Video Services Forum (VSF) Technical Recommendation TR-10-9

Internet Protocol Media Experience (IPMX): Requirements for System Environment and Device Behavior

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Executive Summary

Internet Protocol Media Experience (IPMX) was created to foster the adoption of open standards-based protocols for interoperability over IP in the media and entertainment and professional audio/video industries. IPMX is based on the SMPTE ST 2110 standard and as such the VSF TR-10 suite of Technical Recommendations is a set of differences between SMPTE ST 2110 and IPMX.

This Technical Recommendation documents the minimum requirements for IPMX device with respect to system environment and device behavior. Some of the subject covered in this document include requirements related to network support and how IPMX devices are expected to behave when sending or receiving IPMX streams when PTP is present and when it is not present.

Table of Contents

1 Introduction (Informative)

IPMX, which stands for IP Media Experience, is based on two families of specifications. The SMPTE ST 2110 Professional Media Over Managed IP Networks suite of standards for the transport of video, audio, and ancillary/control signals over IP networks, and the NMOS REST APIs from AMWA, which provide discovery, connection management, and control.

IPMX is an accessible, open standard that meets the needs of professional and consumer video and audio users in a wide variety of contexts while giving manufacturers and developers what they need to build low-latency, interoperable, IP based audiovisual products or applications.

This document covers the system environment and device behavior requirements for IPMX. Other aspects of the IPMX system and their individual requirements are documented in other parts of this Technical Recommendation.

2 Contributors

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

Alain Bouchard (Matrox)	Jack Douglass (PacketStorm)	Phil Bernal (PB Technologies Group)
Andreas Hildebrand (RAVENNA)	Jean Lapierre (Matrox)	Raymond Hermans (Adeas)
Andrew Starks (Macnica)	Jean-Jacques Osytiguy (Matrox)	Ryan Wallenberg (Cobalt)
Ben Cope (Intel)	Jed Deame (Nextera)	Steve Kolta (Mienburg)
Brad Gilmer (VSF)	Leigh Whitcomb (Whitcomb Consulting)	Thomas True (NVIDIA)
Daeton Harris (Diversified)	Marc Levy (Macnica)	Tim Bruylants (intoPIX)
Dan Holland (DHC)	mike boucke (aja)	Wes Simpson (LearnIPvideo.com)
Danny Pierini (Matrox)	Nick Nicas (AT&T)	
Hung Lam (Evertz)	pfrancisco (EvertzAV)	

3 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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4 Conformance Notation

Normative text describes elements of the design that are indispensable or contain the conformance language keywords: "shall," "should," or "may."

Informative text 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 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.

5 Normative References

- TR-10-1:2024 Internet Protocol Media Experience (IPMX): System Timing and Definitions
- TR-10-2:2024 Internet Protocol Media Experience (IPMX): Uncompressed Active Video
- TR-10-3:2024 Internet Protocol Media Experience (IPMX): PCM Digital Audio
- TR-10-4:2023 Internet Protocol Media Experience (IPMX): SMPTE ST 291-1 Ancillary Data
- TR-10-5:2024 Internet Protocol Media Experience (IPMX): HDCP Key Exchange Protocol
- TR-10-6:2022 Internet Protocol Media Experience (IPMX): Forward Error Correction
- TR-10-7:2022 Internet Protocol Media Experience (IPMX): Compressed Video
- TR-10-10:2024 Internet Protocol Media Experience (IPMX): HDMI InfoFrame Packet Transport
- TR-10-11:2024 Internet Protocol Media Experience (IPMX): Constant Bit-Rate Compressed Video
- TR-10-12:2023-2 Internet Protocol Media Experience (IPMX): AES3 Transparent Transport
- AES67-2018 AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability
- Internet Engineering Task Force (IETF) RFC 2474 Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers available at https://www.rfc-editor.org/rfc/rfc2474.txt
- Internet Engineering Task Force (IETF) RFC 2597 Assured Forwarding PHB Group available at https://www.rfc-editor.org/rfc/rfc2597
- Internet Engineering Task Force (IETF) RFC 3246 An Expedited Forwarding PHB (Per-Hop Behavior) available at https://www.rfc-editor.org/rfc/rfc3246.html
- Internet Engineering Task Force (IETF) RFC 3550 RTP: A Transport Protocol for Real-Time Applications available at https://www.ietf.org/rfc/rfc3550.txt

6 Definitions

For the purposes of this document, the terms, and definitions of VSF TR-10-1 and the following apply.

In-Band	Device that uses the same network port for media essence transport and for control.
Out-Of-Band	Device that uses separate network ports for media essence transport and for control.
Frame-to-Frame Interval	The time interval between successive video frames.

7 General Provision

8 RTCP Sender Reports

IPMX Senders shall send RTCP Sender Reports formatted according to TR-10-1 as part of a compound RTCP packets as per IETF RFC 3550 section 6.1.

The IPMX RTCP Sender report shall be the first packet of the compound RTCP packet as per IETF RFC 3550 section 6.1.

`Note: RFC3550 requires that all RTCP packets MUST be sent in a compound packet of at least two individual packets and that a SDES packet containing a CNAME item MUST be included in each compound RTCP packet [RFC3550, section 6.1]; consequently a compound RTCP packet containing a IPMX RTCP Sender Report followed by a RTCP SDES packet containing CNAME is the smallest compound RTCP packet that complies with the requirements of RFC 3550 for a valid RTCP packet.`

9 Synchronous IPMX Sender

An IPMX Sender that generates a synchronous media signal shall include a mediaclk:direct=0 statement in its SDP file.

Examples of IPMX Senders that generate a synchronous signal are:

- IPMX Senders synchronized to a Common Reference Clock with an output signal based on the conversion of a Baseband Sync Media signal
- IPMX Senders with an output signal based on:
  - Digitizing an analog signal
  - Playing a media file
  - Generating a synthetic signal such as a video pattern or tone generator

10 Non-Baseband IPMX Senders

IPMX Video Senders with an output that is not based upon the conversion of a Baseband signal may be unable to report the measured frequency of the pixel clock, total number of horizontal pixels and total number of lines of the Source Media Device signal as required in section 10.2 Baseband Video IPMX Sender Signaling of TR-10-1. Such IPMX Senders shall use the following values instead.

The `htotal` value shall be set to the `width`.

The vtotal value shall be set to the height.

The measuredpixclk value shall be set to the width * height * exactframerate.

Note: width, height and exactframerate are the SDP parameters from the FMTP section of the SDP file as define in SMPTE ST 2110-20 section 7.2.

IPMX Audio Senders with an output that is not based upon the conversion of a Baseband signal may be unable to report the measured sample rate of the Source Media Device signal. Such IPMX Senders shall use the following values when implementing section 10.3 Baseband Audio IPMX Sender Signaling of TR-10-1.

The measuredsamplerate value shall be set to the sample rate of the media stream as signaled in the rtpmap section of the SDP file.

11 IPMX Receiver Synchronization

When an IPMX Receiver attempts to receive a stream from a Sender, the ts-refclk and mediaclk information shall be used to determine how to synchronize the IPMX Receiver to the Sender.

The ts-refclk attribute of the Sender shall be used to identify the reference clock used by the Sender.

The mediaclk attribute shall be used to determine if the Sender is asynchronous or not.

IPMX receivers shall support streams that signal mediaclk:direct=0 and mediaclk:sender.

The presence of the IPMX keyword in the fmtp attribute shall be used to determine if the Sender is an IPMX Sender or not.

If the Sender is an IPMX Sender then RTCP Sender reports that comply with TR-10-1 will be present.

11.1 Synchronizing to an IPMX Sender

An IPMX Receiver shall be able to receive a IPMX media stream when the following conditions are met:

i. The media stream is of a type that the Receiver is capable of receiving.

The IPMX Receiver should use the RTCP Sender report messages to recover the timing information for the IPMX media stream when one of the following conditions are met:

i. The ts-refclk attribute of the IPMX Sender is of the localmac form

ii. The ts-refclk attribute of the IPMX Sender is of the ptp form and the IPMX Receiver is not locked to the same or traceable PTP clock

The IPMX Receiver should use the common reference clock and the RTCP Sender report messages to recover the timing information for the IPMX media stream when the following conditions are met:

i. The ts-refclk attribute is of the ptp form
ii. IPMX Receiver is locked to the same (or traceable PTP clock) used by the Sender

IPMX Sender Reports are used by the IPMX Receiver to retrieve the timing information of the IPMX media stream.

11.2 Frame-to-Frame Interval

IPMX Senders shall send the first packet of each frame at regular intervals that corresponds to the Frame-to-Frame Interval. The difference between the maximum and minimum of this interval measured over a 2 second period shall not exceed 2 mSec.

IPMX Senders shall send IPMX Sender Reports for each frame at regular intervals that correspond to the Frame-to-Frame Interval. The difference between the maximum and minimum of this interval measured over a 2 second period shall not exceed 2 mSec.

For a Baseband IPMX Sender the Frame-to-Frame Interval shall correspond to the timing of their baseband input signal.

For a IPMX Senders not based on the conversion of a baseband signal, the Frame-to-Frame interval shall correspond to nominal frame rate of the media signal.

11.3 Receiver Compatibility with SMPTE ST 2110, AES67 or a IPMX Synchronous Sender

An IPMX Receiver compliant to this section shall be able to receive a media stream when the following conditions are met:

The media stream is of a type that the Receiver is capable of receiving

ii. The ts-refclk attribute of the Sender is of the ptp form.
iii. The IPMX Receiver is locked to the same ptp clock (or traceable PTP clock) used by the Sender.
iv. The mediaclk attribute of the Sender is direct:0 (i.e. the media clock of the stream is aligned with the ptp clock at epoch).

The IPMX Receiver should use the common reference clock to recover the timing information for the media stream.

```
NOTE: RFC 3550 recommends that the initial value of the RTP
timestamp be random. In TR-10, we override this with a
requirement for a zero-offset relationship to the Timestamp
Reference Clock (in the case when the Media Clock is
directly referenced to the Timestamp Reference Clock).
Receivers designed to maintain compatibility with other RTP
implementations might need to comply with the RTP
provisions in those RTP standards, specifically the
possibility that the offset could be non-zero.
```

12 IPMX Receiver vs PTP refclk

IPMX Senders and Receivers using a PTP Common Reference Clock should monitor for changes in their synchronization status during transmission. Senders should update their clock source description when a change is detected.

13 Receiver alignment of multiple input streams

When an IPMX Receiver attempts to align multiple IPMX video and audio streams, the ts-refclk information of all senders shall be examined. If all streams share the same reference clock, their RTP timestamp can be assumed to have a common origin and may be used to align all streams.

```
Note: It is sufficient that the streams share the same reference
clock, the IPMX Receiver does not need to share that same
reference clock.
```

14 DHCP

IPMX Devices shall support DHCP for configuration of all their network interfaces.

IPMX Devices shall make DHCP the default configuration method for all their network interfaces.

IPMX Devices shall support the following list of DHCP provided information: IP address, subnet mask, default gateway, DNS server, domain name.

IPMX Devices shall provide a method for users to enter all above DHCP configuration information when a DHCP server is not available.

IPMX Devices shall be able to operate when only the IP address, subnet mask and gateway are configured.

15 DNS-SD Browsing

IPMX DEVICES shall support both mDNS and unicast DNS for DNS-SD browse operations,

IPMX DEVICES shall default to using both mDNS and unicast DNS for DNS-SD browse operations.

IPMX DEVICES shall provide a user mechanism for limiting DSN-SD browse operations to the unicast DNS method.

IPMX DEVICES shall provide a user mechanism for limiting DSN-SD browse operations to the mDNS method.

When an IPMX Device is configured to perform DNS-SD browse operation using both mDNS and unicast DNS:

- DNS-SD browse operation using unicast DNS shall be performed first.
- If the DNS-SD browse operation using unicast DNS is successful, the mDNS method shall not be used.
- If the DNS-SD browse operation using unicast DNS is not successful, then the mDNS method shall be used.

Note: A DNS-SD operation is considered successful when a requested service is discovered even if the service is unresponsive.

When performing a DNS-SD browse using either method, if multiple results are returned:

- The IPMX Device shall select the service with the best priority.
- If the selected service is unresponsive, the IPMX Device shall select the service with the next best priority.
- If none of the discovered services are responsive, the IPMX Device shall perform a new DNS-SD browse and start the selection process again.

Once a service has been selected and is responsive, the IPMX Device shall perform no further DNS-SD browse operation for this service. If the selected service subsequently becomes unresponsive, the IPMX Device shall perform a new DNS-SD browse and start the selection process again.

Note: The DNS-SD browse selection process described above is designed to ensure that IPMX Devices exhibit consistent and predictable behavior when discovering and selecting services. It also aims to provide predictable behavior when services become unavailable, especially when more than one provider of a given service type is available (for example, to provide failover capability). When mDNS is used for DNS-SD operations, the above selection process helps prevent rogue services from taking over either maliciously or by mistake.

For example, consider the case when two NMOS IS-04 Registration services are provided: a main one with a priority of 50 and a backup one with a priority of 80. In this case, the DNS-SD process described above would result in all IPMX devices selecting the main server. IF the main NMOS IS-04 server subsequently goes offline, all IPMX Devices will switch to the backup service. However, when the main server comes back online the IPMX devices will not automatically return to the main NMOS IS-04 server. This behavior allows the system administrator to pick IF and WHEN they want all devices to go back to the main server. To force the devices to revert to the main server, the system administrator could simply make the backup server unavailable, thereby forcing all IPMX devices to perform a fresh DNS-SD browse, find the main server and register with it thereby restoring normal operation.

Re-examining this same example in an mDNS environment: if a Rogue NMOS IS-04 server with a better priority than the current service appears all IPMX devices will stay attached to the current server. If a new IPMX Device comes online during the time when a rogue service is present, that IPMX Device will select the rogue server. There is no avoiding this; in a mDNS environment the system administrator will need to find and remove the rogue service to solve this issue. The goal of this behavior is to prevent the current operations from being disturbed by the rogue mDNS server.

16 Quality of service

To facilitate the implementation of suitable quality of service (QoS) in a IPMX network, IPMX Devices shall implement the DiffServ method as described in RFC 2474. DiffServ uses the DSCP field in each IP packet header to mark packets according to their traffic class so that the network can easily recognize packets that need to be treated preferentially.

IPMX Devices conforming to TR-10-1 shall mark their PTP packets with a default value of EF (46) in the DSCP field as defined in RFC 3246 and specified in AES-67 section 6.2.

IPMX Senders conforming to TR-10-2, TR-10-4, TR-10-7 and TR-10-11 shall use a default value of AF42(36) for the DSCP field as defined in RFC 2597.

IPMX Senders conforming to TR-10-3 and TR-10-12 shall use a default value of AF41 (34) for the DSCP field as defined in RFC 2597 and specified in AES-67 section 6.2.

IPMX Senders conforming to TR-10-5, TR-10-6 and TR-10-10 shall mark their packets with the same DSCP value as the respective RTP stream packets.

IPMX Senders shall mark outgoing RTCP Sender report packets with the same DSCP value as the respective RTP stream packets.

IPMX Devices should provide a user mechanism for selecting the DSCP markings of the generated streams.

17 IPv4 Multicast Streams addressing

IPMX Devices shall support IPv4 multicast streams.

IPMX Senders shall use a default UDP port value of 5004 and should provide a user mechanism for selecting a different value.

IPMX Devices shall support IGMP V3 and shall use the source-specific method with the source address information provided in the SDP object.

IPMX Devices shall support IGMP V2.

IPMX Devices shall provide a user mechanism for selecting the IGMP version to use.

IPMX Devices shall not use 224.0.0.0 through 224.0.1.255 for their IPv4 multicast streams.

IPMX Receivers shall support the entire range of multicast addresses from 224.0.2.0 through 239.255.255.255 for their IPv4 multicast streams.

IPMX Senders shall support 239.0.0.0 through 239.127.255.255 and should support 224.0.2.0 through 239.255.255.255 for their IPv4 multicast streams.

IPMX Senders shall include source address information in the SDP object.

17.1 Default multicast IPv4 address

When no user defined value is provided, IPMX Senders shall use the following method to assign a default IPv4 multicast address for their media stream.

Given an IPMX Sender having a media network port with a IPv4 address of A.B.C.D and supporting multiple media streams. The default multicast address for a given IPMX media stream shall be 239.S.C.D where S is the stream number. Where S shall be greater than 0 and less than 128.

For example, an IPMX Sender that has both a video and audio stream and whose media port has the IPv4 address of 192.168.123.45 would be compliant to this specification if it used a default multicast address of 239.1.123.45 for its video stream and 239.2.123.45 for its audio stream.

A method shall be provided for a user to change this default value.

Once a user defined value is provided, the user value shall be used, including when the IPMX device restarts.

18 In-Band vs Out-Of-Band Operation

IPMX Devices may have a separate network port for NMOS control in addition to the network port used to transmit or receive their media essence and offer Out-Of-Band NMOS operation.

IPMX Devices that support both In-Band and Out-Of-Band NMOS operation shall default to Out-Of-Band NMOS operation when their control port is active. These IPMX Devices shall offer a user selectable option to select In-Band NMOS operation instead.

19 HDCP

IPMX Devices may have separate network port for HKEP control in addition to the network port used to transmit or receive their media essence and offer Out-Of-Band HKEP operation.

IPMX Devices that support both In-Band and Out-Of-Band HKEP operation shall default to In-Band HKEP. Out-Of-Band capable IPMX Device should offer a user selectable option to select Out-Of-Band HKEP operation instead.

20 SDP file vs RGB vs Colorimetry

When signaling `colorimetry` for sRGB or sYCC, IPMX Senders should use `BT709`.