RAVENNA 2020 Webinar Series

Introduction
to
AES67 & SMPTE ST 2110

Tue, Apr 28, 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/ST2110-compliant (*built-in*)

Relevant Standards

- **AES67**
  - defines high-performance AoIP interoperability
- **SMPTE ST 2110 (SMPTE ST 2059)**
  - defines elementary essence data transport on managed IP networks
- **AMWA NMOS**
  - defines upper layer operational & management functionalities
- **AES70**
  - defines device control & connection management
- **AES X242**
  - defines real-time audio meta data transport over IP

AES67

What was the original goal?

- “Provide a method to connect disparate Audio-over-IP systems to achieve workaround-free networked audio interoperability”

AES67

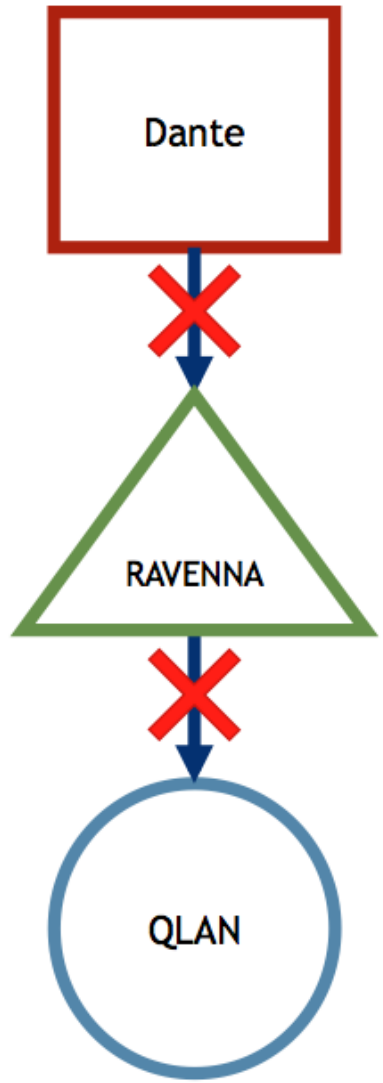
What is AES67?

- 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

AES67

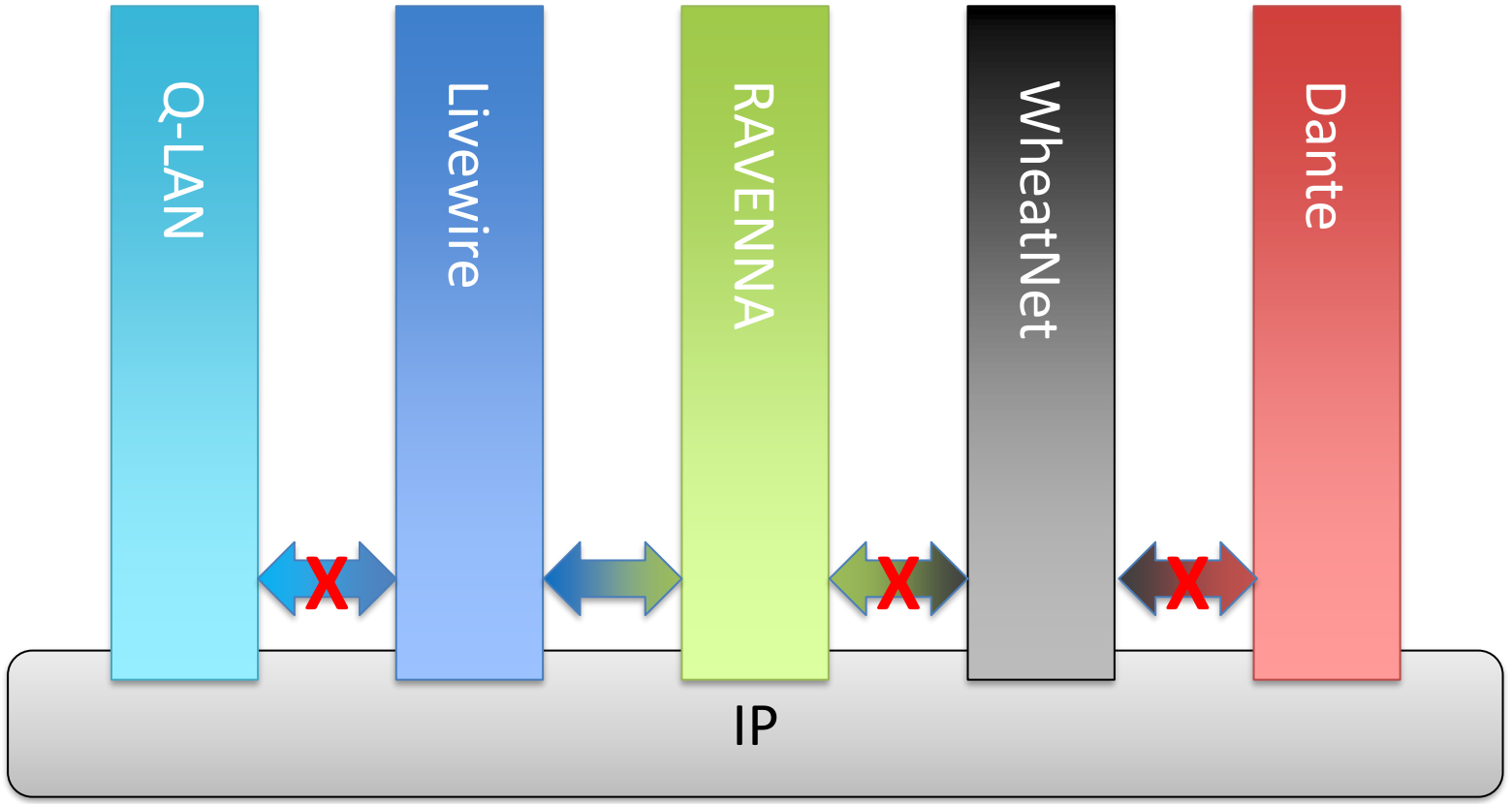
Problem Statement

- 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



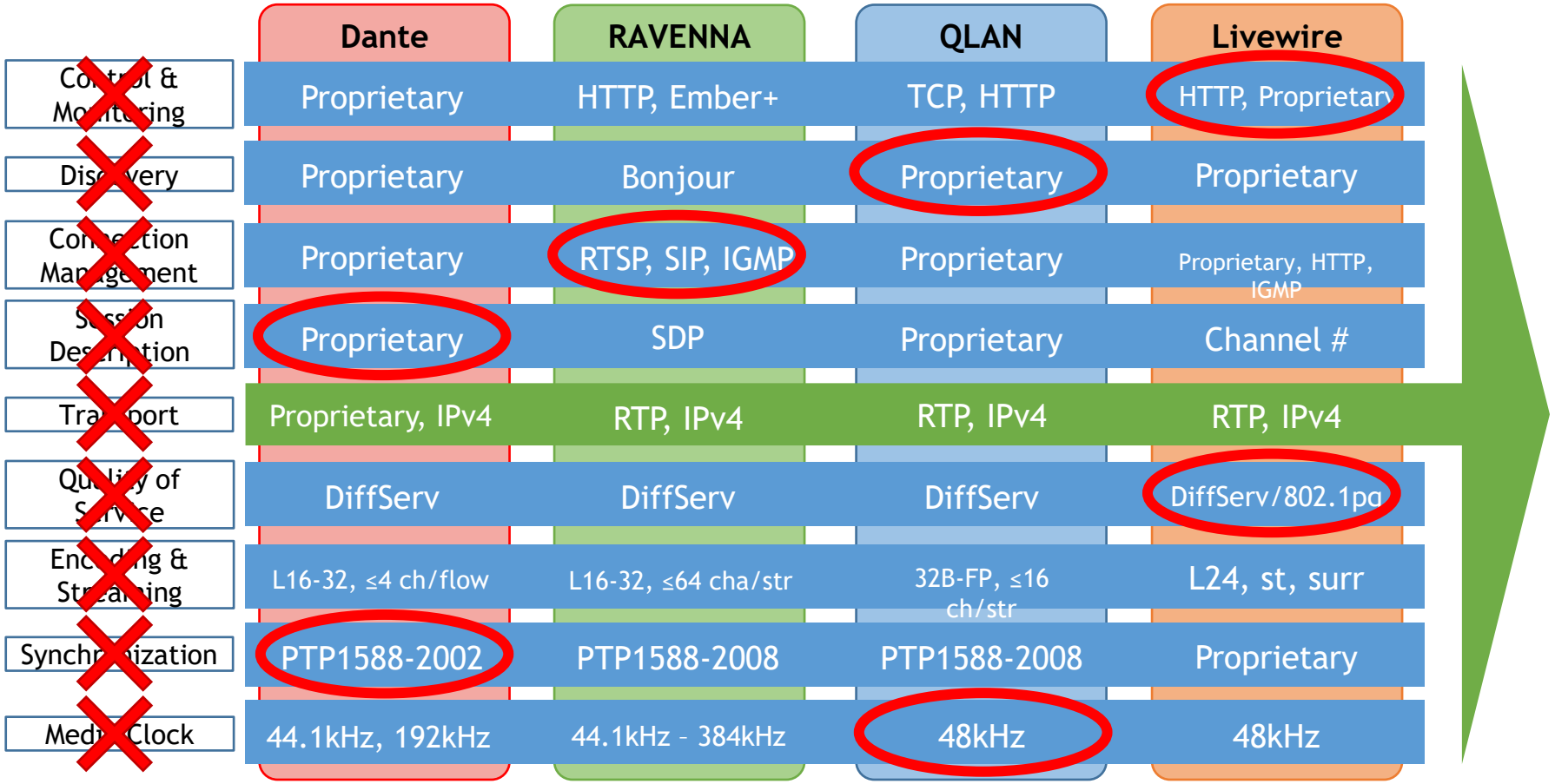
AES67

AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability

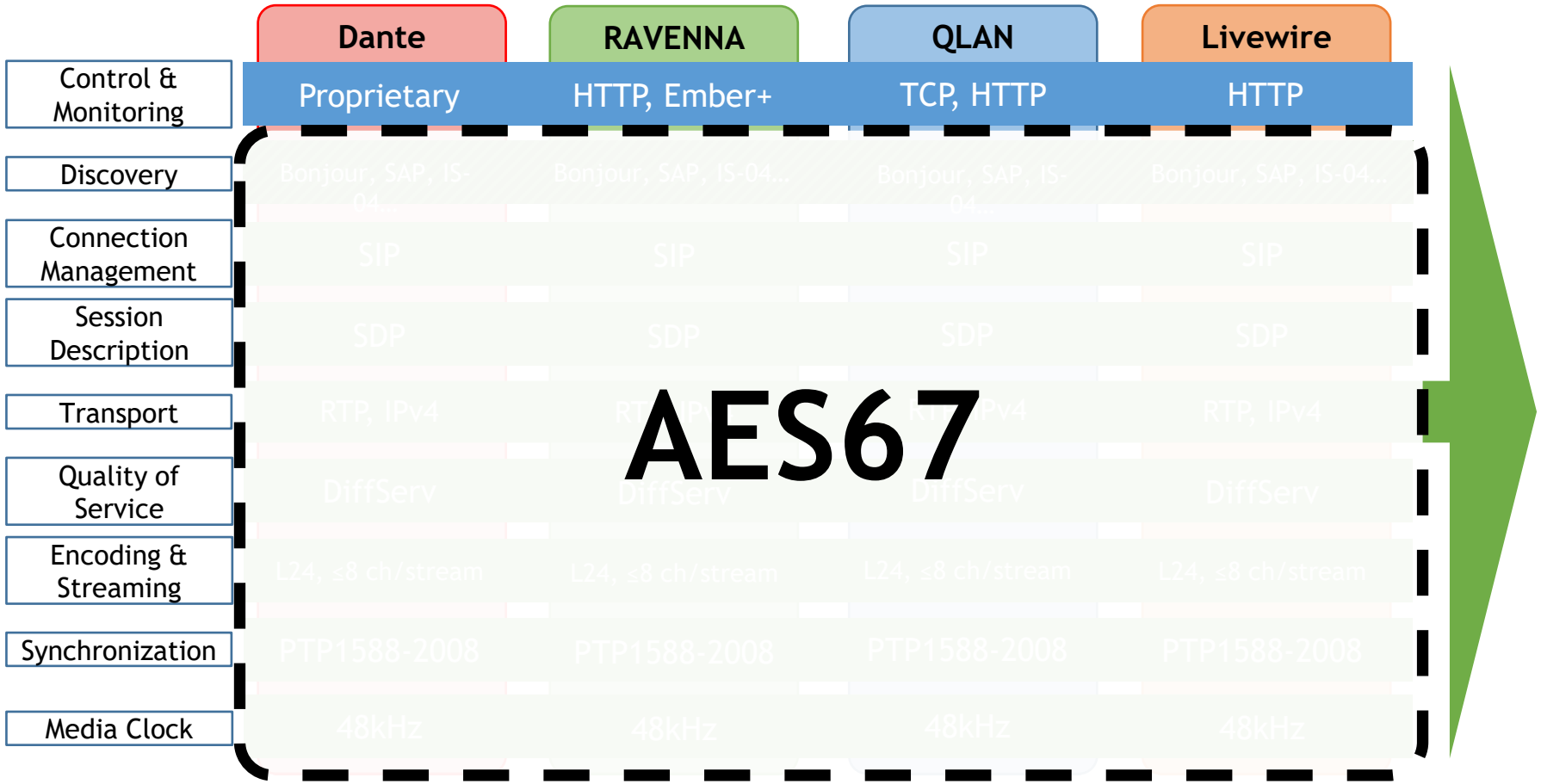


AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability

The Road to Incompatibility…



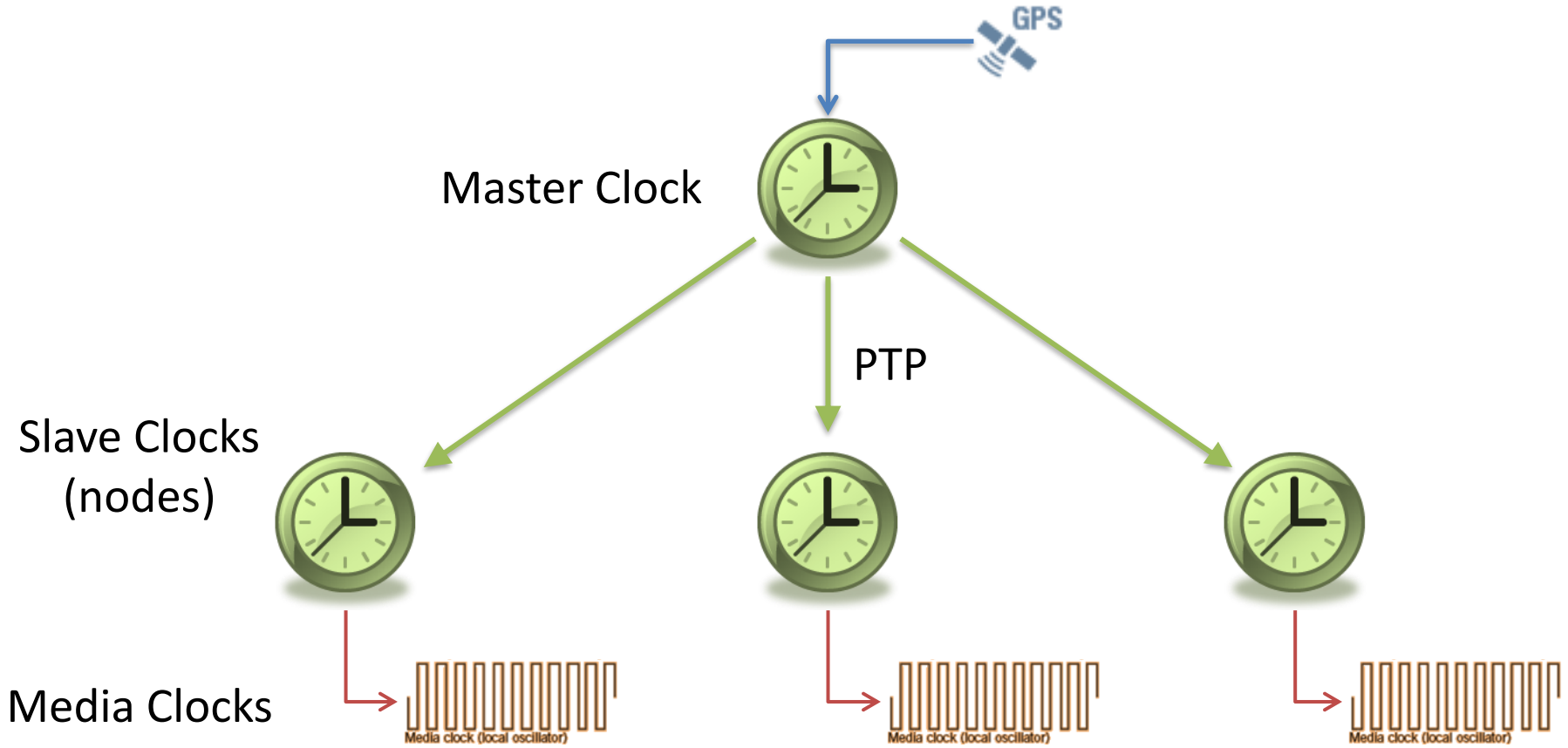
The Road to Incompatibility…



AES67 technology components

Media Clock	48 kHz
Synchronisation	IEEE 1588-2008 (PTPv2)

AES67 synchronization & media clocks



AES67 technology components

Transport	RTP / UDP / IP, unicast & multicast
Media Clock	48 kHz
Synchronisation	IEEE 1588-2008 (PTPv2)

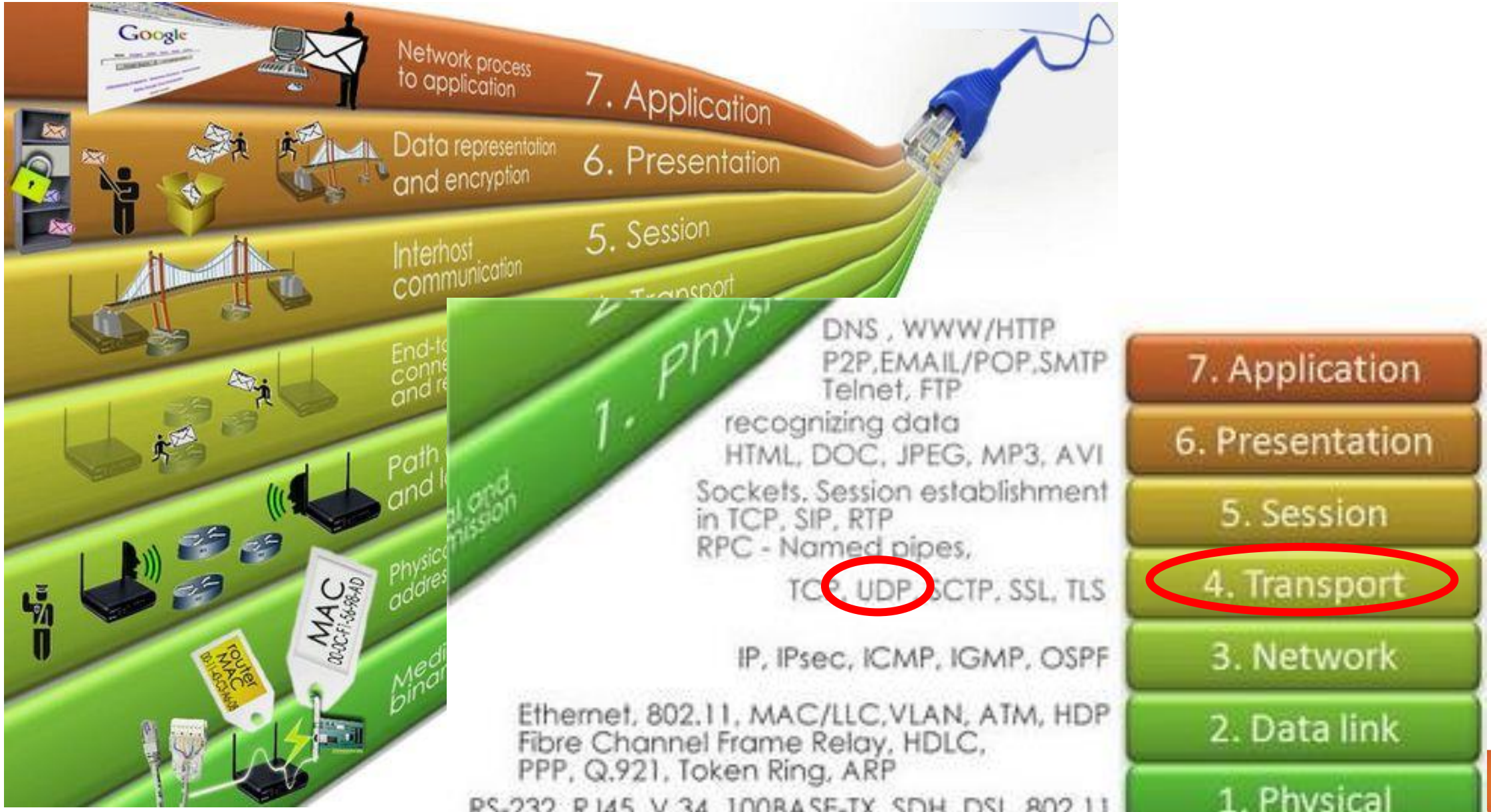
AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability

DNS , WWW/HTTP
P2P,EMAIL/POP,SMTP
Telnet, FTP
recognizing data
HTML, DOC, JPEG, MP3, AVI
Sockets, Session establishment
in TCP, SIP, RTP
RPC - Named pipes,
TCP, UDP, SCTP, SSL, TLS
IP, IPsec, ICMP, IGMP, OSPF
Ethernet, 802.11, MAC/LLC,VLAN, ATM, HDP
Fibre Channel Frame Relay, HDLC,
PPP, Q.921, Token Ring, ARP
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, 802.11

7. Application
6. Presentation
5. Session
4. Transport
3. Network
2. Data link
1. Physical

ALC NetworX

AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability



AES standard for audio applications of networks - High-performance streaming audio-over-IP interoperability

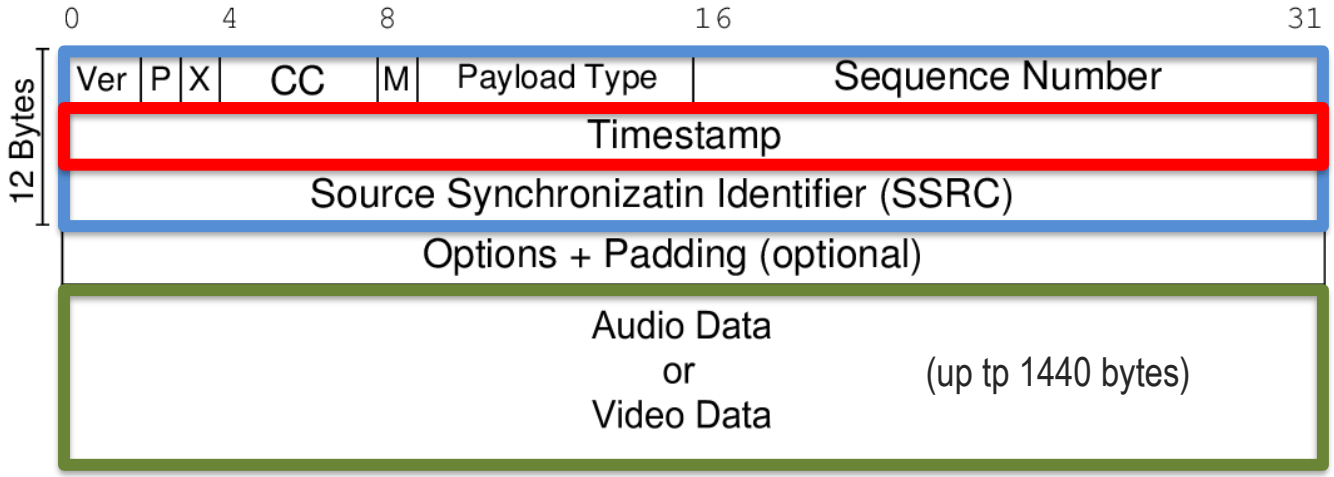
RTP - Real-time Transport Protocol (RFC 3550)

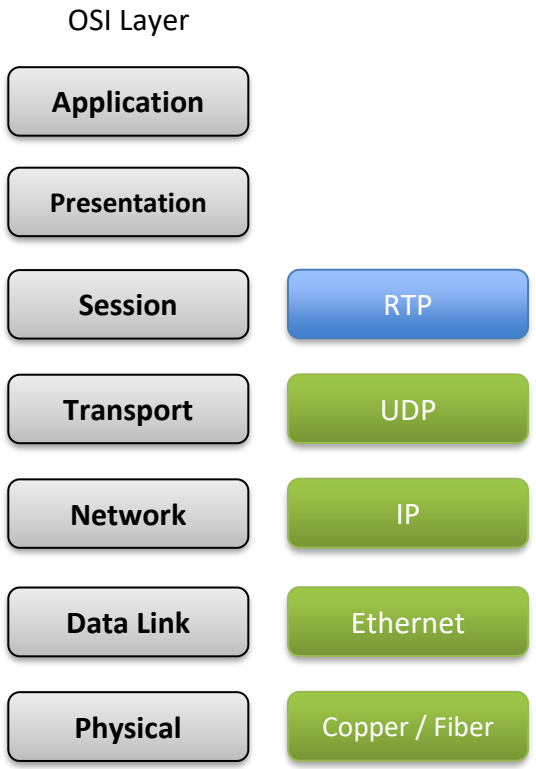
- A format-agnostic transport protocol for real-time media data
- Includes time information for precise media alignment

RTP header

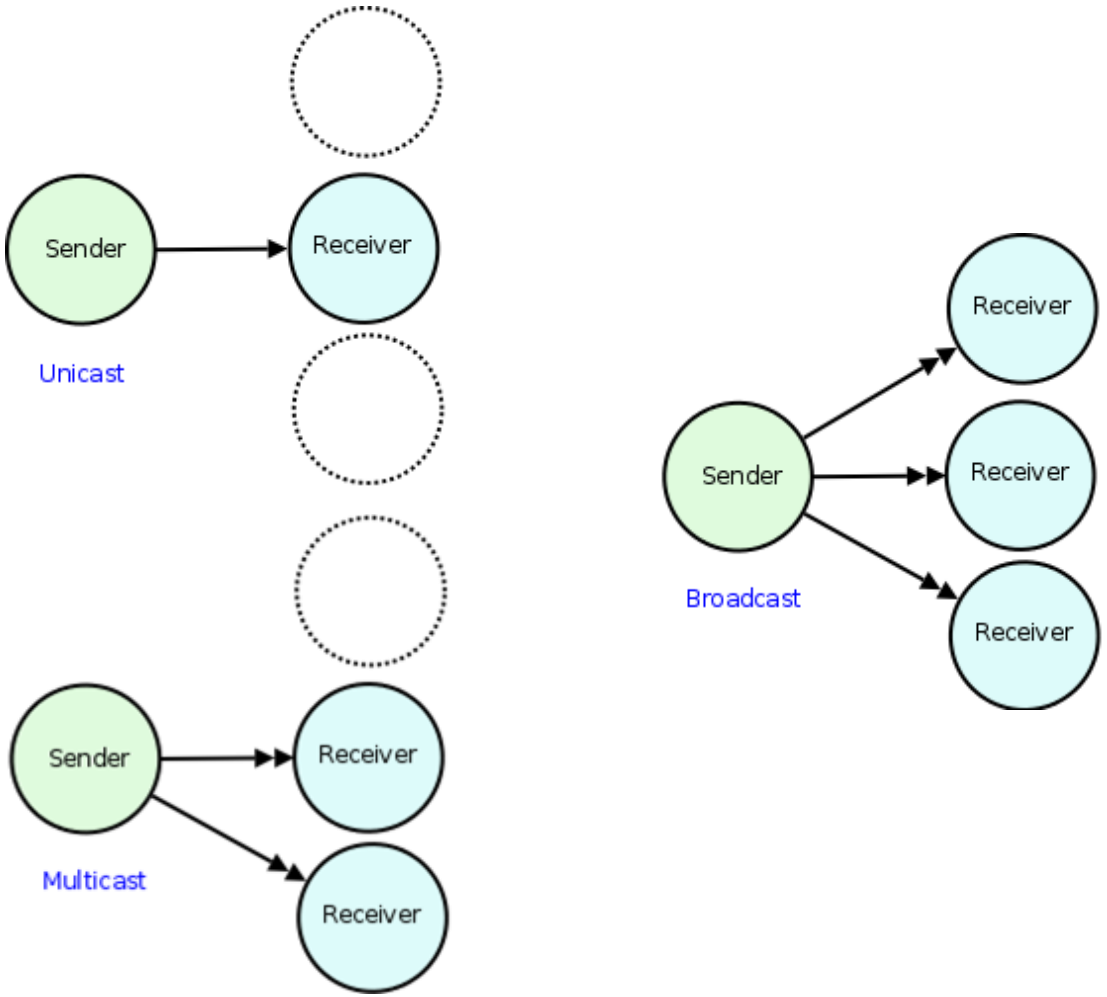
Timestamp

RTP payload

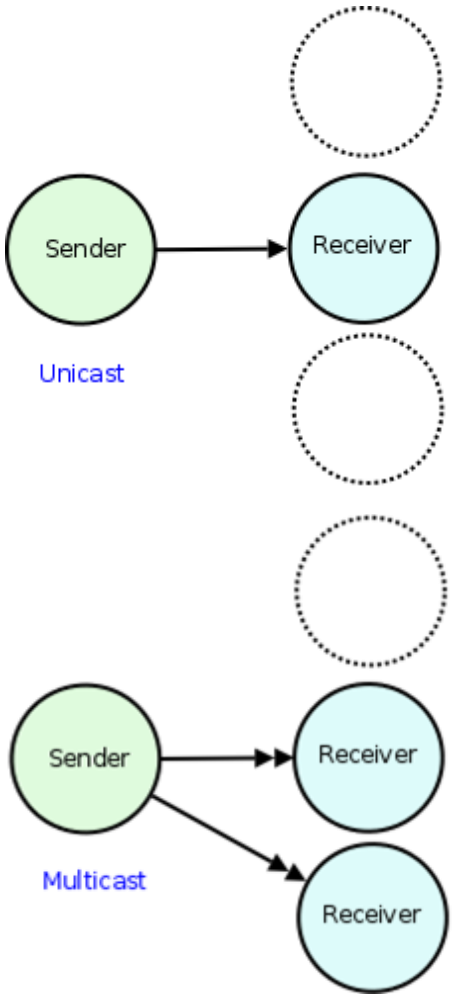


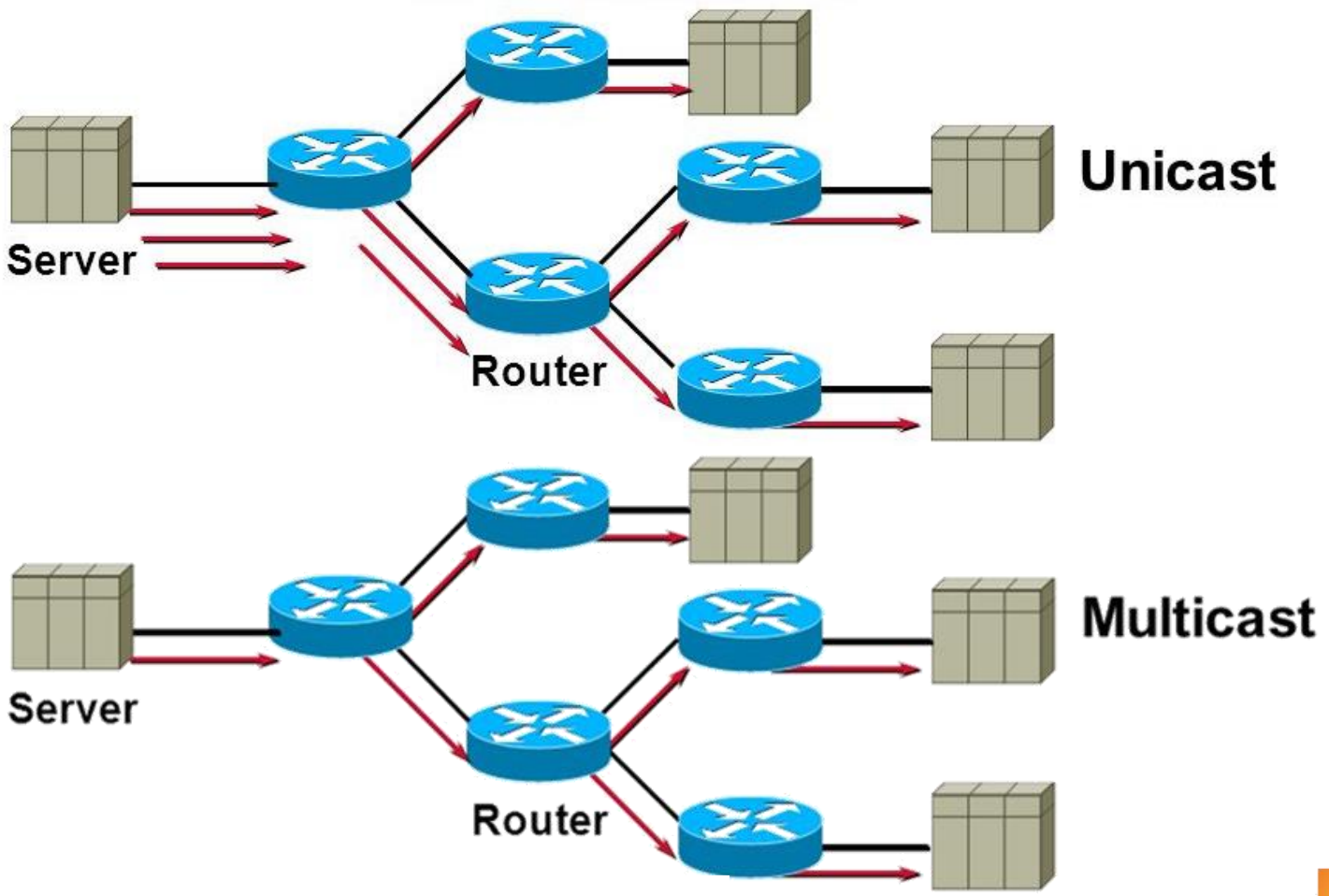


Unicast vs. Multicast



Unicast vs. Multicast





AES67 technology components

QoS	Differentiated Services (DiffServ w/ 3 CoS)
Transport	RTP / UDP / IP, unicast & multicast
Media Clock	48 kHz
Synchronisation	IEEE 1588-2008 (PTPv2)

QoS – Differentiated Services (DiffServ)

AES67 technology components

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)

AES67 Encoding Examples

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

#1: 16 bit PCM, 2 channels, 48 samples (1 ms @ 48 kHz): 192 bytes	mandatory
#2: 24 bit PCM, 2 channels, 48 samples (1 ms @ 48 kHz): 288 bytes	
#3: 24 bit PCM, 8 channels, 48 samples (1 ms @ 48 kHz): 1152 bytes	
#4: 16 bit PCM, 2 channels, 192 samples (4 ms @ 48 kHz): 768 bytes	optional
#5: 24 bit PCM, 2 channels, 96 samples (1 ms @ 96 kHz): 576 bytes	
#6: 24 bit PCM, 64 channels, 7 samples (0.15 ms @ 48 kHz): 1344 bytes	RAVENNA

How to differentiate between various payload formats?

AES67 technology components

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)

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
```

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)

AES67

AES67 - Status

2013 – initial publication

- 3 years of work
- 100+ participants (manufacturers, consultants, system integrators, end users)

2015 – first revision

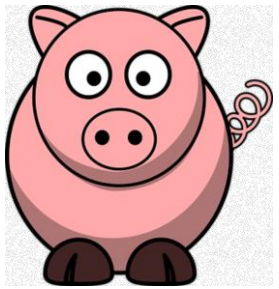
- Corrigendum & clarifications
- Backward compatibility (no new requirements)

2018 – second revision

- Further clarifications
- Backward compatibility (no new requirements)
- PICS* added

** Protocol Implementation Conformance Statement*
PICS Summaries at: http://www.aes.org/standards/PICS_Repository/

AES67



Current status

- Task Group is working on further topics (multicast addressing, SDP, homologation w/ ST 2110 etc.)
- Interested parties are invited to join SC-02-12-M

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”)

SMPTE ST 2110 – Professional Media over Managed IP Networks

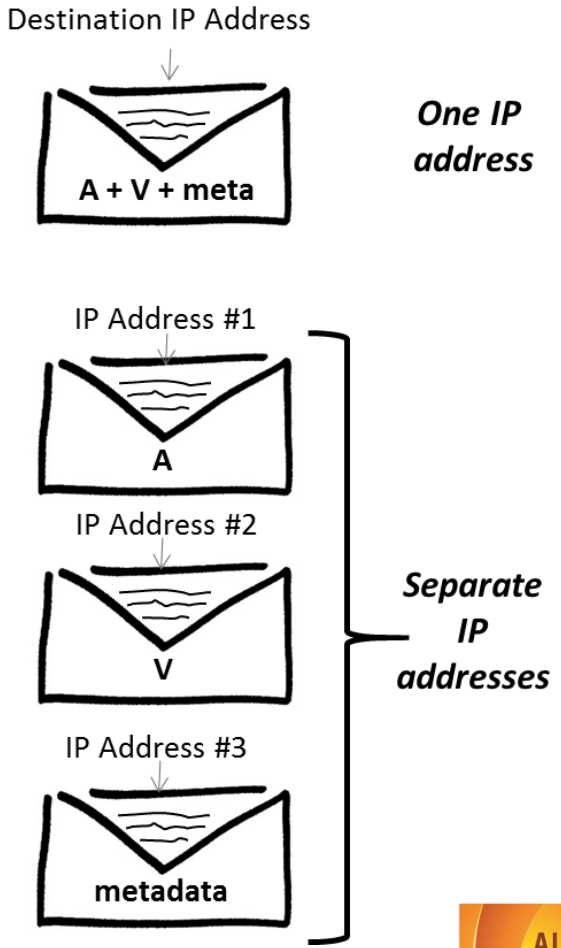
The SMPTE ST 2110 standards suite specifies

- 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

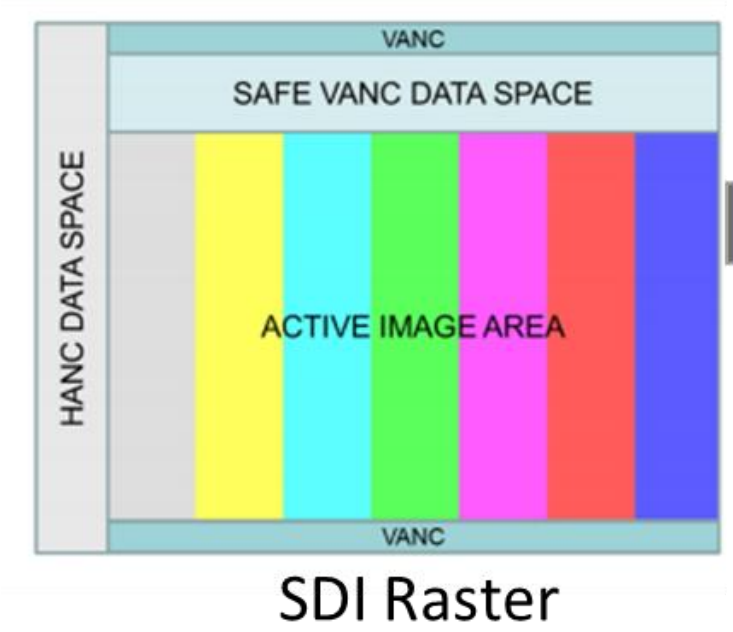
Two Fundamental Approaches to IP Transport

- **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



The Bundled Approach: SMPTE ST 2022-6



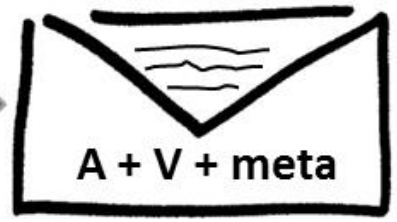
SDI Raster

IP Packetization of SDI Raster

Method: **SMPTE ST 2022-6**

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

One Destination IP Address

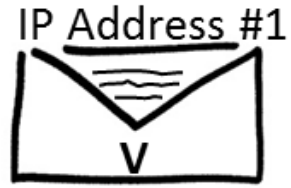


Published beginning in 2012

The Essence-based Approach: SMPTE ST 2110

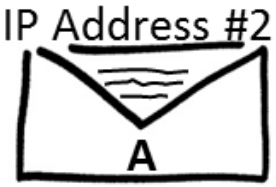
Active Video

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



Audio

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



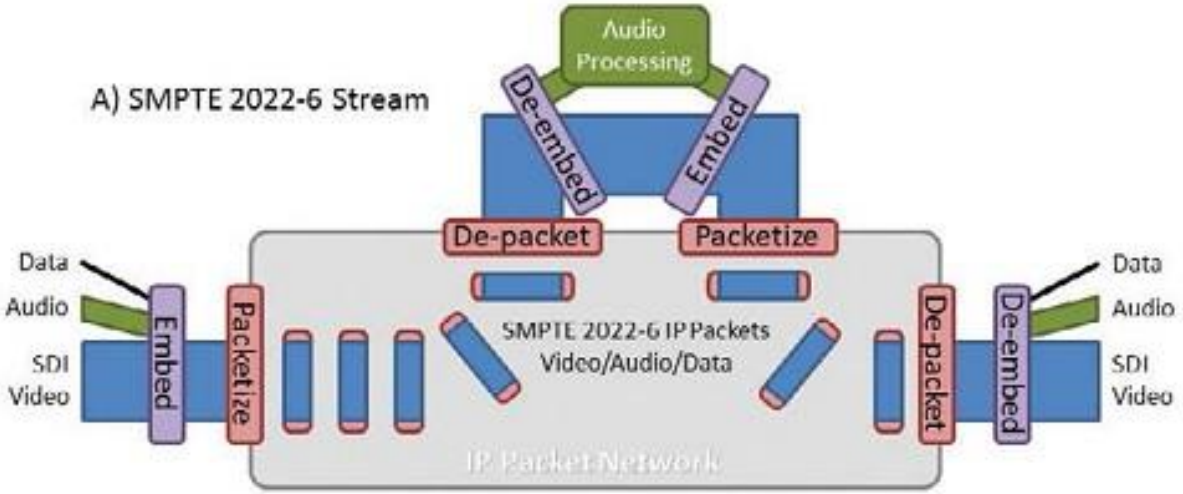
Metadata

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

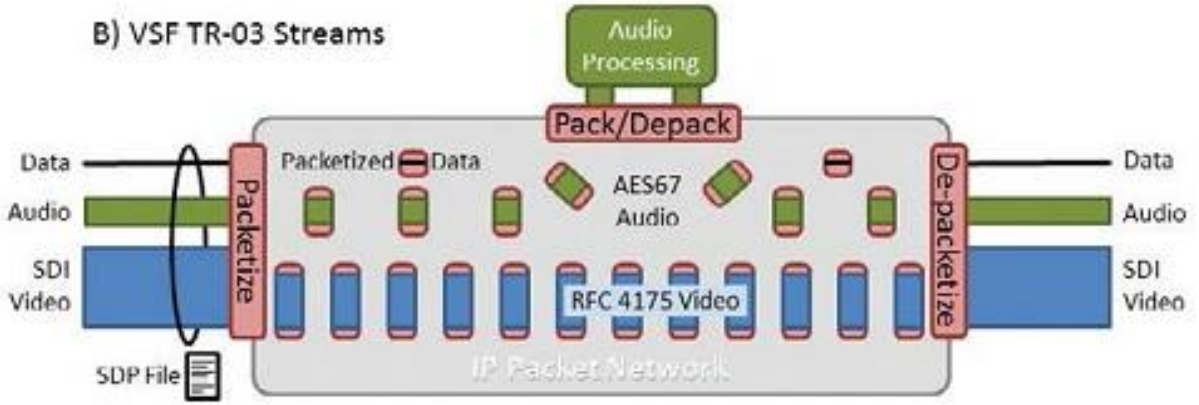
Published in 2017

Bundled vs. Essence-based Approach

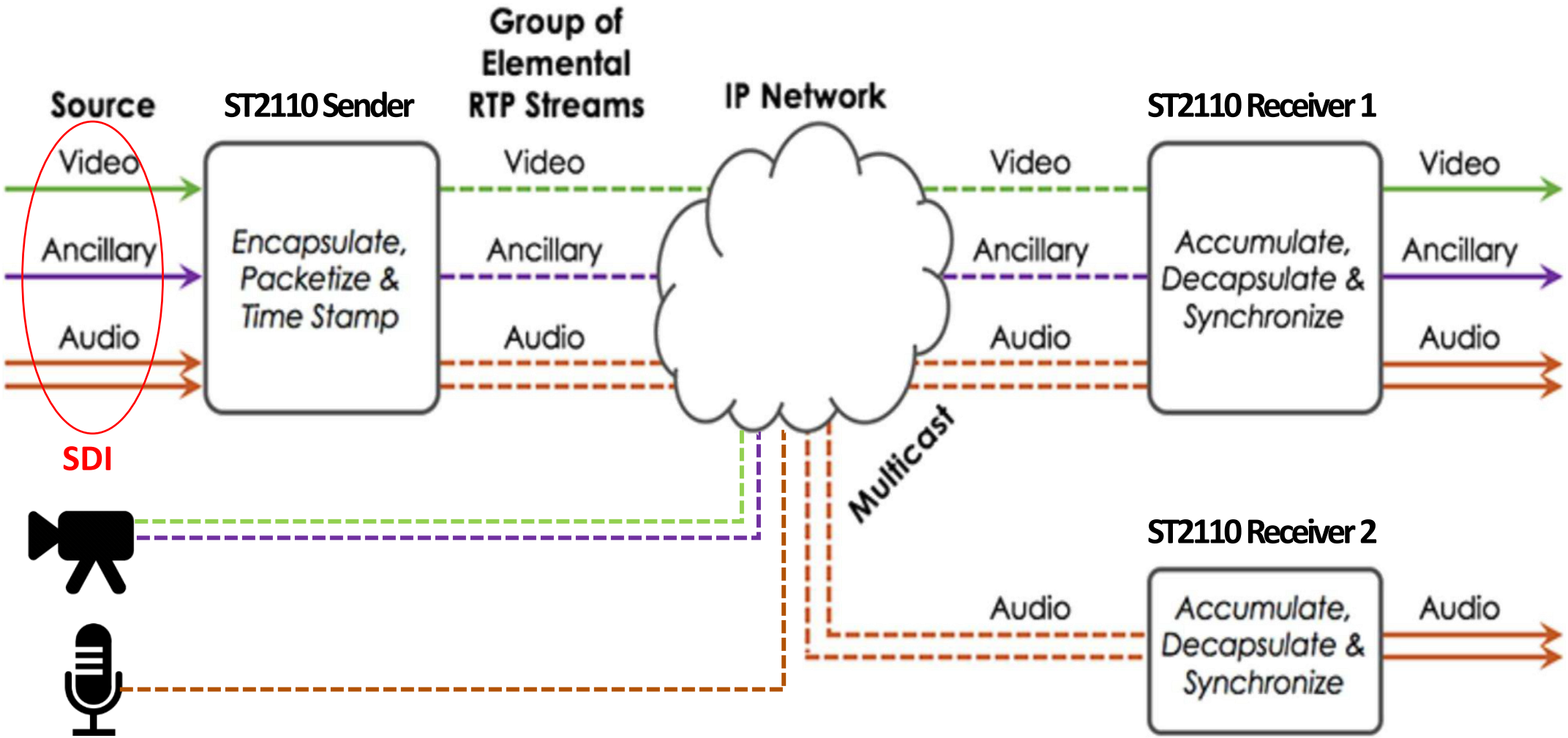
ST 2022-6



ST 2110



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)

Synchronization and Alignment in ST 2110

Precision Time Protocol (IEEE 1588-2008)

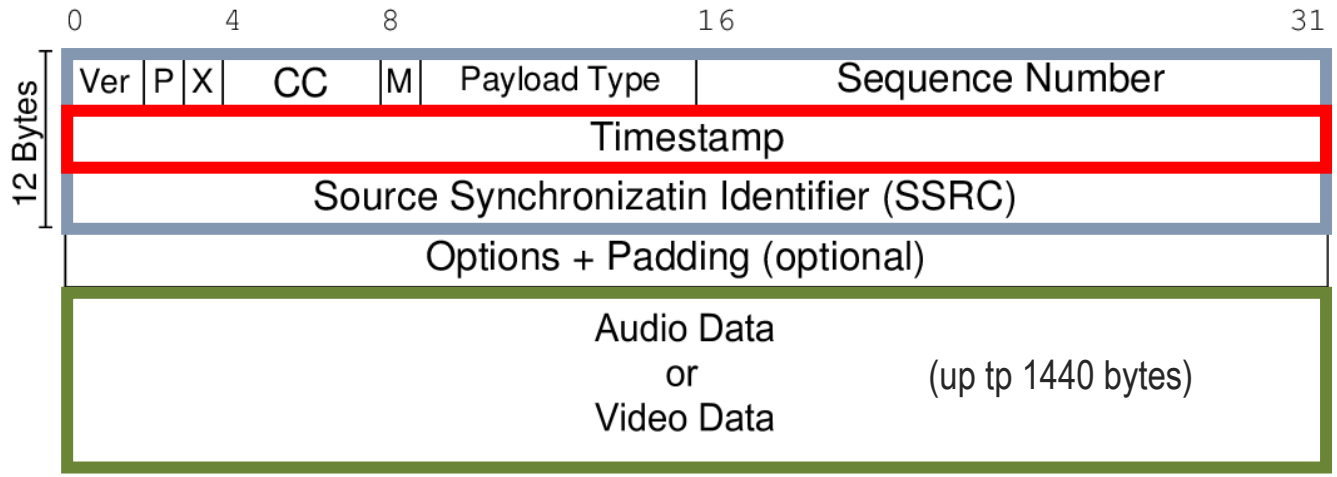
- A method for distributing precise, GPS-referenced time over an IP network
- Proven technology used in multiple industries
- Used for synchronization and alignment of devices and media signals

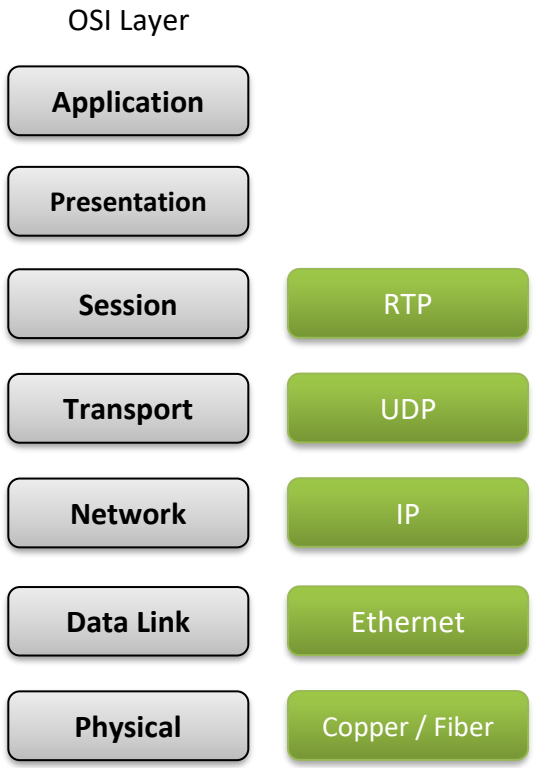
Both AES67 and SMPTE ST 2110 use PTP

Media Transport in ST 2110

Real-time Transport Protocol (RFC 3550)

- A format-agnostic transport protocol for real-time media data





Signalization in ST 2110

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=ptime:1
```

SMPTE ST 2110-20 Video - Uncompressed

Specifies the payload format for **uncompressed active video** essence

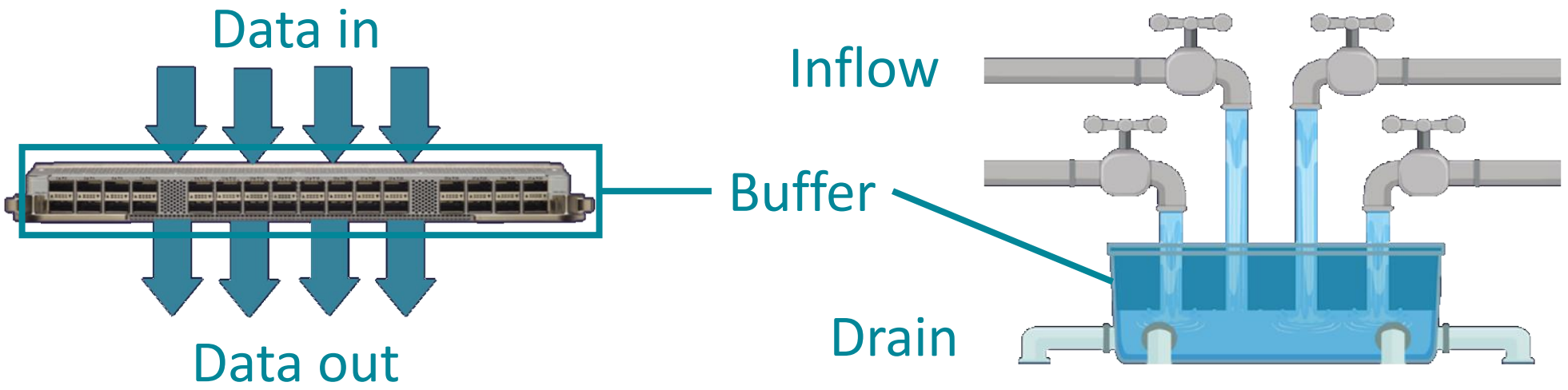
- Raster size independent ▸ up to 32K x 32K pixels
- Agnostic to:
  - Colour sampling: 4:1:1 to 4:4:4+
  - Bit depth: 8 to 16-Bit+
  - Frame-rate: 23.98 to 120 fps+
- Support for HDR ▸ PQ & HLG
- Significant bandwidth efficiency,

  i.e. 1080p50:
  - ST 2022-6 = 3,074Gbps
  - ST 2110-20 = 2,143Gbps ⇨ 30% bandwidth saving!

SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

Problem Overview

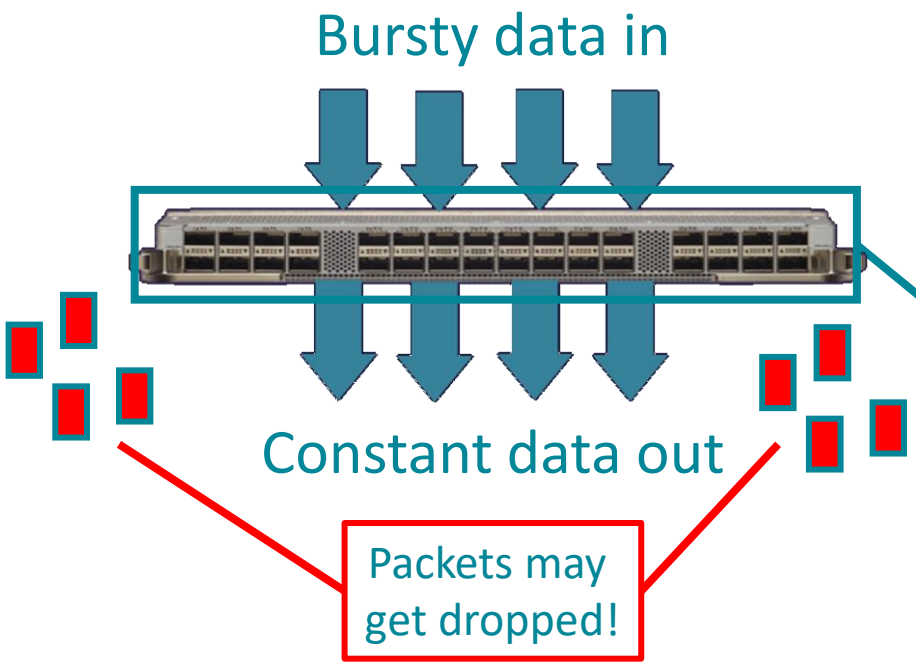
- Video flows require fairly high data rates
- Multiples flows are concurrently traversing the network
- Network switches (and receivers) have limited buffer capacity
- Constant data flow will not overload the buffers as long as total used bandwidth stays below maximum bandwidth



SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

Problem Overview

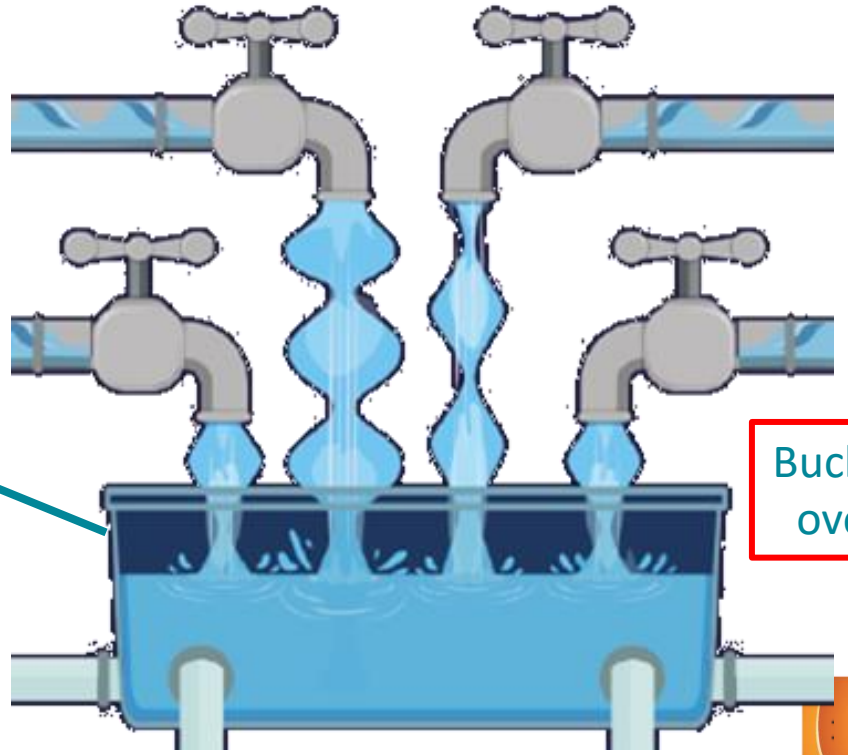
- Random and unregulated traffic patterns may temporarily overflow buffers, even if average bandwidth is not exceeded



Bursty inflow

Larger buffer required

Constant drain



SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

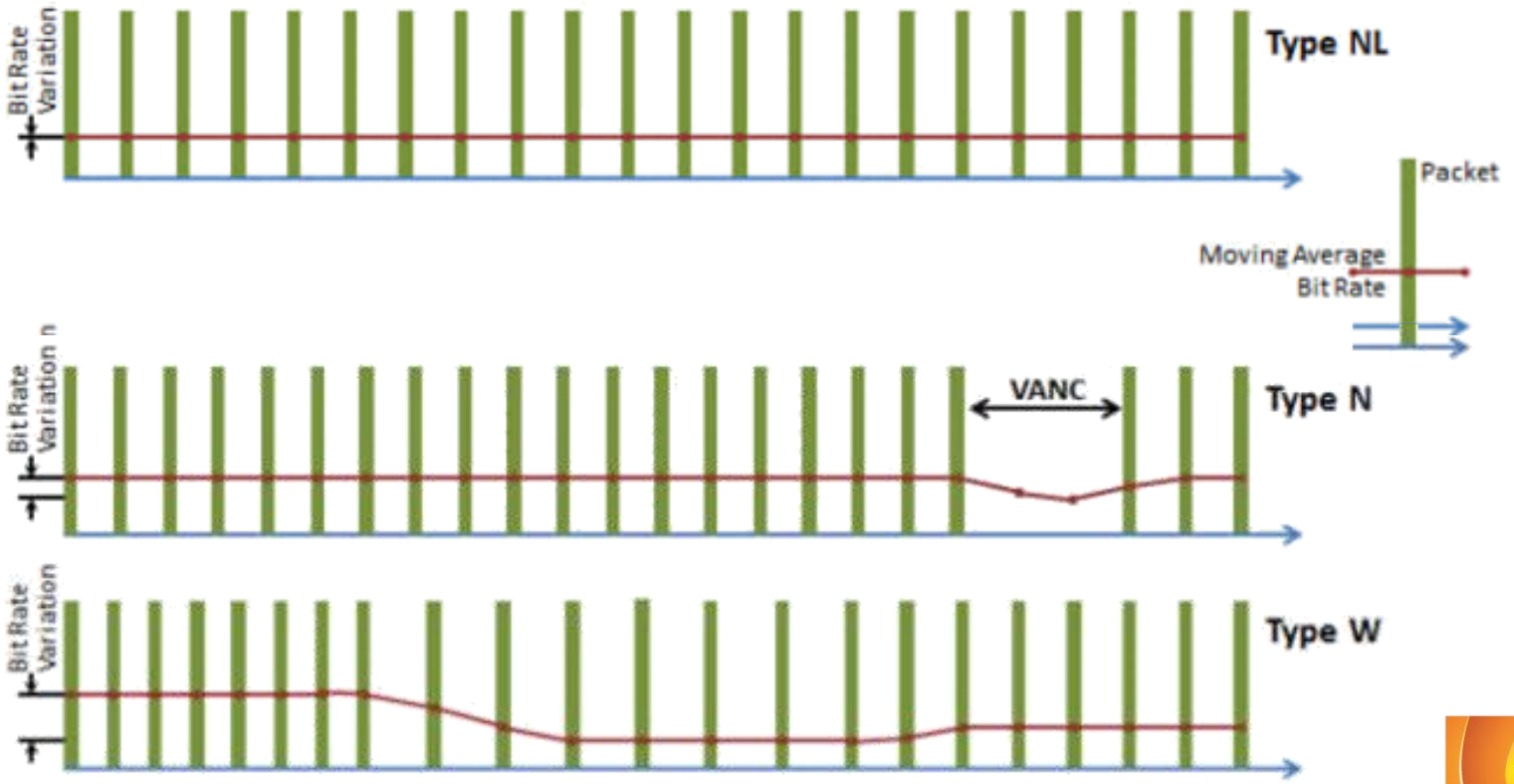
Solution

- Define sender drain behaviour (packet egress pacing and spacing) and (receiver) buffer requirements
- Sender drain behaviour defined on “leaky bucket” model with different characteristics
- 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)

SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

Solution

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



SMPTE ST 2110-21
Traffic Shaping and Delivery Timing for Video

Solution

- Define sender drain behaviour (packet egress pacing and spacing)
- 3 models:
  - 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=fmtp: line:
  - TP=2110TPN
  - TP=2110TPNL
  - TP=2110TPW
- Has impact on buffer requirements of network switches and receiver devices and sender / receiver compatibility

SMPTE ST 2110-22 Video Compressed

Specifies the payload format for **constant bit-rate compressed video** formats

- 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
- Constant bit-rate:
  - no specific codec / compression technology defined
  - codecs registered / enumerated in SMPTE registry,
    i.e. Generic VC2, HT J2K, JPEG-XS, …

SMPTE ST 2110-30 Linear PCM Audio

Specifies the payload format for **PCM digital audio** streams

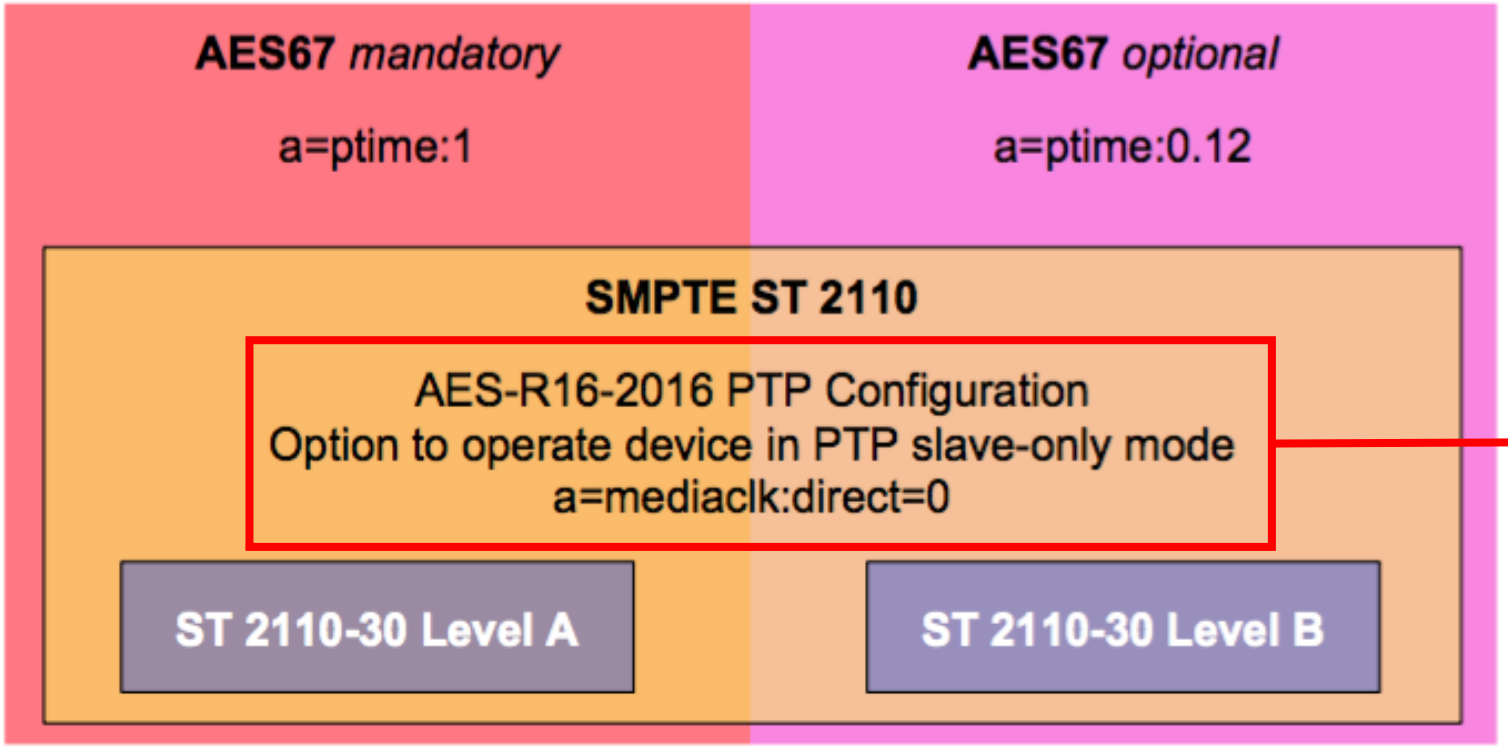
- Uncompressed Linear PCM Audio only
- Based on AES67
- Relatively flexible:
  - 48kHz and 96kHz sampling
  - 16 and 24-bit depth
  - Variable packet timing - 125us to 1ms
  - Channel-count based on packet timing

    - from 8 channels @ 1ms up to 64 channels @ 125us (conformance levels A / B / C)

AES67

SMPTE ST 2110-30 and AES67 Compatibility

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

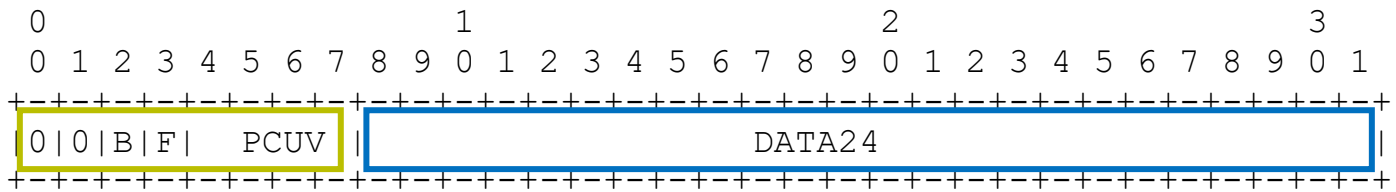


Constraints!

- ⇨ AIMS WP on *„AES67 / ST2110 Commonalities & Constraints“*
- ⇨ Follow-up webinar May 12th *(„The Audio Files“)*

SMPTE ST 2110-31 AES3 Audio

- 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



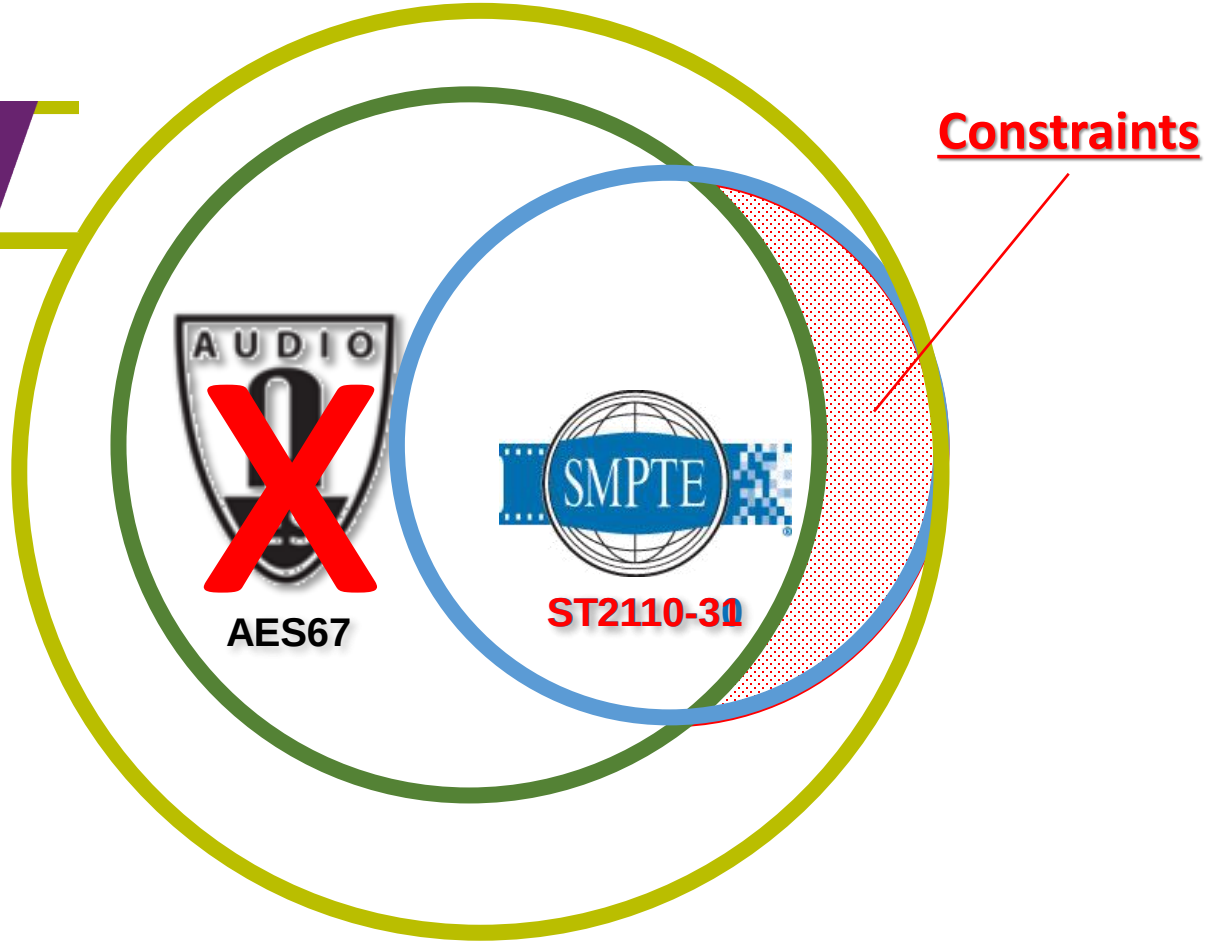
  - RTP payload format signaled in SDP:

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

  - retains all other SDP parms

SMPTE ST 2110-31 and AES67 Compatibility

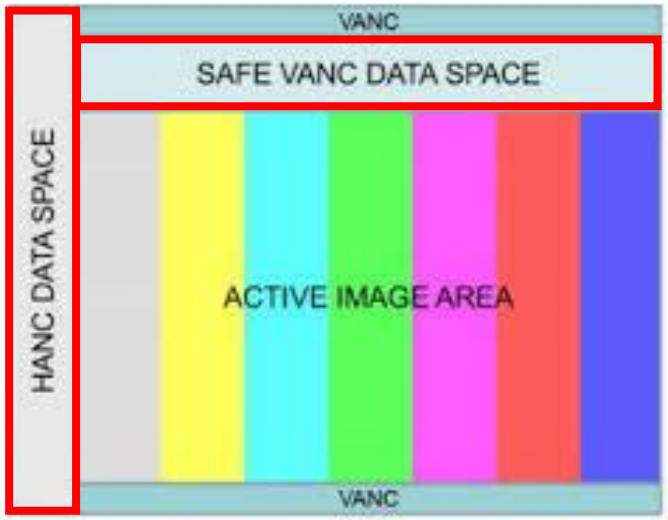
RAVENNA AES67 built-in Now with ST2110!



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)**:**

- 2110-23: Single Video Essence Transport over Multiple 2110-20 Streams
  - defines how to split high-bandwidth signals into several lower-bandwidth ST2110-20 tributary streams (constraints, grouping, addressing, RTP timestamps, SDP …)
- 2110-24: Transport of SD Signals
  - defines how to transport SD-formatted signals into ST2110 streams (packetization, 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

Questions?

ST2110 / AES67 Resources:

RAVENNA AES67 built-in — www.ravenna-network.com/resources

AIMS Alliance for IP Media Solutions — www.aimsalliance.org (resources)

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

You've made it!

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