal layer T1; a decoder that had previously only been decoding temporal layer T0 would be able to decode layer T1 starting at frame 6.

An inherently temporally nested stream is shown below. The "<--" indicates a coding dependency.

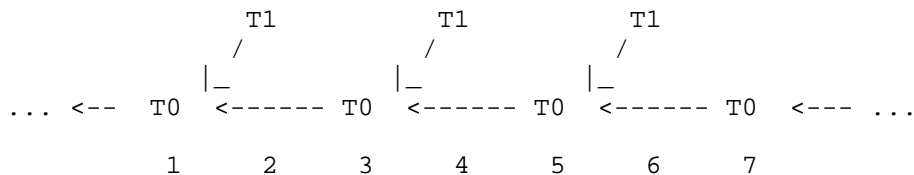


Figure 4: An Inherently Temporally Nested Stream

In Figure 4, the stream is temporally nested in its ordinary structure; a decoder receiving layer T0 can begin decoding layer T1 at any point.

A "layer index" is a numeric label for a specific spatial and temporal layer of a scalable stream. It consists of both a

"temporal-layer ID" identifying the temporal layer and a "layer ID" identifying the spatial or quality layer. The details of how layers of a scalable stream are labeled are codec specific. Details for several codecs are defined in Section 4.

3. Layer Refresh Request

A layer refresh frame can be requested by sending a Layer Refresh Request (LRR), which is an RTCP [RFC3550] payload-specific feedback message [RFC4585] asking the encoder to encode a frame that makes it possible to upgrade to a higher layer. The LRR contains one or two tuples, indicating the temporal and spatial layer the decoder wants to upgrade to and (optionally) the currently highest temporal and spatial layer the decoder can decode.

The specific format of the tuples, and the mechanism by which a receiver recognizes a refresh frame, is codec dependent. Usage for several codecs is discussed in Section 4.

The design of LRR follows the FIR model (Section 3.5.1 of [RFC5104]) for its retransmission, reliability, and use in multipoint conferences.

The LRR message is identified by RTCP packet type value PT=PSFB and FMT=10. The Feedback Control Information (FCI) field MUST contain one or more LRR entries. Each entry applies to a different media sender, identified by its Synchronization Source (SSRC).

3.1. Message Format

The FCI for the Layer Refresh Request consists of one or more FCI entries, the content of which is depicted in Figure 5. The length of the LRR feedback message MUST be set to $2+3*N$ 32-bit words, where N is the number of FCI entries.

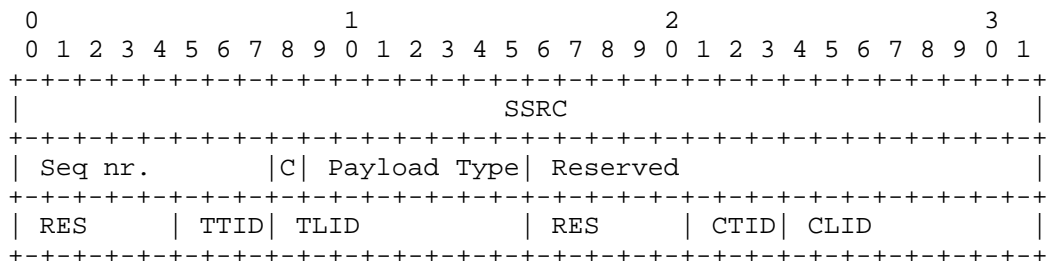


Figure 5: Layer Refresh Request FCI Format

Synchronization Source (SSRC) (32 bits):

The SSRC value of the media sender that is requested to send a layer refresh point.

Seq nr. (8 bits):

The command sequence number. The sequence number space is unique for each pairing of the SSRC of command source and the SSRC of the command target. The sequence number SHALL be increased by 1 for each new command (modulo 256, so the value after 255 is 0). A repetition SHALL NOT increase the sequence number. The initial value is arbitrary.

C (1 bit):

A flag bit indicating whether the Current Temporal-layer ID (CTID) and Current Layer ID (CLID) fields are present in the FCI. If this bit is 0, the sender of the LRR message is requesting refresh of all layers up to and including the target layer.

Payload Type (7 bits):

The RTP payload type for which the LRR is being requested. This gives the context in which the target layer index is to be interpreted.

Reserved (RES) (three separate fields of 16 bits / 5 bits / 5 bits):

All bits SHALL be set to zero by the sender and SHALL be ignored on reception.

Target Temporal-layer ID (TTID) (3 bits):

The temporal-layer ID of the target layer for which the receiver wishes a refresh point.

Target Layer ID (TLID) (8 bits):

The layer ID of the target spatial or quality layer for which the receiver wishes a refresh point. Its format is dependent on the payload type field.

Current Temporal-layer ID (CTID) (3 bits):

If C is 1, the ID of the current temporal layer being decoded by the receiver. This message is not requesting refresh of layers at or below this layer. If C is 0, this field SHALL be set to zero by the sender and SHALL be ignored on reception.

Current Layer ID (CLID) (8 bits):

If C is 1, the layer ID of the current spatial or quality layer being decoded by the receiver. This message is not requesting refresh of layers at or below this layer. If C is 0, this field SHALL be set to zero by the sender and SHALL be ignored on reception.

When C is 1, TTID MUST NOT be less than CTID, and TLID MUST NOT be less than CLID; at least one of either TTID or TLID MUST be greater than CTID or CLID, respectively. That is to say, the target layer index <TTID, TLID> MUST be a layer upgrade from the current layer index <CTID, CLID>. A sender MAY request an upgrade in both temporal and spatial or quality layers simultaneously.

A receiver receiving an LRR feedback packet that does not satisfy the requirements of the previous paragraph, i.e., one where the C bit is present but the TTID is less than the CTID or the TLID is less than the CLID, MUST discard the request.

| Note: The syntax of the TTID, TLID, CTID, and CLID fields
| match, by design, the TID and LID fields in [RFC9626].

3.2. Semantics

Within the common packet header for feedback messages (as defined in Section 6.1 of [RFC4585]), the "SSRC of packet sender" field indicates the source of the request, and the "SSRC of media source" is not used and SHALL be set to zero. The SSRCS of the media senders to which the LRR command applies are in the corresponding FCI entries. An LRR message MAY contain requests to multiple media senders, using one FCI entry per target media sender.

Upon reception of an LRR, the encoder MUST send a decoder refresh point (see Section 2.1) as soon as possible.

The sender MUST respect bandwidth limits provided by the application of congestion control, as described in Section 5 of [RFC5104]. As layer refresh points will often be larger than non-refreshing frames, this may restrict a sender's ability to send a layer refresh point quickly.

An LRR MUST NOT be sent as a reaction to picture losses due to packet

loss or corruption; it is RECOMMENDED to use a PLI (Picture Loss Indication) [RFC4585] instead. An LRR SHOULD be used only in situations where there is an explicit change in a decoder's behavior: for example, when a receiver will start decoding a layer that it previously had been discarding.

4. Usage with Specific Codecs

In order for an LRR to be used with a scalable codec, the format of the temporal and layer ID fields (for both the target and current layer indices) needs to be specified for that codec's RTP packetization. New RTP packetization specifications for scalable codecs SHOULD define how this is done. (The VP9 payload [RFC9628], for instance, has done so.) If the payload also specifies how it is used with the Video Frame Marking RTP Header Extension described in [RFC9626], the syntax MUST be defined in the same manner as the TID and LID fields in that header.

4.1. H.264 SVC

H.264 SVC [RFC6190] defines temporal, dependency (spatial), and quality scalability modes.

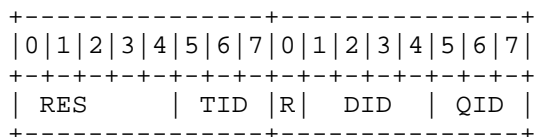


Figure 6: H.264 SVC Layer Index Fields Format

Figure 6 shows the format of the layer index fields for H.264 SVC streams. The "R" and "RES" fields MUST be set to zero on transmission and ignored on reception. See Section 1.1.3 of [RFC6190] for details on the dependency_id (DID), quality_id (QID), and temporal_id (TID) fields.

A dependency or quality layer refresh of a given layer in H.264 SVC can be identified by the I bit (idr_flag) in the extended Network Abstraction Layer (NAL) unit header, present in NAL unit types 14 (prefix NAL unit) and 20 (coded scalable slice). Layer refresh of the base layer can also be identified by its NAL unit type of its coded slices, which is "5" rather than "1". A dependency or quality layer refresh is complete once this bit has been seen on all the appropriate layers (in decoding order) above the current layer index (if any, or beginning from the base layer if not) through the target layer index.

Note that as the I bit in a Payload Content Scalability Information (PACSI) header is set if the corresponding bit is set in any of the aggregated NAL units it describes; thus, it is not sufficient to identify layer refresh when NAL units of multiple dependency or quality layers are aggregated.

In H.264 SVC, temporal layer refresh information can be determined from various Supplemental Encoding Information (SEI) messages in the bitstream.

Whether an H.264 SVC stream is scalably nested can be determined from the Scalability Information SEI message's temporal_id_nesting flag. If this flag is set in a stream's currently applicable Scalability Information SEI, receivers SHOULD NOT send temporal LRR messages for that stream, as every frame is implicitly a temporal layer refresh point. (The Scalability Information SEI message may also be available in the signaling negotiation of H.264 SVC as the sprop-scalability-info parameter.)

If a stream's `temporal_id_nesting` flag is not set, the Temporal Level Switching Point SEI message identifies temporal layer switching points. A temporal layer refresh is satisfied when this SEI message is present in a frame with the target layer index, if the message's `delta_frame_num` refers to a frame with the requested current layer index. (Alternately, temporal layer refresh can also be satisfied by a complete state refresh, such as an Instantaneous Decoding Refresh (IDR).) Senders that support receiving an LRR for streams that are not temporally nested MUST insert Temporal Level Switching Point SEI messages as appropriate.

4.2. VP8

The VP8 RTP payload format [RFC7741] defines temporal scalability modes. It does not support spatial scalability.

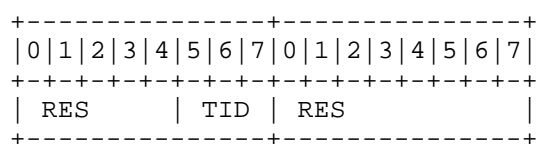


Figure 7: VP8 Layer Index Field Format

Figure 7 shows the format of the layer index field for VP8 streams. The "RES" fields MUST be set to zero on transmission and be ignored on reception. See Section 4.2 of [RFC7741] for details on the TID field.

A VP8 layer refresh point can be identified by the presence of the Y bit (see [RFC7741]) in the VP8 payload header. When this bit is set, this and all subsequent frames depend only on the current base temporal layer. On receipt of an LRR for a VP8 stream, a sender that supports LRRs MUST encode the stream so it can set the Y bit in a packet whose temporal layer is at or below the target layer index.

Note that in VP8, not every layer switch point can be identified by the Y bit since the Y bit implies layer switch of all layers, not just the layer in which it is sent. Thus, the use of an LRR with VP8 can result in some inefficiency in transmission. However, this is not expected to be a major issue for temporal structures in normal use.

4.3. H.265

The initial version of the H.265 payload format [RFC7798] defines temporal scalability, with protocol elements reserved for spatial or other scalability modes (which are expected to be defined in a future version of the specification).

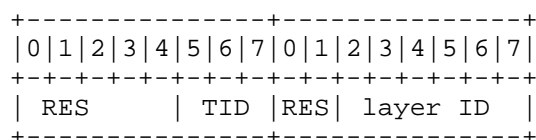


Figure 8: H.265 Layer Index Fields Format

Figure 8 shows the format of the layer index field for H.265 streams. The "RES" fields MUST be set to zero on transmission and ignored on reception. See Section 1.1.4 of [RFC7798] for details on the layer ID and TID fields.

H.265 streams signal whether they are temporally nested by using the `vps_temporal_id_nesting_flag` in the Video Parameter Set (VPS) and the

sps_temporal_id_nesting_flag in the Sequence Parameter Set (SPS). If this flag is set in a stream's currently applicable VPS or SPS, receivers SHOULD NOT send temporal LRR messages for that stream, as every frame is implicitly a temporal layer refresh point.

If a stream's sps_temporal_id_nesting_flag is not set, the NAL unit types 2 to 5 inclusively identify temporal layer switching points. A layer refresh to any higher target temporal layer is satisfied when a NAL unit type of 4 or 5 with TID equal to 1 more than current TID is seen. Alternatively, layer refresh to a target temporal layer can be incrementally satisfied with a NAL unit type of 2 or 3. In this case, given current TID = T0 and target TID = TN, layer refresh to TN is satisfied when a NAL unit type of 2 or 3 is seen for TID = T1, then TID = T2, all the way up to TID = TN (note that TN and T0 refer to nonce variables in this instance). During this incremental process, layer refresh to TN can be completely satisfied as soon as a NAL unit type of 2 or 3 is seen.

Of course, temporal layer refresh can also be satisfied whenever any Intra-Random Access Point (IRAP) NAL unit type (with values 16-23, inclusively) is seen. An IRAP picture is similar to an IDR picture in H.264 (NAL unit type of 5 in H.264) where decoding of the picture can start without any older pictures.

In the (future) H.265 payloads that support spatial scalability, a spatial-layer refresh of a specific layer can be identified by NAL units with the requested layer ID and NAL unit types between 16 and 21, inclusive. A dependency or quality layer refresh is complete once NAL units of this type have been seen on all the appropriate layers (in decoding order) above the current layer index (if any, or beginning from the base layer if not) through the target layer index.

5. Usage with Different Scalability Transmission Mechanisms

Several different mechanisms are defined for how scalable streams can be transmitted in RTP. Section 3.7 of "A Taxonomy of Semantics and Mechanisms for Real-Time Transport Protocol (RTP) Sources" [RFC7656] defines three mechanisms: Single RTP stream on a Single media Transport (SRST), Multiple RTP streams on a Single media Transport (MRST), and Multiple RTP streams on Multiple media Transports (MRMT).

The LRR message is applicable to all these mechanisms. For MRST and MRMT mechanisms, the "media source" field of the LRR FCI is set to the SSRC of the RTP stream containing the layer indicated by the Current Layer Index (if "C" is 1) or the stream containing the base encoded stream (if "C" is 0). For MRMT, the LRR message is sent on the RTP session on which this stream is sent. On receipt, the sender MUST refresh all the layers requested in the stream, simultaneously in decode order.

6. SDP Definitions

Section 7 of [RFC5104] defines Session Description Protocol (SDP) procedures for indicating and negotiating support for Codec Control Messages (CCM) in SDP. This document extends this with a new codec control command, "lrr", which indicates support of the LRR.

Figure 9 gives a formal Augmented Backus-Naur Form (ABNF) [RFC5234] showing this grammar extension, extending the grammar defined in [RFC5104].

```
rtcp-fb-ccm-param =/ SP "lrr"      ; Layer Refresh Request
```

Figure 9: Syntax of the "lrr" CCM

The Offer-Answer considerations defined in Section 7.2 of [RFC5104]

apply.

7. Security Considerations

All the security considerations of FIR feedback packets [RFC5104] apply to LRR feedback packets as well. Additionally, media senders receiving LRR feedback packets MUST validate that the payload types and layer indices they are receiving are valid for the stream they are currently sending, and discard the requests if not.

8. IANA Considerations

This document defines a new entry to the "Codec Control Messages" registry of the "Session Description Protocol (SDP) Parameters" registry group, according to the following data:

Value Name: lrr
Long Name: Layer Refresh Request Command
Usable with: ccm
Mux: IDENTICAL-PER-PT
Reference: RFC 9627

This document also defines a new entry to the "FMT Values for PSFB Payload Types" registry of the "Real-Time Transport Protocol (RTP) Parameters" registry group, according to the following data:

Name: LRR
Long Name: Layer Refresh Request Command
Value: 10
Reference: RFC 9627

9. References

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