Video Services Forum (VSF)
Technical Recommendation TR-09-1

Transport of ST 2110 media essences over Wide Area Networks – Data Plane

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Executive Summary

SMPTE ST 2110 has been evolved to enable media production facilities to use IP connectivity for all media flow and control.

The standard is focused on intra-campus-based connections with negligible latencies and jitter, negligible packet loss, and uncontended high bandwidth.

With the increasing trend towards mesh/distributed/remote production and multi-campus operation, there is a need to define recommendations for the transport of the ST 2110 media essences over Wide Area Networks (WANs) and an associated control plane with appropriate security considerations.

This Technical Recommendation defines a method of media flows and related control plane information being shared securely and robustly over Wide Area connectivity. It is formed in two parts – a data plane section defining media flow transport and a control plane section defining the communications. This part defines the data plane.

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1   Introduction

As broadcasters look to extend their IP production beyond the boundaries of their facility, to facilitate essence-based remote production and federated production, there is a requirement to define the best practice and recommendations for interoperability.

This Technical Recommendation defines a method of media flows and related control plane information being shared securely and robustly over Wide Area connectivity (WAN). It is formed in two parts – a data plane section defining media flow transport and a control plane section defining the communications.

1.1   Contributors

The following individuals participated in the Video Services Forum 2110-WAN activity group which developed this technical recommendation. (listing people that attended multiple meetings, taken over final 9 months of drafting). The affiliations shown are those during the majority of the drafting time – some have subsequently changed.

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1.2   About the Video Services Forum

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- 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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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

SMPTE ST 2022-5:2013, Forward Error Correction for Transport of High Bit Rate Media Signals over IP Networks (HBRMT)

SMPTE ST 2022-7:2019, Seamless Protection Switching of RTP Datagrams

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

IETF RFC 3551, RTP Profile for Audio and Video Conferences with Minimal Control

TR-06-3:2022 RIST Protocol Specification – Advanced Profile

TR-08:2022 Transport of JPEG XS Video in ST 2110-22

4   Document Aims and Parts (informative)

The VSF TR-09 series defines a data plane for media flows and associated control information, and a control plane for determining which flows are present and for controlling the routing and enabling of such flows.

This document (TR-09-1) defines the data plane requirements and implementation, and a companion document (TR-09-2) defines the control plane elements

The documents define the behavior of a virtual gateway device that sits at the WAN boundary of a facility. This device performs the functions needed to interconnect two or more facilities. Some of the functions performed by this gateway include:

- Network Address Translation between the addressing schemes used in the two facilities (and a potential third scheme as the traffic flows across the wide area)
  - This includes both translating the addresses for the actual data flows, and modifying any control data structures or information associated with the data flows (e.g. NMOS resources and SDP files)
- Managing the bandwidth across the WAN link(s) to ensure that there is never a situation where more data is being sent from a facility than the WAN link can accept
- Where NMOS is being used within a facility, the creation of virtual NMOS resources advertised into each facility to represent the resources that are being extended from the remote facility(s)
- Providing a security boundary between the facility and the WAN link(s)

- The gateway may include a compression and decompression function (most commonly for video essences), due to the constrained bandwidth nature of some WAN links.

The gateway providing the inbound sources to a site reconciles the IDs signaled across the WAN connection (defined in the companion TR-09-2) with those used within the facility (which may or may not be NMOS-based).

5   Components and Selecting Appropriate Combinations for Applications (informative)

The remainder of this document defines the different components in the ST 2110/WAN toolkit. It is expected that most applications will only use a subset of this toolkit, and different components are applicable to different use cases (for example based upon the bitrates involved and the types of networks being used for transport).

A feature declaration template is available in appendix A, to indicate which components are available in a given product/solution. Vendors/solutions are be encouraged to publish their feature declaration table.

6   Data Plane Encapsulation and Tunneling

When sending traffic over WAN links, particularly ones which are not dedicated private circuits there are advantages to encapsulating all related flows together.

The VSF RIST group has published TR-06-3, which builds on the existing VSF RIST specifications TR-06-1 and TR-06-2, to describe a method of encapsulating any data using a "anything over RTP" approach. The TR-06-3 specification provides:

- a means of fragmenting packets which are larger than the MTU of the WAN circuit
- two recommended methods of encrypting tunnel traffic to provide security when data is carried over shared infrastructure, carried over from TR-06-2
- a means of specifying a lossless compression method for data transport for non-media flows
- an ARQ/NACK based system for requesting retransmission of lost packets, using the same UDP port as is used for the main data flow
- a means of generating FEC for the main data flow and encapsulating such FEC traffic onto the same UDP port as is used for the main data flow

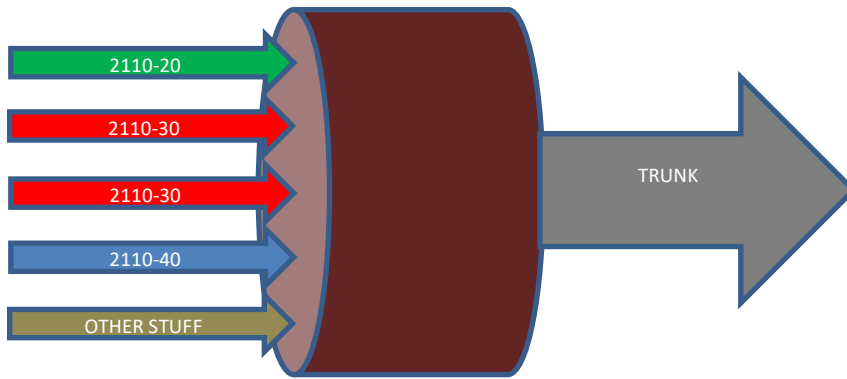TR-06-3 shall be used when tunnelling is required as part of TR-09-1.

Figure 1: tunneling of multiple essences

7   Data Plane Integrity Protection

7.1   Three integrity protection techniques (informative)

Below are the three techniques that are available for protecting the integrity of data transported using this recommendation.

Typical solutions would offer one or more of these techniques, but it is expected to be unlikely that all the techniques would be in use at the same time.

In a distributed production environment, low latency is typically a key requirement. The three techniques described below potentially incur significantly different levels of latency. The latency of the three techniques also scales differently as the rate of the protected flow changes. These characteristics are described in the subsections below.
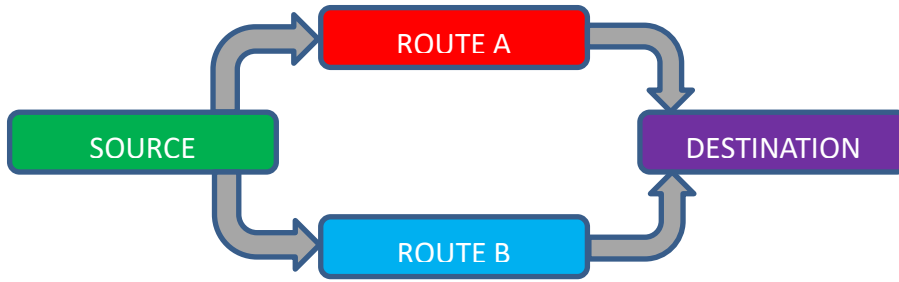
7.2   RTP Merge

To achieve RTP Merge protection, the diversely routed packet protection and defined in SMPTE ST 2022-7 shall be used. This standard is applicable to all RTP flow types. See Figure 2 below.

Note: The differential transport delay between the diverse RTP connections to be merged is expected to be significantly greater than those in a typical facility environment.

ST 2022-7 implementations used for this recommendation shall be able to reconcile up to 100ms of differential delay.

Note: In TR-06-3, techniques are described for using both 1+1 and striping variants of multi-link protection. It is anticipated that for most ST 2110/WAN applications 1+1 will be the main form in use, but the use of other patterns is not prohibited.

Note: RTP Merge is the lowest latency technique of the protection mechanisms documented here, as the only required latency is that of the diverse path time between the two flows. It comes at the expense of typically requiring double the bandwidth of an unprotected stream.

Figures 2: RTP merge

7.3 FEC

FEC may be applied to the individual essence flows or applied across the tunnel as a whole.

Note: One possible parameter for defining which is required would be the bitrates of the essence flows – it may be that uncompressed video flows encapsulated with ST 2110-20 require the FEC to be implemented in hardware/firmware that may make the flexibility of having the packets encapsulated before applying FEC impractical.

For flows which are encapsulated using the tunneling protocol defined previously, any requirement for FEC shall be satisfied by applying ST 2022-5 protection to the RTP flow for the tunnel in the manner described in TR-06-3. For simplicity of transport, the single UDP port version of what is described there should be used.

Such FEC shall be limited to a single instance (i.e. column only FEC), and with a maximum product of the two dimensions being 100 packets. See figure 3.

For cases where the FEC is applied to the individual essences, any existing protection standard for those essence types shall be applied e.g ST 2022-1 for Transport Streams and ST 2022-5 for ST 2022-6. Where an FEC standard does not exist for the essence type, the above, FEC recommendation of a single instance of ST 2022-5 FEC with a maximum product of 100 packets applies.

Note: FEC latency depends significantly on the bitrate of the flow being protected. This is one of the main reasons that it is recommended that tunneling is used to aggregate any required flows together before applying FEC. This also has the advantage that the packets for all related flows are subject to the same FEC processing delay, removing any requirement to re-align flows after protection.
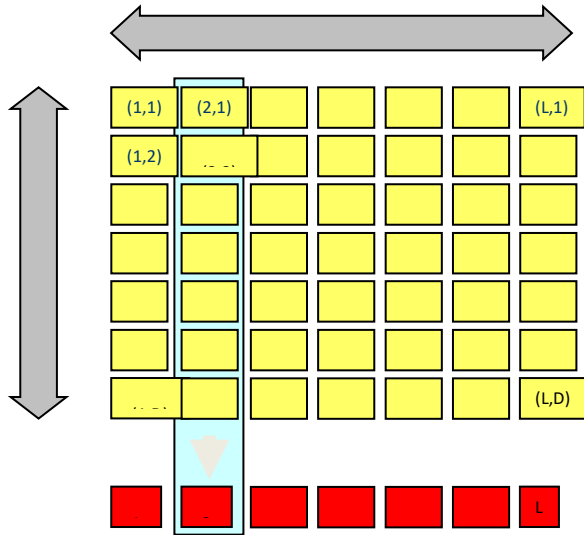
Figure 3: Column FEC

7.4 ARQ/NACK

Note: Many private leased line provisions of connectivity will perform sufficiently well in terms of the integrity of transport for the use of either RTP merge and/or FEC to be adequate. For less pristine connectivity, retransmission-based protection mechanisms may provide a better solution to achieve full integrity than applying a high level of FEC.

Note: For connections where the round-trip time is very low, and the expected packet loss rate is also low, there may be cases where an ARQ mechanism gives lower overhead than an FEC based mechanism and also provides the required end-to-end delay characteristic after recovery.

For applications where an ARQ mechanism is required, the method defined in TR-06-3 shall be used. See Figure 4 below.
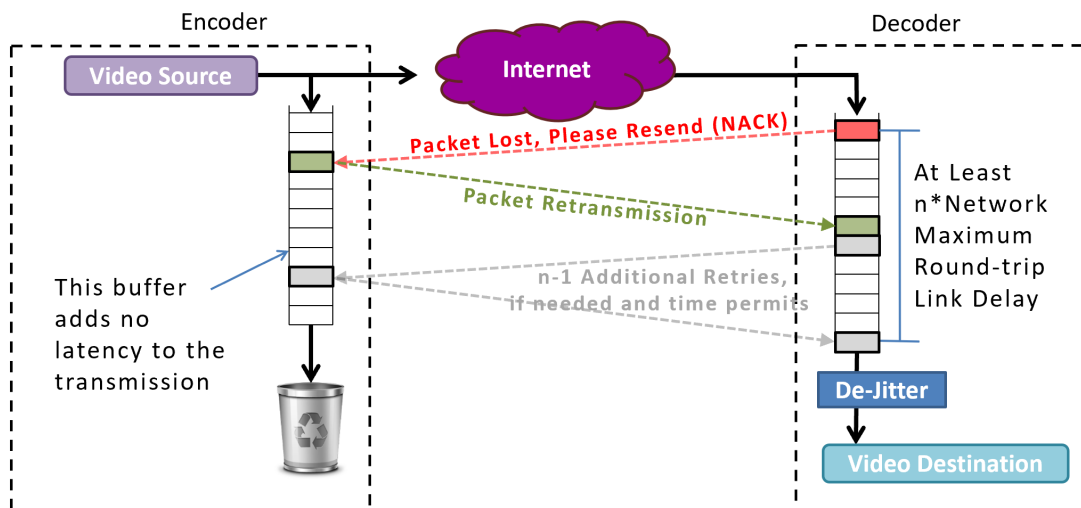

Figure 4: ARQ

8   Essence Alignment

At a minimum, at the egress from a facility, the RTP timestamps of all related essences shall represent the time offset between the flows. Ideally, all flows should, additionally, be time aligned at this egress point. See Figure 5 below.
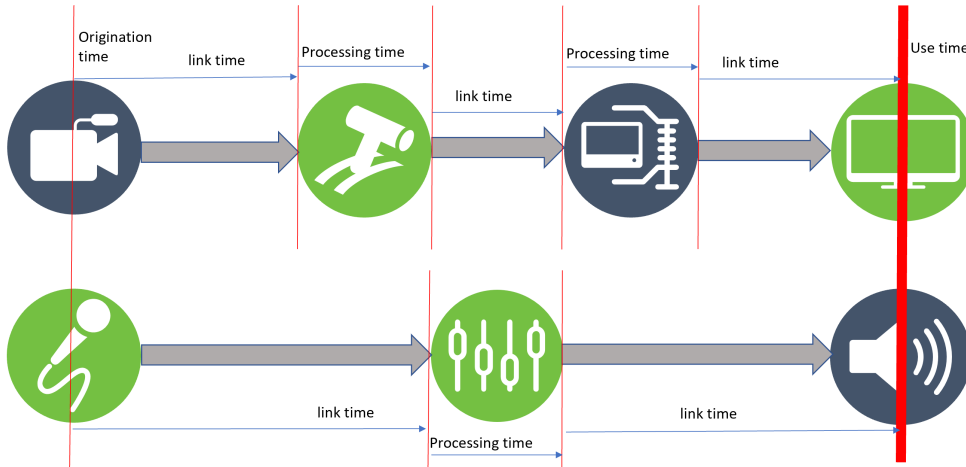

Figure 5: Essence Alignment

9   Video Essence Compression

Where it is required to compress video essences for transport between facilities, ST 2110-22 shall be used. This is a generic wrapper which can contain one of a number of compression techniques. For low latency applications, JPEG-XS compression should be used. The JPEG-XS stream shall be encapsulated using VSF TR-08

10 Other Data Transport and Protection (informative)

The tunneling protocol defined above is capable of supporting the transport of other non-media, non-UDP data. By transporting this other data within a tunnel, it is possible to protect it using any of the mechanisms defined above.

11 Security

If encryption of media flows is required, the recommended tunneling protocol shall be used, with one of the encryption techniques specified in TR-06-3.

Note: The two main techniques are one based on DTLS and another based on an in-band PSK encryption.

Appendix A

As the capabilities described within this document form a 'tool kit' of which products/solutions may support any of the described capabilities, the following is a suggested declaration template, to indicate which components are available in a given product/solution. Vendors/solutions are encouraged to publish their feature declaration table with regard to the elements of TR-09-01 that are supported.

Feature (referencing document)	Comments	Supported (Y/N)
6: Tunneling (TR-06-3)	Specify which tunneling option used	
7.1: RTP merge (ST 2022-7)		
7.2: FEC (ST 2022-5, bounded)	Specify tunnel and/or essence FEC	
7.3: ARQ (TR-06-3)	Specify buffering limits	
8: Essence alignment	Absolute or RTP-relative to be stated	
9: Compression (TR-08)		
11: Encryption (TR-06-03)	State which encryption supported	