JT-NM Tested August 2022
SMPTE ST 2110 Media Nodes
Results Catalog

”JT-NM Tested Program August 2022” SMPTE ST 2110 Results Catalog

Abstract and motivation behind the program

The JT-NM Tested program offers documented insight into how vendor equipment conforms to specific SMPTE standards and AMWA NMOS specifications. Vendors who meet the testing criteria will have the opportunity to display badges and make public statements about their participation. The JT-NM Tested Catalog lists vendor results along with a detailed test plan. Anyone with the equipment listed in the test plan may execute the tests which were administered by the JT-NM test team, and you are encouraged to do so.

It is important to note that the JT-NM Tested program is not a certification program; rather, it is a snapshot in time of how vendor equipment conforms to key parts of SMPTE standards and AMWA NMOS specifications.

Notation used in the document

JT-NM Tested Catalog results are presented as a capability map. This allows readers, especially end users, to focus on the capabilities demonstrated by devices during the JT-NM Tested event. JT-NM Catalogs use the following terms to characterize test results:

Capable (green mark):
A test item marked as ‘Capable’ means a device has demonstrated a capability that was required as part of a test listed in a JT-NM Tested Test Plan.

Capability not Demonstrated (no mark):
A test item marked as ‘Capability not Demonstrated’ means that a device did not demonstrate a capability that was required as part of a test listed in a JT-NM Tested Test Plan. Examples of why a capability might not have been demonstrated include: the test was not applicable to this type of device (e.g., an audio-only device has no video capability), the device could not demonstrate capabilities that met the requirements of that test, the functionality was not implemented by design, the vendor requested that the capability not be tested, the capability could not be tested.

JT-NM Tested August 2022 – SMPTE ST 2110 Testing Results

Device Under Test		Device Under Test Details					
Vendor Name	Model	Type of Product/Functional Description	HW version	SW Version	Tx, Rx, Tx/Rx	Video only, Audio Only, Full	Format: HD / UHD
Adeas/Nextera	SDI IP Gateway	SDI-IP, IP-SDI Gateway	V3.5	V3.5	Tx/Rx	Full	2160p50
Appear	IPx210 JPEG-XS Decoder	IP Gateway, JPEG-XS decoder	01.0000	1.8.0	Tx/Rx	Full	2160p50
arkona technologies	at300	IP gateway, video and audio processing	AT300	2.1.52	Tx/Rx	Full	2160p50
Bridge Technologies	VB440	IP Monitor and Generator	MK3	6.0.2	Tx/Rx	Full	2160p50
Deltacast	IP Virtual Card	Software stack for ST 2110 video streaming	n/a	1.3	Tx/Rx	Full	2160p50
Evertz	ev670-X30	Virtualized Media Processing Platform	ev670	1218-L	Tx/Rx	Full	2160p50
Evertz	670IPG-X19	Virtualized Media Processing Platform	670IPG	590-F	Tx/Rx	Full	2160p50
EVS Broadcast Equipment SA	Neuron	Network Attached Processor	0.2	5.4.1	Tx/Rx	Full	2160p50
Grass Valley	LDX 150	Camera	LDX 150	16.0	Tx/Rx	Full	2160p50
Imagine Communications	Selenio Network Processor (SNP)	SDI-IP, IP-SDI Gateway	V1.0	2.1.2.12	Tx/Rx	Full	2160p50
Leader Electronics Corp.	LV5600	SDI / IP Waveform monitor	LV5600	6.3	Tx/Rx	Full	2160p50
Matrox	VERO	ST2110 Reference Sender/Capture	1.0	1.3	Tx/Rx	Full	2160p50
Nevion	Virtuoso	IP Media processing node/gateway	1.0	1.7.4	Tx/Rx	Full	2160p50
NVIDIA	Rivermax 1.20	ST 2110 Narrow Tx/Rx using COTS NIC	n/a	1.20	Tx/Rx	Full	2160p50
Panasonic Connect	KAIROS AT-KC100	Live Video Production Platform	AT-KC100	1.2.3	Tx/Rx	Full	2160p50
Panasonic Connect	KAIROS AT-KC1000	Live Video Production Platform	AT-KC1000	1.2.3	Tx/Rx	Full	2160p50
Pebble	Integrated Channel	Playout Server	1	2.2.1	Tx/Rx	Full	2160p50
PHABRIX	QxL (Tx/Rx)	SDI/IP Rasterizer	n/a	4.7	Tx/Rx	Full	2160p50
Riedel Communications	MN-FusioN-6-B	ST2110-SDI Gateway	400	4.0	Tx/Rx	Full	2160p50
Riedel Communications	MN-FusioN-3-B	ST2110-SDI Gateway	400	4.0	Tx/Rx	Full	2160p50
Riedel Communications	MuoN B	ST2110-SDI Gateway	400	4.0	Tx/Rx	Full	2160p50
Ross	Ultrix-IP-IO	12G Router / IP Gateway	n/a	4.8.1	Tx/Rx	Full	2160p50
Sony	NXLK-IP50Y series	SDI-IP Gateway (Sony's ST2110/NMOS Core implementation)	NXLK-IP50Y	3.12	Tx/Rx	Full	2160p50
Telestream	PRISM MPS300	SDI/IP Waveform Monitor	MMC25 revB	3.3	Tx/Rx	Full	2160p50
Telestream	PRISM MPD300	SDI/IP Waveform Monitor	MMC25 revB	3.3	Tx/Rx	Full	2160p50
Telestream	PRISM MPI2-25	SDI/IP Waveform Monitor	MMC25 revA	3.3	Tx/Rx	Full	2160p50
Telestream	Inspect 2110	IP Video Monitor	v1.0	4.0.1-2	Tx/Rx	Full	2160p50
Vizrt	VizEngine	Character Generator/Render Engine	n/a	5.0.0	Tx/Rx	Full	2160p50
Appear	IPx210 JPEG-XS Encoder	IP Gateway, JPEG-XS encoder	01.0000	1.8.0	Tx/Rx	Full	1080p50
Cobalt Digital	Indigo 2110-DC-01	IP Gateway and Processing	B	1.1.2	Tx/Rx	Full	1080p50
DekTec Digital Video BV	DTA-2110	ST 2110 sender and receiver	V1.0	V1.0	Tx/Rx	Full	1080p50
EVS Broadcast Equipment SA	XT-VIA	Live Production Server	6.3	20.3.21	Tx/Rx	Full	1080p50
Grass Valley	XCU UNIVERSE UXF	Base Station	XCU UNIVERSE UXF	20.0	Tx/Rx	Full	1080p50
Grass Valley	AMPP Edge	2110 (Tx/Rx)	N/A	1.2.17	Tx/Rx	Full	1080p50
Macnica	EASYSS10	SDI to ST2110 Gateway	EASYSS10	3.4.1	Tx/Rx	Full	1080p50
Panasonic Connect	AK-NP600 10G MoIP Board for AK-UCU600	Camera Control Unit for Studio Camera System	AK-NP600	13.1C-000-01.4F	Tx/Rx	Full	1080p50
Ross	Newt	2110 - SDI/HDMI Point-of-use gateway	n/a	5.0a	Tx/Rx	Full	1080p50
TAG Video Systems	MCM-9000	Probing & IP Multiviewer	n/a	5.7.9	Tx/Rx	Full	1080p50
NEC Corporation	HD-IPO	IntegratedPlayoutServer	1.2.1.34	1.2.1.17	Tx/Rx	Full	1080i59.94
Appear	ECx210 Decoder	HEVC decoder with ST2110 output	03.1778	1.14.1	Tx	Full	2160p50
Appear	SIx110 JPEG-XS Encoder	SDI to ST2110 Gateway	02.1774	2.14.3	Tx	Full	2160p50
Macnica	M2S	ST2110 streaming library SDK (Tx)	n/a	2.0.0	Tx	Full	2160p50
Sencore	MRD 7000	4K/4HD Decoder with ST2110 output	n/a	1593-G7C5B446F	Tx	Full	2160p50
Sumavision	S010	Baseband Live Processor (Tx)	V1.1	V1.0.1	Tx	Full	2160p50
Village Island	VICO-4L-XS-IP Encoder	4K JPEG-XS ST2110 Encoder Encap	4	v0.6.6.1	Tx	Full	2160p50
Village Island	VICO-4L-ST2110 Encoder	4K /4HD ST2110 Encapsulator	4.1	v0.6.2.7	Tx	Full	2160p50
Matrox	ConvertIP DSS-TX	ST 2110-22 Sender	3	1.01	Tx	Full	1080p50
MediaKind	RX1	ST2110 sender	n/a	v14	Tx	Full	1080p50
PHABRIX	SxTAG (Encap)	SDI/IP Handheld Waveform Monitor	n/a	2.01	Tx	Full	1080p50
Appear	ECx210 Encoder	HEVC encoder with ST2110 input	03.1726	1.14.1	Rx	Full	2160p50
Appear	SIx110 JPEG-XS Decoder	ST2110 to SDI Gateway	02.1774	2.14.3	Rx	Full	2160p50
Macnica	M2S	ST2110 streaming library SDK (Rx)	n/a	2.0.0	Rx	Full	2160p50
Sumavision	S010	Baseband Live Processor (Rx)	V1.1	V1.0.1	Rx	Full	2160p50
Village Island	VICO-4L-XS-IP Decoder	4K JPEG-XS ST2110 Decoder Decap	4	v0.7.8.9	Rx	Full	2160p50
Village Island	VICO-4L-ST2110 Decoder	4K /4HD ST2110 Decapsulator	4.1	v0.7.2.8	Rx	Full	2160p50
Vizrt	ChannelRecorder	File Capture Device	n/a	2.1.0	Rx	Full	2160p50
Matrox	ConvertIP DSS-RX	ST 2110-20/-22 Receiver	3	1.01	Rx	Full	1080p50
Matrox	ConvertIP DSH-RX	ST 2110-20/-22 Receiver	3	1.01	Rx	Full	1080p50
MediaKind	Encoding Live / CE1 / Aquila	ST2110 receiver	n/a	v14 / V2.0	Rx	Full	1080p50
PHABRIX	Qx (Rx)	SDI/IP Rasterizer	n/a	4.7	Rx	Full	1080p50
PHABRIX	SxTAG (Decap)	SDI/IP Handheld Waveform Monitor	n/a	2.01	Rx	Full	1080p50
Adeas/Nextera	HDMI IP Gateway	HDMI-IP JPEG-XS Encoder Gateway	V1.0	V1.0	Tx	Video Only	2160p50
Adeas/Nextera	IP HDMI Gateway	IP-HDMI JPEG-XS Decoder Gateway	V1.0	V1.0	Rx	Video Only	2160p50
Calrec Audio Ltd	Impulse Core	ST2110-30 IP Audio Router and Mixing Console	RY6427-8	Impulse 2.2.25	Tx/Rx	Audio Only	N/A
Calrec Audio Ltd	Type R Core	ST2110-30 IP Audio Router and Mixing Console	US6493-2	Type R 2.2.17	Tx/Rx	Audio Only	N/A
Calrec Audio Ltd	Type R IO Box	Baseband Audio to ST2110-30 IP Convertor	US6525-2	IO 2.2.18	Tx/Rx	Audio Only	N/A
Calrec Audio Ltd	Modular IO Box	Baseband Audio to ST2110-30 IP Convertor	UJ6429	IO 2.2.18	Tx/Rx	Audio Only	N/A
Calrec Audio Ltd	Fixed Format IO Box	Baseband Audio to ST2110-30 IP Convertor	SU6529	IO 2.2.18	Tx/Rx	Audio Only	N/A
DirectOut GmbH	MONTONE.42	MADI/AES67/RAVENNA converter	4.7	4.33	Tx/Rx	Audio Only	N/A
DirectOut GmbH	PRODIGY RAV.IO	AES67/RAVENNA interface card for PRODIGY series	0.26	0.74	Tx/Rx	Audio Only	N/A
DirectOut GmbH	ANDIAMO	32ch AD/DA converter	0.26	0.74	Tx/Rx	Audio Only	N/A
DirectOut GmbH	EXBOX.RAV	MADI/AES67/RAVENNA converter	0.26	0.74	Tx/Rx	Audio Only	N/A
Merging Technologies	Anubis - ZMAN platform	Audio Gateway	2	1.4	Tx/Rx	Audio Only	N/A
Riedel Communications	Artist AES67 Card AES67-108 G2	AES67 4-Wires In/Out for Intercom Frame	n/a	8.3	Tx/Rx	Audio Only	N/A
Riedel Communications	Artist AES67 Card UIC-128	AES67 4-Wires In/Out for Intercom Frame	n/a	8.3	Tx/Rx	Audio Only	N/A
Riedel Communications	RSP-1232 HL	Intercom Panel with AES67 4-Wires I/O	n/a	1.5.2	Tx/Rx	Audio Only	N/A
Ross	IGGY-MADI	AES67 - MADI Point-of-use gateway	n/a	2.0	Tx/Rx	Audio Only	N/A
Ross	BACH openModule OM512	OEM AES67 Gateway Module	n/a	1.0.19	Tx/Rx	Audio Only	N/A
Ross	BACH Liberty	OEM AES67 Gateway Module	0.6.2	4.2.23	Tx/Rx	Audio Only	N/A
Ross	BACH Minuet	OEM AES67 Gateway SoC	0.6.2	4.2.23	Tx/Rx	Audio Only	N/A
Georg Neumann GmbH	KH 750 AES67	DSP-controlled subwoofer with redundant AES67	KH750.2021	4.2.23	Rx	Audio Only	N/A
Georg Neumann GmbH	KH 150 AES67	DSP-controlled studio monitor with redundant AES67	KH150.2022	4.2.23	Rx	Audio Only	N/A
Riedel Communications	Audio Monitoring App	AES67 Monitoring on a RSP-1232 panel	n/a	1.0	Rx	Audio Only	N/A
Riedel Communications	Audio Monitoring App	AES67 Monitoring on a RSP-1216 panel	n/a	1.0	Rx	Audio Only	N/A

Test group	Test no.	Test
1. General Network Interface Tests	1.1.0	Management Network Interface Test
	1.1.1	Ping Response
	1.1.2	TTL > 16
	1.1.3	DHCP
	1.2.0	Media Network Interface(s) Test
	1.2.1	Ping Response
	1.2.2	TTL > 16
	1.2.3	DHCP
	1.2.4	Ping Response (secondary interface)
	1.2.5	TTL > 16 (secondary interface)
	1.2.6	DHCP (secondary interface)
2. Media Network Related Tests	2.1.0	Basic PTP Configuration Test
	2.1.1	Ping Response - Seperate port for PTP?
	2.1.2	Assign PTP domain
	2.1.3	Locked to PTP
	2.1.4	No GM role
	2.1.5	No reply to TLV mngmt msg's
	2.4.0	Basic Multicast Configuration Test
	2.4.1	Multicast address config SRC/DST
	2.4.2	Multicast address config SRC/DST (-7)
	2.5.0	Extended Multicast configuration Test
	2.5.1	Multicast address config SRC/DST
	2.5.2	Forbidden Multicast Range
	2.5.3	Multicast address config SRC/DST (-7)
3. ST 2110-10 Tests	3.1.0	IGMPv3
	3.1.1	IGMPv3
	3.2.0	IGMPv3 - SSM
	3.2.1	IGMPv3 - (S, G)
	3.3.0	SDP
	3.3.1	SDP exposed
	3.3.2	SDP valid
4. ST 2110-20 Tests	4.1.0	ST 2110-20 Stream - Tx Basic
	4.1.1	Stream - Tx validation
	4.1.2	Valid MAC address
	4.2.0	Stream - Tx Visual Validation
	4.2.1	Stream - Decoded by reference Rx
	4.3.0	ST 2110-21 compliance test Tx
	4.3.1.1	Transmitting - N
	4.3.1.2	Transmitting - NL
	4.3.1.3	Transmitting - W
	4.3.1.4	Network Compatibility Model (Cmax)
	4.3.1.5	Virtual Receiver Buffer Model (VRX)
	4.4.0	RTP Timestamp
	4.4.1	RTP TS Locked and in boundaries
	4.5.0	Reception of GPM and BPM streams
	4.5.1	Stream - Rx Visual Validation
	4.6.0	ST 2110-21 compliance test Rx
	4.6.1.1	Receiving - N
	4.6.1.2	Receiving - NL
	4.6.1.3	Receiving - W
	4.7.0	Stream - Visual Validation Rx
	4.7.1	Stream - Rx Receive Stream
	4.7.2	Stream - Rx Visual Validation
	4.7.3	Stream - Looped back stream decoded

LEGEND

Green square = Capable

White square = Capability not demonstrated

JT-NM Tested August 2022 – SMPTE ST 2110 Testing Results

Device Under Test

Vendor Name	Model
Adeas/Nextera	SDI IP Gateway
Appear	IPx210 JPEG-XS Decoder
arkona technologies	at300
Bridge Technologies	VB440
Deltacast	IP Virtual Card
Evertz	ev670-X30
Evertz	670IPG-X19
EVS Broadcast Equipment SA	Neuron
Grass Valley	LDX 150
Imagine Communications	Selenio Network Processor (SNP)
Leader Electronics Corp.	LV5600
Matrox	VERO
Nevion	Virtuoso
NVIDIA	Rivermax 1.20
Panasonic Connect	KAIROS AT-KC100
Panasonic Connect	KAIROS AT-KC1000
Pebble	Integrated Channel
PHABRIX	QxL (Tx/Rx)
Riedel Communications	MN-FusioN-6-B
Riedel Communications	MN-FusioN-3-B
Riedel Communications	MuoN B
Ross	Ultrix-IP-IO
Sony	NXLK-IP50Y series
Telestream	PRISM MPS300
Telestream	PRISM MPD300
Telestream	PRISM MPI2-25
Telestream	Inspect 2110
Vizrt	VizEngine
Appear	IPx210 JPEG-XS Encoder
Cobalt Digital	Indigo 2110-DC-01
DekTec Digital Video BV	DTA-2110
EVS Broadcast Equipment SA	XT-VIA
Grass Valley	XCU UNIVERSE UXF
Grass Valley	AMPP Edge
Macnica	EASYSS10
Panasonic Connect	AK-NP600 10G MoIP Board for AK-UCU600
Ross	Newt
TAG Video Systems	MCM-9000
NEC Corporation	HD-IPO
Appear	ECx210 Decoder
Appear	SIx110 JPEG-XS Encoder
Macnica	M2S
Sencore	MRD 7000
Sumavision	S010
Village Island	VICO-4L-XS-IP Encoder
Village Island	VICO-4L-ST2110 Encoder
Matrox	ConvertIP DSS-TX
MediaKind	RX1
PHABRIX	SxTAG (Encap)
Appear	ECx210 Encoder
Appear	SIx110 JPEG-XS Decoder
Macnica	M2S
Sumavision	S010
Village Island	VICO-4L-XS-IP Decoder
Village Island	VICO-4L-ST2110 Decoder
Vizrt	ChannelRecorder
Matrox	ConvertIP DSS-RX
Matrox	ConvertIP DSH-RX
MediaKind	Encoding Live / CE1 / Aquila
PHABRIX	Qx (Rx)
PHABRIX	SxTAG (Decap)
Adeas/Nextera	HDMI IP Gateway
Adeas/Nextera	IP HDMI Gateway
Calrec Audio Ltd	Impulse Core
Calrec Audio Ltd	Type R Core
Calrec Audio Ltd	Type R IO Box
Calrec Audio Ltd	Modular IO Box
Calrec Audio Ltd	Fixed Format IO Box
DirectOut GmbH	MONTONE.42
DirectOut GmbH	PRODIGY RAV.IO
DirectOut GmbH	ANDIAMO
DirectOut GmbH	EXBOX.RAV
Merging Technologies	Anubis - ZMAN platform
Riedel Communications	Artist AES67 Card AES67-108 G2
Riedel Communications	Artist AES67 Card UIC-128
Riedel Communications	RSP-1232 HL
Ross	IGGY-MADI
Ross	BACH openModule OM512
Ross	BACH Liberty
Ross	BACH Minuet
Georg Neumann GmbH	KH 750 AES67
Georg Neumann GmbH	KH 150 AES67
Riedel Communications	Audio Monitoring App
Riedel Communications	Audio Monitoring App

5. ST 2110-22 Tests

5.1.0	5.1.1	5.1.2	5.2.0	5.2.1	5.3.0	5.3.1	5.4.0	5.4.1	5.5.0	5.5.1	5.6.0	5.6.1	5.7.0	5.7.1	5.7.2	5.7.3
SMPTE 2110-22 Stream - Basic Test Tx	Stream - Tx validation	Valid MAC address	Stream - Tx Visual Validation	Stream - Decoded by reference Rx	ST 2110-21 compliance test Tx	-22 Sender Type (N, NL, W)	RTP Timestamp	-22 RTP TS Locked and in boundaries	Stream - Basic Test Rx	Stream -22 Rx Visual Validation	ST 2110-21 compliance test Rx	Reception of (N, NL, W)	Stream -22 Visual Validation Rx	Stream -22 Rx Receive Stream	Stream -22 Rx Visual Validation	Stream - Looped back stream decoded

6. ST 2110-30 Tests

6.1.0	6.1.1	6.1.2	6.1.3	6.2.0	6.2.1	6.3.0	6.3.1	6.4.0	6.4.1	6.5.0	6.5.1.1	6.5.1.2	6.5.1.3	6.5.2	6.5.3
Stream - Basic Test Tx	Stream -30 Tx validation	-30 Valid MAC address	-30 DSCP according to AES67	Stream - audible Validation Tx	Stream -30 Decoded by reference Rx	-30 Tx jitter	-30 Tx PDV	-30 RTP Timestamp	-30 RTP TS Locked and in boundaries	Stream - audible Validation Rx	Receive Stream Level A	Receive Stream Level B	Receive Stream Level C	Stream -30 Rx Audible Validation	Stream -30 Looped back stream decoded

7. ST 2110-31 Tests

7.1.0	7.1.1	7.2.0	7.2.1	7.3.0	7.3.1	7.3.2	7.4.0	7.4.1	7.5.0	7.5.1	7.6.0	7.6.1.1	7.6.1.2	7.6.1.3	7.6.2	7.6.3	7.7.0	7.7.1
Stream - Tx Jitter Test	-31 Tx PDV	Stream - Tx Timestamp	-31 RTP TS Locked and in boundaries	Stream - Tx Basic Validation	Stream -31 Tx validation	-31 Valid MAC address	Stream - Tx Audible Validation	Stream -31 Decoded by reference Rx	Stream - Tx Bit-Transparancy Test	Stream - valid AES3 from reference Rx	Stream - Rx Audible Validation	Receive Stream Level A	Receive Stream Level B	Receive Stream Level C	Stream -31 Rx Audible Validation	Stream -31 Looped back stream decoded	Stream - Rx Bit-Transparancy Test	Stream - Rx valid AES3

8. ST 2110-40 Tests

8.1.0	8.1.1	8.1.2	8.1.3	8.1.4	8.2.0	8.2.1	8.3.0	8.3.1	8.3.2	8.3.3	8.3.4
Stream - Tx Basic Validation	DID/SDIDs match description	Legal SDI line and sample fields	Correct marker and field bits	Payload Error Free	RTP Timestamp	RTP TS: locked and within boundaries	Stream - Rx Basic Validation	Valid -40 pass through	Timecode check	Valid ANC in SDI	Show list of DID/SDIDS

9. ST 2022-7 Tests

9.1.0	9.1.1	9.1.2	9.1.3	9.1.4	9.2.0	9.2.1	9.2.2	9.2.3	9.3.0	9.3.1	9.3.2	9.3.3
Stream - Tx Basic Redundancy Test	Reference Rx receives Red/Blue (without errors)	Assign independant IPv4 Addresses	Stream - Rx validation Audio/Video/Anc	Different IP/MAC addresses for Red/Blue	Stream - Rx Basic Redundancy Test	Assign independant IPv4 Addresses	Stream - Rx visual validation	One path lost test	Seamless Protection Switching Test	Loss of 25%	Loss of 25% + Diff. Latency	Loss of 25% + Diff. Latency + PDV

LEGEND

Green square = Capable

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JT-NM TESTED SMPTE ST 2110 08 / 22

Appendix

JT-NM Tested August 2022

SMPTE ST 2110 Media Nodes

Test Plan

”JT-NM Tested Program August 2022” SMPTE ST 2110 Test Plan v.1.2

Changelog to v1.1

- This is a post-face-to-face event update that reflects the changes introduced by the testing and experts teams on-site and outlines additional support equipment used during the testing.

Changelog to v1.0

- Test 3.3 updated.

Changelog to “JT-NM Tested March 2020 Program” Test Plan v.1.3 (pre-COVID)

- Pre-COVID on-site test plan v.1.3. is used as the basis for this revision.
- Initial release. This document may undergo changes ahead of the final version.
- It is recommended that participants of previous JT-NM Tested events carefully familiarize themselves with the new revision of the test plan.
- Editorial corrections and ambiguities resolution throughout the text.
- PTP Testing simplified.
- Added ST 2110-22/JPEG-XS tests.
- Minor improvements to multiple tests.
- Clarified timestamp behavior in ST 2110-30 and ST 2110-31 tests and added sender jitter tests.

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To avoid potential mistakes in the test descriptions outlined in this test plan, the wording “pass/no pass” is preserved in the criteria descriptions.

Acknowledgment

This Test Plan was prepared by an expert group within the Joint Task Force on Networked Media (JT-NM) with key contributions from: Bill Mclaughlin (EEG, Ai Media), Claudio Becker-Foss (DirectOut GmbH), Felix Poulin (CBC/Radio-Canada), Gerard Phillips (Arista Networks), Ievgen Kostiukevych (European Broadcasting Union), Jack Douglass (PacketStorm Communications), Jean Lapierre (Matrox), John Mailhot (Imagine Communications), Leigh Whitcomb (Imagine Communications), Mike Overton (Telestream), Mike Waidson (Telestream), Pavlo Kondratenko (European Broadcasting Union), Pedro Ferreira (Bisect), Prinyar Boon (Phabrix), Willem Vermost (Vlaamse Radio- en Televisieomroeporganisatie/VRT).
The testplan was executed on site by the following experts: Benno Sonder (DirectOut GmbH), Bruce Devlin (MrMXF / SMPTE), Claudio Becker-Foss (DirectAudio), Jack Douglas (Packetstorm), Kenneth Jonassen (Bridge Technologies), Mike Overton (Telestream), Nicolas Sturmel (Mergin Technologies), Pavlo Kondratenko (EBU), Pedro Ferreira (Bisect), Prinyar Boon (Phabrix), Steffen Benz (RBT), Wes Simpson (Learn IP Video), Willem Vermost (VRT / EBU SD&A) - ST 2110 Testing team leader and with support from Ievgen Kostiukevych (EBU) - JT-NM Tested event coordinator and Brad Gilmer (Gilmer and associates) - Executive director of AMWA and VSF, JT-NM Admin boad member

Applicable Standards, Specifications and versions

- **SMPTE ST 2059-1:2021 -** Generation and Alignment of Interface Signals to the SMPTE Epoch - https://ieeexplore.ieee.org/document/9452725
- **SMPTE ST 2059-2:2021 -** SMPTE Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications - https://ieeexplore.ieee.org/document/9452731
- **SMPTE ST 2110-10:2017 -** Professional Media over Managed IP Networks: System Timing and Definitions - https://ieeexplore.ieee.org/document/8165974
- **SMPTE ST 2110-20:2017 -** Professional Media over Managed IP Networks: Uncompressed Active Video - https://ieeexplore.ieee.org/document/8167389

- **SMPTE ST 2110-21:2017 -** Professional Media over Managed IP Networks: Traffic Shaping and Delivery Timing for Video - https://ieeexplore.ieee.org/document/8165971
- **SMPTE ST 2110-22:2019 -** Professional Media Over Managed IP Networks: Constant Bit-Rate Compressed Video - https://ieeexplore.ieee.org/document/8809389
- **SMPTE RP 2110-25:2022 (Draft, SMPTE Final Committee Draft)**
- **SMPTE ST 2110-30:2017 -** Professional Media over Managed IP Networks: PCM Digital Audio - https://ieeexplore.ieee.org/document/8167392
- **SMPTE ST 2110-31:2018 -** Professional Media over Managed IP Networks: AES3 Transparent Transport - https://ieeexplore.ieee.org/document/8454952
- **SMPTE ST 2110-40:2018 -** Professional Media over Managed IP Networks: SMPTE ST 291-1 Ancillary Data - https://ieeexplore.ieee.org/document/8353279
- **SMPTE ST 2022-7:2019** - Seamless Protection Switching of SMPTE ST 2022 IP Datagrams - https://ieeexplore.ieee.org/document/8716822
- Internet Engineering Task Force (IETF) **RFC 3376** Internet Group Management Protocol, Version 3 https://www.ietf.org/rfc/rfc3376.txt
- **JT-NM TR-1001-1:2020 -** https://static.jt-nm.org/documents/JT-NM_TR-1001-1_2020_v1.1.pdf
- **AES67-2015 -** AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability
- **VSF TR-08:2021** - Transport of JPEG XS Video in ST 2110-22 https://vsf.tv/download/technical_recommendations/VSF_TR-08_2021-08-09.pdf

Equipment used during testing

The following equipment was selected by the JT-NM Tested Experts Group to support the “JT-NM Tested” event. In a number of cases, other vendors’ equipment would have worked equally well. To preserve the integrity of the testing environment, the team needed to choose one set of support equipment. The listing of a company below should not be taken to indicate that this is the only equipment that could have performed the tasks required. Note also that support equipment was *not* “JT-NM Tested” unless it is specifically listed in the test results matrix, and that no special status is awarded by the JT-NM to these companies other than to note that the JT-NM appreciates their support. Except for the JT-NM face-to-face events, it is never expected that the same test and measurement, network, PTP, or reference equipment be used for self-testing or independent testing.

Test and measurement equipment and software used during the event

- BridgeTech VB440
    - https://bridgetech.tv/vb440/

- EBU Live IP Software Toolkit (EBU LIST)
  - https://tech.ebu.ch/list
- Packetstorm CRS, Network Emulator (6XG / 8XG), VIP Monitor
  - https://packetstorm.com/packetstorm-products/
- Phabrix Qx/QxL
  - https://www.phabrix.com/products/qxl/
  - https://www.phabrix.com/products/qx/
- Telestream PRISM
  - https://www.tek.com/prism-media-monitoring-and-analysis-platform
- Wireshark (with ST 2110 dissectors)
  - https://github.com/NEOAdvancedTechnology/smpte2110-20-dissector
  - https://www.intopix.com/blogs/post/Deep-dive-into-SMPTE-ST2110-22-with-Wireshark-Dissector
  - https://github.com/NEOAdvancedTechnology/smpte2110-40-dissector

Reference senders and receivers used during the event

- DirectOut MONTONE.42
  - https://www.directout.eu/en/products/montone42/
- EEG Alta™ IP Video Caption Encoder
  - https://eegent.com/products/X6KO3ARIL9X1VEIU/altaTM-ip-video-caption-encoder
- Imagine Communications SNP
  - https://imaginecommunications.com/product/selenio-network-processor-snp/
- Matrox Vero
  - https://www.matrox.com/en/video/products/infrastructure/st2110-signal-generator-diagnostic-appliance/vero
- Phabrix QxL
  - https://www.phabrix.com/products/qxl/
- SDI source(s), SDI monitor(s), SDI DA(s), SDI router(s), audio source(s), audio monitor(s)
  - EVS
    - https://evs.com/
  - Imagine Multiviewer
    - https://imaginecommunications.com/product-function/multiviewers/
  - Imagine Communications Magellan Control System
    - https://imaginecommunications.com/product/magellan-control-system/
  - Video Clarity ClearView Player 4K
    - https://videoclarity.com/cvpproducts/
  - Riedel Mediornet
    - https://www.riedel.net/en/products-solutions/distributed-video-networks
  - TAG Multiviewer

- https://tagvs.com/

Network switches used during the event

The section lists some of the models and software versions of Arista switches used during the face-to-face event. The list is not extensive.

Network switches used at the event were provided by Arista and included the following platforms and software versions:

- Arista 7280R3-32D4 (EOS Version 4.27.4.1M)
  - https://www.arista.com/assets/data/pdf/Datasheets/7280R3-Data-Sheet.pdf
- Arista Arista 7050X3-48YC12 (EOS Version 4.27.4.1M)
  - https://www.arista.com/assets/data/pdf/Datasheets/7050X3-Datasheet.pdf
- Arista 7280SR2-48YC6 (EOS Version 4.27.4.1M)
  - https://www.arista.com/assets/data/pdf/Datasheets/7280R-DataSheet.pdf
- Arista 7020TRA-48 (EOS Version 4.27.4.1M)
  - https://www.arista.com/assets/data/pdf/Datasheets/7020R-48_Datasheet.pdf

Network topology is described in “JT-NM Tested 2022 Spreadsheet”.

Systems used for NMOS infrastructure

The systems used for NMOS infrastructure are discussed in the “JT-NM Tested August 2022 NMOS/TR-1001 Test Plan”.

PTP configuration used during the event

The PTP Grandmaster(s) used during the event - Tektronix **SPG8000A**.
The network switches will be configured in a **Boundary Clock** mode.
Multicast communication mode for all messages will be used (except for management TLV responses).
The PTP profile details will be provided at the time of testing. The parameters provided will be within the values allowed by SMPTE ST 2059-2:2021.

General statements and terms

- This test plan outlines the principles and methods for the IP Media Endpoints testing which are applied for on-site testing at the face-to-face events, but can and should also be applied for self-testing as well as independent testing. Therefore, except for the JT-NM face-to-face events, it is never expected that the same test and measurement, network, PTP, or reference equipment is used for self-testing or independent testing.

- When validating the Device Under Test (DuT) against other reference senders and/or receivers, in case of the suspected possibility of test failure by DuT - multiple tries with different reference devices and with various test and measurement equipment will be attempted before making final conclusions. However, the ability of the team to retest will be limited due to time and resource constraints.
- The execution of the tests will be done with common sense in mind. Ambiguities will be addressed by the test team on a case-by-case basis.
- If the DuT fails any particular test, a Vendor representative will be given an opportunity to explain and discuss the results.
- Vendor representatives will be given the IP and PTP configuration parameters via the event spreadsheet well ahead of time before the testing..
- Vendor representatives will be expected to configure their equipment themselves.
- Standard MTU size (1500 octets) will always be expected.
- All baseband signals and/or files required for the testing will be provided.
- Vendors may not change software/firmware once testing has commenced but may adjust settings on their products as necessary during the testing process.
- Throughout the text the term “disruption” is used, It may be applied to baseband signals and/or IP streams.
    - Disruption on a transmitting IP Media Node includes but is not limited to:
        - Black lines in the video essence
        - Frozen/dropped frames in the video essence
        - Mutes or pops in the audio essence
        - Distorted or lost symbols in the ancillary essence
        - Discontinuity of RTP sequence numbers
        - Change in RTP timestamps by more than a duration of a video frame/audio frame.
    - A disruption on an IP Rx Media Node includes but is not limited to:
        - Black lines in the video essence
        - Frozen/dropped frames in the video essence
        - Mutes or pops in the audio essence
        - Distorted or lost symbols in the ancillary essence
    - A disruption in the baseband signal includes but not limited to:
        - Black lines in the video essence
        - Frozen/dropped frames in the video essence
        - Mutes or pops in the audio essence
        - Distorted or lost symbols in the ancillary data
- The JT-NM Tested team reserves the right to update the “JT-NM Tested Program” Test Plans as required.

Descriptions of the tests

1. General Network Interface Tests

*If a device does not provide means to display the management IP address assigned by the DHCP - it may be assigned a static address.

Description: This set of Tests is expected to validate the general network-related functionality of a media device.

First steps:

At the time of testing, Testers will provide the Vendor representative with a set of parameters consisting of:

- A unicast host IPv4 address
- A subnet mask from the range from /8 to /30
- A default gateway IPv4 address

Sets of parameters will be provided for essence interface(s) and for management interface(s) (if an out-of-band management interface is present for the DuT). The Vendor representative will be expected to configure the DuT with the given sets of parameters. Additionally, the DHCP server will be active in the network and it will be preferred for the DuT to receive the parameters via it. If the DuT has no out-of-band management interface(s) and uses inband management via essence interface(s), only a set of parameters for essence interface(s) will be provided, and the test 1.1. will be skipped.

1.1. Management Network Interface Test*

*Only applied to devices with out-of-band management interface(s). If a device does not provide the means to display the management IP address assigned by the DHCP - it may be assigned a static address.

Description: Tests the ability of DuT to receive the IPv4 address, subnet mask, and default gateway parameters for a management interface via DHCP. Also tests blocking of ICMP messages and TTL values of ICMP replies. The DuT will be pinged from a host in another subnet. DuT is expected to reply to ICMP echo requests (ping) coming from another subnet, while properly utilizing a default gateway, and with TTL > 16. This test will not involve an IP address change, a demonstration of basic configurability will suffice. The manual configurability of these parameters will also be expected. If the DuT does not support DHCP, the manual configurability of these parameters is acceptable. The ICMP ping test will be done twice with 2 payloads: 32 and 56 bytes, the DuT is expected to properly reply to both.

Validation method: Console log from a device sending ICMP echo requests is used for validation.

Pass criteria:

- The DuT assumes the parameters assigned via DHCP, or manually, can be pinged from a host on another subnet. The TTL value of ICMP echo reply to both payload sizes is > 16.

No pass criteria:

- The DuT does not assume the parameters assigned via DHCP (if tested), or manually, or cannot be pinged from a host on another subnet with one or both payload sizes.

1.2. Media Network Interface(s) Test*

* DHCP variant of this test is part of NMOS/TR-1001-1 testing. If a device has inbound management and does not provide means to display the management IP address assigned by the DHCP - it may be assigned a static address.

Description: Tests the ability of DuT to receive the IPv4 address, subnet mask, and default gateway parameters for a media interface(s) via DHCP. Also tests blocking of ICMP messages and TTL values of ICMP replies. The DuT will be pinged from a host in another subnet. DuT is expected to reply to ICMP echo requests (ping) coming from another subnet, while properly utilizing a default gateway, and with TTL > 16. This test will not involve an IP address change, a demonstration of basic configurability will suffice. The manual configurability of these parameters will also be expected. If the DuT does not support DHCP, the manual configurability of these parameters is acceptable.

If a device has ST 2022-7 multiport capabilities - both ports will be tested. The ICMP ping test will be done twice with 2 payloads: 32 and 56 bytes, the DuT is expected to properly reply to both.

Validation method: Console log from a device sending ICMP echo requests is used for validation.

Pass criteria:

- The DuT assumes the parameters assigned via DHCP, or manually, can be pinged from a host on another subnet. The TTL value of ICMP echo to both payload sizes reply is > 16.

No pass criteria:

- The DuT does not assume the parameters assigned via DHCP (if tested), or manually, or cannot be pinged from a host on another subnet with one or both payload sizes.

2. Media Network Related Tests

Description: This set of Tests validates the basic and advanced behaviors of the DuT related to PTP synchronization and multicast addressing capabilities.

First steps:

At the time of testing, Testers will provide to the Vendor representative sets of parameters consisting of:

- A PTP profile values compliant to SMPTE 2059-2:2021. Any parameter values allowed by the profile may be used.
- A set of multicast addresses.
- Source-specific multicast (SSM) will not be tested.

The Vendor representative will be expected to configure the DuT with the given sets of parameters.

2.1. Basic PTP Configuration Test

Description: The Test validates the basic PTP behavior of the DuT in slave only mode (defaultDS.slaveOnly set to TRUE). A set of PTP-related tests will be executed to test:

- The DuT that has a dedicated network port for PTP (not management and not an essence port) will be expected to expose the IP address configurability as per test 1.2.
- The ability of the DuT to lock to the Grandmaster with a freely assignable PTP Domain number and follow the parameters of the PTP profile communicated by a Grandmaster and Master port to which the DuT is connected to: The PTP profile values may be modified in a Grandmaster, the DuT will be expected to re-lock to it. **Validation method:** DuT visual reporting of PTP lock status, a PTP log of the DuT, and/or Wireshark/PTP Track Hound analysis.
- The ability of the DuT to be set in a slave-only mode: the DuT is expected not to assume a Grandmaster role even if there is no Grandmaster present. **Validation method:** by changing the PTP domain setting on the DuT, the flow of valid PTP announce messages is interrupted, DuT visual reporting of PTP lock status, a PTP log of the DuT, or a Wireshark/PTP Track Hound analysis of a PTP communication from a mirrored port of the switch connected to the DuT is used to analyze the behavior of the DuT.
- The ability of the DuT to maintain proper PTP communication according to the parameters communicated by a Grandmaster: the DuT is expected to keep a stable lock to PTP and maintain the messages rate communicated by a Grandmaster. **Validation method:** DuT visual reporting of PTP lock status, or a PTP log of the DuT, a Wireshark/PTP Track Hound analysis of a PTP communication from a mirrored port of the switch connected to the DuT.
- The ability of the DuT not to reply to TLV management messages with multicast acknowledgment. **Validation method:** The PTP Grandmaster will be using the defined PTP profile as per SMPTE ST 2059-2 and will be sending the SMPTE TLV management messages once per second. Wireshark will be used to monitor from a mirrored port of the switch connected to the DuT and to verify that the BC is sending the TLV to the DuT and that the DuT while being locked to PTP, is not responding inappropriately.

Pass criteria:

- 1.1The DuT’s dedicated PTP port* can be pinged from a host on another subnet. The TTL value of the ICMP echo reply is > 16.
  *Only applicable to DuT that has a dedicated PTP port
- It is possible to freely assign PTP domain parameters into DuT.
- The DuT can lock to the Grandmaster, can maintain a stable lock, and maintains PTP communication according to the parameters communicated by a Grandmaster.
- The DuT does not assume a master role if there is no Grandmaster present.
- The DuT does not reply to TLV management messages with multicast acknowledgment.

No pass criteria:

- The DuT’s dedicated PTP port* cannot be pinged from a host on another subnet.
  *Only applicable to DuT that has a dedicated PTP port
- It is not possible to freely assign PTP domain parameters into DuT.
- The DuT cannot lock to the Grandmaster, cannot maintain a stable lock, or does not maintain PTP communication according to the parameters communicated by a Grandmaster.

- The DuT assumes a Grandmaster role if there is no Grandmaster present.
- The DuT replies to TLV management messages with multicast acknowledgment.

2.2. RX Device PTP Grandmaster Failover Test with "*a=ts-refclk:ptp=GM-ID"* in a Reference TX SDP

*As this test may be disruptive, it may be postponed and performed after the rest of the tests are executed. Given the time and resources limitations, this test may be dropped.

Description:** The test validates the receiver's behavior during and after a PTP Grandmaster failover event between 2 equivalent Grandmasters while receiving a stream from a reference TX device that indicates "a=ts-refclk:ptp=GM-ID" in the SDP object.

**The motivation for this test is that some users report that during PTP GM failover events, disruptions on some Media Nodes have been observed. While not formally in any standard, users have the expectation that a PTP GM failover event shall not cause disruptions on Media Node outputs.

Validation method: PTP awareness is disabled on the switch interface. The DuT is then expected to lock to a dedicated PTP testing master clock. This dedicated PTP clock will have the traceable flag set to true in its Announce messages as well as advertised Clock Accuracy of <= 1us (codes 0x020-0x23). The DuT will be expected to receive a stream from the special reference transmitter. The SDP object of that stream will indicate the same reference clock that the DuT is being locked to (a=ts-refclk:ptp=GM-ID). After the stable lock and reception are established, a BMCA between the current master and a backup clock is triggered by changing the Priority 1 value on the master clock thus implying a grandmaster changeover for the DuT and for the reference transmitter. It is a given that the selected reference transmitter does not suffer any disruption during the PTP master change and properly amends the "a=ts-refclk:ptp" field in the SDP object. The Priority 1 value of the original master clock is then reverted back to its original value thus triggering it to take over again as the best master.

It is expected that the DuT does not demonstrate any disruption in the output (baseband or loopback) of the stream being received during both of these changeovers.

Pass criteria:

- The DuT can lock to each of the devices that become the Grandmaster during the failover transitions. The locking determination will use the same locking criteria as 2.1.
- The DuT is able to receive and reproduce/loopback the stream from the dedicated reference transmitter
- The DuT does not demonstrate disruption in the stream reproduction during both PTP GM changeovers

No Pass criteria:

- The DuT is not able to lock to all of the devices that become Grandmaster during the failover transitions. The locking determination will use the same locking criteria as 2.1.
- The DuT is not able to receive and reproduce/loopback the stream from the dedicated reference transmitter

- The DuT demonstrates any kind of disruption in the stream reproduction during any of the PTP GM changeovers

2.3. TX Device PTP Grandmaster Failover Test

*As this test may be disruptive, it may be postponed and performed after the rest of the tests are executed. Given the time and resource limitations, this test may be dropped.

Description:** The test validates the transmitter’s behavior during and after a PTP Grandmaster failover event between 2 equivalent Grandmasters.

**The motivation for this test is that some users report that during GM failover events, disruptions on some Media Nodes have been observed. While not formally in any standard, users have the expectation that a GM failover event shall not cause disruptions on Media Node outputs.

Validation method: PTP awareness is disabled on the switch interface. The DuT is then expected to lock to a dedicated PTP testing master clock. This dedicated PTP clock has the traceable flag set to true in its Announce messages as well as advertises its Clock Accuracy of <= 1us (codes 0x020-0x23). The DuT will be expected to transmit a stream into the general network area. The SDP object of that stream may or may not be generated and may or may not indicate that it is generated from a traceable source (a=ts-refclk:ptp=traceable, or a=ts-refclk:ptp=GM-ID). The stream is then received by a reference receiver. After the stable lock and reception are established, a BMCA between the current master and a backup clock is triggered by changing the Priority 1 value on the master clock thus implying a grandmaster changeover for the DuT, while the reference receiver remains locked to the general master. If an SDP Object is generated, it is expected that the DuT will either update the GM-ID after no more than 20 seconds after the DuT is locked to the grandmaster***, or preserve the “traceable” in the SDP object of the stream. The Priority 1 value of the original master clock is then reverted back to its original value thus triggering it to take over again as the best master. It is a given that the reference device itself does not demonstrate any disruption because of SDP object change and will accept streams with both GM-ID or “traceable” in the SDP object, or without the SDP at all.

It is expected that there is no disruption of the stream generated by the DuT during both of the changeovers (as monitored by the reference receiver).

***20 seconds is arbitrary, but recommended maximum time for the SDP object updating. A longer time is discouraged, but will not result in not passing the test.

Pass criteria:

- The DuT can lock to each of the devices that become the Grandmaster during the failover transitions. The locking determination will use the same locking criteria as 2.1.
- The DuT is able to generate a valid stream that can be received by the reference receiver
- The DuT does not demonstrate disruption in the outgoing stream during both PTP GM changeovers
- If SDP object of the stream is generated - it indicates either “a=ts-refclk:ptp=traceable”, or “a=ts-refclk:ptp=GM-ID” for current active Grandmaster

No Pass criteria:

- The DuT is not able to lock to all of the devices that become Grandmaster during the failover transitions. The locking determination will use the same locking criteria as 2.1.

- The DuT is not able to generate a valid stream or it cannot be received by the reference receiver
- Any kind of disruption is observed in the generated stream during any of the PTP GM changeovers
- If SDP object of the stream is generated - The generated SDP object of the stream does not indicate a=ts-refclk:ptp=traceable, or a=ts-refclk:ptp=GM-ID for current active Grandmaster

2.4. Basic Multicast Configuration Test

Description: The Test validates the basic configurability of source and destination multicast IPv4 addresses of the DuT. An ability to independently configure a given set of source and destination multicast IPv4 addresses randomly picked in the 239.0.0.0/8 range is expected. If the DuT is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected. If the DuT is a sender and a receiver, it is expected that it is possible to configure both a source and a destination multicast IPv4 addresses independently and at the same time. This test is also applied for ST 2022-7 capable products with the same configurability and independence expected on both interfaces.
Validation method: Visible acknowledgment of parameters by the DuT without errors.
Pass criteria:

- The DuT allows independent configuration of source and destination multicast addresses* randomly picked as defined in the description.
  *If a device is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected
- The ST 2022-7 capable DuT allows independent configuration of source and destination multicast addresses randomly picked as defined in the description on both of its interfaces.

No pass criteria:

- The DuT does not allow independent configuration of source and destination multicast addresses* randomly picked as defined in the description.
  *If a device is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected
- The ST 2022-7 capable DuT does not allow independent configuration of source and destination multicast addresses randomly picked as defined in the description on both of its interfaces.

2.5. Extended Multicast Range Configurability Test

Description: The Test validates the advanced configurability of source and destination multicast IPv4 addresses of the DuT. An ability to independently configure a given set of randomly picked source and destination multicast IP addresses in the 224.0.2.0 - 239.255.255.255 range is checked. If the DuT is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected. If the DuT is a sender and a receiver, it is expected that it is possible to configure both a source and a destination multicast IPv4 addresses

independently and at the same time. It is also expected that the DuT shall not allow the use of 224.0.0.0 - 224.0.1.255 range. This test counts towards NMOS/TR-1001-1 testing since the 224.0.2.0 - 239.255.255.255 range is mandated in TR-1001-1.This test is also applied for ST 2022-7 capable products with the same configurability and independence expected on both interfaces.
Validation method: visible acknowledgment of parameters by the DuT without errors.
Pass criteria:

- The DuT allows independent configuration of source and destination multicast addresses* randomly picked as defined in the description.
  *If a device is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected
- The DuT doesn’t allow the use of 224.0.0.0 - 224.0.1.255 multicast address range.
- The ST 2022-7 capable DuT allows independent configuration of source and destination multicast addresses randomly picked as defined in the description on both of its interfaces.

No pass criteria:

- The DuT does not allow independent configuration of source and destination multicast addresses* randomly picked as defined in the description.
  *If a device is a sender only (a receiver only), the configuration of a destination (source) multicast IPv4 address only will be expected
- The DuT allows the use of 224.0.0.0 - 224.0.1.255 multicast address range.
- The ST 2022-7 capable DuT does not allow independent configuration of source and destination multicast addresses randomly picked as defined in the description on both of its interfaces.

3. ST 2110-10 Tests

Description: This set of Tests validates the basic DuT’s conformance to SMPTE ST 2110-10.
First steps: For DuT with receiving capabilities: the Vendor representative is provided with a multicast IPv4 address with an active stream (audio/video depending on DuT capabilities) that is present and active in the network and requested to receive this stream. For DuT with sending capabilities: an SDP object verification is done. The ability to decode a stream and/or produce a valid stream is neither verified nor expected at this stage.

3.1. IGMPv3 test for a receiver

Description: The Vendor representative is requested to have their DuT join a given multicast group. IGMPv3 communication is expected between the DuT and a switch. Use of Source-Specific Multicast is not expected in this test and the DuT is expected to use a (*, G) IGMPv3 group report (from any source address).
Validation method: IGMP communication is monitored via switch IGMP messages debugging on a DuT switchport, or alternatively with Wireshark from a mirrored port of the switch connected to the DuT, if required.

Pass criteria:

- The DuT maintains IGMPv3 communication with a switch.

No pass criteria:

- The DuT uses another version of IGMP.

3.2. IGMPv3 SSM test for a receiver

Description: The Vendor representative is requested to have their DuT join a given multicast group using Source Specific Multicast (SSM). IGMPv3 communication is expected between the DuT and a switch and the DuT is expected to use a (S, G) IGMPv3 group report (from a particular source address).

Validation method: IGMP communication is monitored via switch IGMP messages debugging on a DuT switchport, or alternatively with Wireshark from a mirrored port of the switch connected to the DuT, if required.

Pass criteria:

- The DuT maintains IGMPv3 communication with a switch and successfully joins a multicast group with a particular source using (S, G) group report.

No pass criteria:

- The DuT uses another version of IGMP, cannot join the multicast group, or uses (*, G) group report.

3.3. SDP object verification for a sender

Description: The Vendor is expected to demonstrate that the DuT has a user-accessible way to expose a valid SDP object. This test is performed alongside tests 4_TX, 5_TX, 6_TX, 7_TX and 8_TX. The SDP object is checked for the respected essence type (-20, -22, -30, -31 and/or -40) when a stream is initiated. If an SDP object is exposed via NMOS IS-04 - this will be accounted for the NMOS/TR-1001-1 testing. The DuT is also expected to correctly dynamically update the SDP object if the stream parameters are changed.

Validation method: an exposed SDP object is checked with SDPoker and/or manually. The SDP object is then compared with the required parameters listed below. For an ST 2022-7 flow, the parameters should be identical for the Red and Blue flows and the SDP shall match both flows.
The stream parameters may be requested to be changed and the change must become reflected in the updated SDP object.

The following parameters will be verified for all essence types:

- RTP Header parameters duplicated in the SDP:
    - c=IN <dest IP address>
    - a=source-filter (<dest IP address> <source ip address>)
    - a=fmtp:<PT>
- SSRC (if present)

Note: the o=<source IP address> may not match the flow due to NAT

The following parameters will be verified for 2110-20 essence types:

- 2110-20 Required Media type Parameters:
  - media clock rate (eg 90000)
  - media type (m=video)
  - width
  - height
  - exactframerate
  - sampling
  - depth
  - colorimetry
  - PM
  - SSN
  - TCS (if present, absent = SDR)
  - interlace (if present, absent = Progressive)
  - segmented (if present, absent = not segmented)
  - RANGE (if present, absent = narrow)
  - MAXUDP (if present, absent = standard)
  - PAR (if present, absent = 1:1)

- 2110-21 Required Parameter
  - TP

- 2110-21 Optional parameters
  - TROFF (absent = default)
  - CMAX (absent = sender class)

- The following parameters will be verified for 2110-30/31 essence types:
  - ptime
  - media type (m=audio)
  - rtpmap: payload format (eg L24, AM824)
  - rtpmap: sampling rate (eg 48000)
  - rtpmap: channel count (eg 2)
  - mediaclk:direct=0
  - fmtp: channel-order (if present)

- The following parameters will be verified for 2110-40 essence types:
  - media clock rate (eg 90000)
  - media type (m=video)
  - DID_SDID (if present)
  - VPID_Code (if present)

Pass criteria:

- The DuT exposes a user-accessible and valid SDP object that matches the essence format.
- No warnings from SDPoker and no warnings from Phabrix QxL are produced.
- The SDP object is correctly updated following the change in the stream parameters.

No pass criteria:

- The Vendor representative is not able to demonstrate that the DuT supports user-accessible SDP data, or the SDP object is not valid.
- The SDP object is not updated following the change in the stream parameters or is updated incorrectly.

4_TX. ST 2110-20 Tx tests*

*Applicable only to DuT with 211-20 video transmitting capabilities

Description: This set of tests validates the basic DuT’s conformance to SMPTE ST 2110-20.

First steps: The Vendor representative will be provided with a multicast IPv4 address, a port number, and video format parameters (1080i50 and/or 1080p50). DuT is expected to be able to initiate a stream with given parameters. Standard MTU size will always be expected. The DuT may use either GPM or BPM for generating the TX stream, a reference receiver will be able to accept both. Separate testing of UHD capabilities (2160p50) will be executed. It will be reflected accordingly in the results spreadsheet (e.g. 4.2-UHD).

4.1. Stream basic test Tx

Description: The Vendor representative is expected to configure the DuT so that it initiates a stream of a given configuration with the given multicast address and port number. Packets of the stream are expected to have valid source and destination MAC and IPv4 addresses.

Validation method: Stream is analyzed in real-time (and/or captured and analyzed offline) via IGMP join and/or from a mirrored port of the switch connected to the DuT. Source and destination MAC and IPv4 addresses are validated either by a test and measurement equipment or manually using Wireshark.

Pass criteria:

- DuT is capable of initiating a stream with given IPv4 address parameters, and video format parameters.
- Stream uses a valid multicast MAC address.

No pass criteria:

- DuT is not capable of initiating a stream with given IPv4 address parameters, and video format parameters.
- Stream uses an invalid multicast MAC address.

4.2. Stream visual validation Tx

Description: A stream initiated during test 4.1. is received with a reference receiver. A basic subjective visual test is done. The stream is expected to have no obvious visual artifacts of digital nature or any other disruptions.
Validation method: A stream is visualized using a reference receiver. If a reference receiver is not capable of decoding the stream - a test and measurement device is used to analyze the stream. The stream will be observed for at least ~60 seconds.
Pass criteria:

- The stream can be received and decoded by a reference receiver and/or a majority of the test equipment. The video signal is free from artifacts of a digital nature or any other disruptions.

No pass criteria:

- The stream cannot be decoded or contains disruptions. A Vendor representative will have an opportunity to articulate why this might be ok.

4.3. ST2110-21 profile sender compliance test Tx

Description: A stream generated during test 4.1. is expected to be compliant to SMPTE ST 2110-21 with either N, NL, or W profile. A stream will be analyzed with a test and measurement device to validate conformance.
Validation Method: The generated essence stream will be analyzed for good behavior according to the network compatibility model and the virtual receive buffer model. The stream will be analyzed online. It can also be analyzed offline with a network capture. For 2110-20 streams, If the SDP object includes the announcement of the Media Type Parameter TR_{OFFSET}, it will be considered in the VRX results analysis.

Maximum allowable C_{MAX} and VRX_{FULL} for 2110-20 streams:

V	H	T	Color	bit	C_{MAX} N	C_{MAX} W	VRX_{FULL} N	VRX_{FULL} W
1280	720	50	4:2:2	8	4	16	8	720
1280	720	60	4:2:2	8	4	16	8	720
1280	720	50	4:2:2	10	4	16	8	720
1280	720	60	4:2:2	10	4	16	8	720
1920	1080	25	4:2:2	10	4	16	8	720

1920	1080	50	4:2:2	10	4	16	8	720
1920	1080	60	4:2:2	10	5	16	8	726
1920	1080	50	4:2:2	12	5	16	8	726
3840	2160	50	4:2:2	10	17	33	26	2420
3840	2160	60	4:2:2	10	21	40	32	2904
3840	2160	120	4:2:2	10	42	80	64	5808
3840	2160	120	4:4:4	12	75	145	116	10455
3840	2160	120	4:4:4	16	100	193	154	13940

Table 1 - Informative: SMPTE ST 2110-21:2017- Jan 25th, 2019

Pass criteria:

- The test passes if the maximum level of the network compatibility model does not exceed the maximum as described in the standard for the given type of sender (N, NL, W), the maximum level of the virtual receive buffer does not exceed the value described in the standard and the virtual receive buffer does not underrun.

No pass criteria:

- The measured value exceeds the defined maximum or the virtual receive buffer underruns or If the arrival time of the first packet for each frame or field is drifting (this indicates the sender may not be locked to PTP).

4.4. RTP-Timestamp-Test

Description: A stream initiated during test 4.1. is expected to have a media clock to RTP clock offset equal to zero (a=mediaclk:direct=0), The relation between the instantaneous RTP timestamp and PTP is expected to remain stable with time.

Validation Method: The instantaneous value of the RTP timestamp is analyzed by a test and measurement device and is related to the current PTP time. The instantaneous value of the RTP timestamp is expected not to be in the future, and not to be more than 1 ms in the past (unless there is a clear justification for it to be off, e.g frame synchronization). It is assumed that a stream has originated in the DuT and is not being “processed”. Therefore the question of re-timestamping is not considered.

Pass criteria:

- The instantaneous value of the RTP timestamp of the stream is not in the future, not more than 1 ms in the past (unless justified), and preserves a stable relation to the PTP (should not “drift”).

No pass criteria:

- The instantaneous value of the RTP timestamp of the stream is in the future, more than 1 ms in the past (unless justified), or “drifts”.

4_RX. ST 2110-20 Rx tests*

*Applicable only to DuT with video receiving capabilities for uncompressed (2110-20)

Description: This set of Tests validate the basic video receiving capabilities of the DuT.

First steps: The Vendor representative is given a multicast source IPv4 address(es), port number, and video format (1080i50 and/or 1080p50). The streams will be generated by the reference sender using either GPM or BPM. It is expected that the DuT is able to receive both. Standard MTU size will always be used. The stream will be a Narrow Gapped stream. Separate testing of UHD capabilities (2160p50) will be executed. It will be reflected accordingly in the results spreadsheet (e.g. 4.6-UHD-20).

4.5. Reception of GPM and BPM streams by 2110-20 receivers

Description: The 2110-20 DuT is expected to be able to receive the streams with both BPM and GPM used.

Validation Method: The reference stream can be received by the DuT without disruptions. Two reference streams will be provided, one with GPM, and one with BPM. Receivers should be able to receive both reference streams.

Pass criteria: The DuT passes the test if it is able to receive and display both streams (simultaneously, or one at a time) without disruptions. Devices which are not intended to display the stream will be allowed to suggest appropriate alternative criteria (e.g. loop it back into the network)

No pass criteria: The DuT fails the test if it is not able to receive and display either of two streams without disruptions, or suggest an appropriate alternative.

4.6. ST 2110-21 profile receiver compliance test Rx

Description: The Vendor representative is expected to set up the DuT to join a multicast group provided at the time of the test, in order to receive a stream generated by a reference sender.

Validation Method: The reference stream can be received by the DuT without disruptions.

If the presented DuT is presented as a Wide receiver, the reference sender will be set up as a Wide sender within the boundaries of prescribed values. If the presented DuT is presented as a Narrow receiver, the reference sender will be set up as a Narrow sender within the boundaries of the prescribed values.

Pass criteria: The DuT passes the test if it is able to receive and display the stream without disruptions. Devices that are not intended to display the stream will be allowed to suggest appropriate alternative criteria (e.g. loop it back into the network)

No pass criteria: The DuT fails the test if it is not able to receive and display the stream without disruptions, or suggest an appropriate alternative.

4.7. Stream visual validation Rx

Description: the DuT is expected to be able to receive and to decode reference stream(s). A basic subjective visual test is done. The stream is expected to have no obvious visual artifacts of digital nature or any other disruptions.
Validation method: A stream is visualized using the DuT. If the DuT is not capable of reproducing the stream, it is allowed to loopback the stream back into the network and the visual test is done on a reference device. The stream will be observed for at least ~60 seconds.
Pass criteria:

- The DuT is capable of receiving a stream according to its capabilities.
- The stream can be decoded by the DuT. The video signal is free from artifacts of a digital nature or any other disruptions.
- If the stream is looped back into the network - the looped stream can be decoded by a reference receiver. The video signal is free from artifacts of a digital nature or any other disruptions.

No pass criteria:

- The stream cannot be decoded and shows visible artifacts or any other disruptions. A Vendor representative will have an opportunity to articulate why this might be ok.

5_TX. ST 2110-22/JPEG-XS Tx tests

*Applicable only to DuT with 2110-22 JPEG-XS-compressed video transmitting capabilities..
Description: This set of tests validate the basic DuT’s conformance to ST 2110-22 (with JPEG XS).
First steps: The Vendor representative will be provided with a multicast IPv4 address, a port number, and video format parameters (1080i50 and/or 1080p50). DuT is expected to be able to initiate a stream with given parameters. Standard MTU size will always be expected. Separate testing of UHD capabilities (2160p50) will be executed. It will be reflected accordingly in the results spreadsheet (e.g. 4.2-UHD). The ST 2110-22/JPEG-XS streams shall conform to VSF TR-08 Section 7, 8.1, 9, and 10. A nominal rate of 3bpp shall be used. Conformance Level “All” and “FHD” shall both be “Capability Set A Intra-facility”.

5.1. Stream basic test Tx

Same as test 4.1 except with ST 2110-22/JPEG-XS stream.

5.2. Stream visual validation Tx

Same as test 4.2 except with ST 2110-22/JPEG-XS stream.

5.3. ST2110-21 profile sender compliance test Tx

Same as test 4.3 except no VRX testing will be done.

5.4. RTP-Timestamp-Test

Same as test 4.4 except with ST 2110-22/JPEG-XS stream.

5_RX. ST 2110-22/JPEG-XS Rx tests*

*Applicable only to DuT with the video receiving capabilities for 2110-22/JPEG-XS
Description: This set of Tests validates the basic video receiving capabilities of the DuT.
First steps: The Vendor representative is given a multicast source IPv4 address(es), port number, and video format (1080i50 and/or 1080p50). Standard MTU size will always be used. The stream will be a Narrow Gapped stream. Separate testing of UHD capabilities (2160p50) will be executed. It will be reflected accordingly in the results spreadsheet (e.g. 5.6-UHD-22).

5.5. Reception of streams by 2110-22 receivers

Same as test 4.5 except with ST 2110-22/JPEG-XS stream.

5.6. ST 2110-21 profile receiver compliance test Rx

Same as test 4.6 except with ST 2110-22/JPEG-XS stream.

5.7. Stream visual validation Rx

Same as test 4.7 except with ST 2110-22/JPEG-XS stream.

6_TX. ST 2110-30 Tx tests*

Description: This set of Tests validate the basic audio transmitting capabilities of DuT.
First steps: The Vendor representative is given a multicast destination IPv4 address(es)**, port number, channel configuration**, and audio packetization parameters (packet time)**. The bit depth of the stream is always expected to be 24 bit. Standard MTU size will always be expected. DSCP values for QoS are expected to be configured according to AES67: EF(46) for PTP packets, AF41 (34) for RTP packets, DF (0) for other traffic.
*Applicable only to DuT with audio transmitting capabilities

**Depending on DuT capabilities (e.g. if a device supports the transmission of up to 8 channels with 1ms or up to 64 channels with 125 us packet time - a random number, but not more than 8 channels with either 1ms or 64 channels with 125 us packet time may be selected to be tested.

6.1. Stream - Basic Test

Description: The Vendor representative is expected to configure the DuT such that it initiates a stream of a given configuration and to a given multicast address and port number. Packets of the stream are expected to have valid source and destination MAC and IPv4 addresses, and the DSCP values according to AES67-2015.
Validation method: the stream is analyzed in real-time (and/or captured and analyzed offline) from a mirrored port of the switch connected to the DuT. Source and destination MAC and IPv4 address as well as DSCP values are validated either by a test and measurement equipment or manually using Wireshark.
Pass criteria:

- DuT is capable of initiating a stream with given IPv4 address parameters, channel configuration, and audio packetization parameters.
- Stream uses a valid multicast MAC address.
- DSCP markings are set according to AES67.

No pass criteria:

- DuT is not capable of initiating a stream with given IP address parameters, channel configuration, and audio packetization parameters.
- Stream uses an invalid multicast MAC address.
- DSCP markings do not match AES67 requirements.

6.2. Stream - audible Validation Tx

Description: A stream initiated during test 5.1. is received with a reference receiver. A basic subjective audition test is done. The stream is expected to have no obvious audible artifacts of digital nature (pops, clicks, distortion) or any other disruptions.
Validation method: A stream is auditioned using headphones connected to a reference receiver for at least ~60 seconds. If a reference receiver is not capable of decoding the stream - a test and measurement device is used to analyze the stream.
Pass criteria:

- The stream can be received and decoded by a reference receiver and/or a majority of the test equipment. The audio signal is free from artifacts of a digital nature or any other disruptions.

No pass criteria:

- The stream cannot be decoded or has disruptions. A Vendor representative will have an opportunity to articulate why this might be ok.

6.3. ST 2110-30 sender jitter test Tx

Description: A stream generated during test 6.1. is expected to be compliant with packet delay variation limits. (see definition below)

Validation Method: The generated essence stream will be analyzed for good behavior according to AES67-2015 section 7.5. The stream will be analyzed (peak hold for at least 1 minute) or offline with a network capture of 1 minute. (Limitation: this does not catch long-term occasional jitter events)

Maximum allowable packet delay variation for ST 2110–30 streams (based on AES67-2015 section 7.5, here we define the terms “Should limit” and “Shall limit” in order to simplify the language in this section. with corresponding measures for Time Stamp Delay Factor (TSDF, EBU Tech 3337) and Packet Interval Time (PIT).

	“Should limit”	“Shall limit”
Senders allowed PDV	<= 1 PT	<= 17 PT
PT = 1 ms	TSDF <= 1 ms PIT: Max - Min =< 1 ms PIT Mean = 1 ms	TSDF <= 17 ms PIT: Max - Min =< 17 ms PIT Mean = 1 ms
PT = 125 us	TSDF <= 125 us PIT: Max - Min =< 125 us PIT Mean = 125us	TSDF <= 2.125 ms PIT: Max - Min <= 2.125 ms PIT Mean = 125us

Pass criteria:

- The test passes if the allowable packet delay variation does not exceed the measurements specified in the grid.

No pass criteria:

- The measured value exceeds the defined maximum.

6.4. ST 2110-30 RTP-Timestamp-test

Description: A stream initiated during test 5.1. is expected to have a media clock to RTP clock offset equal to zero (a=mediaclk:direct=0), The relation between the instantaneous RTP timestamp and PTP is expected to remain stable with time.

Validation Method: The instantaneous value of the RTP timestamp is analyzed by a test and measurement device and is related to the current PTP time. The instantaneous value of the RTP timestamp is expected not to be in the future. It should be measured between 1 packet time in the past and a tolerance corresponding to the encapsulation time (1 packet time), the allowed packet delay

variation for the corresponding sender type (“Should limit” or “Shall limit”), and some network travel time (up to 1 packet time), unless there is a clear justification for it to be off, e.g frame synchronization.

Sender as measured in 5.3	“Should limit”	“Shall limit”
	< 3 PT	< 20 PT
PT = 1 ms	Max Latency < 3 ms	Max Latency < 20 ms Avg Latency (over 1 s) < 2.5 ms*
PT = 125 us	Max Latency < 375 us	Max Latency < 2.5 ms

*additional average control to keep A/V sync possible

Pass criteria:

- The instantaneous value of the RTP timestamp of the stream is not in the future, not more than the Maximum in the table in the past (unless justified), and preserves a stable relation to the PTP (should not “drift”). In addition, for “Shall limit”, the average value of the RTP timestamp (over 1 second) is less than 2.5 ms in the past.

No pass criteria:

- The instantaneous value of the RTP timestamp of the stream in the future, or in the past by more than the corresponding value in the table (unless justified), or “drifts”.

6_RX. ST 2110-30 Rx tests*

Description: This set of Tests validates the basic audio receiving capabilities of DuT.
First steps: The Vendor representative is given multicast source IPv4 addresses**, port number, channel configuration**, RTP payload ID, and audio packetization parameters (packet time)**. The streams will be generated by the reference sender. The bit depth of the streams is always 24 bit. Standard MTU size will always be used.

*Applicable only to DuT with audio receiving capabilities

**Depending on DuT capabilities (e.g. Level A - 1 to 8 channels with 1 ms packet time, Level B - 8 channels with 125 us packet time, Level C - 64 channels with 125 us packet time)

6.5. Stream - audible Validation Rx

Description: the DuT is expected to be able to receive and decode reference stream(s) with the given parameters. It is expected that the DuT will either allow configuration of the incoming RTP payload ID or will promiscuously accept any incoming RTP payload ID. A basic subjective audition test is done. The stream is expected to have no obvious audible artifacts of digital nature (pops, clicks, distortion) or any other disruptions. The DuT is not expected to reproduce all channels from the stream if it is not designed to do so (e.g. a stereo-output device will be expected to receive an 8-channel stream, but output a minimum of selected 2 channels).

Validation method: A stream is auditioned using headphones connected to the DuT for ~60 seconds. If a DuT outputs audio embedded in SDI - an SDI analyzer will be used. For receivers that do not provide audio output, a Vendor representative will be allowed to suggest an alternative method to verify fidelity. The Testing team must approve any alternative methods.

Pass criteria:

- The DuT is capable of receiving streams according to its capabilities (Level A, B, or C)
- The streams can be received and decoded by the DuT. The audio signal is free from artifacts of a digital nature or any other disruptions.
- If a stream is looped back into the network - the looped stream can be decoded by a reference receiver. The audio signal is free from artifacts of a digital nature or any other disruptions.

No pass criteria:

- The stream cannot be received and decoded or has disruptions. A Vendor representative will have an opportunity to articulate why this might be ok.

7_TX. ST 2110-31 Tx tests*

Description: This set of Tests validate the capabilities of the DuT to transmit bit-transparent audio while preserving the AES3 channel status bits. All ST 2110-31 tests will be done using 24-bit PCM audio. Non-PCM formats (e.g. Dolby E) are out of the scope of these tests.

First steps: The vendor representative is given a multicast destination IPv4 address(es)**, port number, channel configuration**, and audio packetization parameters (packet time)**. The bit depth of the stream is always expected to be 32 bit (according to AM824). Standard MTU size will always be expected. The transmitter must have a bit transparent base-band interface to source the test signal (AES, MADI, or SDI).

*Applicable only to DuT with audio transmitting capabilities

**Depending on DuT capabilities (e.g. if a device supports the transmission of up to 6 channels with 1ms or up to 60 channels with 125 µs packet time - a random number, but not more than 6 channels with either 1ms or 60 channels with 125 µs packet time may be selected to be tested.

7.1. ST 2110-31 sender jitter test Tx

Same as test 6.3 except with ST 2110-31 stream.

7.2. ST 2110-31 RTP-Timestamp-test

Same as test 6.4 except with ST 2110-31 stream.

7.3. Stream - Basic Test

Description: The Vendor representative is expected to configure the DuT such that it initiates a stream of a given configuration and to a given multicast address and port number. Packets of the stream are expected to have valid source and destination MAC and IPv4 addresses.
Validation method: A stream is analyzed in real-time (and/or captured and analyzed offline) from a mirrored port of the switch connected to the DuT. Source and destination MAC and IPv4 addresses are validated either by a test and measurement equipment or manually using Wireshark.
Pass criteria:

- DuT is capable of initiating a stream with given IPv4 address parameters, channel configuration, and audio packetization parameters.
- Stream uses a valid multicast MAC address.

No pass criteria:

- DuT is not capable of initiating a stream with given IP address parameters, channel configuration, and audio packetization parameters.
- Stream uses an invalid multicast MAC address.

7.4. Stream - audible Validation Tx

Description: A stream initiated during test 7.3. is received with a reference receiver. A basic subjective audition test is done. The stream is expected to have no obvious audible artifacts of digital nature (pops, clicks, distortion) or any other disruptions.
Validation method: A stream is auditioned using headphones connected to a reference receiver for at least ~60 seconds. If a reference receiver is not capable of decoding the stream - a test and measurement device is used to analyze the stream.
Pass criteria:

- The stream can be received and decoded by a reference receiver and/or a majority of the test equipment. The audio signal is free from artifacts of a digital nature or any other disruptions.

No pass criteria:

- The stream cannot be decoded or has disruptions. A Vendor representative will have an opportunity to articulate why this might be ok.

7.5. Bit-Transparency-test

*Test 7.5 is only applicable to the devices that pass the ST 2110-31 streams from the baseband into IP. In case a DUT does not have any baseband connectivity, test 7.5 is not applicable.
Description: A stream initiated during test 7.3 is expected to have an audio encoding according to AM824, including AES3 channel status bits.

Validation Method: The DuT will be provided with a 32-bit test signal (AES3, either natively or embedded in MADI or SDI, depending on the capabilities of the DuT). The stream generated by the DuT will be received by the reference receiver and converted bit-transparently into MADI. The resulting AES3 bitstream will be analyzed with a Bit Scope and compared to the test signal.
Pass criteria:

- The reference receiver can receive the stream properly and generate a valid AES3 signal from it without altering any data.
- Bit Scope analysis shows valid AES3 user bits and audio on all 24 remaining bits.

No pass criteria:

- It is not possible to re-generate a valid AES3 signal from the incoming stream.
- Bit Scope analysis shows invalid AES3 channel status data.

7_RX. ST 2110-31 Rx tests*

Description: This set of Tests validate bit-transparent audio receiving capabilities of DuT.
First steps: The DuT must provide a bit-transparent baseband interface, such as AES3, MADI, or SDI. The Vendor representative is given a multicast source IPv4 address(es), port number, channel configuration**, audio packetization parameters (packet time)**, and the RTP payload ID. The streams will be generated by the reference sender. The bit depth of the stream is always 32 bit (according to AM824). Standard MTU size will always be used.
*Applicable only to DuT with audio receiving capabilities
**Depending on DuT capabilities (e.g. Level A - 6 channels with 1 ms packet time, Level B - 8 channels with 125 us packet time, Level C - 60 channels with 125 us packet time)

7.6. Stream - audible Validation Rx

Description: The DuT is expected to be able to receive and decode reference stream(s). It is expected that the DuT will either allow configuration of the incoming RTP payload ID or will promiscuously accept any incoming RTP payload ID. A basic subjective audition test is done. The stream is expected to have no obvious audible artifacts of digital nature (pops, clicks, distortion) or any other disruptions. The DuT is not expected to reproduce all channels from the stream if it is not designed to do so (e.g. a stereo-output device will be expected to receive a 6-channel stream, but output a minimum of selected 2 channels).
Validation method: A stream is auditioned using headphones connected to the DuT for at least ~60 seconds. If a DuT outputs audio embedded in SDI - an SDI analyzer will be used. For receivers that do not provide audio output, a Vendor representative will be allowed to suggest an alternative method to verify fidelity. The Testing team must approve any alternative methods.
Pass criteria:

- The DuT is capable of receiving a stream according to its capabilities (Level A, B, or C)
- The stream can be decoded by the DuT. The audio signal is free from artifacts of a digital nature or any other disruptions.

- If the stream is looped back into the network - the looped stream can be decoded by a reference receiver. The audio signal is free from artifacts of a digital nature.

No pass criteria:

- The stream cannot be decoded or has disruptions. A Vendor representative will have an opportunity to articulate.

7.7. Bit transparency validation Rx

*Test 7.7 is only applicable to the devices that pass the ST 2110-31 streams from IP into baseband. In case a DUT does not have any baseband connectivity, test 7.7 is not applicable.

Description: The DuT is expected to receive the reference stream and generate a valid AES3 compliant signal with unaltered channel status data from it. The AES3 signal may be embedded in MADI or SDI, depending on the capabilities of the DuT.

Validation method: The re-generated base-band signal is converted to MADI without altering the data and measured with a Bit Scope.

Pass criteria:

- The re-generated base-band signal is detected as a valid AES3 signal with 24-bit audio and contains correct channel status information.

No pass criteria:

- The re-generated base-band signal is not decodable as a valid AES3 signal.
- Bit Scope measurement shows incorrect channel status information.

8_TX. ST 2110-40 Tx tests*

Description: This set of Tests is expected to validate the basic ancillary data transmitting capabilities of the DuT. The actual services used during the tests will be provided at a later stage.

First steps: The Vendor representative is given a multicast destination IPv4 address(es) and a port number. Standard MTU size will always be expected.

*Applicable only to DuT with ancillary data transmitting capabilities

** 1080i50 stream will be used for this test

8.1. Stream -40 validation Tx

Description: The Vendor representative is expected to be able to configure the DuT such that it initiates a valid ancillary data stream with a given multicast address and port number. The Vendor representative will announce the used DID/SDIDs values to the testing team. It is suggested, but not required, to fulfill the requirement by transmitting 4302 OP47 Teletext subtitling data for 1080i50 “PAL” frame rates.

Validation Method:

- The ancillary data stream is received by a T&M device to validate the stream.

Pass criteria:

- The stream contains the DID/SDIDs matching the prior Vendor representative’s description

- The stream uses legal values for all SDI line and sample fields
- The stream uses the 'marker' and 'field' bits correctly for the intended video standard
- The stream payload errors are not detected

No pass criteria:

- The stream DID/SDIDs values do not match prior Vendor representative’s description
- The stream does not use legal values for all SDI line and sample fields
- The stream does not use the 'marker' and 'field' bits correctly for the intended video standard
- The stream payload errors are detected

8.2 RTP Timestamp Test

Description: A stream initiated during test 8.1 is expected to have a media clock to RTP clock offset equal to zero (a=mediaclk:direct=0). The relation between the instantaneous RTP timestamp and PTP is expected to remain stable with time.
Validation Method: The instantaneous value of the RTP timestamp is analyzed by a test and measurement device and is related to the current PTP time. The instantaneous value of the RTP timestamp is expected not to be in the future, nor to be more than 35 milliseconds in the past.
Pass Criteria:

- The instantaneous values of the RTP timestamps of the stream are not in the future relative to PTP-locked packet capture time, are not more than 35 milliseconds in the past, and preserve a stable relation to PTP over the course of the capture (should not “drift”).

No Pass Criteria:

- The instantaneous value of the RTP timestamps in the stream are in the future relative to PTP-locked packet capture time, are more than 35 milliseconds in the past, or drift over the course of the capture.

8_RX. ST 2110-40 Rx tests*

Description: This set of Tests validates the basic ancillary data receiving capabilities of DuT. The actual services used during the tests will be provided at a later stage.
First steps: A Vendor representative is given a multicast IPv4 address(es) and a port number of a valid ancillary data stream. Standard MTU size will always be used.
*Applicable only to DuT with ancillary data receiving capabilities
** 1080i50 stream will be used for this test

8.3. Stream -40 validation Rx

Description: The Vendor representative is expected to configure the DuT to join an SMPTE ST 2110-40 stream generated by a reference sender. It is expected that the DuT will either allow configuration of the incoming RTP payload ID or will promiscuously accept any incoming RTP payload ID. A single source multicast stream will be provided that contains 6101 North American closed captions (CTA-608/708) with actual text in them, plus at least one other 'surprise' DID/SDID.

Validation Method: the DuT is expected to demonstrate at least one of the following features to demonstrate successful reception and use of the packets:

- Pass the contents of the received stream through without data loss to a transmitted 2110-40 stream that meets the requirements of the transmitter test (sections 8.1 and 8.2)
- Display the text of the closed captions on a monitoring terminal or video overlay.
- Output the ANC packets into SDI video where they can be observed by the reference SDI receiver to contain all data from the reference 2110-40 stream, including preservation of line numbers and horizontal positioning from the 2110-40 packet
- Provide a "packet list" display that at a minimum shows the complete list of DID/SDIDs found in the multicast to demonstrate correct reception

Pass criteria:

- the DuT is capable of receiving and decoding an ancillary data stream as demonstrated by one of the methods described in the Validation Method without disruptions.

No pass criteria:

- the DuT is not capable of receiving an ancillary data stream, cannot demonstrate proper reception and interpretation of the stream through any of the features described in the Validation Method, or demonstrates data loss, corruptions or disruptions in passing through or interpreting the reference transmission.

9. ST 2022-7 tests*

Description: This set of tests validates that the DuT is able to properly transmit and receive redundant (Red path and Blue path) video (-20, -22), audio (-30, -31), and/or ancillary (-40) streams according to the SMPTE ST 2022-7**.** This test will be applied to all devices with respected 2022-7 capabilities alongside the basic essence tests (4_TX, 4_RX, 5_TX, 5_RX, 6_TX, 6_RX, 7_TX, 7_RX, and/or 8_TX, 8_RX).

First steps: a Vendor representative is given a set of multicast IPv4 addresses and port numbers. The DuT will be expected to initiate or receive an ST 2022-7 compliant redundant stream with a given set of parameters. The essence type will be picked according to the type of tests performed alongside (4_TX, 4_RX, 5_TX, 5_RX, 6_TX, 6_RX, 7_TX, 7_RX, and/or 8_TX, 8_RX). It is expected that the DuT has no multicast IP addressing limitations when receiving or generating ST 2022-7 streams (within the limits of the tests 2.4 and 2.5 and independently for both interfaces)

*Applicable only to DuT with -20, -22, -30, -31 and/or -40 senders with 2022-7 capability

9.1. Stream - Basic Redundancy Test Tx*

Description: This test validates that the DuT is able to properly transmit redundant (Red path and Blue path) video (-20, -22), audio (-30, -31), and/or ANC (-40) ST2022-7 streams**.** The DuT is expected to be able to initiate a redundant stream with different destination multicast IPv4 and MAC addresses on Red Path and Blue Path. The unicast source IPv4 and MAC addresses of the Red Path and Blue Path are expected to be different.

Validation Method: The Red and Blue streams generated by the DuT will be analyzed with a T&M device and/or received by a reference receiver(s) to determine if both streams are compliant with ST 2110-20, -22, -30, -31 or -40, depending on the essence under test.

Pass criteria:

- A reference receiver is able to correctly receive and process both streams as a valid ST-2022-7 pair.
- It is possible to independently assign destination multicast IPv4 addresses on both interfaces within the limits of tests 2.4 or 2.5.
- The DuT is able to initiate a valid redundant stream with different destination multicast IPv4 and MAC addresses on Red Path and Blue Path.
- The unicast source IPv4 and MAC addresses of the Red Path and Blue Path are different.

No pass criteria:

- A reference receiver is not able to correctly receive and process both streams as a valid ST-2022-7 pair.
- It is not possible to independently assign destination multicast IPv4 addresses on both interfaces within the limits of tests 2.4 or 2.5.
- The DuT is not able to initiate a valid redundant stream with different destination multicast IPv4 and MAC addresses on Red Path and Blue Path.
- The unicast source IPv4 and MAC addresses of the Red Path and Blue Path are the same.

*Applicable only to DuT with -20, -22, -30, -31 and/or -40 senders with 2022-7 capability

9.2. Stream - Basic Redundancy Test Rx*

Description: This test validates that the DuT is able to properly receive redundant (Red path and Blue path) video (-20), audio (-30), and/or ANC (-40) ST2022-7 streams with a different source, multicast, IPv4 and MAC addresses on Red Path and Blue Path initiated by a reference sender**.** The unicast source IPv4 and MAC addresses of the Red Path and Blue Path will be different. The DuT is expected to have different unicast IPv4 and MAC addresses on redundant ports.

Validation Method: One of the switch interfaces, to which the DuT is connected, is disabled (logically, not physically). It is expected that DuT will demonstrate no disruption in stream reproduction. Visual reporting, video/audio output, and/or logging of the DuT will be used to validate proper redundant stream receiving. The MAC address table of a switch is used to validate if redundant ports of the DuT have different MAC addresses.

Pass criteria:

- It is possible to independently assign source multicast IPv4 addresses on both interfaces within the limits of tests 2.4 or 2.5.
- The DuT Receiver is able to properly receive a redundant (Red Path and Blue Path) video, audio, and/or ancillary stream with different host IPv4 addresses and multicast mac addresses without errors.
- The DuT demonstrates no disruption in the stream reproduction after losing one of the paths.
- The unicast IPv4 and MAC addresses of redundant ports of the DuT are different.

No pass criteria:

- It is not possible to independently assign source multicast IPv4 addresses on both interfaces within the limits of the tests 2.4 or 2.5.
- The DuT Receiver is not able to properly receive a redundant (Red Path and Blue Path) video, audio, and/or ancillary stream with different host IPv4 addresses and multicast mac addresses.
- The DuT demonstrates disruption in the stream reproduction after losing one of the paths.
- The unicast IPv4 and MAC addresses of redundant ports of the DuT are the same.

*Applicable only to DuT with -20, -22, -30, -31 and/or -40 senders with 2022-7 capability

9.3. Seamless Protection Switching Test

Description: This test validates that the DuT receiver has properly implemented Seamless Protection Switching (Hitless Protection) on ST 2022-7 redundant streams (Red path and Blue path) video (-20), audio (-30), and ancillary (-40) when both paths are impaired with a network emulator. The following impairments may be applied:

- Synchronized Alternating Loss of 25%:
    - Packet loss using RTP Sequence Number Pattern on Red Path (XXXX XXXX 00XX XXXX) and Blue Path (XXXX XXXX 11XX XXXX). This results in a 25% packet loss and ensures that different packets are dropped in each path.
    - For self-testing/independent testing - Any other method to achieve a 25% synchronized alternating packet loss may be used.
- Differential Latency with Synchronized Alternating Loss of 25%
    - Packet loss using RTP Sequence Number Pattern on Red Path (XXXX XXXX 00XX XXXX) and Path 2 (XXXX XXXX 11XX XXXX) with Delay of 150μs in Blue Path. This results in a 25% packet loss, ensures that different packets are dropped in each path, and provides a delta delay of 150μs between paths.
    - For self-testing/independent testing - Any other method to achieve 25% synchronized alternating packet loss and a delta delay of 150μs between paths may be used.
- Differential Latency and Packet Delay Variation (PDV/Jitter) with Synchronized Alternating Loss of 25%.
    - Packet loss using RTP Sequence Number Pattern on Red Path (XXXX XXXX 00XX XXXX) and Blue Path (XXXX XXXX 11XX XXXX) with Delay of 90μs and Jitter (Non-Reordering) of 60μs. This results in a 25% packet loss, ensures that different packets are dropped in each path, and provides a delta delay of 150μs and a Jitter of 60us between paths.
    - For self-testing/independent testing - Any other method to achieve 25% synchronized alternating packet loss, a delta delay of 150μs between paths and a non-reordering jitter of 60μs may be used.

Informative:
As with the rest of the test plan, prior to the event, a participant should self-test their RX DuT with any test case that demonstrates ST 2022-7 functionality. A test case that demonstrates ST 2022-7 functionality is a test case that causes dropped packets on both links and the same RTP sequence number is not dropped on both links. The possible tests that can be executed with any network emulator include but are not limited to:

- *The "zebra" pattern explained above*
- *Alternate dropping a frame on each link*
- *Dropping all the RTP marker packets on Red Path and dropping some non-marked packets on the Blue Path*
- *Dropping 3 packets on Red Path, then 6 packets on Blue Path, then repeat*
- *Dropping 11 packets on Red Path then 22 packets on Blue Path, then repeat*
- *Dropping packets on Red Path for 10 seconds and then dropping packets on Blue Path for 10 seconds*

During the on-site validation the following tests will be applied given the availability of specialized equipment:
9.3.1 Synchronized Alternating Burst Loss of 25%.
9.3.2 Differential Latency with Synchronized Alternating Burst Loss of 25%.
9.3.3 Differential Latency and Packet Delay Variation (PDV/Jitter) with Synchronized Alternating Burst Loss of 25%.

Test #	Sync Burst Loss (Continuous)	Path 1 RTP Seq Number Pattern	Path 2 RTP Seq Number Pattern	T1	Imp	T2	Imp	T3	Imp	Drop Now (Pkts) Red Path	Delay (us) Blue Path	PDV (us) Blue Path NRO Peak
8.3.1B	25%	XXXX XXXX 00XX XXXX	XXXX XXXX 11XX XXXX	5s	no	10s	dec	10s	no	1000		
8.3.2 B	25%	XXXX XXXX 00XX XXXX	XXXX XXXX 11XX XXXX	5s	no	10s	dec	10s	no	1000	150	
8.3.3B	25%	XXXX XXXX 00XX XXXX	XXXX XXXX 11XX XXXX	5s	no	10s	dec	10s	no	1000	90	60

Table 2 - Informative: Sample of the Network Emulator Setup used on-site

Informative:
Testing for loss of ancillary data will be performed during on-site validation using a special closed caption pattern with densely packed text data to make it easier to see any discontinuities in the receiver output using only a standard on-screen caption decoder (IP or SDI). Sample clips demonstrating this data will be made available to participants ahead of the test. However, in

self-test vendors may use any ancillary packet data stream along with a method that will reliably detect discontinuities in this data stream.

Validation Method: Where available/applicable - video/audio/ancillary output will be observed to validate a proper implementation of Seamless Protection Switching (Hitless Protection) of redundant ST 2022-7 streams. Visual reporting and/or logging of the DuT may also be used.

Pass criteria:

- The DuT receiver is able to properly and without any disruption receive a redundant ST 2022-7 streams with test conditions 9.3.1, 9.3.2, and 9.3.3

No pass criteria:

- The DuT receiver is not able to properly receive redundant ST 2022-7 streams with test conditions 9.3.1, 9.3.2 and 9.3.3 without errors (video artifacts, audio artifacts and/or loss of ancillary data) or any other disruption.