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New Era of ST 2110 Compliance Testing With PICS and RP 2110-25

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Introdução:

Este artigo é um grande achado, praticamente um guia de boas práticas para ST 2110. Explico! A SMPTE está criando **Declarações de Conformidade de Implementação** desse protocolo, o que eles chamam de PICS, para o conjunto de padrões. Estão escrevendo Práticas de Recomendação (RP) da 2110-25 (Mídia Profissional sobre Redes IP Gerenciadas). O artigo descreve o trabalho e os resultados alcançados na forma de documentos (PICs) para o conjunto de padrões ST 2110 e o documento RP 2110-25, visando melhorar a testagem e a medição das implementações ST 2110. Dessa forma você vera como garantir a conformidade e a interoperabilidade das implementações, incluindo a experiência adquirida durante vários eventos de testes, alem, é claro, das explicações de como esses eventos de interoperação aconteceram. Como eu disse um verdadeiro achado!! Boa leitura.

Tom Jones Moreira

Abstract

The overall adoption of SMPTE ST 2110 standards and the Advanced Media Workflow Association Networked Media Open Specifications (AMWA NMOS) grows. To serve the industry with a better understanding of these standards and specifications, the Joint Task Force on Networked Media (JT-NM) introduced the JT-NM Tested program. After running the "Tested Program" several times, a number of pain points became clear. These underpinned feedback on the documents and other questions, such as how to improve and scale up this kind of event. To assist with this, SMPTE is creating Protocol Implementation Conformance Statements (PICS) for the ST 2110 standard suite, recommended practice (RP) 2110-25 (Professional Media Over Managed Internet Protocol (IP) Networks: Measurement Practices), and the JT-NM has the JT-NM Tested program. The article outlines the work and the achieved results in the form of PICS documents for the SMPTE ST 2110 standard suite and the RP 2110-25 document to provide for better testing and measurement of SMPTE ST 2110 implementations. We discuss the ways to ensure compliance and interoperability of implementations, including the experience gained during several JT-NM Tested events. We explain how these interop events are operated, the value they bring, and how the PICS will enhance such future events. Another important aspect is monitoring and measuring the implementations' operation parameters, such as packet pacing. A specific problem discussed is the uniformity and consistency of such measurements among the different SMPTE ST 2110 equipment vendors.

Keywords

European Broadcasting Union (EBU), interoperability, Joint Task Force on Networked Media (JT-NM), protocol implementation conformance statements (PICS), SMPTE

> **The JT-NM Tested program is a partnership between the JT-NM and industry vendors to provide information that aids the transition from SDI to IP.**

Introduction

The Joint Task Force on Networked Media (JT-NM) Tested program, organized by the JT-NM,[1,2] gave rise to substantial confusion among test and measurement manufacturers. It soon became apparent that similar measurements had different names, that the polarity of the formula had been reversed, or that the algorithm used looked at the problem so differently that different results were observed. Not a big deal in itself, but when measuring electrical voltage, for example, one expects the same number of volts with each device from each manufacturer. It became clear that, if customers were given test and measurement sets from different manufacturers, this situation would not contribute to great confidence. There was clearly a need for a common nomenclature, well-defined formulas, and algorithms to unambiguously measure ST 2110[3]-capable devices. Another important learning point from these tested events was how to scale up events like this, enabling self-testing, and determine what portions of the standard are optional and necessary. The latter may sound obvious, but even among seasoned experts, it was not always clear.

As a solution to these problems, SMPTE launched two new initiatives. On the one hand, a recommended practice (RP) for media-over-Internet Protocol (IP), ST 2110 measurements (SMPTE RP 2110-25), and, on the other hand, a "protocol implementation conformance statement" (PICS)[4] per document in the ST 2110 suite.

What is JT-NM Tested and Updates to the ST 2110 Testing

The JT-NM Tested program is a partnership between the JT-NM and industry vendors to provide information that aids the transition from serial digital interface (SDI) to IP.

As the industry's use of IP matures, the JT-NM Tested program offers prospective purchasers of

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IP-based equipment well-documented insights into the extent to which vendor equipment conforms to the relevant SMPTE standards, Advanced Media Workflow Association Networked Media Open Specifications (AMWA NMOS)[5] specifications, and industry recommendations.

The first two iterations of the JT-NM Tested program took place in April 2019, prior to the 2019 National Association of Broadcasters (NAB) Show, and in August 2019, prior to International Broadcasting Convention (IBC) 2019. The third iteration was held virtually in March 2020 due to the COVID-19 pandemic. The fourth edition has taken place once again as an in-person event in Wuppertal, Germany, in August 2022, prior to IBC 2022.

The program is sponsored by the JT-NM and administered by the European Broadcasting Union (EBU) in partnership with experts from Vlaamse Radio en Televisie (VRT) (Flemish Radio and Television),[i] Canadian Broadcasting Corporation (CBC)/Radio Canada,[ii] British Broadcasting Corporation (BBC) Research and Development,[iii] Rundfunk-Betriebstechnik (RBT),[iv] and multiple industry vendors.

The success of the JT-NM Tested program is evident through the recognition it has gained, both in the industry and in user communities, as a major driving force for the adoption of open media-over-IP standards and specifications. The results published in the JT-NM Tested catalogs are now widely used as a key input for request for information (RFI) and request for proposals (RFP) processes.

The previous JT-NM Tested program iterations were targeted exclusively toward testing endpoints. It is assumed and expected that the on-site network, IEEE 1588 Precision Time Protocol (PTP),[6] and test and measurement infrastructure are robust and transparent. However, in an attempt to broaden the scope of the program and encourage a unified, open control plane adoption, the March 2020 event has included testing of some network services (NMOS IS-04[7] registries) and broadcast controllers. These additional tests have now become the integral part of the NMOS testing in the fourth edition of the program.

While the initial ambition for the August 2022 testing round was to base the new ST 2110 test plan fully on new PICS[4] and introduce a new format for testing, unfortunately, it had to be dialed down due to the complexity of the complete testing procedures overhaul. Instead, the team decided to gradually roll out the alignment with the PICS[4] document over the next program rounds.

However, some major test and measurement additions and changes were still introduced in the August 2022 program edition. Support for ST 2110-22[8] with JPEG XS[9] testing has been added, and support for ST 2110-31[10] testing was finalized. Some additional real-world PTP testing scenarios have been added. While the RP 2110-25 was not officially published at the time of testing, the teams took the opportunity to conduct an industry-wide alignment and interoperability exercise, demonstrating the relevance and importance of this recommendation. Additionally, the use of RP 2059-15[11] was strongly recommended at the event.

Cybersecurity remains an essential and integral part of the JT-NM Tested program. The industry is rapidly moving into the new reality of broadcast information technology (IT) with the inherited risks like a networked device not fully patched becoming a possible entry point or an attack vector into the rest of the media network. Therefore, every device connected to the event's media or management network is evaluated and scanned. The equipment vendors are expected to fill in a specially designed questionnaire that aims to give the cybersecurity team a perspective and a context of how a device is expected to behave in the network, what ports are kept open and for what reasons, and how a device is updated and managed. This helps eliminate false-positive results and also allows the cybersecurity team to draw more educated conclusions on a particular product. While the individual results are not published for obvious reasons, the team thoroughly investigates every threat discovered and follows up with a vendor to clarify and suggest potential mitigation plans. The overall results are then anonymized and published in a general state of the industry report.

Protocol Implementation Conformance Statements

A PICS[4] is a structured document that asserts what specific requirements are met by a given implementation of a protocol standard. In other words, PICS provides a checklist of the standard's requirements, a form that the author of the implementation fills out to indicate whether all of the mandatory requirements were met in the process of implementing the standard, which optional requirements were implemented and which were not, and whether the standard provides a choice of two or more options for the implementation (or a range of values for some parameter of the standard).

PICS benefits the users and the implementers in several ways. First, it is a way to help the implementers to make sure that none of the mandatory requirements were missed or overlooked. PICS documents also provide additional clarifications to the standards. PICS documents provide an invaluable source of comprehensive information regarding the implementation, which might be used, for example, in the procurement process, or when choosing one of the many available implementations. Finally, this helps ensure interoperability among different implementations.

PICS is widely used in the IT industry, for example, every IEEE 802 document, including the ethernet

[i] https://www.vrt.be/

[ii] https://cbc.radio-canada.ca/

[iii] https://www.bbc.co.uk/rd

[iv] https://www.rbt-nbg.de/

sections, must have a PICS proforma. The first standard in the media-over-IP production family of standards to get a PICS proforma was AES67 in its 2018 version.[12] SMPTE used this PICS as an example. ST 2110 PICS looks similar to AES67-2018, and most of the concepts are the same, but we also did some things differently. Most importantly, we got away from providing the "not applicable" option in the answers to every requirement. As the previous experience with JT-NM Tested events showed, very often, this became a topic of long discussions regarding the implementations—whether a specific requirement was applicable to this exact implementation or not. So, instead, where this was necessary, we limited the scope of implementations, for which each specific requirement was applicable by asking questions. The answer to such a question is supposed to deterministically designate if this specific requirement is applicable to this specific implementation or not.

In the approach that we took, we have put every requirement from the standard in a table (**Tables 1** and **2**). Each row of the table is one separate requirement from the standard. The requirements are listed in the second column of this table. The first column is used to give a number to every requirement. This is already important because it makes it easier to refer to a specific need (clause) in the standard. The third column is used to categorize every requirement—whether this is a mandatory requirement (the one that includes the keywords "shall" or "shall not"), a strong suggestion ("should" or "should not"), optional ("may" or "need not"), or whether it is an informational clause or requires no test to prove the compliance of the implementation. The fourth column is used to clarify the requirement, where deemed useful, and gives guidance on how to properly answer the main question of the PICS proforma, which is the final fifth column—whether this requirement is supported in the implementation or not. The last two columns are also sometimes used to provide additional details about the implementation, such as in the case where one of the multiple options is to be selected for the implementation.

There are two approaches to formatting PICS—sometimes, it is an annex to the standard itself, and in other cases, it is a separate document. We chose the latter approach. Each ST 2110 PICS will constitute a separate RP document, which will have the number of the original document plus 100 (100 + *X*, where *X* is the number after the dash in ST 2110-X document designation). For example, the PICS for ST 2110-10[13] is RP 2110-110.

While working on a set of PICS documents for the ST 2110 family of standards, there were additional findings. Most importantly, the process of creating PICS helped improve the standards themselves by providing feedback

Table 1. Section of the PICS proforma for ST 2110-10.

Statement Number	Feature	Requirement Level	PICS Response Instructions and Questions	Supported
6.1-1	The network interfaces of devices specified in this standard shall support IPv4, wherein streams are transported using IP version 4 as specified in IETF RFC 791.	1	Mark as supported if the device supports IPv4.	Yes [X] No [ ]
6.1-2	Devices should support IPv6 as specified in IETF RFC 2460	2	Mark as supported if the device supports IPv6.	Yes [ ] No [X]
6.2-1	All of the streams specified in this standard shall use the Realtime Transport Protocol as specified in IETF RFC 3550.	1	Mark as supported if the device supports streams that use the Realtime Transport Protocol.	Yes [X] No [ ]

Table 2. Section of the PICS proforma for ST 2110-10, with the questions limiting the scope of implementations to which the requirement is applicable.

Statement Number	Feature	Requirement Level	PICS Response Instructions and Questions	Supported
6.3-3	All receivers shall be capable of receiving UDP packets up to the standard UDP size limit.		Does the device contain one or more receivers?	Yes [X] No [ ]
		1	Mark as supported if the device is capable of receiving UDP packets up to the size of 1,460 octets.	↳ Yes [X] No [ ]
6.3-4	Senders shall ensure that there are no fragmented IP packets in the egress interface of the sender, notwithstanding the provisions of IETF RFC 791 which might allow them.		Does the device contain one or more senders?	Yes [ ] No [X]
		1	Mark as supported if the device ensures that there are no fragmented IP packets in its egress interface, notwithstanding the provisions of IETF RFC 791 which might allow them.	↳ Yes [ ] No [ ]

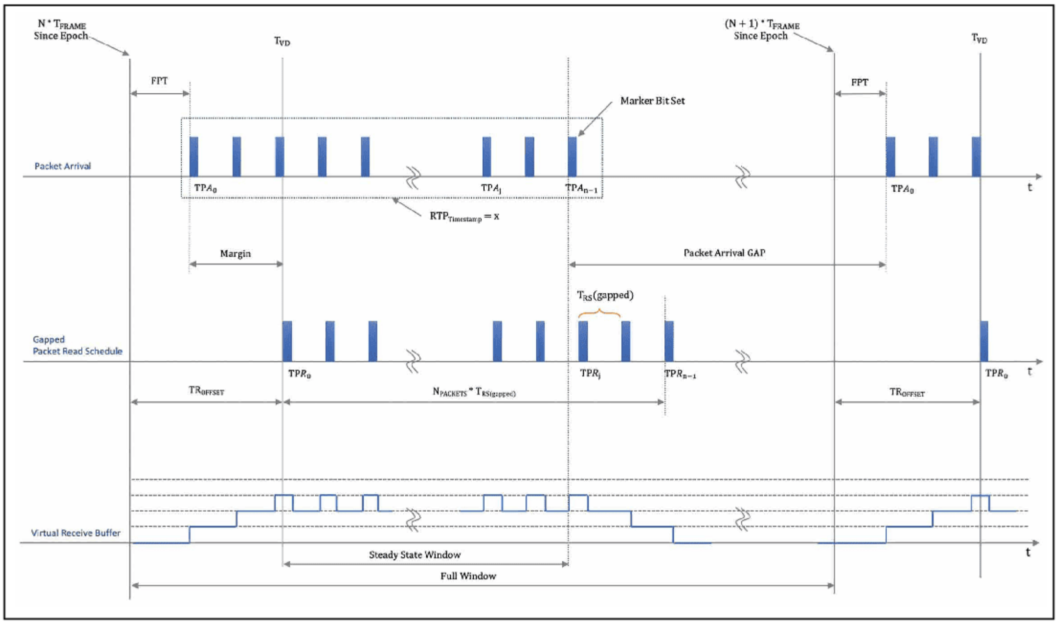

FIGURE 1. Diagram illustrating different measurements.

to the 32NF committee. The PICS group had to carefully look over each requirement, allowing for the identification and correction of typos, minor inconsistencies, or even more serious issues. This way, PICS contributes to the improvement of not only standard implementations, but also of the standards themselves. Based on their observations, the authors recommend that PICS be included in every new SMPTE standard that is released in the future.

SMPTE RP 2110-25

What are We Trying to Fix?

During the conceptual phase, construction, or during the operational life of an IP-based media facility, one needs test and measurement equipment. During the 2019 JT-NM Tested Event in Houston, the test team had access to not only a variety of test equipment, each with his or her specific specialty, but also a fair amount of overlap of measurements. The overlapping measurements were conveniently used not only to ensure consistency of test and measurement equipment, on the one hand, but also to simply have confirmation of the measurement, on the other hand. It did not take much time before the test team had to deal with substantial confusion.

Most of the test kits had been created in parallel with the writing of the SMPTE ST 2110 standard suite. Since nomenclature and formulas may be in flux until the document is published or simply do not specify a practical test for a particular concept being introduced, not all test and measurement kits use exactly the same nomenclature or formulas that probably should do the same thing.

Diagram

The diagram in **Fig. 1** consists of three parts. The upper part of this diagram demonstrates when packets arrive at the ethernet interface at the receiver. The middle part is what we know from the SMPTE ST 2110-21[14] document: the gapped packet read schedule. The read schedule describes at what moment in time (TPR_j) the receiver consumes the packets out of its receiver buffer and reconstructs the video frame. The lower part of the diagram demonstrates the fullness of the virtual receiver buffer, which is a function of the arrival of the packets and the reading of the packets.

Zones of Interest

The diagram illustrates two different zones of interest. The “full window” and the “steady-state window.” The “full window” can be defined as the *time between the arrival of the first packet (TPA_0)* up to the reading of the last packet out of the receiving buffer ($TPR_{\text{Npacket -1}}$).

The “steady-state window” measures from TPR_0 to TPA_{n-1}. This is from time TR_{OFFSET} to the “M” bit, which is the time period from the first read to the last write. This will give a minimum reading within the steady-state window and will ignore the gap minimum of a gapped schedule. It is also possible to post- process or window the full measurement window dataset to generate the steady-state measurement dataset.

Nomenclature and Formulas

One of the most common parameters tested by all available measuring instruments gave rise to the diagram illustrating the various measurements as further detailed in **Table 3**. When is the first package of a frame available relative to T_{VD}?[v] During the first event, it became very clear that communication about this measurement was becoming difficult. Because TPR_0 is a value that must be calculated as a function of the “packet read schedule.” So what can

[v] T_{VD}—a point in time given by $(N \times T_{FRAME}) + TR_{OFFSET}$, where N is an integer and the time scale has its origin at the SMPTE epoch as defined in SMPTE ST 2059-1.

Table 3. Overview of defined measurements.

2110	Measurement	Abbreviation	Formula
20	First packet time	FPT	$TPA_0 - T_{CF}$
20	RTP_{OFFSET}	RTP_{OFFSET}	$RTP_{Timestamp\_encoded} - T_{CF}$
20	Video latency	VL	$TPA_0 - RTP_{Timestamp\_encoded}$
20	Margin	M	$TR_{OFFSET} - FPT$
20	Gap	GAP	$TPA_{0(CF)} - TPA_{N\_PACKETS\ -1\ (CF-1)}$
21	C Instantaneous	C_{INST}	Algorithm
21	Virtual receive buffer	VRX	Algorithm
30	Audio delay variance	ADV	Algorithm
30	Packet interval time	PIT	*
30	Audio latency	AL	$TPA - RTP_{Timestamp\_encoded}$
30	Audio video differential latency	AVDL	AL – VL
40	First packet time	FPT	$TPA_0 - T_{CF}$
40	RTP_{OFFSET}	RTP_{OFFSET}	$RTP_{Timestamp\_encoded} - T_{CF}$
40	ANC latency	ANCL	$TPA_0 - RTP_{Timestamp\_encoded}$
40	ANC video differential latency	ANCVDL	ANCL-VL
40	Relative RTP_{OFFSET}	RRTPO	$RTP_{Timestamp(encoded)\ (video)} - RTP_{Timestamp(encoded)\ (anc)}$
40	Metadata margin	MM	$(VL\text{-}ANCL) - T_{VBK} + T_{EPO}$

actually be measured? One can measure the arrival of the packets at the receiving party. Therefore, the upper part of the diagram was added to clearly distinguish between the theoretical "read schedule" and the arrival of the packets at the receiving end. Once it became clear what was meant, it looked like every test and measurement device used a different name to indicate this measurement. Different names for this test were already circulating: video timing, video to PTP, PTP to video, first packet timing, first packet offset, stream timing, and so on.

In the most positive case, the return value of the measurement produced the same value, but sometimes the polarity was reversed. In some cases, even the values were different. It became clear that if customers were given test and measurement equipment from different manufacturers, this situation would not contribute to great confidence in the standards.

This RP specifies recommended nomenclature for measurements on SMPTE 2110 systems, together with their associated formulas for consistency in implementation and reporting of measurements. Not all of the measurements fit into a single basic formula and so require an algorithm.

This RP specifies recommended nomenclature for measurements on SMPTE 2110 systems, together with their associated formulas for consistency in implementation and reporting of measurements. For these methods, their characteristics and differences are described along with ways to report the results so that users understand the differences.

Algorithms

Not all required measurements can be represented by a simple formula. Some measurements require a process or set of rules to be followed in calculations or other operations; this is also called an algorithm.

Conclusion

As the overall adoption of SMPTE ST 2110 and AMWA NMOS has grown, a number of practical problems have emerged. Several initiatives by the JT-NM and SMPTE have addressed these challenges. The JT-NM Tested program provides impartial standardized testing for SMPTE ST 2110, AMWA NMOS, and JT-NM TR-1001-1.[15] While the program does not test all aspects of the standard, it covers the key items and equipment receiving the JT-NM certifications (as shown in **Fig. 2**). Badges that have been tested rarely cause interop issues. Additionally, the program tests several real-world scenarios addressing common potential operational issues. This is especially appreciated by end users.

The SMPTE PICS documents assist both vendors and users in determining whether an implementation meets the requirements of the standard. We anticipate that they will be used in the procurement process as well as in future JT-NM Tested events for testing. Overall, this will aid in the industry's implementation of the ST 2110 standards.

With the RP 2110-25 published, the test and measurement industry will have guidance on a specific set of unified measurements. The consistent naming and formulas

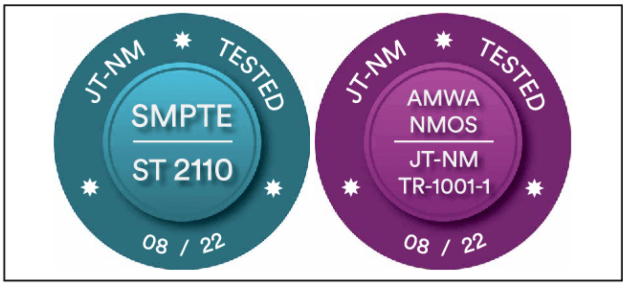

FIGURE 2. JT-NM Tested August 2022 badges awarded to the tested products.

will enable users of equipment from different manufacturers to better compare and understand the characteristics of ST 2110 equipment. As a result of these efforts, the user will gain more confidence in the technology and its various implementations.

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