Preamble to Video Services Forum (VSF) Technical Recommendation TR-06-4 Part 1

November 1, 2022

The Reliable Internet Stream Transport (RIST) project was initiated as an Activity Group under the auspices of the Video Services Forum in 2017. To date, the group has produced three specifications, released as TR-06-1 (RIST Simple Profile, published in 2018 and updated in 2020), TR-06-2 (RIST Main Profile, published in 2020 and updated in 2021 and 2022), and TR-06-3 (RIST Advanced Profile, published in 2021 and updated in 2022).

The RIST Activity Group is currently working on a series of ancillary features for the RIST Specifications. These ancillary features may be applicable to multiple RIST Profiles, and are expected to be released as TR-06-4 Parts. This document is TR-06-4 Part 1, Source Adaptation. One of the functions included in the various RIST Profiles is packet loss recovery. However, if the network capacity falls below the stream rate, the source itself will need to react in order to keep the stream healthy. The options available to the stream source are to either reduce the bit rate, or re-route the stream (if possible). This Specification defines a protocol for the stream receiver to provide feedback information to the source, so that such actions can be taken.

Work continues within the group towards developing additional RIST specifications that include additional features. As the Activity Group develops and reaches consensus on new functions and capabilities, these documents will also be released in support of the RIST effort. For additional information about the RIST Activity group, or to find out about participating in the development of future specifications, please visit http://vsf.tv/RIST.shtml

Video Services Forum (VSF) Technical Recommendation TR-06-4 Part 1

Reliable Internet Stream Transport (RIST) Source Adaptation

Approved November 1, 2022

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Executive Summary

This Technical Recommendation defines source adaptation extensions to RIST Simple Profile, TR-06-1, and RIST Advanced Profile, TR-06-3. There are two aspects to source adaptation:

- Some sources, such as encoders with variable bit rate capability, can dynamically adapt their output based on network conditions.
- Some sources using multiple network connections in parallel can dynamically change the traffic mix over the various connections based on network conditions.

This Recommendation defines a protocol to provide network condition information to the source, in order to achieve the above functionality. The actual algorithms are left at the discretion of the implementer.

Recipients of this document are invited to submit technical comments. The VSF also requests that recipients notify us of any relevant patent claims or other intellectual property rights of which they may be aware, that might be infringed by any implementation of the Recommendation set forth in this document, and to provide supporting documentation.

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1 Introduction (Informative)

As broadcasters and others increasingly utilize unconditioned Internet circuits to transport high-quality video, the demand grows for systems that can compensate for the packet losses and delay variation that often affect these streams. A variety of solutions are currently available on the market; however, incompatibilities exist between devices from different suppliers.

The Reliable Internet Stream Transport (RIST) project was launched specifically to address the lack of compatibility between devices, and to define a set of interoperability points through the use of existing or new standards and recommendations.

This Specification defines a protocol to provide network condition feedback to a source, so it can dynamically adapt its output to the current network state. Previous RIST Specifications defined recovery and signaling methods to address packet loss; however, such methods are insufficient if the network capacity falls below the source bit rate. In such situations, the only alternatives are for the source to either reduce its bit rate or use a different set of links.

1.1 Contributors

The following individuals participated in the Video Services Forum RIST working group that developed this technical recommendation.

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This technical recommendation builds upon VSF TR-06-1 and VSF TR-06-3. The list of contributors to these documents can be found in section 1.1 of each document.

1.2 About the Video Services Forum

The Video Services Forum, Inc. (www.videoservicesforum.org) is an international association dedicated to video transport technologies, interoperability, quality metrics and education. The VSF is composed of service providers, users and manufacturers. The organization's activities include:

- providing forums to identify issues involving the development, engineering, installation, testing and maintenance of audio and video services;
- exchanging non-proprietary information to promote the development of video transport service technology and to foster resolution of issues common to the video services industry;
- identification of video services applications and educational services utilizing video transport services;

- promoting interoperability and encouraging technical standards for national and international standards bodies.

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2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except the Introduction and any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 References

VSF TR-06-1:2020, Reliable Internet Stream Transport (RIST) Protocol Specification – Simple Profile

VSF TR-06-2:2022, Reliable Internet Stream Transport (RIST) Protocol Specification – Main Profile

VSF TR-06-3:2022, Reliable Internet Stream Transport (RIST) Protocol Specification – Advanced Profile

IETF RFC 3550, RTP: A Transport Protocol for Real-Time Applications

Any mention of references throughout the rest of this document refers to the versions described here, unless explicitly stated otherwise.

4 Source Adaptation Architecture (Informative)

RIST Simple and Advanced Profiles defined an ARQ scheme to recover lost packets on an Internet link. However, the available bandwidth of Internet links fluctuates. This is especially true for cellular connections. If the available bandwidth falls below the stream bit rate, no amount of ARQ will recover the lost packets. The stream bit rate must therefore be reduced or rerouted by the sender when this occurs.

Protocols such as HLS and DASH achieve this function in a receiver-driven fashion. The sender provides a number of discrete bit rates, and the client picks the one most suitable to its current network conditions. There are transition points where the client can move up or down in bit rate seamlessly. Such protocols are well suited for one-to-many distribution scenarios where latency is not an issue, and the receivers do not need to interact with the senders.

In a one-to-one transmission scenario, where low latency is important, the sender can control the transmission rate (or routing in a multi-link scenario) as a function of the network conditions. Many encoders can switch bit rate on-the-fly in a seamless fashion. Proprietary versions of such systems have been available in the market for a while – all the current cell bonding systems work in this fashion. However, as with ARQ before RIST, there is no recognized interoperable standard or specification. This Technical Recommendation addresses this point.

Another application is adaptive multi-link. Adaptive multi-link allows the sender to fine-tune the partitioning of the stream between different links based on the current link conditions. The sender can optimize the packet sending on each link to provide the best reliable delivery when network conditions change over time.

The system architecture is depicted in Figure 1.

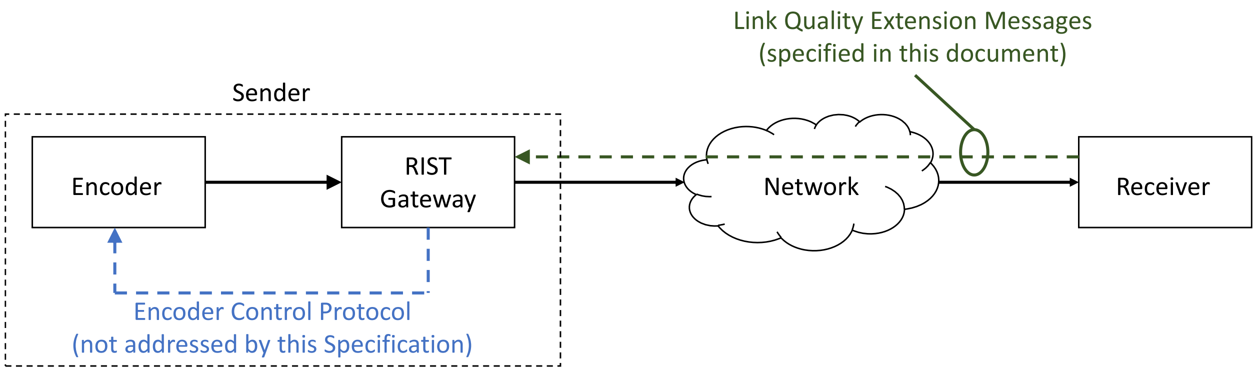

Figure 1: System Architecture

In Figure 1, a sender is transmitting a **single** stream to one or more receivers. Two protocols are identified:

- **Link Quality Extension Messages:** These are administrative messages from the receiver to enable the sender to change the transmission bit rate based on network conditions. These messages are defined in this Specification.
- **Encoder Control Protocol:** This is relevant only if the sender is composed of two distinct devices: an encoder and a RIST gateway. This protocol allows the RIST gateway to control the rate of the encoder on-the-fly and is unnecessary if the encoder and the RIST gateway are the same device. This protocol is not included in this Specification since it would typically apply to legacy encoders that use a proprietary method for controlling the bit rate of the encoded stream.

5 Link Quality Messages

The purpose of the Link Quality Messages is for the receiver to provide the sender feedback on the current link quality. The sender can use these messages to adapt the encoder bit rate or, in a multi-link situation, adjust the stream allocation between the links.

5.1 General Definition of the Link Quality Message for all RIST Profiles

This section describes the Link Quality Message. This definition is a common definition, applicable to all relevant RIST Profiles. The actual encapsulation of the message is profile-dependent and is described later in this document. Link quality messages are sent from the stream receiver to the stream sender.

The Link Quality Message is shown in Figure 2.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Sequence Number                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Reporting Period (ms)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     NACK Window Size (ms)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Count of source packets received                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Count of original packets lost                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Count of retransmitted packets received             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Count of recovered packets                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Count of unrecovered packets                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Count of late packets                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              Measured Data Bandwidth (kbits/sec)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        Measured Retransmission Bandwidth (kbits/sec)          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Link Quality Message

The stream receiver shall set the fields in Figure 2 as follows:

- **Sequence Number:** 32 bits
  The stream receiver shall set this field to a monotonically increasing message sequence number, applicable only to Link Quality Messages. It allows the stream sender to detect lost or duplicate Link Quality messages. There is no retransmission mechanism for lost Link Quality messages.
- **Reporting Period (ms):** 32 bits
  The stream receiver shall set this field to the duration of the reporting period, expressed in milliseconds.
- **NACK Window Size (ms):** 32 bits
  The stream receiver shall set this field to its current NACK window setting, expressed in milliseconds.
- **Count of source packets received**: 32 bits
  The stream receiver shall set this field to the number of source packets received during the reporting period. Source packets shall include:
  - Original stream packets, identified by the use of an even SSRC in Simple Profile and or by the R flag set to zero in the Advanced Profile RTP header.

    - SMPTE ST 2022 FEC packets
    - RTT Echo Response packets
    - TR-06-2 Keep-Alive packets
    - Advanced Profile Flow Attribute control messages
- **Count of original packets lost:** 32 bits
  The stream receiver shall set this field to the number of original packets lost during the reporting period.
- **Count of retransmitted packets received**: 32 bits
  The stream receiver shall set this field to the number of retransmitted packets (odd SSRC in Simple Profile, R flag set to one in the Advanced Profile RTP header) received during the reporting period.
- **Count of recovered packets**: 32 bits
  The stream receiver shall set this field to the number of packets originally lost and then recovered through retransmission or FEC during the reporting period.
- **Count of unrecovered packets**: 32 bits
  The stream receiver shall set this field to the count of unrecovered packets during the reporting period. These would be packets that were not recovered during the NACK window.
- **Count of late packets:** 32 bits
  The stream receiver shall set this field to the count of source packets received too late to be used (i.e., outside the NACK window). More specifically, packets whose sequence number is earlier (lower, taking into account wraparound) than the last packet released from the NACK buffer. This count does not include retransmitted packets received late.
- **Measured Data Bandwidth (kbits/sec)**: 32 bits
  The stream receiver shall set this field to the number of payload bits in the source packets plus the RTP header bits (including any extensions) received during the reporting period, divided by the reporting period in seconds and rounded to the closest 1000 bits/sec.
  NOTE: Since NULL packet deletion will be in use, it is not possible to compute the measured data bandwidth from the number of packets received.
- **Measured Retransmission Bandwidth (kbits/sec)**: 32 bits
  The stream receiver shall set this field to the total number of retransmitted payload data bits plus the RTP header bits (including any extensions) received during the reporting period, divided by the reporting period in seconds and rounded to the closest 1000 bits/sec.
  NOTE: Since NULL packet deletion may be in use, it is not possible to compute the measured retransmission bandwidth from the number of retransmissions received.

The reporting periods shall be contiguous in time. Namely, the period covered by the report with sequence number *N* shall start exactly at the end of the period covered by the report with sequence number *N* - 1.

A stream receiver shall send the report immediately at the end of the reporting period.

Consecutive reporting periods may be of different durations. If the network conditions deteriorate rapidly, the stream receiver may elect to send the next report earlier, covering a shorter period.

If DTLS or any other encryption/tunneling/security mechanism is being used to secure the link, the statistics included in the above message shall be calculated after decryption. More specifically, any security handshake packets and encapsulation overhead outside the RTP headers shall not be included in the statistics. In the specific case of Advanced Profile PSK encryption and hashing, the relevant fields are part of the RTP header and shall be included in the bit rate computation.

In a multi-link situation (either seamless switching or bonding), the stream receiver shall transmit reports on all links as close as possible to simultaneously.

5.2 RIST Simple Profile Implementation

In RIST Simple Profile, the stream receiver is required to send RTCP Receiver Reports (RR) messages back to the stream sender. The Link Quality messages defined in section 5.1 shall be added to the existing RR messages as "profile-specific extensions", as defined in RFC 3550 Section 6.4.2 and shown in Figure 3.

```
        0                   1                   2                   3
        0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
header |V=2|P|    RC   |   PT=RR=201   |             length            |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                     SSRC of packet sender                     |
       +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
report |                 SSRC_1 (SSRC of first source)                 |
block  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  1    | fraction lost |       cumulative number of packets lost       |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |           extended highest sequence number received           |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                      interarrival jitter                      |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                         last SR (LSR)                         |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                   delay since last SR (DLSR)                  |
       +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
report |                 SSRC_2 (SSRC of second source)                |
block  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  2    :                               ...                             :
       +=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
       :  profile-specific extension: Link Quality message (44 bytes)  :
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: Adding Link Quality Messages to an RR Message

RIST Simple Profile also allows for empty RR messages, without any report blocks. Stream receivers may use the same extension mechanism to add Link Quality Messages to an empty RR message, as indicated in Figure 4.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|V=2|P|    RC=0  |   PT=RR=201    |           length=12           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     SSRC of packet sender                       |
+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+=+
|                Link Quality message (44 bytes)                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Adding Link Quality Messages to an empty RR Message

In the empty RR message, the source SSRC is not present. In a multicast scenario where there are multiple senders using the same address and port, the source SSRC is necessary to identify the stream in question. If the source SSRC is required for identification purposes, the stream receiver shall not use an empty RR.

5.3 RIST Main Profile Implementation

RIST Main Profile is a tunneling method for RIST Simple Profile and other generic data. Therefore, the messages defined for Simple Profile in section 5.2 above shall be carried transparently over the RIST Main Profile tunnel.

5.4 RIST Advanced Profile Implementation

In RIST Advanced Profile, packet recovery applies to the tunnel as a whole, and a tunnel may be carrying multiple streams. The receiver feedback mechanism using Link Quality Messages can be used for controlling/throttling other data types in addition to video. Therefore, in RIST Advanced Profile, the Link Quality Messages shall apply to the tunnel as a whole, and not to a specific stream inside the tunnel.

RIST Advanced Profile uses RTP but does not require the use of RTCP, in order to keep the tunnel to a single UDP port. Therefore, instead of using the RR extension described above, the Advanced Profile Implementation shall use a Tunnel Control Message to encapsulate the Link Quality Message. This encapsulation shall be performed using the two new Control Index values for Global and Link Specific messages, as shown in Table 1.

Table 1: Updated Advanced Profile Control Index List

Control Index	Message Type	Mandatory
0x0000	NACK Bitmask	
0x0001	NACK Range	
0x0002	**Receiver Link Quality Report – Global**	
0x0003	**Receiver Link Quality Report – Link Specific**	
0x0004-0x000F	Reserved for future NACK messages	
0x0010	RTT Echo Request	
0x0011	RTT Echo Response	Yes
0x0012-0x001F	Reserved for future RTT messages	
0x0020	ST 2022-5 FEC Row Packet	
0x0021	ST 2022-5 FEC Column Packet	
0x0022	ST 2022-1 FEC Row Packet	
0x0023	ST 2022-1 FEC Column Packet	
0x0024-0x002F	Reserved for future FEC messages	
0x0030-0x77FF	Reserved for future control messages	
0x7800-0x7FFF	Reserved for private vendor use	
0x8000	RIST Main Profile Keep-Alive message	Yes
0x8001	Flow Attribute message	
0x8002-0x800F	Reserved for future tunnel messages	
0x8010	Advanced Profile SRP authentication for PSK sessions	
0x8011	PSK Future Nonce Announcement Message	
0x8012-0x801F	Reserved for future authentication messages	
0x8020	Control Message Unsupported Response	
0x8021-0xF7FF	Reserved for future control messages	
0xF800-0xFFFF	Reserved for private vendor use	

The tunnel receiver shall encapsulate the Link Quality Messages in Advanced Profile Control Messages as indicated in Figure 5.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Control Index = 0x0002/3   |          Length = 44          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
:                Link Quality Message (44 bytes)                :
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 5: Link Quality Message encapsulation in Advanced Profile

All Advanced Profile Devices supporting Source Adaptation shall implement the Receiver Link Quality Reports – Global, as defined in section 5.1. Advanced Profile devices with multi-link support should implement the Receiver Link Quality Reports – Link Specific. Receiver Link

Quality Reports – Global shall be sent over all links, followed by the Link Specific version if supported.

If the Advanced Profile tunnel is being used to carry an RTP stream, the receiver of this RTP stream may generate and transmit the extended RTCP RR messages described in section 5.2, if such receiver had access to the individual statistics of the packets for that stream. Senders and receivers may use this mechanism.

5.5 Multi-Link Operation

When operating in multi-link mode, the receiver shall operate as follows:

- The receiver shall send Global Link Quality messages on every link. If supported, Link-Specific messages shall be sent immediately after the Global version.
- Link quality messages shall be sent as close to simultaneously as possible on each link, and shall have the same sequence number. Messages with the same sequence number in different links shall refer to the exact same time period.
- In Simple Profile RR messages and in Advanced Profile Control messages with Control Index = 0x0002, the parameters reported shall be global statistics, as defined in section 5.5.1.
    - In asymmetric links (i.e., different channels for each direction), the receiver shall only use Global Link Quality Messages.
- In Advanced Profile control messages with Control Index = 0x0003 (Link-Specific messages), the parameters reported in the messages shall be calculated as described in section 5.5.2.

NOTE: Link-Specific Messages are not supported in RIST Simple Profile.

5.5.1 Receiver Link Quality Reports - Global

Global Link reports shall combine all the information of all the links into one report, and this same report shall be sent through all links. In a multi-link scenario, the parameters shall be defined in the same manner as for the single-link case, with the following additions:

- **Count of Source Packets Received:** this count shall include duplicates, including replicated packets transmitted by the sender over multiple links for redundancy purposes.
- **Count of Retransmitted Packets Received:** this count shall include retransmissions received over all links.
- **Count of Late Packets:** this count shall include late packets received over all links. Duplicates shall not be excluded.
- **Measured Data Bandwidth:** this measurement shall include duplicates, in the same manner as the Count of Source Packets Received.
- **Measured Retransmission Bandwidth:** this shall be the combined measured bandwidth of retransmitted packets over all links, computed as defined above.

5.5.2 Receiver Link Quality Reports – Link Specific

Link-Specific reports are only available in Advanced Profile, with Control Index = 0x0003. These reports shall include the same parameters as the global version but shall be computed using only the packets received in that particular link, with the exceptions noted in Table 2.

Table 2: Link-Specific Parameters

Parameter	**Link-Specific**	**Global**
Count of Source Packets Received	✓	
Count of Source Packets Lost		✓
Count of Retransmissions Received	✓	
Count of Recovered Packets	✓	
Count of Unrecovered Packets		✓
Count of Late Packets	✓	
Measured Data Bandwidth	✓	
Measured Retransmission Bandwidth	✓	

6 Algorithm Examples (Informative)

The encoder rate adaptation and link adaptation algorithms are left at the discretion of the implementer. This section provides very simple example algorithms.

6.1 Encoder Rate Adaptation Example

The following example algorithm is proposed:

- If the number of unrecovered packets is zero, and the number of lost packets is less than a certain level, the encoder can increase the bit rate.
- If the number of unrecovered packets is non-zero or the number of lost packets is higher than a certain level, the encoder can decrease the bit rate.

6.2 Multi-Link Path Adaptation Example

Assume a scenario where there are three links, denoted by A, B, and C, depicted in Figure 6.

The sender starts with a traffic partition of 30%, 30%, and 40% for links A, B and C respectively.

When link B shows a 10% increase in dropped packets, the sender can decrease the traffic sent through B to 20% and increase the traffic through A and C to 35% and 45% respectively.

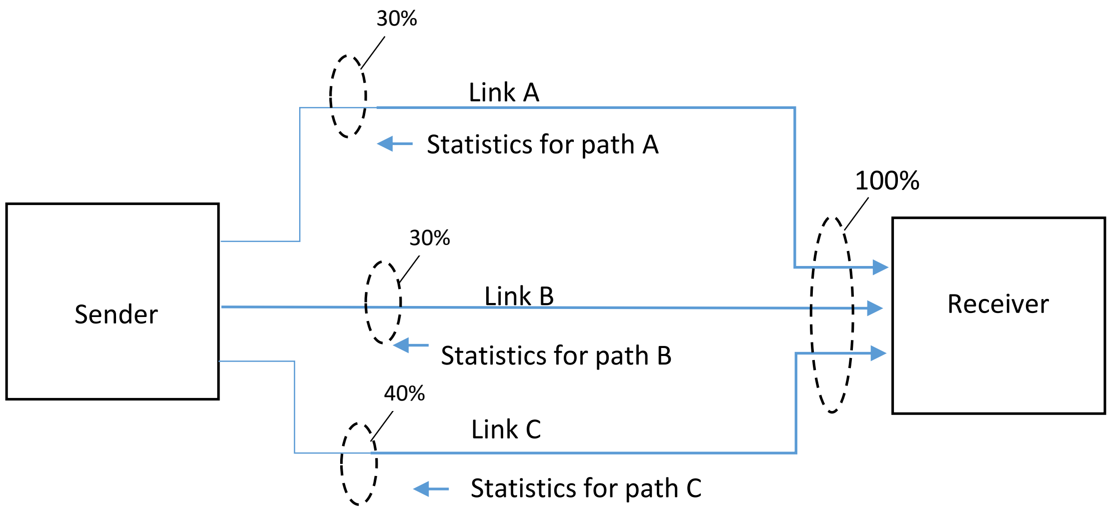

Figure 6: Source Adaptation Example

7 Encoder/Decoder Notes (Informative)

It is assumed that the sender is configured with a maximum bit rate, and most likely with a minimum bit rate. In fact, for a given compression standard, resolution, and frame rate, there is a minimum supportable bit rate, below which operation is not guaranteed.

Many Professional IRDs require a CBR transport stream at their inputs. The bit rate of the Video PID can vary, but the overall transport must be NULL-padded to CBR. This is also the case with many encoders that support on-the-fly rate changes – they must be configured with a transport rate high enough to support the highest desirable video bit rate, and then the video PID bit rate can be controlled, not to exceed the maximum. The transport stream output of such encoders is CBR, and the NULL packet bit rate will change based on the encoder bit rate control.

RIST gateways connected to such encoders and decoders can use the NULL packet deletion feature of RIST Main Profile. A RIST gateway connected to an encoder that produces a CBR transport with a variable NULL packet bit rate will have to remove the NULL packets prior to transmission. A RIST gateway connected to a receiver that requires a CBR transport can NULL-pad the stream to support such a receiver. These operations are independent, and do not necessarily require the NULL packet deletion feature of RIST Main Profile.