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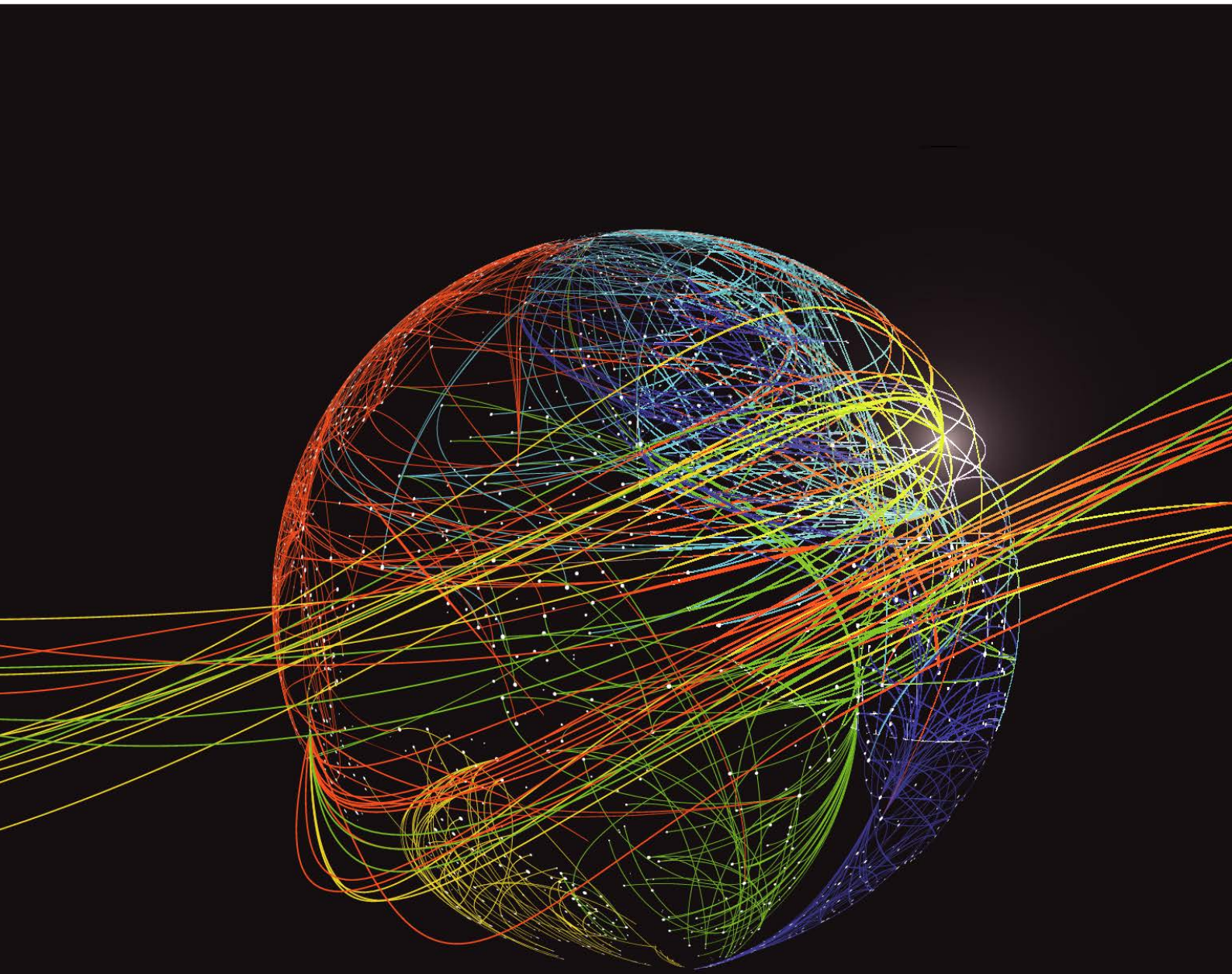

How CBC/Radio-Canada Tested Media-over-IP Devices to Build Its New Facility

By Félix Poulin, Patrick Keroulas, Sunday Nyamweno, Willem Vermost, Pedro Ferreira, and Ievgen Kostiukevych

Introdução:

O artigo a seguir nos brinda com o que há de mais moderno na transmissão de *media* por IP-(MoIP), o que promete trazer uma enorme flexibilidade, embora verdade seja dita, haja um alto custo de complexidade de configuração. Porém, tudo isso, será muito bem recompensado com o poder de interoperabilidade que os novos dispositivos terão baseados no padrão SMPTE ST 2110 E JT-Network Media, ou TR-1001-1 para os íntimos. **Boa leitura!** (Dica: *os diagramas valem muito a pena*).

Tom Jones Moreira

Abstract

The shift toward Media-over-IP (MoIP) promises to bring enormous flexibility, on the one hand, but increases the configuration complexity, on the other. Apart from new skill sets, new tools are needed to test, validate, and monitor new devices based on SMPTE ST 2110 and Joint Task Force on Networked Media (JT-NM) TR-1001-1, and ensure interoperability. Moreover, in a large system, there is a significant need for thorough testing that can be repetitive, leading to wastage of precious time. In addition to creating consistent tests and reporting, automation is needed to speed up the work. This article elaborates how Canadian Broadcasting Corporation (CBC)/Radio-Canada faced the challenges in evaluating the compliance and performance of many new devices from different manufacturers for the production facilities at its new headquarters in Montreal. It covers the test plan that was developed by CBC's lab team and the tools used to complete the titanic task. To cover its testing requirements, CBC collaborated with the European Broadcasting Union (EBU) Live IP Software Toolkit project team by contributing additional functionalities not found in other available tools and to automate the verification of the streams. Being involved in the development of this open source solution has the benefits of building a deep understanding of the standards within the engineering teams and providing an openly documented recipe for measurement as a benchmark for the industry.

The shift toward Media-over-IP (MoIP) promises to bring enormous flexibility, on the one hand, but increases the configuration complexity, on the other. Apart from new skill sets, new tools are needed to test, validate, and monitor new devices based on SMPTE ST 2110 and Joint Task Force on Networked Media (JT-NM) TR-1001-1, and ensure interoperability.

Keywords

Canadian Broadcasting Corporation (CBC)/Radio-Canada, Conformance, European Broadcasting Union (EBU), Live IP Software Toolkit (LIST), Measurement, Media-over-IP (MoIP), SMPTE ST 2110, Test, Validation

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Introduction

Canadian Broadcasting Corporation (CBC)/Radio-Canada is the national public broadcaster in Canada. The headquarters for its French language services is located in Montreal, Quebec. Built in 1973, the 111,000 sq. m (1,200,000 sq. ft.) building with a 25-floor tower is emblematic of the Montreal skyline. However, to cope with the fast-changing media business and the growing cost of real estate, the services will be relocated to a new greenfield building by 2020 (**Fig. 1**).

Moving to the new Media-over-Internet Protocol (MoIP) technology was necessary to achieve the required operational flexibility and the higher density. For instance, **Fig. 2** shows the functional view of the facility, whereas **Fig. 3** shows the same functionality but with pooled resources available to all production workflow—a major benefit of moving to IP.

However, this choice came with the challenges associated with being one of the first major projects in the early days of a new technology: lack of maturity of the technology, the need to build staff know-how, and the limited features of available testing tools.

This major project (**Table 1**) required multiple public tenders and critical decisions to choose the right pieces of equipment that would work together in the whole multivendor system. Furthermore, when the first request for proposal was published in early 2017, SMPTE ST 2110 had not been published and MoIP was new to both the CBC engineering and the manufacturers. CBC's architecture lab had to develop a methodology to deal with the large number of evaluations demanded by this freshly minted technology.

CBC Test Plan

The test plan that was developed is based on verifying compliance to open standards and to specific operational

FIGURE 1. New *Maison de Radio-Canada* in Montreal.

requirements that are tightly integrated to CBC's procurement policies. This allowed requirements to be communicated clearly to vendors while simultaneously allowing objective verification that CBC's needs were met by the vendors' devices during testing.

Training of Internal Stakeholders

Many CBC staff members have taken part in SMPTE webinars and other training activities related to the migration to MoIP. Furthermore, our engineering service drafted our procurement documents based on compliance to the SMPTE standards. What was lacking was a practical understanding of why the various limits set in the standards were important and what the practical implications of falling outside the standards were.

Our test plan was designed to put the theory into practice. To do so, we built a realistic testbed on a spine and leaf network, as will be seen later. This allowed us to augment our knowledge of media networks with the crucial knowledge of how to build IP networks. The test plan, in combination with our testbed, thus served as a training ground for both MoIP and IP networking.

Template-Based Approach

As many parts of the standards ecosystem were still developing, as also our understanding, a template-based approach was taken so that it could be easily updated as required.

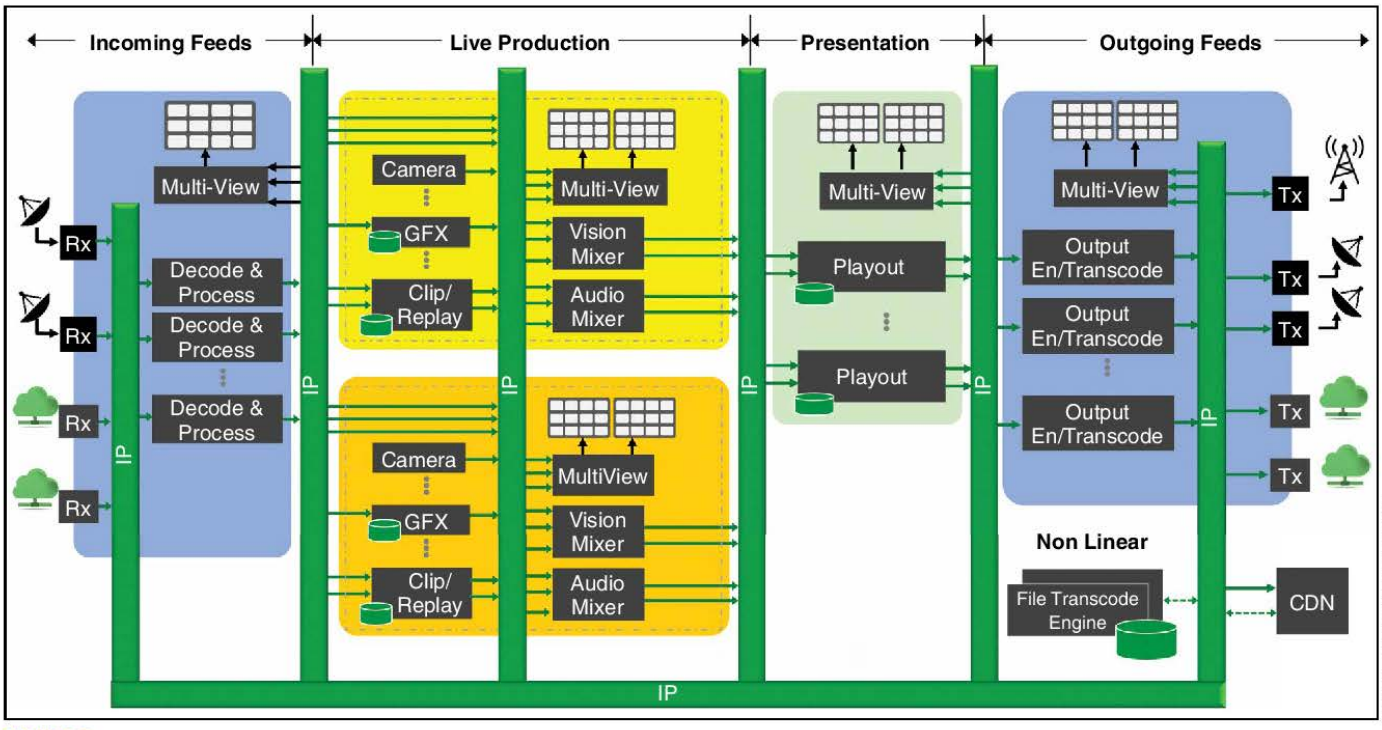
The test plan was divided into nine categories:

- Video | ST 2110-20[1]
- Audio | ST 2110-30[2]
- Traffic Shaping | ST 2110-21[3]
- Ancillary Data | ST 2110-40[4]
- Radio | AES67[5]
- Precision Time Protocol (PTP) | ST 2059[6,7]
- Redundancy | ST 2022-7[8]
- Control & Management | Ember+[9], Networked Media Open Specification (NMOS)[10]
- Security | European Broadcasting Union (EBU) R 148[11]

Figure 4 expands on these nine categories to provide more details on the subjects that are covered.

The template-based approach to testing gave us great flexibility to deal with the volume of devices that needed testing. In practice, we were able to quickly customize test plans on the basis of specific device functionalities. Additionally, it allowed for a consistent presentation of results when the comparative analysis of multiple candidate products was warranted.

The test plan also served as a useful tool for collaboration with other internal operating structures, as it acted as



(IMAGE COURTESY OF MICHEL PROULX)

FIGURE 2. Traditional functional view of a typical media facility.

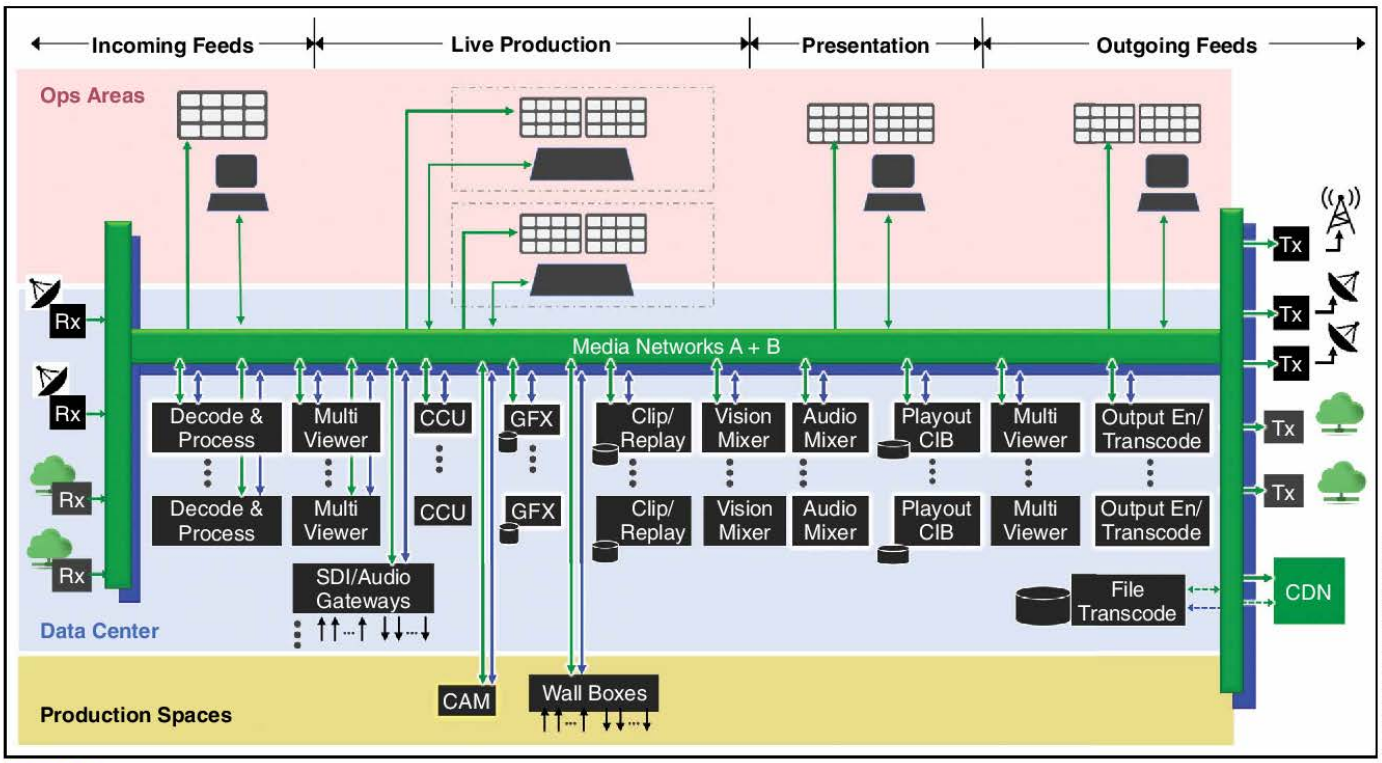


FIGURE 3. Same operational functionality as Figure 2 with shared pooled production capabilities.

the centerpiece for developing specific tasks that needed to be executed by different departments, such as Information Technology (IT), maintenance, and operations.

Moreover, during testing sessions, the test plan facilitated discussion on the various standards in question. It acted as a complement to our other internal training initiatives. By performing the tests as described in the plan, we were able to bring internal stakeholders up to speed on the various standards as well as the use of test and measurement equipments.

Sample Test Plan

EBU Live IP Software Toolkit (LIST)[12] has been an indispensable tool and a central piece of our test plan. **Table 2** is an excerpt from our test plan.

Testbed

The testbed network used to execute our test plan is shown in **Fig. 5**. It follows a similar topology to the full-scale network. It features the following equipment:

- Three Arista 7280 25G/100G switches
  - Spine
  - Media leaf split using Virtual Routing and Forwarding (VRF) routing to separate RED and BLUE redundant networks
  - PURPLE network for devices that have only one media port
- Once Arista 7050 1G/10G
  - Management and PTP distribution

TABLE 1. New *Maison de Radio-Canada* facts and figures.

40,000 sq. m (420,000 sq. ft.) floor space—one-third of the current space
Eleven News studio floors controlled by any of the four automated control rooms
Three general television studios controlled by either of two control rooms
Thirty-six studio television cameras and 56 Pan-Tilt-Zoom cameras for visual radio
Six radio studios with control rooms, 12 self-operated radio studios
Two hundred seventy two faders on audio consoles
Thirty-eight editing suites
Master Control Room designed for the presentation of up to 40 television channels, 40 web streaming channels, and 160 radio channels, for the French Services Network and a full backup for the English Services Network
1 MW fully redundant power
450 Tb/s network capacity, 75 PB storage, 2,800 km of fiber optic strands, 800 km of Cat6 network cable

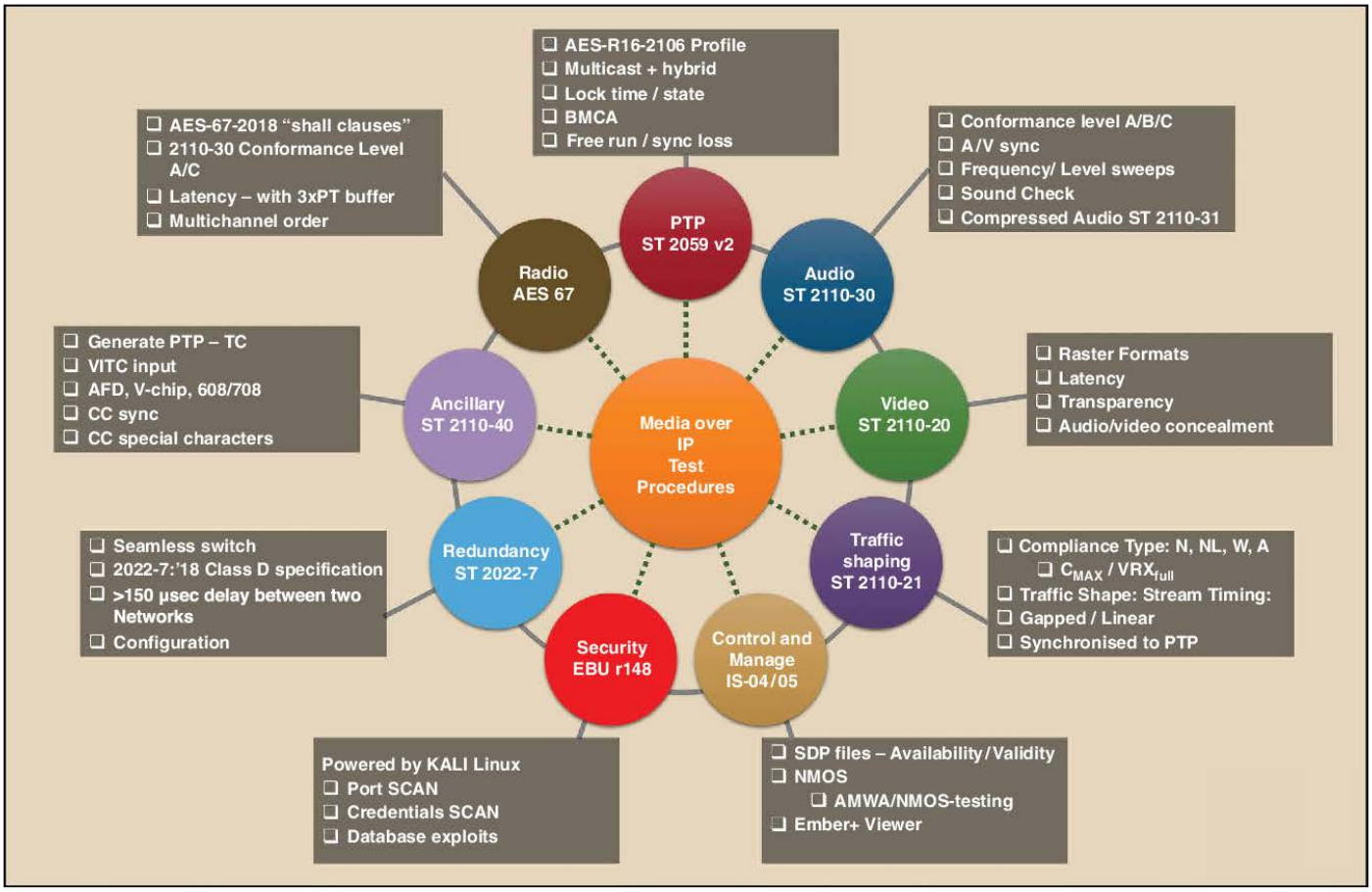


FIGURE 4. CBC Media-over-IP test plan.

- Test and measurement equipment
  - EBU LIST
  - Tektronix PRISM
  - PacketStorm VIP Analyzer
  - KALI Linux
- Reference senders and receivers
  - Embrionix emSFP encapsulators
  - Embrionix emSFP decapsulators
- Control and management
  - NMOS Registry and Discovery service[13]
  - NMOS testing tools[14]

Software Toolkit

Kickstart

During the standardization work of SMPTE ST 2110-21 on Traffic Shaping and Delivery Timing for Video, the EBU had developed some Python scripts[15] as a tool to support the discussions around the definition of new parameters[16] (e.g., VRXFULL, CMAX, and TROFFSET) to help quantify, classify, and determine bounds as pass criteria.

The need for building a common understanding around those new metrics became clear and the EBU

TABLE 2. CBC Media-over-IP sample test procedure.

Traffic Shaping | ST 2110-21	
Test# 20-0	
Title Sender: Type Compliance (N, NL, W)	**Test and supporting equipment** ● EBU LIST with capture
Test Procedure 1. Capture the stream: EBU LIST > Capture page > Select Source(s) > Enter analysis name > Start capture 2. Get the sender's SDP file (device dependent) 3. Save the compliance report: EBU LIST > PCAPs and Streams > Select Capture > Download JSON	**Pass criteria** EBU LIST > Video > Summary ✓ "SMPTE 2110-21 (Cinst)" is GREEN ✓ "SMPTE 2110-21 (VRX)" is GREEN EBU LIST > Video > Analysis ✓ "Compliance" = Type indicated by SDP/ "a=fmtp: TP=2110TPx" [N, NL, W] ✓ "FPO" = "TRODEFAULT" +/– 10 µs except if alternate TROffset is signaled in the SDP: ○ "FPO" = SDP/"a=fmtp TROFF="

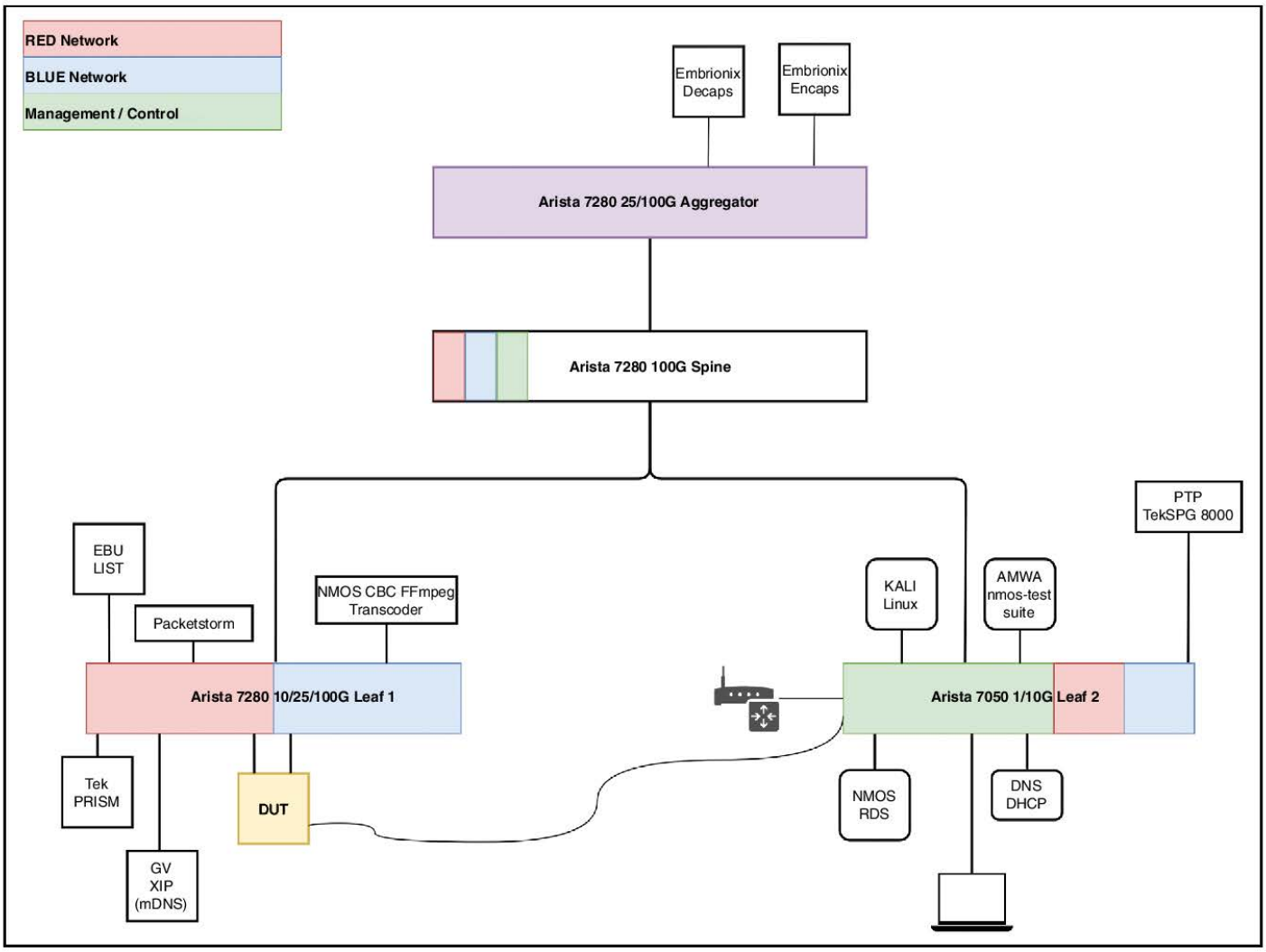


FIGURE 5. CBC spine and leaf testbed showing key test equipment.

moved to an official project to get a practical sense of what makes a sending device "compliant." The LIST project was launched in 2017. In a context where technology is shifting, the EBU is well positioned to gather requirements and concerns from users of analysis tools. The project thus progressed with collaboration on ongoing improvements based on real-life user experience, at a time when turnkey solution offerings from the well-established manufacturers were limited.

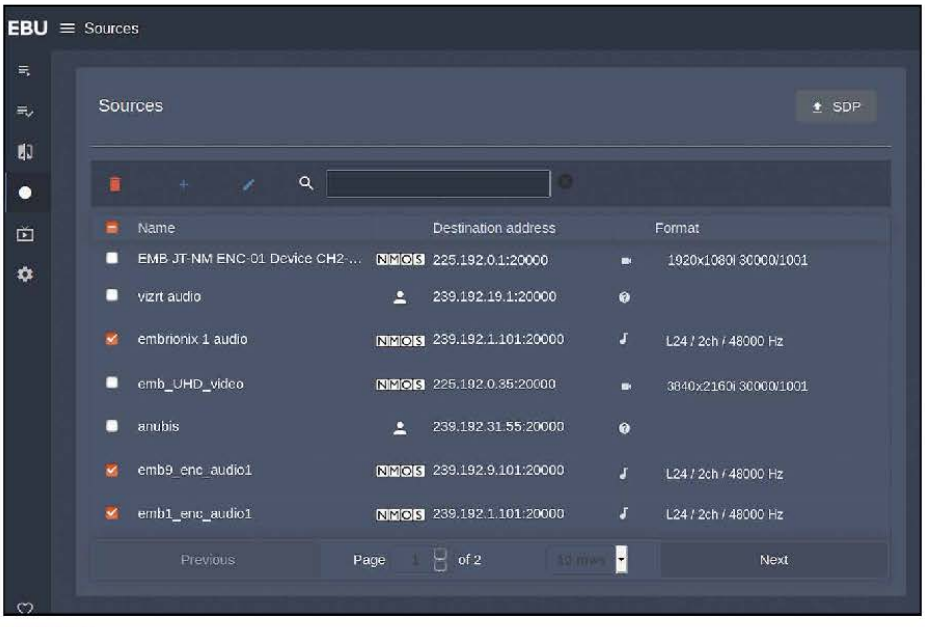


FIGURE 6. Capture from multiple audio sources.

FIGURE 7. Virtual Receiver Buffer (VRX) error visualized in the web graphical interface.

Agile Methodology as a Way to Focus on User Requirements

With regard to the development process, adopting the agile methodology enforces close collaboration between users and developers. The former must play an active role by articulating new requirements, frequently testing and expressing constructive feedback. The latter must be aware of the constraints in a broadcast environment to provide the appropriate User Interface (UI), support service, and training. This mutual engagement in continuously deploying, testing, and giving feedback has created a virtuous circle, ensuring the alignment of development with user expectations.

CBC has contributed to the EBU LIST project since summer 2018, applying an agile methodology to promote the viewpoint of real users as a proactive part of the solution. We strongly believe that this interchange between the software and broadcast experts is a key component for the successful adoption of such a tool as well as for MoIP in general.

Benefits of the Open Source Model

In the ever pogressing globalized economy, Free/Open Source Software (FOSS) has now proved its value in the software industry and beyond. As a matter of fact, a number of major IT companies have integrated this model into their ecosystems, shifting the value from intellectual property to service and collaboration.[17] For instance, the former antagonist, Microsoft, which acquired the social network for developers Github, is now the largest contributor to this platform.[18] Even hardware manufacturers support the Linux Foundation[19] because this model avoids reinventing the wheel and helps to reduce both development costs and time-to-market. The benefit is immediate: the risk and support are shared. Of course, not all FOSS tastes the same success as the widest spread operating system, but they have the potential to mobilize the adaptive task force to ensure reliability and sustainability.[20]

In the scope of MoIP, EBU LIST offers an open reference implementation of compliance validation against SMPTE ST 2110, such that it has been selected as a reference testing tool by the Joint Task Force on Networked Media (JT-NM) tested program.[21] "Code is law," said Lawrence Lessig, referring to the way in which the internet is regulated by the underlying technology and open standards that are open to debate. During the equipment validation sessions, EBU LIST has helped to define a field of discussion between the manufacturers and broadcasters that, in turn, helps to clarify the standards.

And since EBU LIST includes many third-party open source components, CBC has also taken the opportunity to contribute to ancilliary projects, from bug reporting to new features (FFmpeg,[22] SDPoker,[23] NMOS-cpp,[3] libklvanc,[24] etc.). This effort has strengthened the broadcast-developer community and established CBC's position as an active member.

The code of EBU LIST is published on GitHub under the GNU General Public License (GPL) 3.0 license.[25]

Test Automation

When trying to speed up the testing process, it is important to eliminate cumbersome and time-consuming steps. A lot of time is wasted in the manual configuration of the multicast addresses and in the testing of User Datagram Protocol (UDP) port numbers. Therefore, the first consideration was to use the specified Session Description Protocol (SDP) files. The problem with this approach is that the way to get to this SDP file is not standardized and thus there is a need to look beyond SMPTE ST 2110.

The Advanced Media Workflow Association (AMWA) Interface Specifications are an obvious "go-to" solution. The Registration and Discovery service as specified by Interface Specification IS-04 has the exact information needed. It is maintained by a community comprising broadcast and software engineers. This part of NMOS defines how devices can announce themselves and discover other devices in a heterogeneous media network.

EBU LIST keeps track of existing senders by listening to the NMOS registry. The implemented Discovery and Registration service used is Sony's open NMOS-cpp.[13] The EBU LIST visualizes the source list. With one simple click, the capture and analysis process starts—if needed, for multiple streams simultaneously (**Fig. 6**).

In addition to raw measurements and graphs displayed in the web UI, EBU LIST also displays colored badges for every test (**Fig. 7**). The following example demonstrates how a media sender can immediately be validated. In this case, a compliance issue against VRX, as defined by SMPTE ST 2110-21, is detected which raises a flag for the corresponding item in the test plan, that is, "Sender compliance" (21-0 in **Table 2**).

Browsing the UI provides more precision on the issue, whereby a negative VRX value represents a receiver's buffer underflow. Additional conformance information would pop up, such as "Packet Interval Timing" and "Read schedule." In the same way, the audio analyzer qualifies the "Jitter and buffer."

A text report can also be downloaded from the UI to automate the equipment evaluation against an IP test plan. The JavaScript Object Notation (JSON) format is chosen because it is natively supported by the NodeJS server and can be easily parsed by any language script. **Figure 8** shows the detailed results for the VRX issue (in this case, values look shifted of -1666 packets which reveals a nondefault TROFFSET). Plus, a human-readable digest is also exported in the portable document format (PDF).

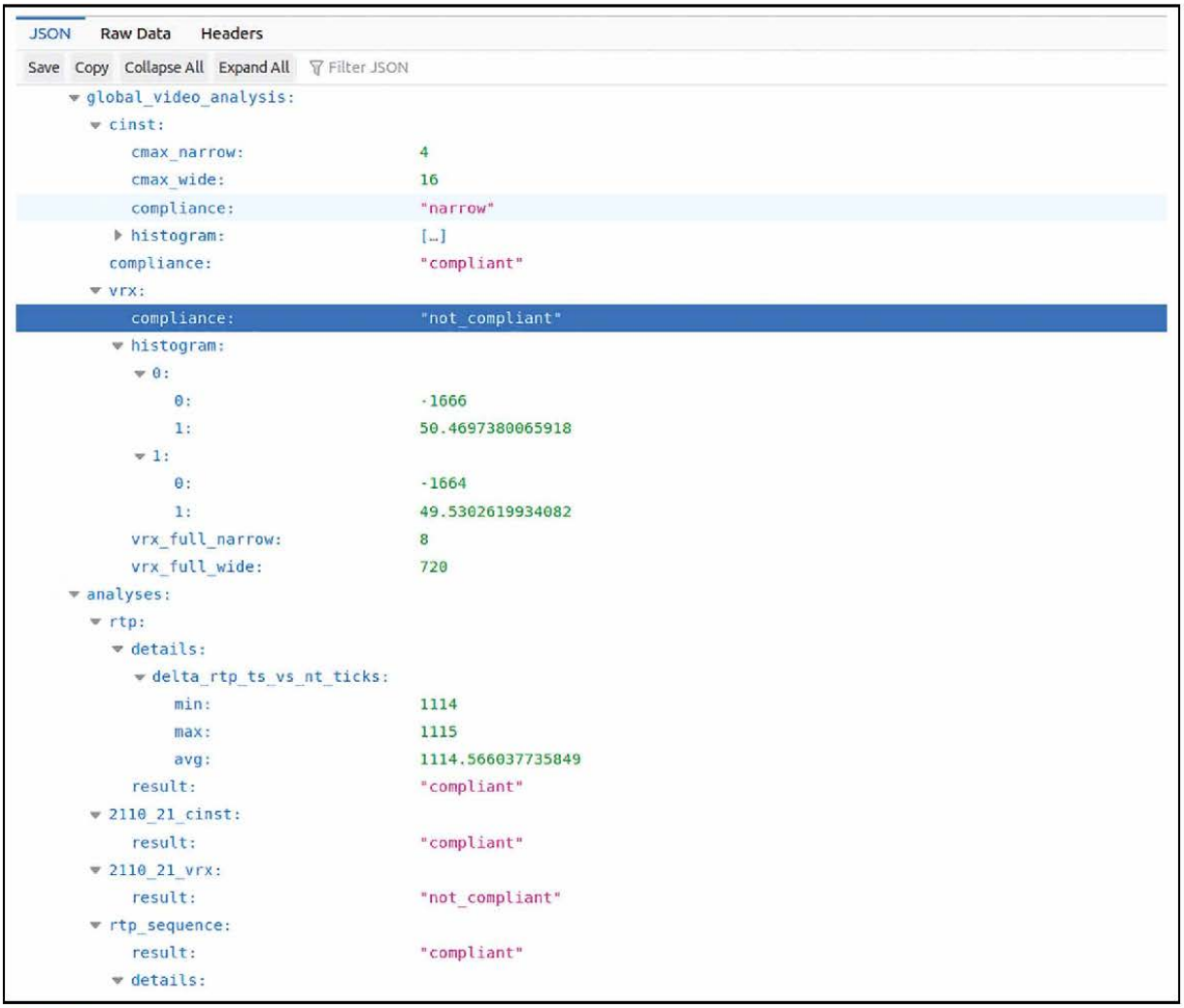


FIGURE 8. VRX detail in video analysis.

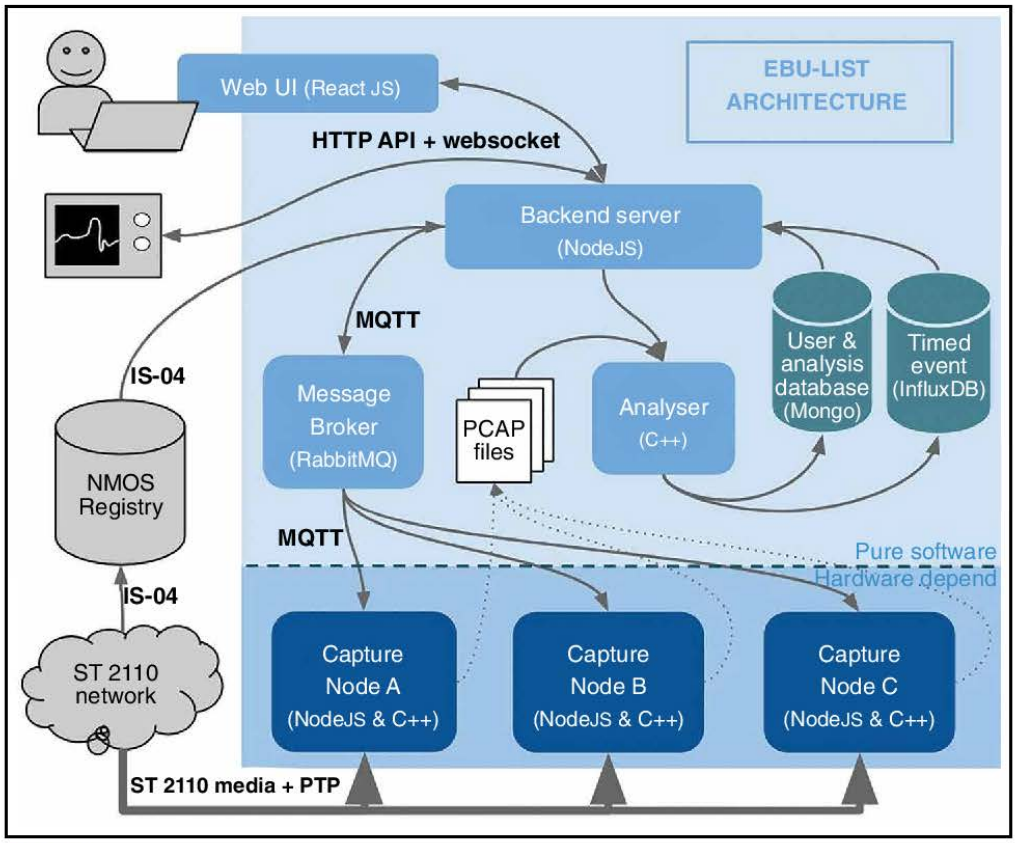


FIGURE 9. LIST software architecture.

Possibilities for the automation of other sections of the test plan, such as media content, are very limited. However, EBU LIST decodes all the essences. Video frames are rasterized, pulse-code modulation (PCM) audio can be listened to by the embedded audio player, and several types of ancillary data, like Closed Caption [Consumer Electronics Association (CEA)-708/Electronic Industries Alliance (EIA)-608] and timecode (SMPTE ST 12-2), are decoded.

Designed for Scalability

Since the beginning, the architecture design has been modular to cover multiple use cases and IT infrastructures. Early versions of EBU LIST were intended to analyze streams previously captured by other devices. Being hardware-agnostic, it can run in virtualized environments—on Docker or even in the cloud.[26]

More recently, EBU LIST's architecture (**Fig. 9**) has evolved to include additional features for automated testing, including a workflow management module, which simplifies the automation of test tasks. This automation module allows EBU LIST, for example, to trigger captures and automate their analysis. One such example is a module that runs tcpdump[27] to perform a capture when the user selects a source—as soon as the capture completes, EBU LIST triggers the analysis of the streams.

This workflow mechanism supports the distributed deployment of capture devices, so it is possible to deploy LIST as a virtual machine or as a container and have it control a swarm of capturing devices installed across the facility.

Limitation of the Testing Methodology and Opportunities for Future Research and Development

EBU LIST does not support cross-checking and correlation between multiple streams. Additional functionality needs to be delivered to enable checking the media transparency of a device or system, its latency, and the compliance of SMPTE ST 2022-7 redundant streams.

Current test automation is focused on transmitting devices (senders). To automate testing of receiving devices, we would need to include a reference synthetic IP media stream generator that can simulate different senders' behaviors, for instance, different types (wide, narrow, etc.), alternate TROffset parameter, Real Time Protocol (RTP) timestamping modes, etc.

The current workflow is sequential: it is required to make a capture and then analyze it. It could be optimized by introducing a continuous capture-analysis or live-analysis workflows that would spare precious operating time and identify occasional glitches.

Finally, a better consistency between test and measurement equipment would ease the interpretation of the results by the users. A common understanding of the underlying assumptions and calculations would need to be reached amongst the developers of such tools.

Conclusion

In choosing to build one of the first major production facilities to be based entirely on MoIP technology, CBC/Radio-Canada is placing itself at the forefront of early testing of

products designed with the new standards. The creation of a comprehensive test plan was essential to deal with the huge volume of testing that came with the integration of a complex, new multivendor installation. By using and actively contributing to the further development of EBU LIST, CBC has been able to accelerate its understanding of the standards and automate certain parts of its test plan, thereby saving time and resources in the context of tight deadlines. The wider community has also benefited, with EBU LIST evolving to become a more fully featured tool that is used during the international test events.

Acknowledgment

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About the Authors

Félix Poulin is with the national public broadcaster CBC/Radio-Canada, Montreal, Canada, where he is the director of the Architecture Lab. The Lab is currently evaluating IP-based equipment for the new headquarters to be on air in 2020. Before that mandate, Poulin was a lead expert on live IP at the European Broadcasting Union (EBU), Geneva, Switzerland, involved with the Joint Task Force on Networked Media (JT-NM), organizing training and events, coordinating expert groups, and the multiaward winning VRT Sandbox LiveIP project. Poulin completed his diploma in electrical engineering at Montreal's Polytechnique, Montreal, Canada, with his final thesis done at Massachusetts Institute of Technology (MIT), Cambridge,

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Patrick Keroulas has developed realtime media software for various industries such as entertainment, aerospace, consumer, and broadcast. He has contributed to implementing SMPTE ST 2110 into FFmpeg. He is currently working on the European Broadcasting Union (EBU) Live IP Toolkit project in the Architecture Lab of CBC/Radio-Canada, Montreal, Canada, supporting the building of the new IP-based facility in Montreal.

Sunday Nyamweno is a lead analyst with CBC/Radio-Canada, Montreal, Canada, where he has been solving problems related to video encoding, satellite transmission, color science, and systems integration, for the past eight years. He received a PhD from McGill University, Montreal, Canada, in 2012, specializing in video compression. Additionally, he possesses an MSc in radio frequency wireless communications from Leeds University, Leeds, U.K.

Willem Vermost recently moved to VRT, Belgium, as a design and engineering manager. Prior to this role, he was the topic lead on the transition to IP-based studios at the European Broadcasting Union (EBU). With 20 years of experience in broadcasting, he is an expert and project manager of international strategic expert groups, and events. He has a master's degree in electronic engineering and in applied computer science. He has worked on various projects, including the multiple award-winning VRT Live IP proof of concepts, the Joint Task Force on Networked Media (JT-NM) Tested Program, and started the open source EBU Live IP Software Toolkit (LIST) project, which has grown to be an international project. He is the co-chair of the EBU group System Design and Interoperability and is an active member of SMPTE.

Pedro Ferreira is a software developer, trainer, and consultant, with more than 20 years of experience in the broadcasting industry. He started his career as a researcher at INESC, Portugal, and then became one of the founders of MOG Technologies, Portugal, where he worked for 15 years, mostly as the chief technology officer. He led the development of many innovative products, such as the MXF:SDK and mxfSPEEDRAIL, as well as several other bespoke projects. He has also been actively involved in the standardization and European Union (EU) research projects since he started his career. He is a member of the Eurovision Academy faculty, where he has trained more than 200 people in subjects like MXF, file-based workflows, and Live-IP. He possesses an MSc in telecommunications and computers.

Ievgen Kostiukevych is a member of the European Broadcasting Union (EBU) Technology and Innovation team. He has gained more than a decade of experience in the broadcasting and sound production industry, including experience in change management, solutions architecture, and Audio-over-IP integration. He is working on projects such as IP networks, Media-over-IP, PTP, and networks programmability and automation. He is a member of SMPTE and Audio Engineering Society (AES).

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