Overview on essential Ingredients

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ALC NetworX, Munich
Andreas Hildebrand, RAVENNA Technology Evangelist
• more than 25 years in the professional audio / broadcasting industry
• graduate diploma in computer science
• R&D, project & product management experience
• member of AES67 TG and ST2110 DG

ALC NetworX GmbH, Munich / Germany
• established 2008
• R&D center
• developing & promoting RAVENNA
• Partnerships with > 40 manufacturers

RAVENNA
• IP media networking technology
• designed to meet requirements of professional audio / broadcasting applications
• open technology approach, license-free
• fully AES67/ST2110-compliant (built-in)
What is IPMX?

Internet Protocol Media Experience
## Proposed Roadmap (Draft)

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- **HDCP**: Copy protection
- **General Purpose I/O**: IR Remotes, GPIO, USB, RS232 over IP
- **NMOS IS-08**: Audio channel mapping
- **IPv6**: Network addressing
- **Security**: Authentication, Encryption

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**Audio over IP Standards & Specifications**

- **AES67**: Audio Over IP
- **SMPTE ST 2110**: Uncompressed Video
- **SMPTE ST 2110-10**: Timing & Definitions
- **SMPTE ST 2110-20**: Uncompressed Video
- **SMPTE ST 2110-21**: Packet Pacing
- **SMPTE ST 2110-30**: AES67 Audio
- **SMPTE ST 2110-31**: AES3 Audio Transport
- **SMPTE ST 2110-40**: Ancillary Data

**ProAV Standards & Specifications**

- **SMPTE ST 2110-22**: CBR Compression in ST 2110
- **ISO/IEC 21122**: JPEG XS Codec
- **NMOS IS-04 & IS-05**: Discovery, registration & connection management
- **EDID / DisplayID / HPD Support**: (Required)
- **HDCP**: (Optional)
- **Copy protection**: (Optional)
- **General Purpose I/O**: (Optional)
- **IR Remotes, GPIO, USB, RS232 over IP**: (Optional)
- **NMOS IS-08**: (Optional)
- **Audio channel mapping**: (Optional)
- **IPv6**: (Optional)
- **Network addressing**: (Optional)
- **Security**: (Optional)
- **Authentication, Encryption**: (Optional)
AES67
- defines high-performance AoIP interoperability

SMPTE ST 2110
- defines elementary essence data transport on managed IP networks

SMPTE ST 2059
- defines PTP profile for SMPTE ST 2110

AMWA NMOS
- defines upper layer operational & management functionalities
  (device discovery & connection management)
What was the original goal?
• “Provide a method to connect disparate Audio-over-IP systems to achieve workaround-free networked audio interoperability”

What is AES67?
• Interoperability Standard for high performance Audio-over-IP networks
• Based on existing protocols and trusted IT standards
  • This ensures compatibility with existing network infrastructure
  • Allows coexistence with other IT data
  • High adoption rate by all major solution providers
**Problem Statement**

- Audio-over-IP (aka Networked Audio) provides simpler and better connection between audio equipment.
- Coupled with many advantages, one clear challenge presented itself: **Compatibility**
- While each Audio-over-IP solution offered in-system connectivity, there was no standard to provide inter-system connectivity.
AES67 technology components

- **Discovery**: Not specified
- **Connection Management**: SIP (unicast), IGMP (multicast)
- **Session Description**: SDP (RFC4566, RFC7273)
- **Encoding**: L16/L24, 1..8 ch, 48 samples
- **QoS**: Differentiated Services (DiffServ w/ 3 CoS)
- **Transport**: RTP / UDP / IP, unicast & multicast
- **Media Clock**: 48 kHz
- **Synchronisation**: IEEE 1588-2008 (PTPv2)
2013 – initial publication
- 3 years of work
- 100+ participants (manufacturers, consultants, system integrators, end users)

2015 – first revision
- Corrigendum & clarifications
- Backward compatibility (no new requirements)

2018 – second revision
- Further clarifications
- Backward compatibility (no new requirements)
- PICS added

Current status
- Task Group is working on further topics (multicast addressing, SDP, homologation w/ ST 2110 etc.)
Further Work in AES Task Groups

AES70 – Open Control Architecture
• Initially published in 2017
• AES70-2018 – improvements + additions (i.e. CM3, web sockets / UDP support, Task mechanism etc.)
• Current work: further improvements, AES70 for AES67 Connection Management, NMOS convergence

X238 – Requirements for Media Network Directories and Directory Services
• setting forth technical recommendations for media network directories and directory-related services
• Covering: Registration, query, and administration protocols; security mechanisms; directory data model; query language and related semantics; scalability strategies

X242 – Streaming audio metadata over IP
• Defining a transport mechanism for real-time audio meta data associated with an AES67 audio stream
• Synchronization, RTP payload format (but agnostic to actual payload data), association & alignment w/ AES67 streams
• Seeking alignment / coordination w/ SMPTE ST 2110-41 ("Transport of Extensible Fast Metadata")
The SMPTE ST 2110 standards suite specifies:

- the transport, synchronization, and description of separate elementary essence streams (video, audio, ancillary data)
- over managed IP networks (at any speed, from 1GbE to 100 GbE and beyond)
- for real-time production, playout, and other professional media applications.
Two Fundamental Approaches to IP Transport

- **Bundled** (Audio, Video, Metadata together)
  - Audio/Video/Metadata/Sync travel *coherently*
  - Requires extra work to “unpack” separate essences

- **Essence-based** (Audio, Video, Metadata separate)
  - Ideal for *Studio/Production* workflows
  - Individual essence kept in sync using PTP timing
IP Packetization of SDI Raster

Method: SMPTE ST 2022-6

- Audio (from HANC)
- Video (from active area)
- Metadata (from VANC)
- Sync/Timing (from frame)
The Essence-based Approach: SMPTE ST 2110

Published in 2017

**IP Packetization of Active Video**
- Method: SMPTE ST 2110-20

**IP Packetization of Audio Channels**
- Method: SMPTE ST 2110-30

**IP Packetization of ANC Data**
- Method: SMPTE ST 2110-40

Published in 2017
Bundled vs. Essence-based Approach

A) SMPTE 2022-6 Stream

B) VSF TR-03 Streams
The Essence Based Approach: SMPTE ST 2110
The SMPTE ST 2110 Suite of Standards

Document structure (published):

- **2110-10: System Timing & Definitions**
  - defines transport layer and synchronization (SMPTE2059, clocks, RTP, SDP etc.)

- **2110-20: Uncompressed Active Video**
  - defines payload format for raw video (RFC4175, RTP, SDP, constraints)

- **2110-21: Traffic Shaping and Delivery Timing for Uncompressed Active Video**
  - defines timing model for senders and receivers (traffic shaping requirements)
The SMPTE ST 2110 Suite of Standards

Document structure (published):

• 2110-30: PCM Digital Audio
  — defines payload format for linear audio (AES67, constraints)

• 2110-31: AES3 Transparent Transport
  — defines payload format for non-linear audio (RAVENNA AM824)

• 2110-40: Transport of SMPTE Ancillary Data
  — defines RTP payload format for SDI ancillary data (new IETF draft)
Precision Time Protocol (IEEE 1588-2008)

- A method for distributing precise, GPS-referenced time over an IP network
- Proven technology used in multiple industries
- Used for synchronization and alignment of devices and media signals

Both AES67 and SMPTE ST 2110 use PTP
**Real-time Transport Protocol (RFC 3550)**

- A format-agnostic transport protocol for real-time media data
- Includes time information for precise media alignment

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<th>Presentation</th>
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<td>Copper / Fiber</td>
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</tbody>
</table>

![RTP Diagram](RTPDiagram.png)

```
Ver | P | X | CC | M | Payload Type | Sequence Number

Timestamp

Source Synchronization Identifier (SSRC)

Options + Padding (optional)

Audio Data
or
Video Data
(up to 1440 bytes)
```
Session Description Protocol (RFC 4566)

- Required to describe stream formatting, synchronization and connection information
- Provided by a sender (or management instance) for each stream
- Human-readable text:

```
v=0
o=1 0 IN IP4 192.168.1.100
s=RAVENNA demo stream
t=0 0
a=ts-refclk:ptp=IEEE1588-2008:00-60-6e-ff-fe-7c-23-0f:0
a=mediaclk:direct=0
m=audio 5004 RTP/AVP 98
a=rtpmap:98 L24/48000/2
c=IN IP4 239.3.14.142
a=recvonly
a=rtpmap:98 L24/48000/2
```
Specifies the payload format for **uncompressed active video** essence

- Raster size independent  ▶ up to 32K x 32K pixels
- Agnostic to:
  - Colour sampling: 4:1:1 to 4:4:4+
  - Bit depth: 8 to 16-Bit+
  - Frame-rate: 23.98 to 120 fps+
- Support for HDR  ▶ PQ & HLG
- Significant bandwidth efficiency,
  
i.e. 1080p50:
  - ST 2022-6 = 3,074Gbps
  - ST 2110-20 = 2,143Gbps

⇒ **30% bandwidth saving!**
Problem Overview

- Video flows require fairly high data rates
- Multiples flows are concurrently traversing the network
- Network switches (and receivers) have limited buffer capacity
- Constant data flow will not overload the buffers as long as total used bandwidth stays below maximum bandwidth
Problem Overview

- Random and unregulated traffic patterns may temporarily overflow buffers, even if average bandwidth is not exceeded.
Solution

- Define sender drain behaviour (packet egress pacing and spacing)*
- 3 models for sender traffic shaping:
  - Narrow-linear (NL) – packet are drained evenly distributed across frame period
  - Narrow (N) – packet drain closely follows SDI signal timing (no packets during VBI and VANC)
  - Wide (W) – allows increased burstiness (accommodates SW-based senders)

*and (receiver) buffer requirements
Solution

- Define sender drain behaviour (packet egress pacing and spacing)
- 3 models:
  - Narrow-linear
  - Narrow
  - Wide
Solution

- Define sender drain behaviour (packet egress pacing and spacing)
- 3 models for sender traffic shaping:
  - Narrow (N) – packet drain closely follows SDI signal timing (no packets during VBI and VANC)
  - Narrow-linear (NL) – packet are drained evenly distributed across frame period
  - Wide (W) – allows increased burstiness (accommodates SW-based senders)
- Sender behaviour is signalled in the SDP in the a=fmt:p: line:
  - TP=2110TPN
  - TP=2110TPNL
  - TP=2110TPW
- Has impact on buffer requirements of network switches and receiver devices and sender / receiver compatibility
SMPTE ST 2110-30 Linear PCM Audio

Specifies the payload format for PCM digital audio streams

- Uncompressed Linear PCM Audio only
- Based on AES67
- Relatively flexible:
  - 48kHz and 96kHz sampling
  - 16 and 24-bit depth
  - Variable packet timing - 125us to 1ms
  - Channel-count based on packet timing
    - 8 channels @ 1ms up to 64 channels @ 125us (conformance levels A / B / C)
- Low-bandwidth consumption, i.e.
  - 8 channels x 24 bits x 48,000 samples = 9.9Mbits/sec (incl. packet overhead)
SMPTES ST 2110-30 and AES67 Compatibility

SMPTES ST 2110-30 is a subset of AES67, adding constraints to clocking and streaming.

- **AES67 mandatory**
  - a=ptime:1

- **AES67 optional**
  - a=ptime:0.12

**SMPTES ST 2110**

AES-R16-2016 PTP Configuration
Option to operate device in PTP slave-only mode
- a=mediaclkdiract=0

**ST 2110-30 Level A**
**ST 2110-30 Level B**
SMPTE ST 2110-31 AES3 Audio Data

Specifies the payload format for transparent transport of **AES3 audio** data

- Can transport any format which can be encapsulated in AES3:
  - L24 PCM w/ AES3 subframe meta data (PCUV bits)
  - non-PCM audio and data formats as defined by SMPTE ST 337 / 338 (i.e. Dolby®E etc.)
- Builds on RAVENNA’s AM824 (IEC 61883-6) payload definition:
  - retains AES67 definitions for synchronization and RTP usage
  - uses 3 bytes for PCM24 + 1 byte for AES3 meta data
  - RTP payload format signaled in SDP:
    - a=rtpmap:<pt> **AM824**/48000/<nchan>
    - retains all other SDP parms
SMPTE ST 2110-40 Transport of Ancillary Data

Specifies the method of transporting (SDI) ancillary data via RTP

- Covers ancillary data as specified in SMPTE ST 291-1, i.e.:
  - Timecode
  - Closed captions
  - Subtitles
  - Active format descriptions

- Not intended for the carriage of audio data (→ SMPTE ST 2110-31) or EDH (error, detection and handling)
The SMPTE ST 2110 Suite of Standards

Document structure (in development):

• 2110-22: Constant Bit-rate Compressed Video
  – defines payload format for CBR compressed video and a SMPTE registry for various payload formats (codecs)

• 2110-23: Single Video Essence Transport over Multiple 2110-20 Streams
  – defines how to split high-bandwidth signals into several lower-bandwidth 2110-20 tributary streams (constraints, grouping, addressing, RTP timestamps, SDP ...)

• 2110-41: Extensible Fast Metadata Transport
  – defines how to transport extensible, dynamic meta data in ST2110 context (including synchronization)
Further Work in SMPTE DGs

**ST 2110**
- 1-year review of: -10 / -20 / -21 / -40
- New work: -24 (SDO Definitions)
- PICS (analog to AES67-2018)

**ST 2059**
- 1-year review of: -1 & -2
- ST 2059 Security
- PTP Monitoring

**Related:**

**VSF**
- ST 2110-over-WAN, ST 2110 format enumeration

**IEEE1588-2020 (PTPv2.1)**
- Improvements and extensions, fully backwards-compatible
What else is required for a working system?

- Establishing connections!* (*and control...)
  - Not covered by SMPTE 2110

- AMWA: Advanced Media Workflow Association
- NMOS: “A growing family of specifications [...] which are complementary to and co-exist with industry specifications like ST2110 and AES67”
NMOS specifications:

- **IS-04: Discovery & Registration**
  - enumeration and registration of available system resources

- **IS-05: Connection Management**
  - connecting receivers to available streams

- **IS-06: Network Control**
  - controlling network resources (configuring routing tables)
NMOS specifications:

• IS-07: Event & Tally Specification
  – communicate current states and state changes

• IS-08: Audio Channel Mapping
  – how to match flow channels with inputs / outputs

• BCP-002-01: Grouping of NMOS Resources
  – identifying which flows are related to each other

• ... more in the works...
Key elements
Identity

Node

Device

Source

Flow

Receiver

Sender

256E5638-0EB2-4E70-B45B-3B24EB6A478

83C42DF8-284E-4351-8349-E50DA22AC419

6B752B84-F855-4E32-9D7F-9619DA31486A

23F85482-7AE1-4366-9D03-8D8483957A91

6C46C3F0-97F0-4B52-9DB5-8D4B0325A488

A3B548F4-99EE-48CF-9582-94A51BDAC1

Aims

Alliance for IP Media Solutions
IS-04
Discovery & Registration

Ensure that parts of a networked media system can find each other
IS-05
Connection Management

Make it simple for applications
to (dis)connect flows
Networked Media Open Specifications

**Application Logic**

- **Query** from IS-04 Registry
- **Registration** to IS-04 Registry
- **Create Connection**
- **stream** any format / protocol

**Node**
- **Device**
  - Sender

**Node**
- **Device**
  - Receiver
Challenge:

6 channel surround audio
Challenge:
Challenge:

Option 1:
6 unicast streams with individual channels

⇒ not very efficient
Challenge:

Option 2:  
1 multicast stream  
w/ all 6 channels
Challenge:

1 multicast stream w/ all 6 channels
IS-08
Audio Channel Mapping

Map flow channels (tracks) to device I/O channels
AMWA NMOS IS-08 - Audio Channel Mapping
AMWA NMOS IS-08 - Audio Channel Mapping

- Interaction with NMOS IS-05 – connecting incoming stream channels to device output channels
Networked Media Open Specifications

AMWA NMOS IS-08: Audio Channel Mapping

IP-SDI Gateway
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<th>Id</th>
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<td>Discovery and Registration</td>
<td>AMWA Specification (Stable)</td>
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More information on
NMOS wiki on Github:

https://github.com/AMWA-TV/nmos/wiki
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<th>Standard</th>
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<td>Precision Time Protocol</td>
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<td>Seamless Protection Switching (RTP streams)</td>
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<td>Timing of ST 2022-6 streams in ST 2110-10 systems</td>
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## Standards: SMPTE ST 2110 Suite

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<td>SMPTE ST 2110 - 21</td>
<td>Video - Traffic Shaping (packet pacing, bursts and gaps)</td>
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<td>Video - Compressed (CBR)</td>
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<td>Audio - Compressed (AES3, non-PCM)</td>
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Questions?
Answers!

ST2110 / AES67 Resources:

www.ravenna-network.com/resources

www.aimsalliance.org (resources)

www.smpte.org/smpte-st-2110-faq
Contact information:
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www.ravenna-network.com