RAVENNA 2020 Webinar Series

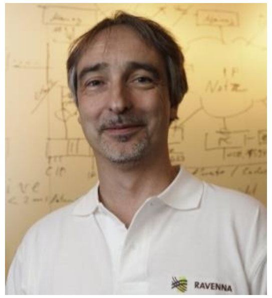
Deeper Dive
into
AES67 & SMPTE ST 2110

("The Audio Files")

Tue, May 12, 2020
15:00 h (CEST)

Presenter: Andreas Hildebrand, ALC NetworX

Your Host



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-compliant (*built-in*)

AES67

AES67-2018 Standard for Audio Applications of Networks:

High-performance Streaming Audio-over-IP Interoperability

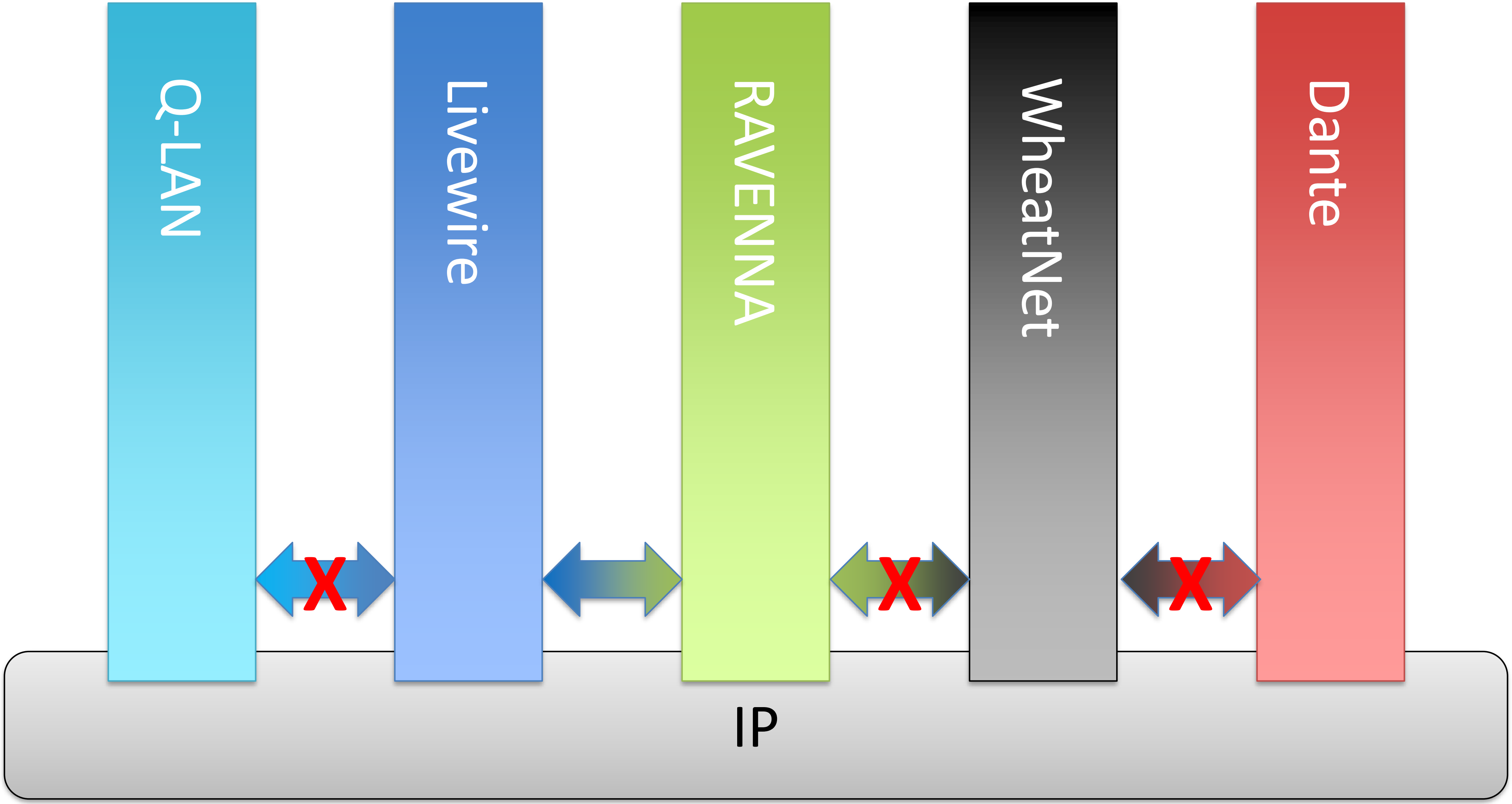
published on September, 11th, 2013

Scope:

- **Interoperability guidelines** for professional, low-latency audio over campus and local area IP networks **using existing protocols wherever possible.**
- Excludes:
  - Non-IP networking
  - Low-bandwidth media
  - Data compression
  - Low-performance WANs and public Internet
  - Video (should provide good basis for follow-on video project)

Goal:

- Technology providers may choose to implement interoperability as a special mode, or transition to it as their native mode


Q-LAN
Livewire
RAVENNA
WheatNet
Dante
X
X
X
IP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AES67
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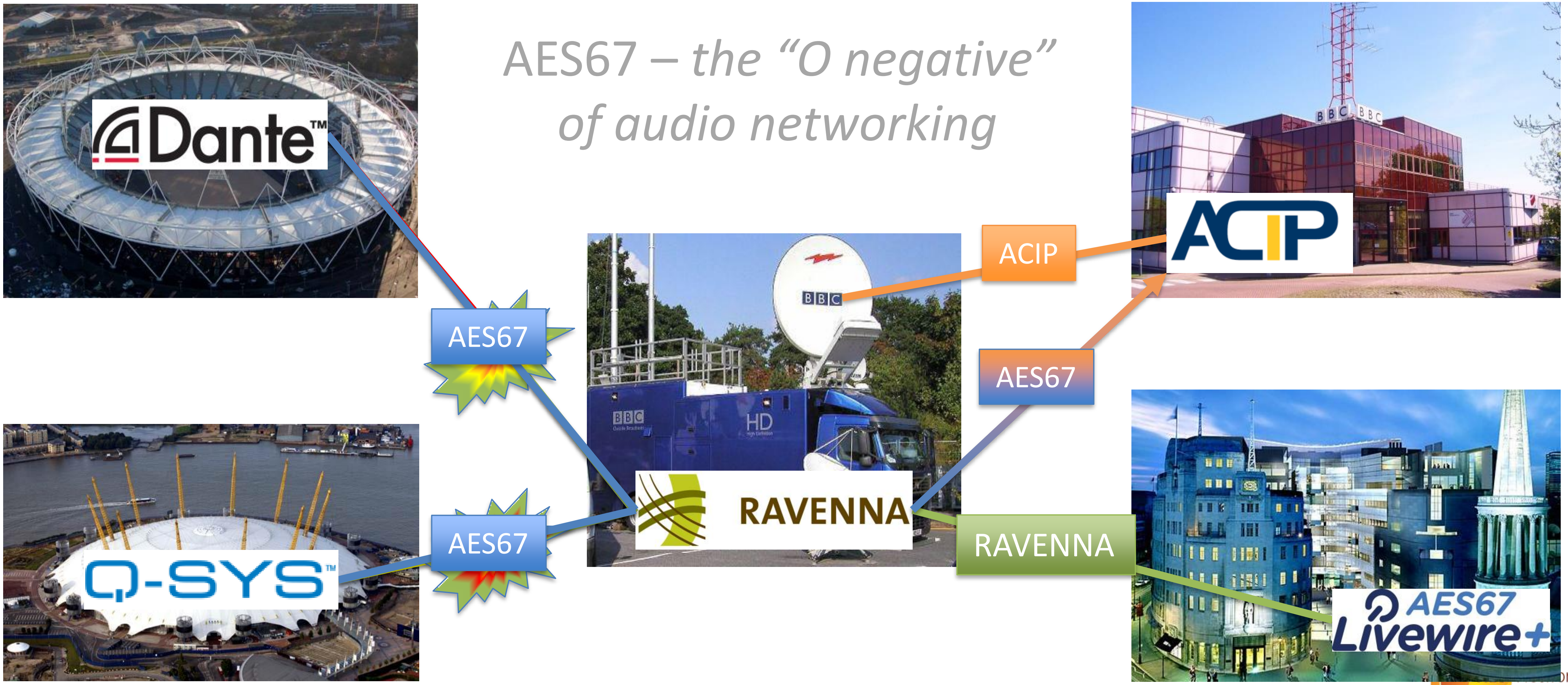
AES67 – *the "O negative" of audio networking*

AES67 – the "O negative" of audio networking



AES67 technology components

Discovery	Not specified (NMOS IS-04/05)
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)

CELEBRATING 10 YEARS RAVENNA AES67 & ST 2110 built-in

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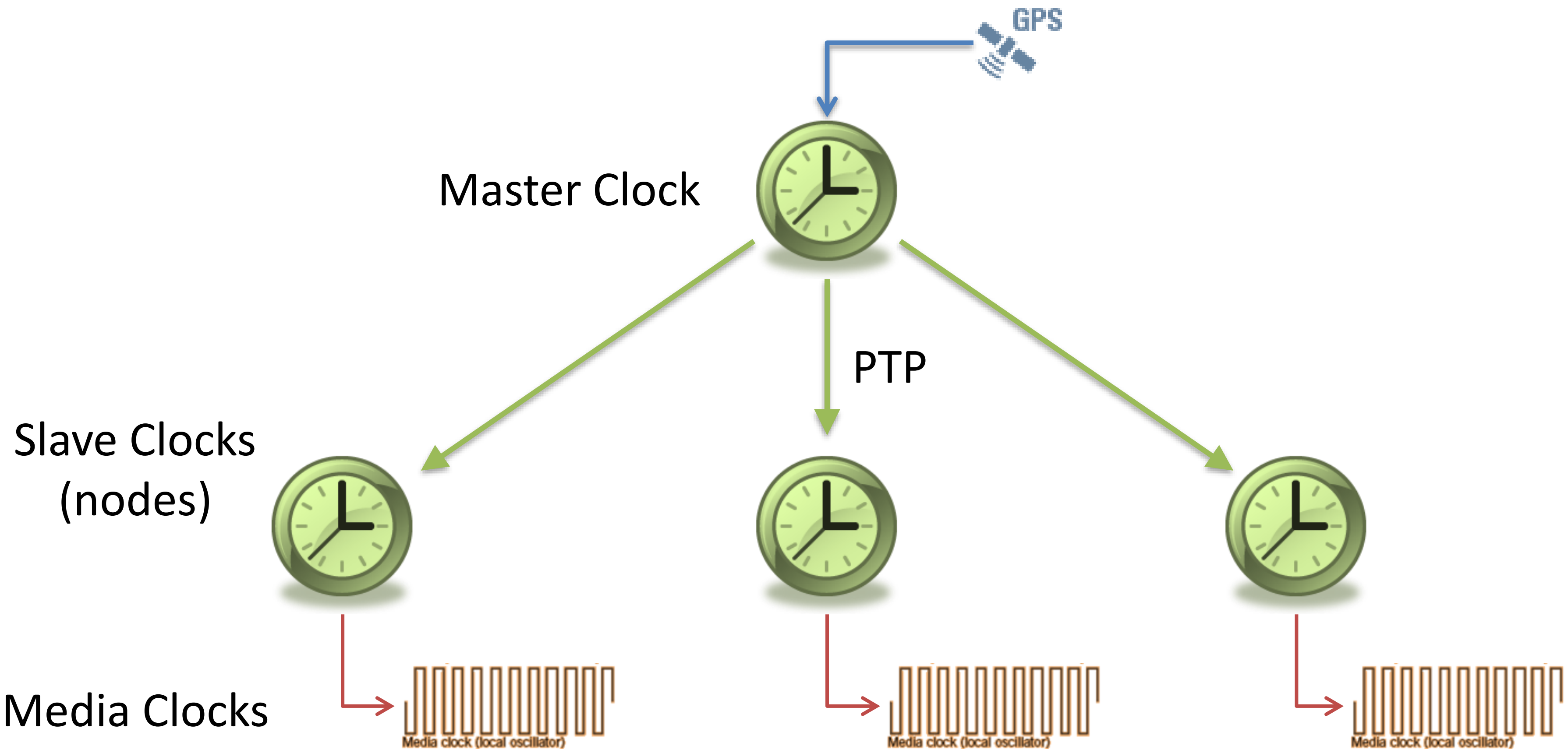
AES67 synchronization & media clocks

- All nodes are running local clocks
- Local clocks are precisely synchronized to a common wall clock via PTP
- Media clocks are generated locally from synchronized local clock
- Generation of any desired media clock (sample rate) possible

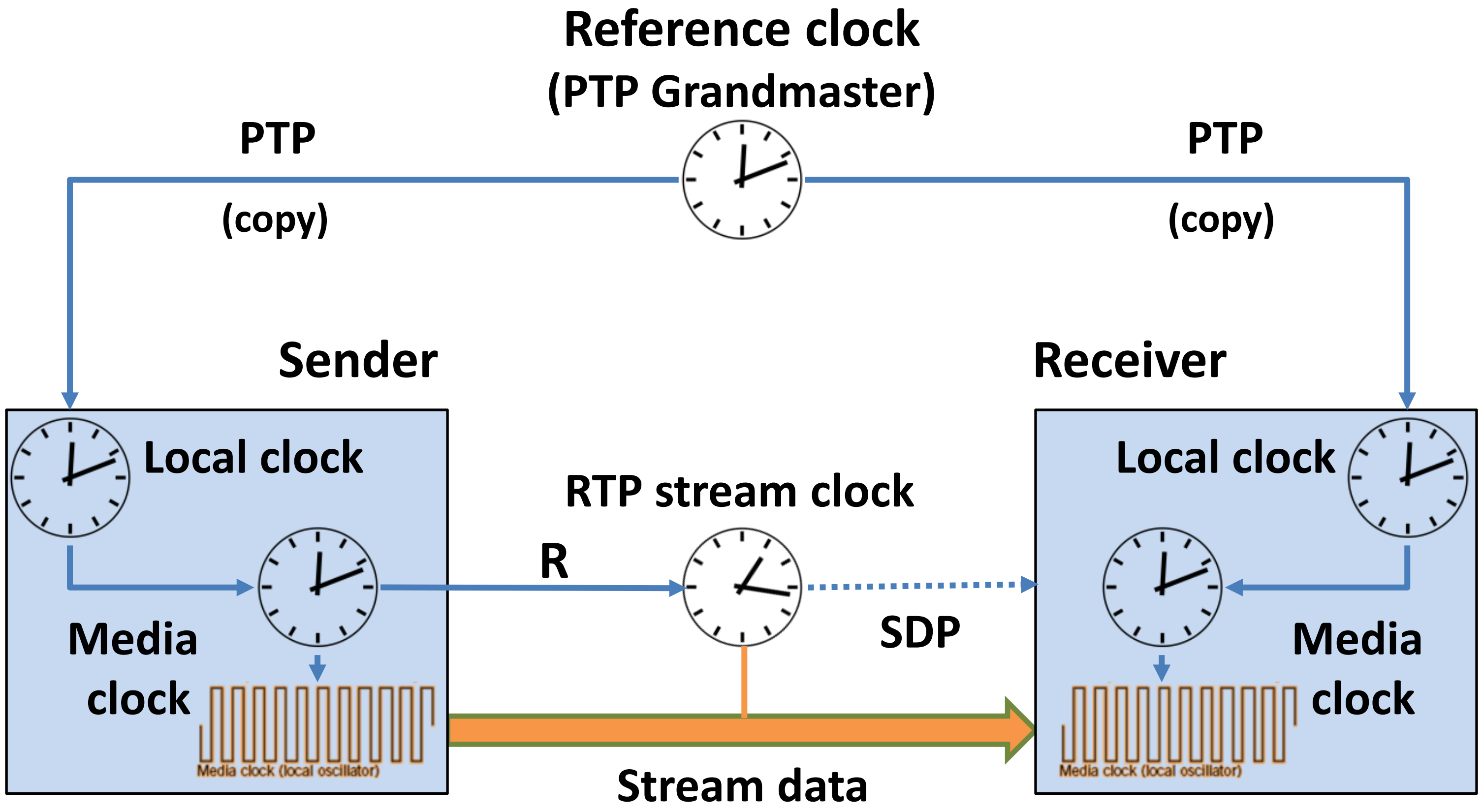
AES67 synchronization & media clocks



AES67 synchronization & media clocks

- 3 type of clocks in the system:
    - Common reference clock (“wall clock“) - provided by a Grandmaster
        - local copy of the wall clock in each node
    - Media clock – derived from the local clock (i.e. 48 kHz for audio, 90 kHz for video)
    - RTP clock (stream clock) – derived from the media clock

AES67 synchronization & media clocks



- Offset **R** is established on stream start-up
- **R** may be random to defeat crypto-text attacks
- This offset will be constant throughout the stream's lifetime

- The offset (**R**) will be conveyed via SDP (a=mediaclk:direct=<offset>)

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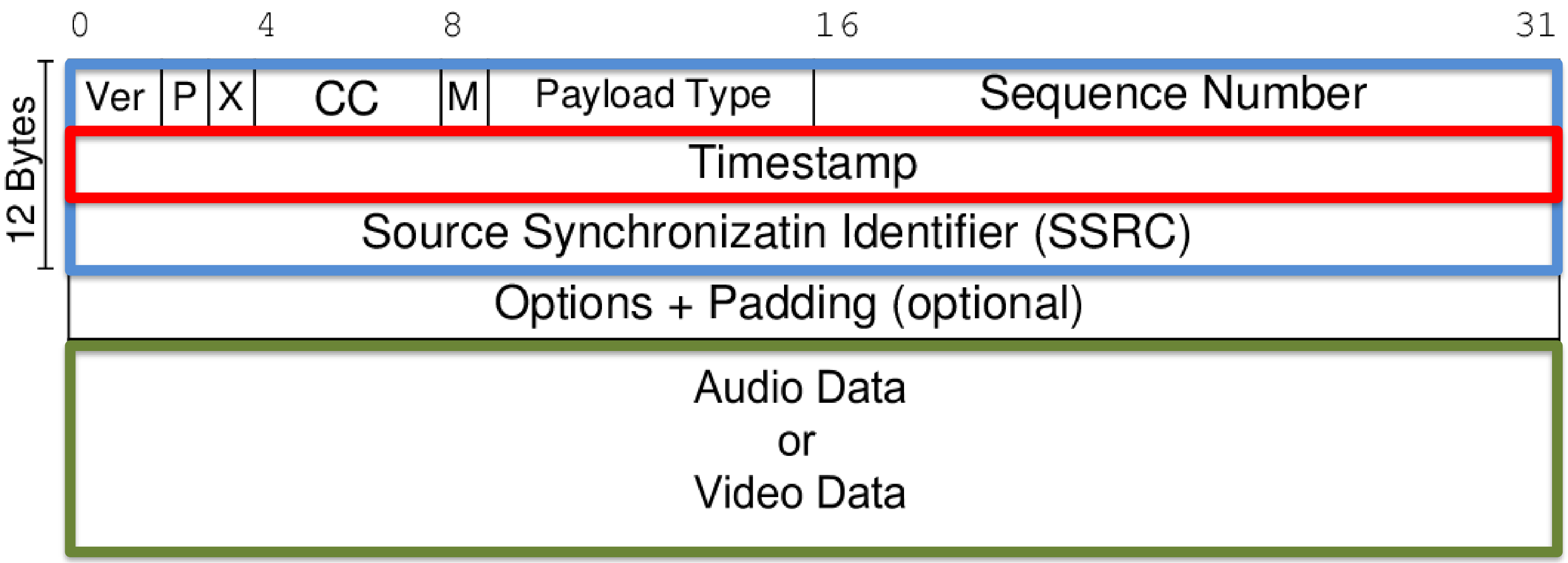
AES67 transport

RTP Packets (Layer 5)

- Consist of RTP header, optional payload headers and the payload itself
- **RTP header** (overhead) = 12 bytes, **RTP payload** (linear audio data) = up to 1440 bytes
- **RTP Timestamp** = **media clock counter** (for linear PCM audio) = 32 bits (4 bytes)
  - ⇨ rollover will occur roughly once per day (~ 1d, 51m, 19s)



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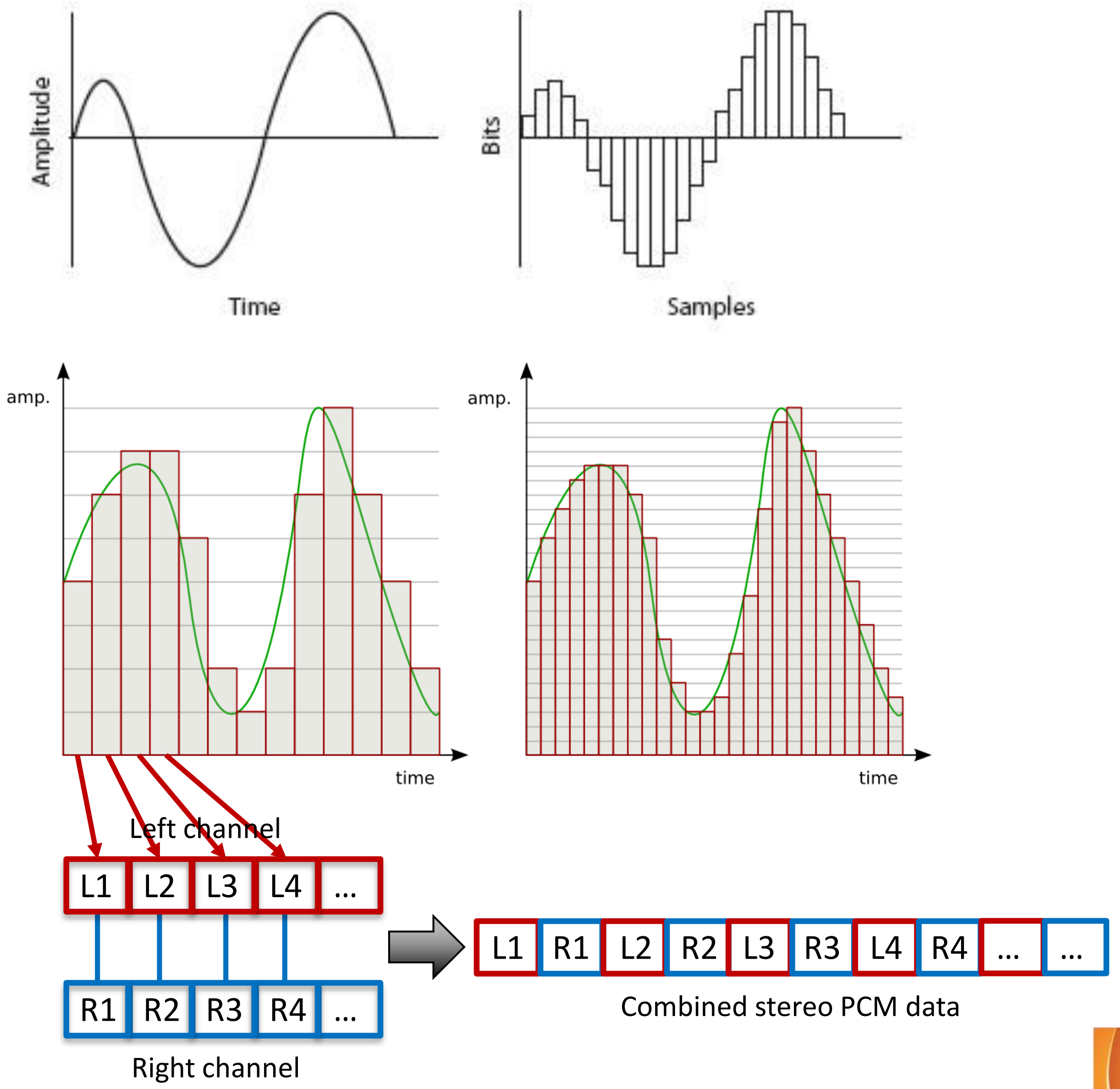
AES67 - mandatory encoding parameter

- **Sampling rate**: 48 kHz
  (optional: 44.1 / 88.2 / 96 kHz)

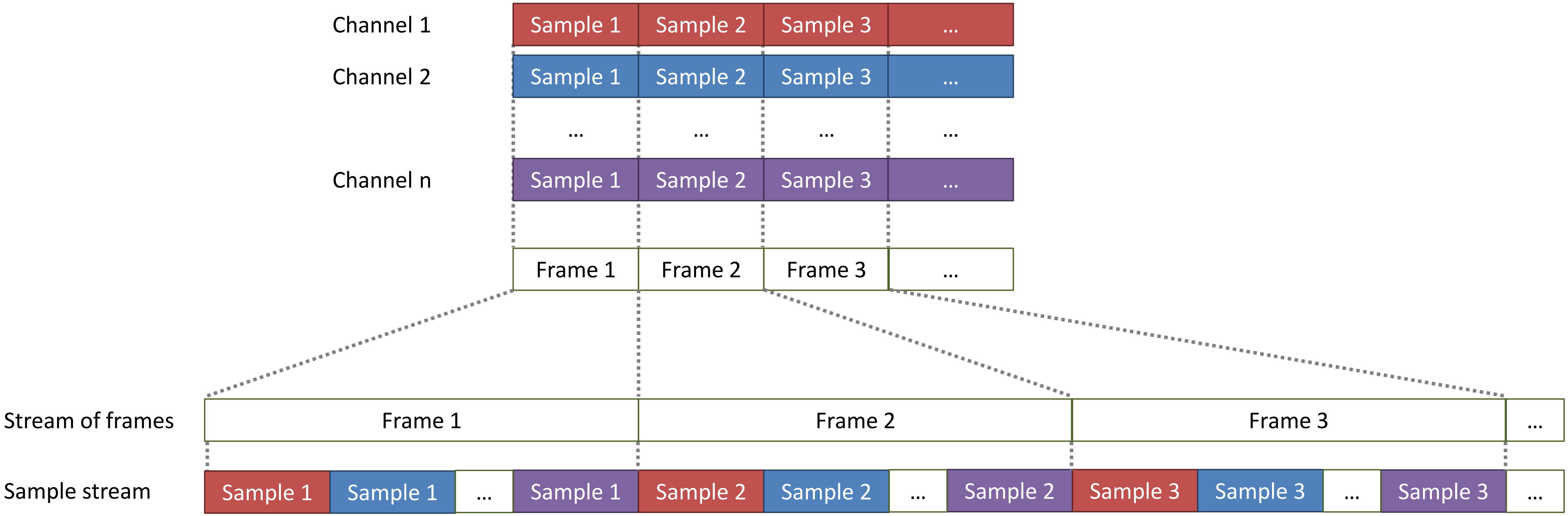
- PCM **bit width**: 16 and 24 bits

- **# of channels** per stream: 1..8



AES67 - mandatory encoding parameter

- **Packet time:** # of frames (samples x channels) per packet at given sample rate



AES67 - mandatory encoding parameter

- Packet time: # of frames (samples x channels) per packet

Packet time	Samples (48 kHz)	Samples (96 kHz)	Samples (44,1 kHz)	Notes
"125 µs"	6	12	6	Compatible with class A AVB transport
"250 µs"	12	24	12	High-performance, low-latency operation. Interoperable with class A and compatible with class B AVB transport.
"333 µs"	16	32	16	Efficient low-latency operation
"1 ms"	48	96	48	Required common packet time for all devices adhering to this standard (see 7.2.1)
"4 ms"	192	n.a.	192	For applications desiring interoperability with EBU Tech 3326 or transport over wider areas or on networks with limited QoS capability

Mandatory packet time: 1 ms (48 frames @ 48 kHz)

dp590_pmd_capture.pcap

AES67 encoding examples

Remember: max. MTU: 1500 bytes, → max. RTP payload size: 1460 (1440) bytes

#1: 16 bit PCM, 2 channels, 48 frames (1 ms @ 48 kHz): 192 bytes

#2: 24 bit PCM, 2 channels, 48 frames (1 ms @ 48 kHz): 288 bytes

#3: 24 bit PCM, 8 channels, 48 frames (1 ms @ 48 kHz): 1152 bytes

mandatory

#4: 16 bit PCM, 2 channels, 192 frames (4 ms @ 48 kHz): 768 bytes

#5: 24 bit PCM, 2 channels, 96 frames (1 ms @ 96 kHz): 576 bytes

optional

#6: 24 bit PCM, 64 channels, 7 frames (0.15 ms @ 48 kHz): 1344 bytes

RAVENNA

How to differentiate between various payload formats?

AES67 technology components

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Connection Management	SIP (unicast), IGMP (multicast)
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Encoding	L16/L24, 1..8 ch, 48 samples
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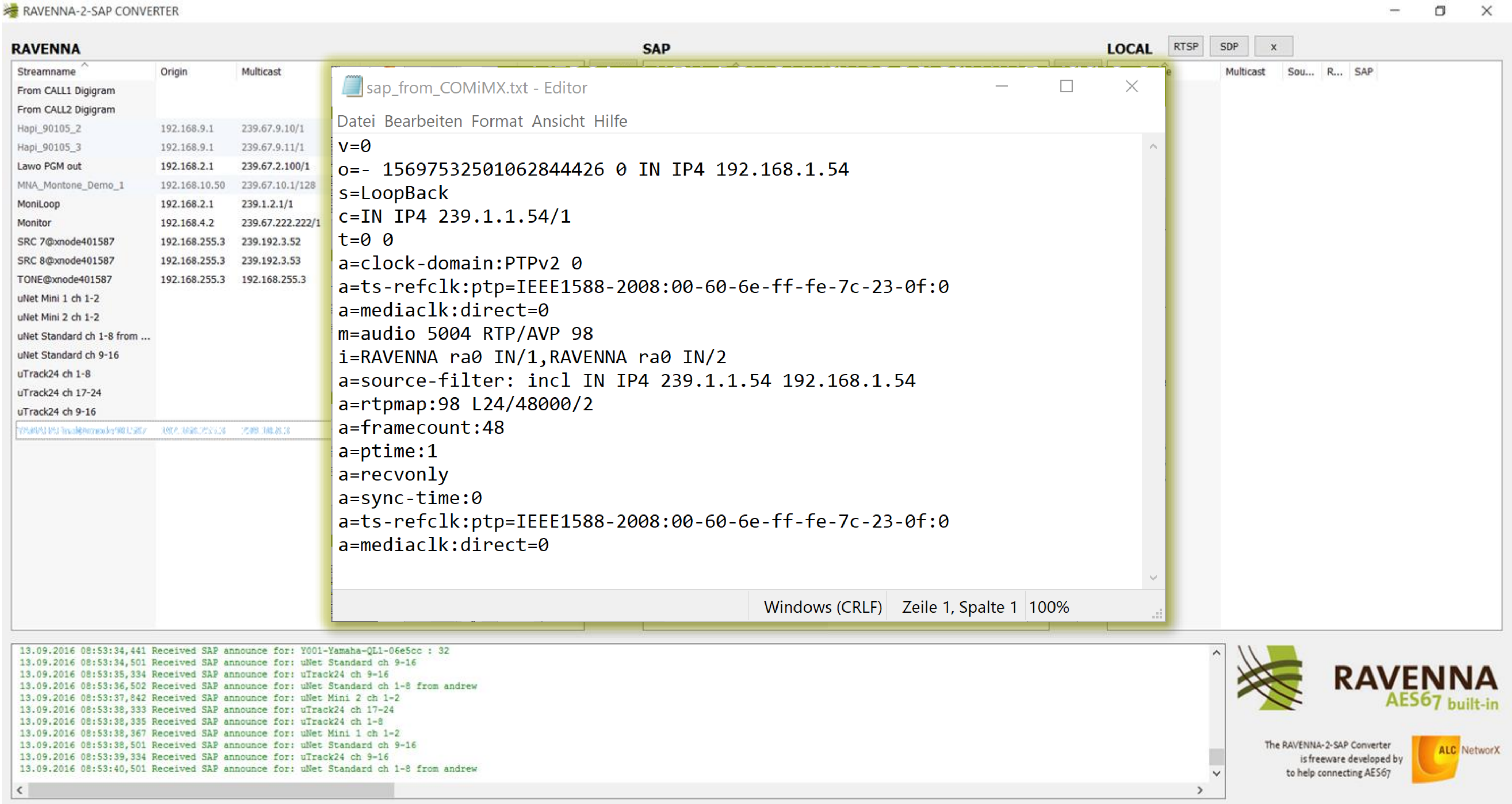
Transport	RTP / UDP / IP, unicast & multicast
Media Clock	48 kHz
Synchronisation	IEEE 1588-2008 (PTPv2)

AES67 - SDP Session Description Protocol (RFC 4556)

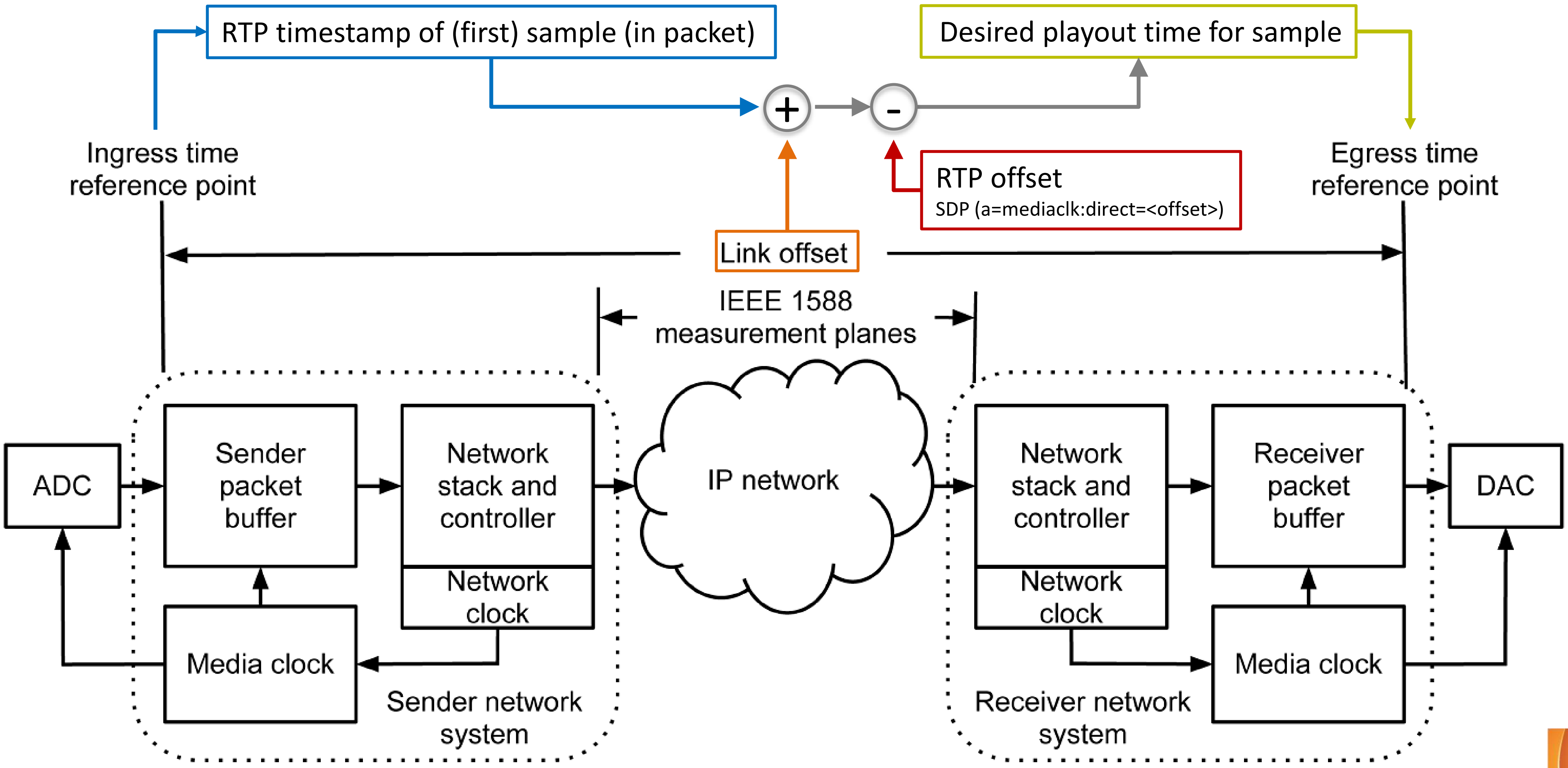
- Required to describe stream formatting, synchronization and connection information
- Provided by a sender (or management instance) for each stream
- Human-readable text:

```
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=ptime:1
```

RAVENNA-to-SAP (RAV2SAP) Converter



AES67 synchronization - link offset (latency)



AES67 synchronization - link offset

Latency (link offset) – determining factors:

- Underlying network technology (Fast Ethernet / Gigabit Ethernet / …)
- Network topology (number of hops, distances)
- Network jitter (switch performance, hops, bandwidth utilization, competing traffic, QoS)
- Stream / packet configuration (samples per packet, sampling rate)

AES67 synchronization - link offset

Latency (link offset) – dependency on frames per packet & sampling rate:

	Bytes per sample	3		MTU-RTP	1460		Freq	48000
	Frames per packet	1	8	12	32	48	128	256
	Latency ms	0,02	0,17	0,25	0,67	1,00	2,67	5,33
Channels	1	3	24	36	96	144	384	768
per	2	6	48	72	192	288	768	1536
frame	3	9	72	108	288	432	1152	2304
	4	12	96	144	384	576	1536	3072
	5	15	120	180	480	720	1920	3840
	6	18	144	216	576	864	2304	4608
	7	21	168	252	672	1008	2688	5376
	10	30	240	360	960	1440	3840	7680

AES67 synchronization - link offset

Latency (link offset) – Worst case latency calculations:

	Bytes		100	1000	Mbit/s			
MTU RTP	1460		Net Data Rate Ethernet					
MTU IP	1472		98,70	987,03	Mbit/s			
MTU Ethernet	1500		Transfer Time					
Ethernet Frame Size	1518	→	123,04	12,30	µs			
Ethernet Frame Size w/ VL	1522	→	123,36	12,34	µs			
Preamble:	8							
Interframe Gap:	12							
Formula for max. Bridge Latency	MaxLatency = t_BridgeDelay + t_MaxFrame + n * t_StreamFrame					n= number of concurrent RTP streams f		
t_BridgeDelay			10,24	1,024	µs			
max. BridgeLatency			258,58	25,86	µs	n= 1		
Max. Ethernet Frame Size	1522							

	1. Hop			2. Hop			3. Hop	
	Bytes	Delay (µs)		Bytes	Delay (µs)		Bytes	Delay
1. stream		FE	GbE		FE	GbE		FE
channels	8			*8*			*8*	
bytes / sample	3			*3*			*3*	
frames/packet	48			*48*			*48*	
sample rate	48000			*48000*			*48000*	
payload	1152			*1152*			*1152*	
frame size	1214			*1214*			*1214*	
frame + pre + IFG	1234			*1234*			*1234*	
→ **Worst Case Latency**		**232,32**	**23,23**		**1945,44**	**194,54**		**3658,56**
Competing streams								
number	0			15			15	
channels	8			8			8	
bytes / sample	3			3			3	
frames/packet	48			48			48	
sample rate	48000			48000			48000	
payload	1152			1152			1152	

AES67 synchronization - link offset

Latency (link offset) – determining factors:

- Underlying network technology (Fast Ethernet / Gigabit Ethernet / …)
- Network topology (number of hops, distances)
- Network jitter (switch performance, hops, bandwidth utilization, competing traffic, QoS)
- Stream / packet configuration (samples per packet, sampling rate)

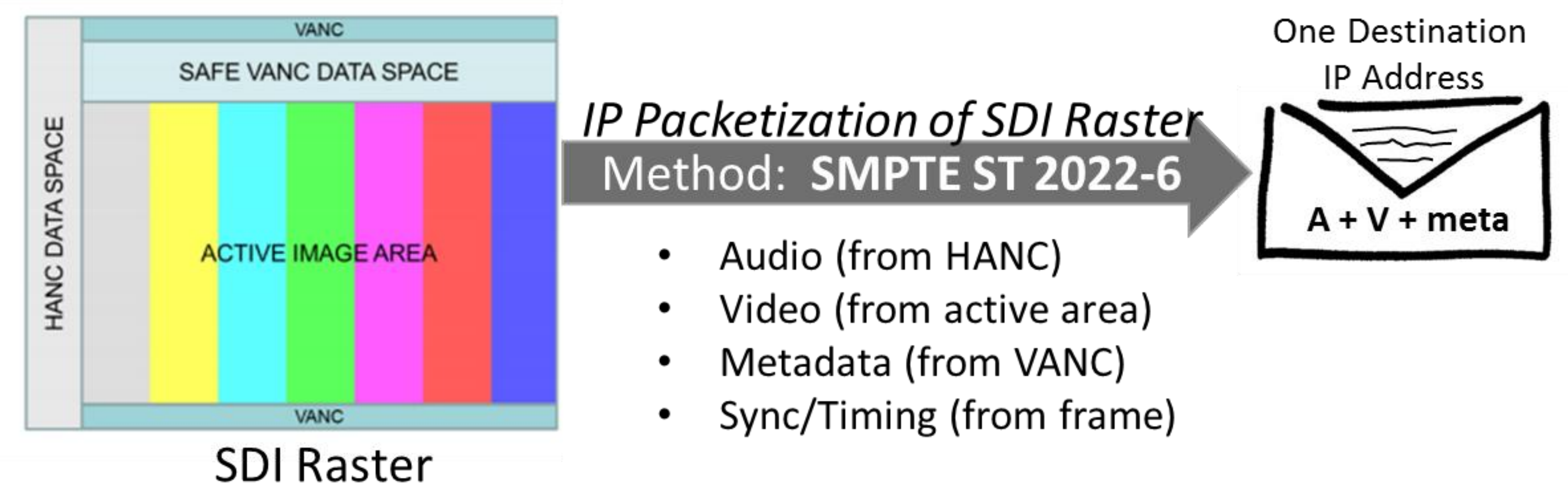
⇨ Base line: sub-milliseconds latency achievable
(even with layer 3 packet-switching technology)

SMPTE ST 2110 –
Professional Media over Managed IP Networks

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

SMPTE ST 2022-6 The "bundled" approach



- Audio (from HANC)
- Video (from active area)
- Metadata (from VANC)
- Sync/Timing (from frame)

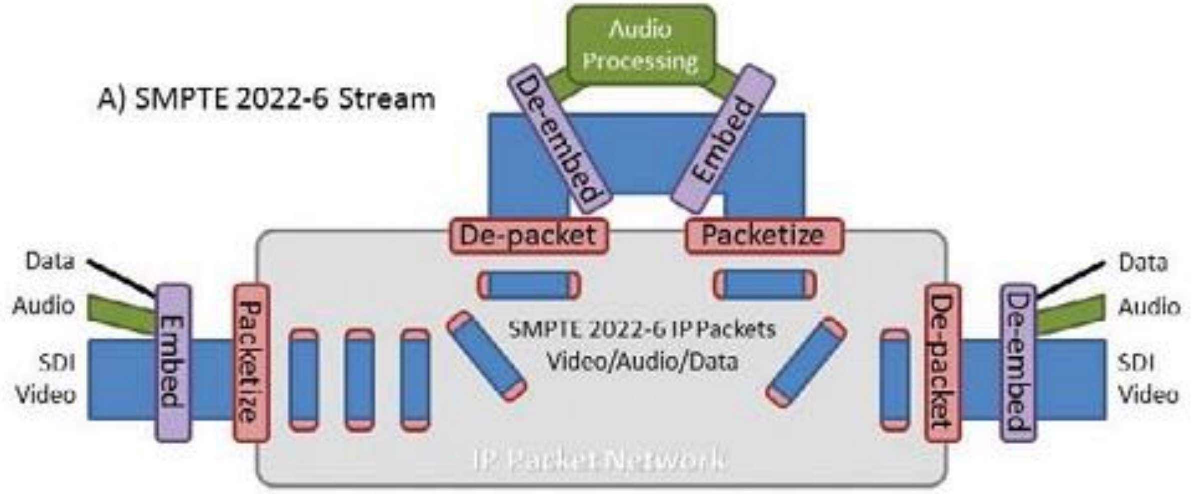
Published beginning in 2012

SMPTE ST 2110 – The essence-based approach

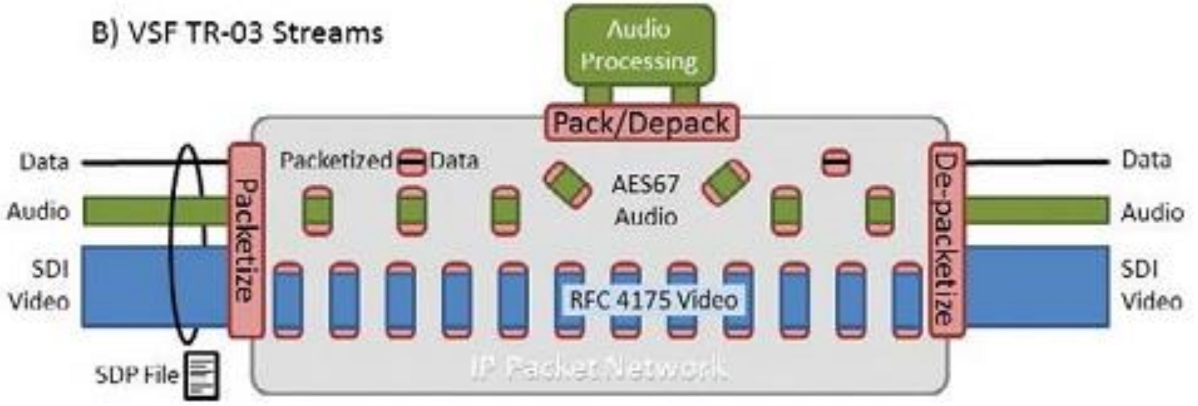
Published in 2017

SMPTE 2022-6 vs. SMPTE ST 2110

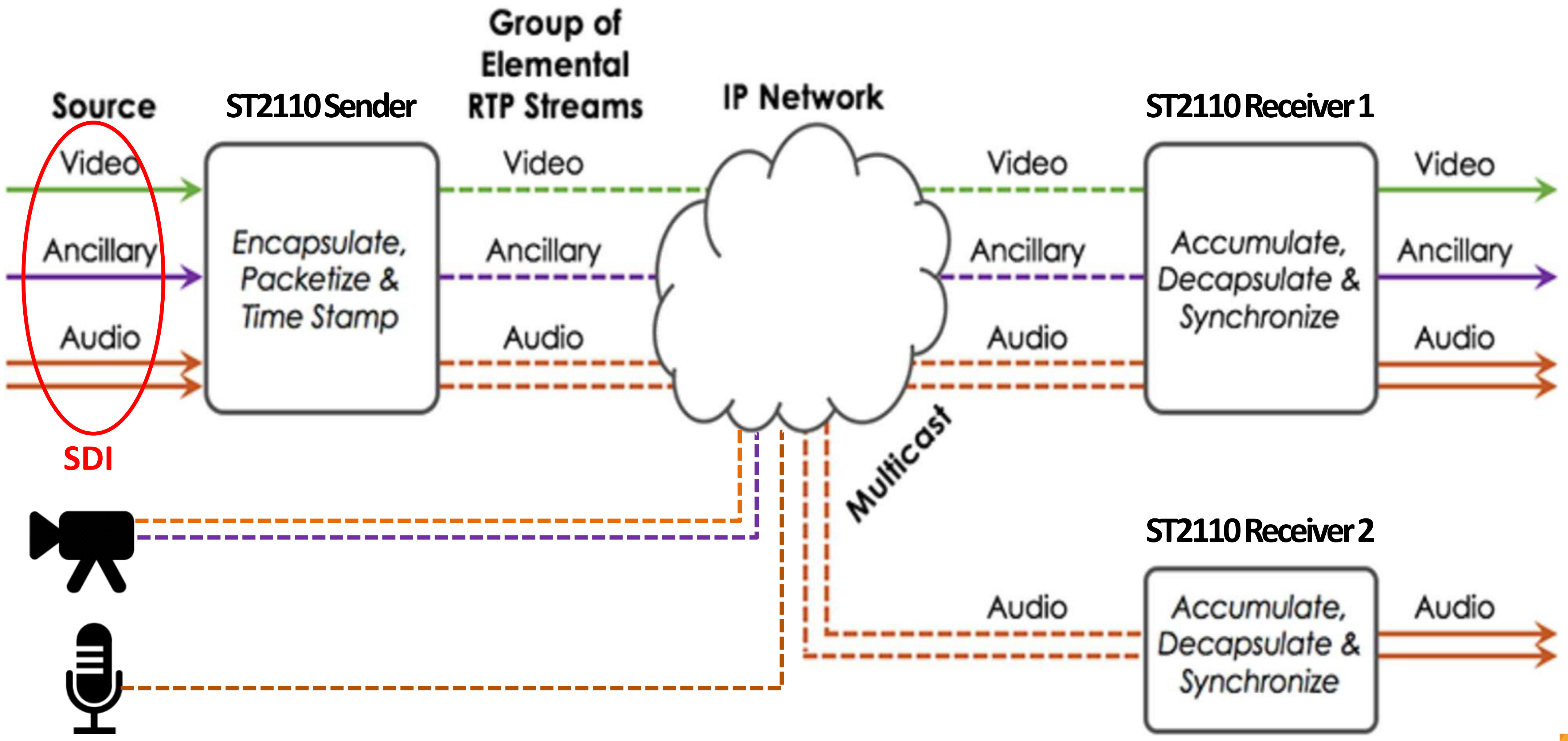
ST 2022-6



ST 2110



SMPTE ST 2110 - Professional Media over Managed IP Networks



SMPTE ST 2110 - Professional Media over Managed IP Networks

Document structure:

- 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)
- 2110-22: Compressed Active Video
  - defines payload format for CBR-compressed video (no codec definition!)

SMPTE ST 2110 - Professional Media over Managed IP Networks

Document structure:

- 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)

SMPTE ST 2110 - Professional Media over Managed IP Networks

Document structure (audio):

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

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SMPTE ST 2110 - Professional Media over Managed IP Networks

Document structure (linear PCM audio):

- 2110-**10**: System Timing & Definitions
  - defines transport layer and synchronization (SMPTE2059, clocks, RTP, SDP etc.)
- 2110-**30**: PCM Digital Audio
  - defines payload format for linear audio (AES67, constraints)

AES67

Constraints!

⇨ AIMS WP on AES67 / ST2110 Commonalities & Constraints

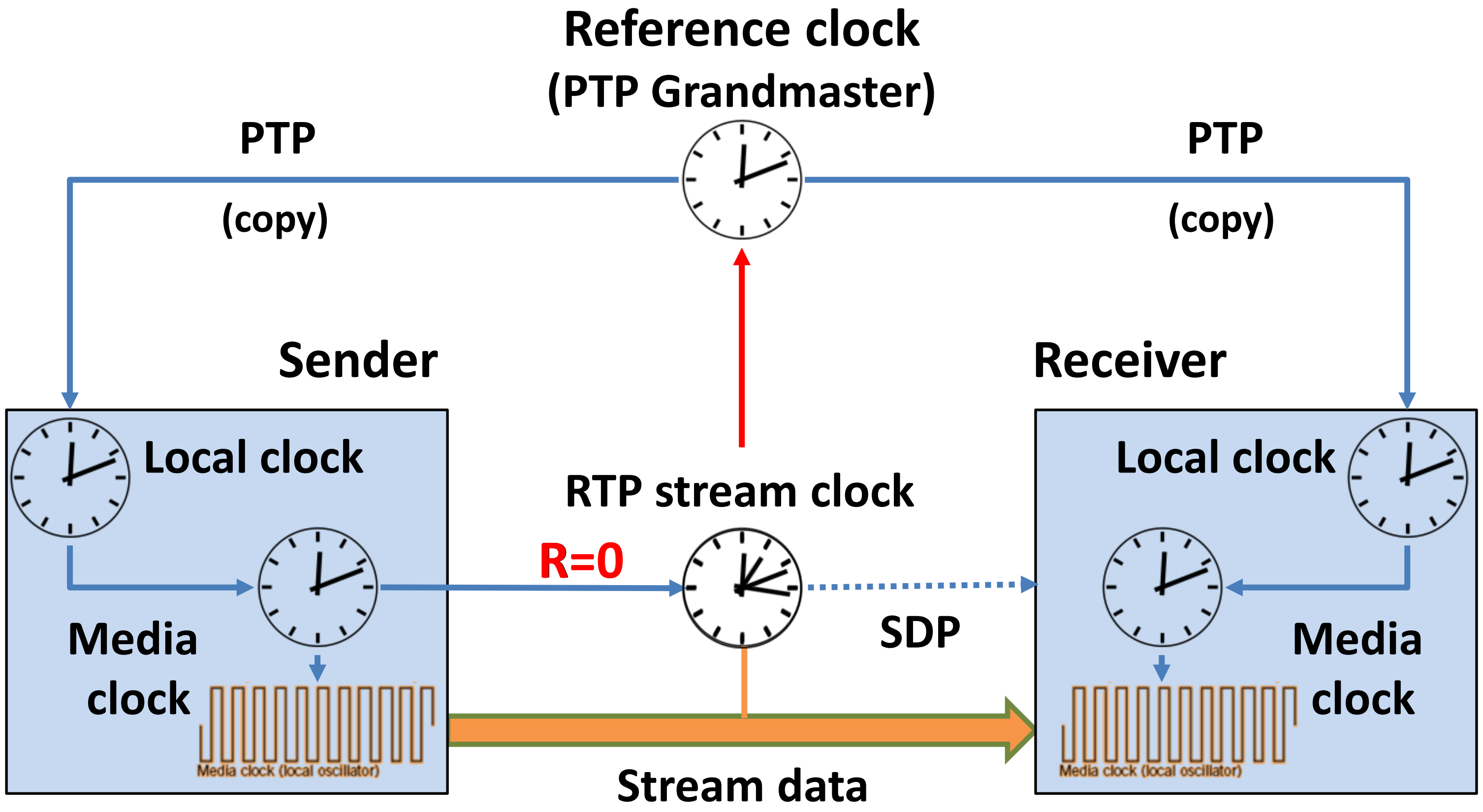
SMPTE ST 2110 - Professional Media over Managed IP Networks

Constraints of 2110-10 & -30 w/ respect to AES67

- Synchronisation & Timing -

- PTP:
  - support of SMPTE 2059-2 required
    - message rate according to AES-R16-2016 (AES67 PTP Media profile)
  - `defaultDS.slaveOnly=true` to intentionally prevent devices from entering PTP master state
  - `a=ts-refclk:ptp=traceable` and `a=tsrefclkts-refclk:localmac=<mac_addr>` allowed
- RTP clock: offset= 0 w/ respect to media clock / reference clock
  - `a=mediaclk:direct=0`

SMPTE ST 2110-10 synchronization & media clocks



- Offset **R** is established on stream start-up
- **R** may be random to defeat crypto-text attacks
- This offset will be constant throughout the stream's lifetime

- The offset (**R**) will be conveyed via SDP (a=mediaclk:direct=<offset>) **– must be "0" in ST2110**

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SMPTE ST 2110 - Professional Media over Managed IP Networks

Constraints of 2110-10 & -30 w/ respect to AES67

- Protocols -

- IGMPv3 required (includes automatic fallback to IGMPv2)
- Support of RTCP not required (but must be tolerated)
- Support of SIP (or any other connection management protocol) not required
- Redundancy (optional): SMPTE 2022-7
  - no identical IP source and destination addresses
- Channel assignment map (SDP attributes - IETF RFC 3190 / SMPTE ST 2067-8) (optional)
  - `a=fmtp:<payload type> channel-order=<convention>.<order>`
  - Examples: `a=fmtp:101 channel-order=SMPTE2110.(51,ST)`
    `a=fmtp:101 channel-order=SMPTE2110.(M,M,M,M,ST,U02)`

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SMPTE ST 2110 - Professional Media over Managed IP Networks

Constraints of 2110-10 & -30 w/ respect to AES67

- 6 conformance levels (packet setup):

Level	To be supported by the Receiver
A (mandatory)	**Reception of 48 kHz streams with 1 to 8 audio channels at packet times of 1 ms**
B	Level A + 1 to 8 channels at packet times of **125** µs
C	Level A + 1 to **64** channels at packet times of **125** µs

AES67 compliant

SMPTE ST 2110 - Professional Media over Managed IP Networks

Constraints of 2110-10 & -30 w/ respect to AES67

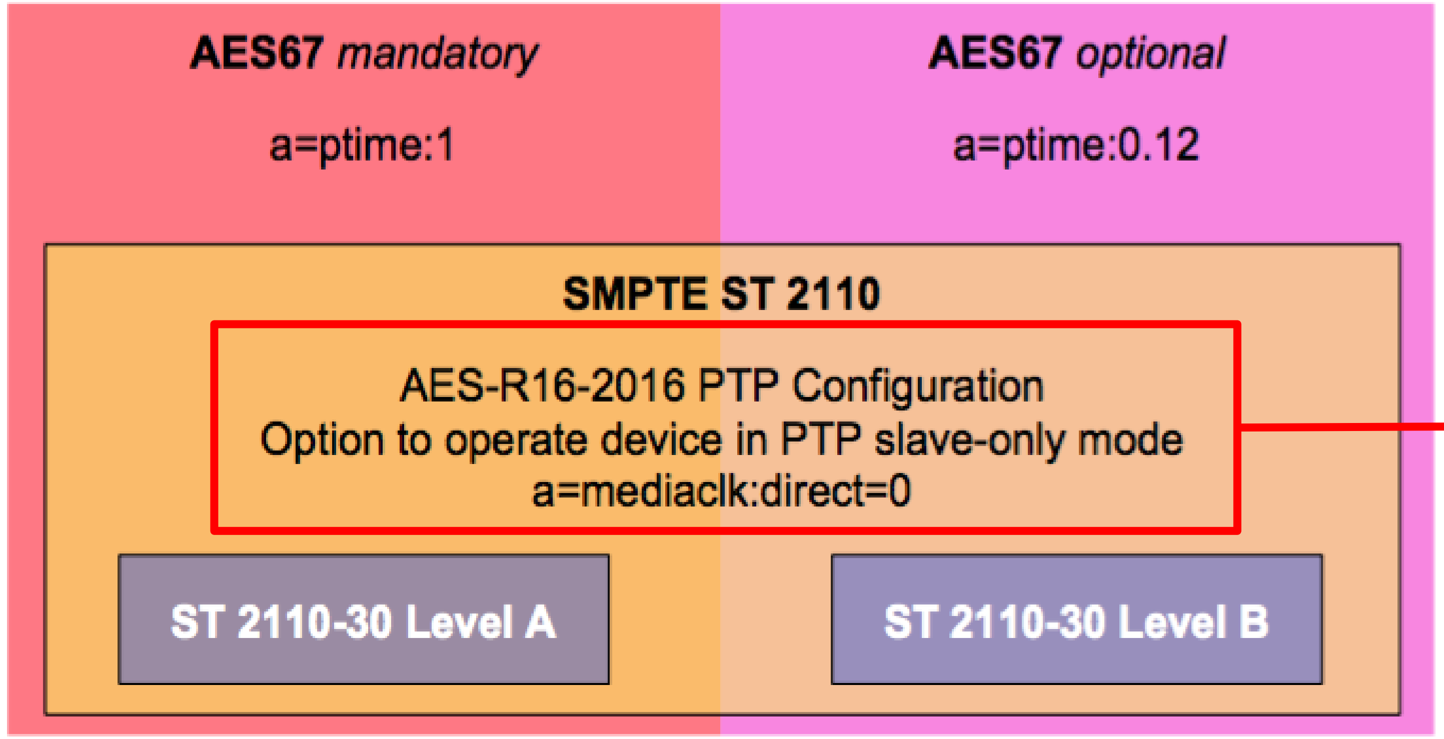
- 6 conformance levels (packet setup):

96 kHz

Level	To be supported by the Receiver
A**X**	Level A (⇨ 48 kHz) + Reception of **96** kHz streams with 1 to **4** audio channels at packet times of 1 ms
B**X**	Level B + AX + 1 to **8** channels at packet times of **125** µs
C**X**	Level C + AX + 1 to **32** channels at packet times of **125** µs

SMPTE ST 2110 - Professional Media over Managed IP Networks

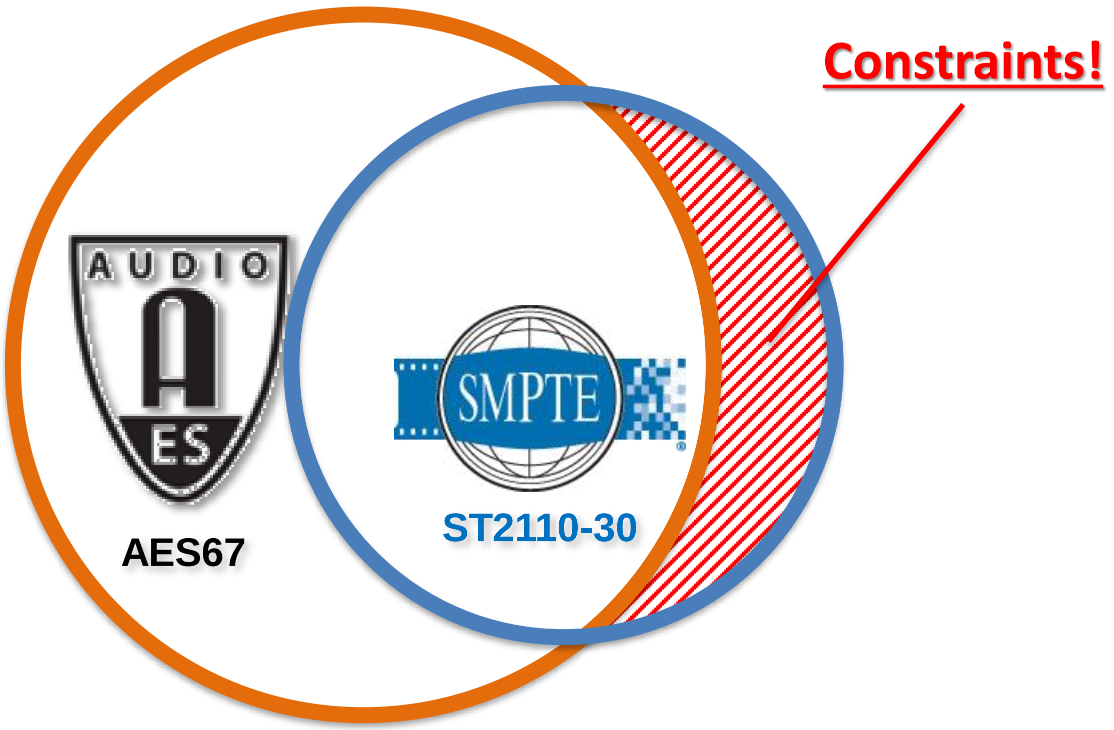
SMPTE ST 2110-30 is a subset of AES67,
adding constraints to clocking and streaming



Constraints!

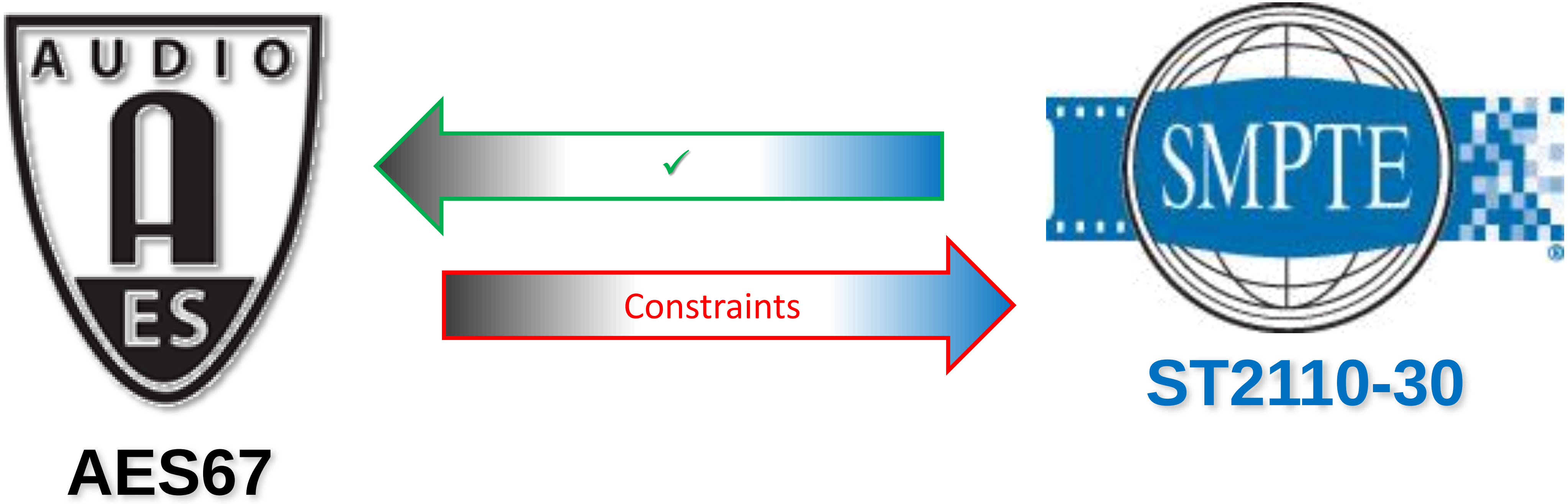
SMPTE ST 2110 - Professional Media over Managed IP Networks

AES67 / ST 2110-30 compatibility?



SMPTE ST 2110 - Professional Media over Managed IP Networks

AES67 / ST 2110-30 stream compatibility?



SMPTE ST 2110 - Professional Media over Managed IP Networks

ST 2110-31 – 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.)

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SMPTE ST 2110 - Professional Media over Managed IP Networks

ST 2110-31 – transparent transport of AES3 audio data

- 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

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|0|B|F|  PCUV |                   DATA24                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

  - RTP payload format signaled in SDP:

    a=rtpmap:<pt> AM824/48000/<nchan> - with <nchan> always being an equal number (stereo channels)

  - retains all other SDP parms

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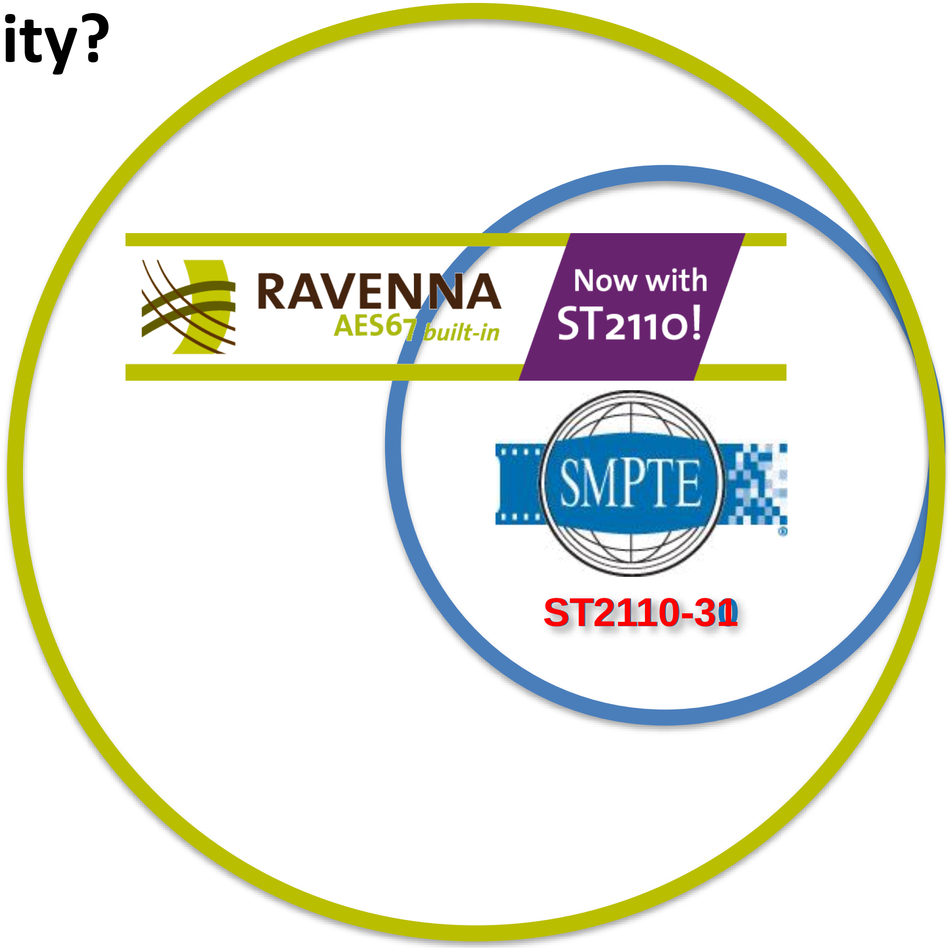
AES67 / ST 2110-31 compatibility?



SMPTE ST 2110 - Professional Media over Managed IP Networks

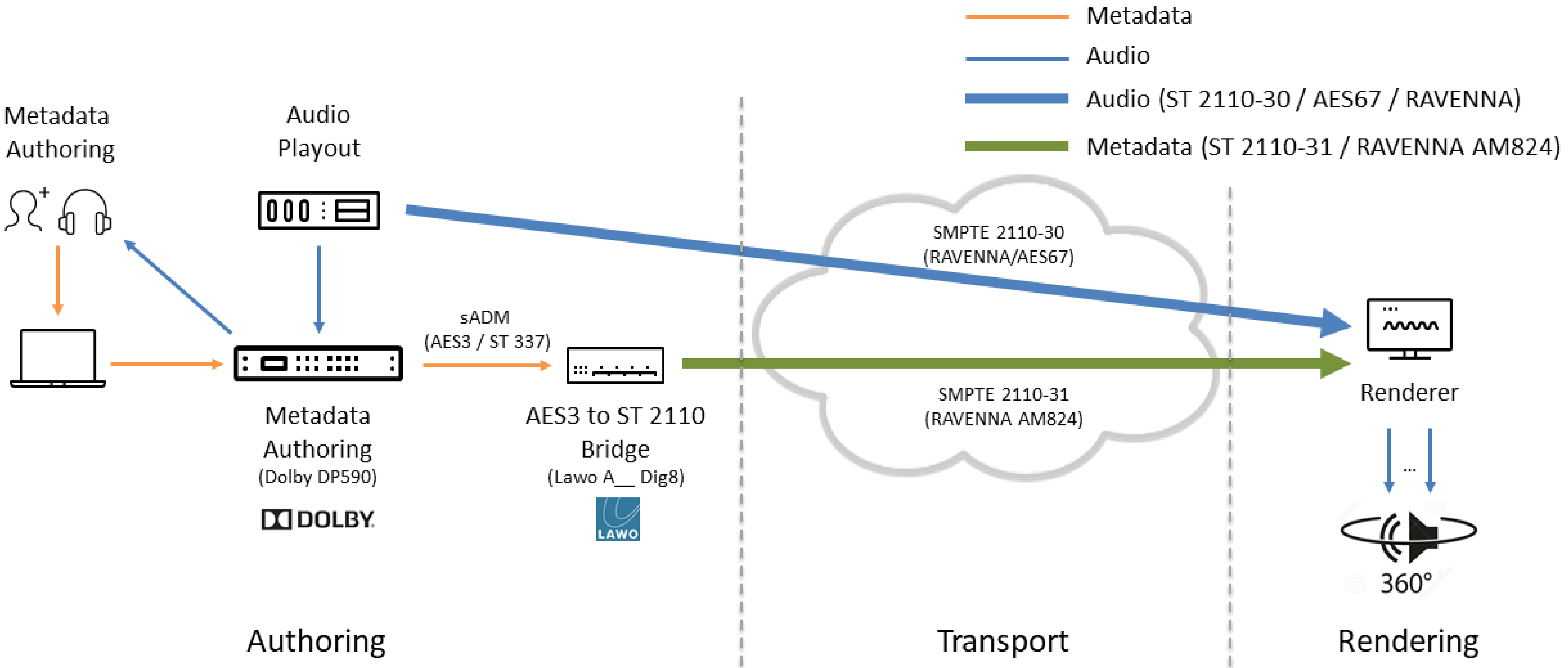
AES67 / ST 2110-31 stream compatibility?

[ST 2110 / AM824 profile]

[add‘l requirements (discovery)]

ST2110-31

SMPTE ST 2110 - The Audio Parts



Questions?

Answers!

ST 2110 / AES67 Resources:

www.ravenna-network.com/resources

www.aimsalliance.org (resources)

www.smpte.org/smpte-st-2110-faq

You‘ve made it!

Contact information:

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RAVENNA
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www.ravenna-network.com

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