Tektronix

IP Transition Case Study

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Case Studies

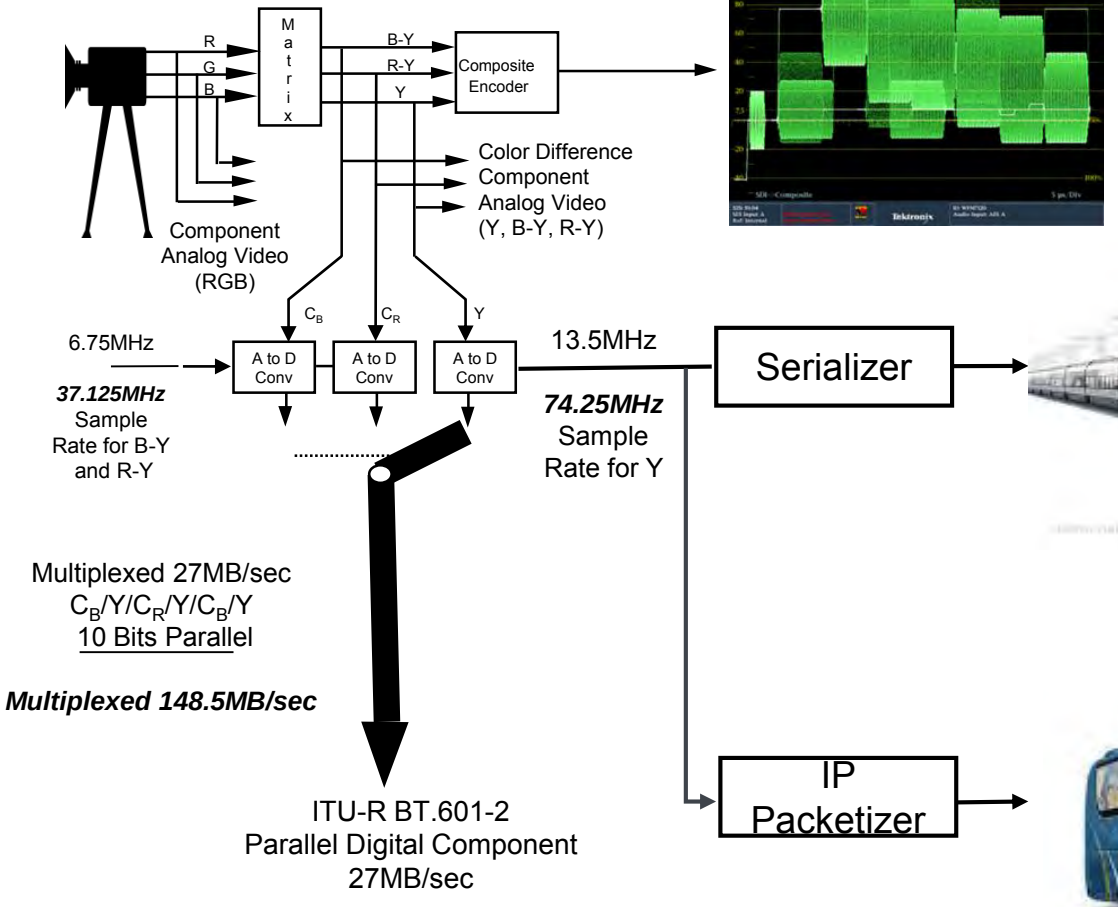
Over the past few years Tektronix has participated in:

- All the ST2110 Inter-ops
- Many Proof of Concept Systems
- Small hybrid ST20220-6 or ST2110 Systems
- Full ST2110 and PTP Implementations

Things we need to remember

- The main goal of the Video industry is to get the RGB signals from a Camera to the RGB inputs of a Display at the best Quality possible.
- ST2110 defines an I/O for Video, Audio and Ancillary Data
  - An I/O that will significantly change the way we design systems
  - We need additional tools to make the transition seamless for the operators
    - NMOS, SDN and API
- ST2110 does not change how IP works
  - Multicast static streams
  - Multicast managed streams (IGMP)
- Using IP and PTP for Video and Timing does not automatically solve timing issue.
  - Long distance feeds will still have the same or greater delay using IP

Video I/Os



Analog Composite Video (PAL/NTSC/SECAM)

270Mb/sec
1.485Gb/sec
Plus 3g,6g &12g

ST2022-6
ST2110

Will need not only deal with the travel distance
But will also with varying traffic conditions.

Basics of ST2110 specs

- 2110-**10**: system timing
- 2110-**20**: video
  - 2110-**21**: video distribution in time (timing model)
  - 2110-22: Compressed Video Essence (in progress)
- 2110-**30**: audio
  - 2110-**31**: support for legacy AES3 (in progress)
- 2110-**40**: Ancillary data
- 2022-7: Seamless Protection Switching

ST 2022-6 vs ST 2110

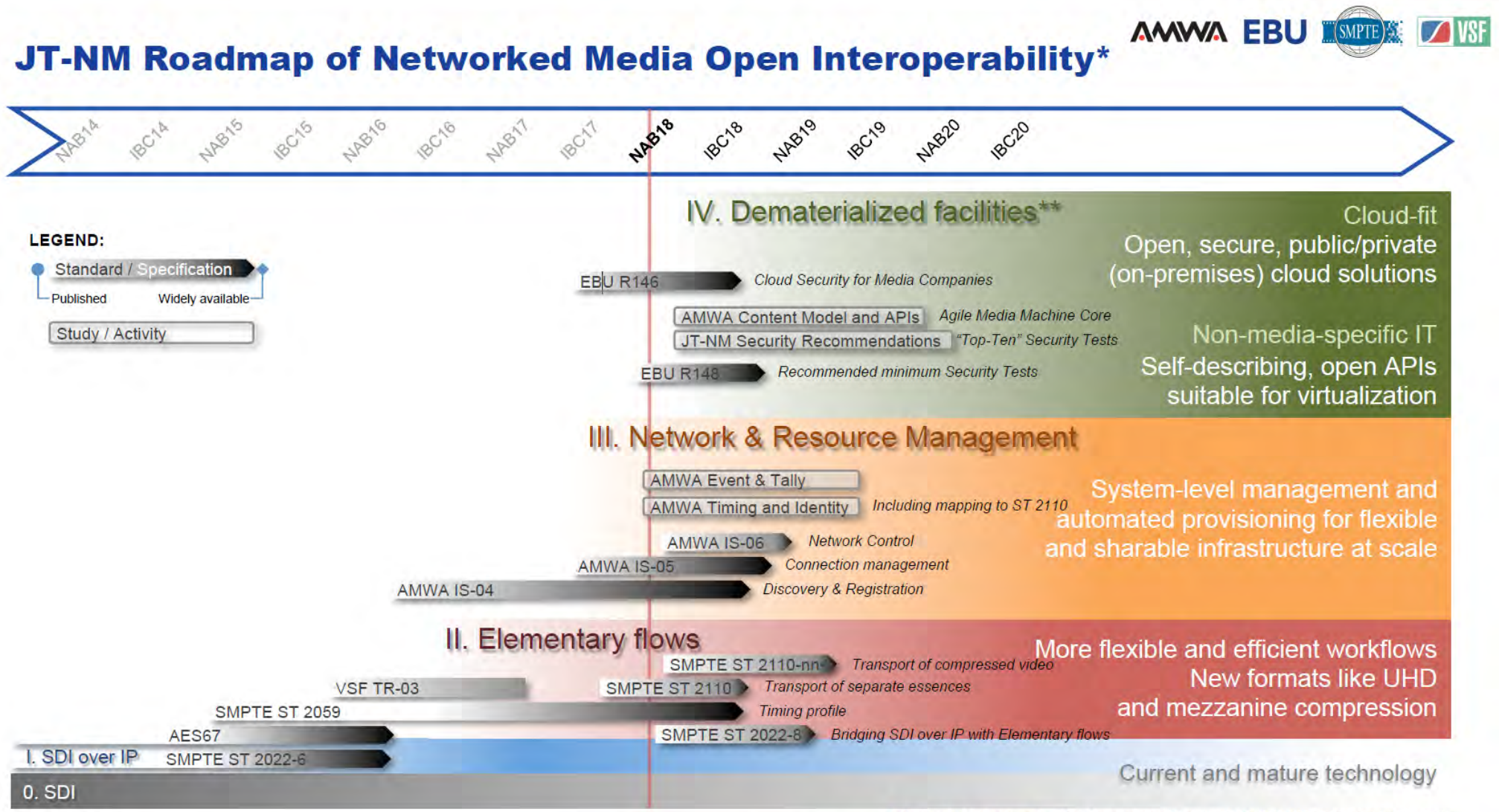
2022-6

- Bundled (Audio, Video, Metadata together)
  - Audio/Video/Metadata/Sync travel coherently
  - Need to unpack to use separate essences
  - All packets have a timestamp based on when it was created
- Suited for Playout/Distribution workflows
  - WAN/Contribution across timing domains

2110

- Essence Based (Audio, Video, Metadata separate)
- Ideal for Studio/Production workflows
- Individual essence kept in sync using PTP timing
- All packets of a given video frame share the same timestamp

The ST2110 Standard is still evolving



✚ Number not yet assigned. **See Dematerialized Facilities FAQ at JT-NM.org for more information.
* JT-NM assumption as of March 2018 and will evolve over time. Visit JT-NM.org for the latest update. Feedback to jt-nm-info@videoservicesforum.org

Lessons Leaned

- The ST2110 Standard is still evolving
- Manufacturers ST2110 product still in development
  - Beta Code
  - Still working to implement all the parts of ST2110
- Every ST2110 deployment is an InterOp
  - Getting different pieces of equipment to work together
  - Devices are in different stages of development
- Need a mechanism to verify sources before connecting the IP Switch
- PTP (ST2059) is a stable standard
  - More challenging than Black Burst

Verifying Your Multicast Flows

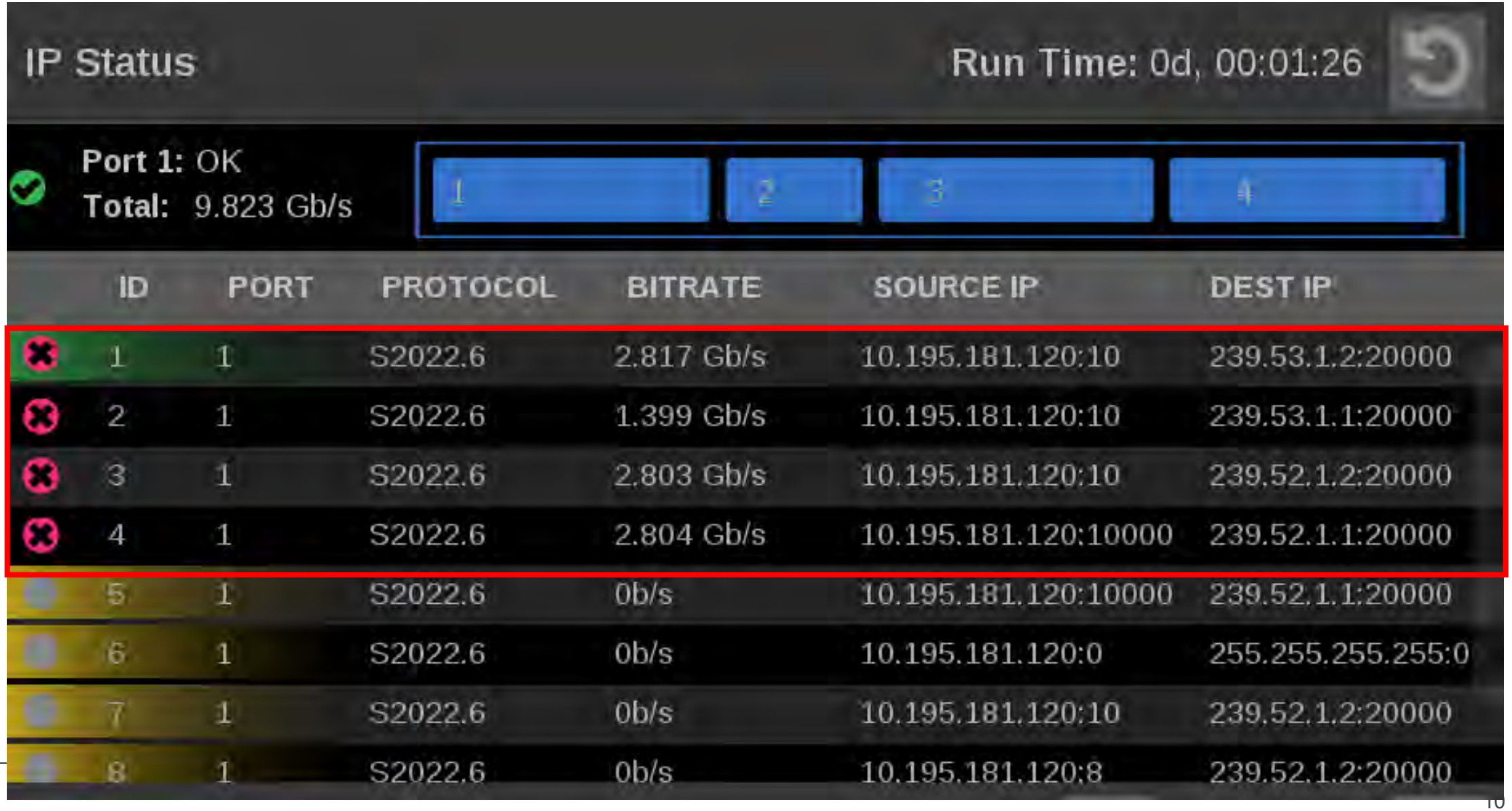
END DEVICES CONNECT TO THE ROUTERS AS A STATIC MULTICAST

Verify the following

- Protocols
- Bitrates
- Multicast

Before connecting to the router

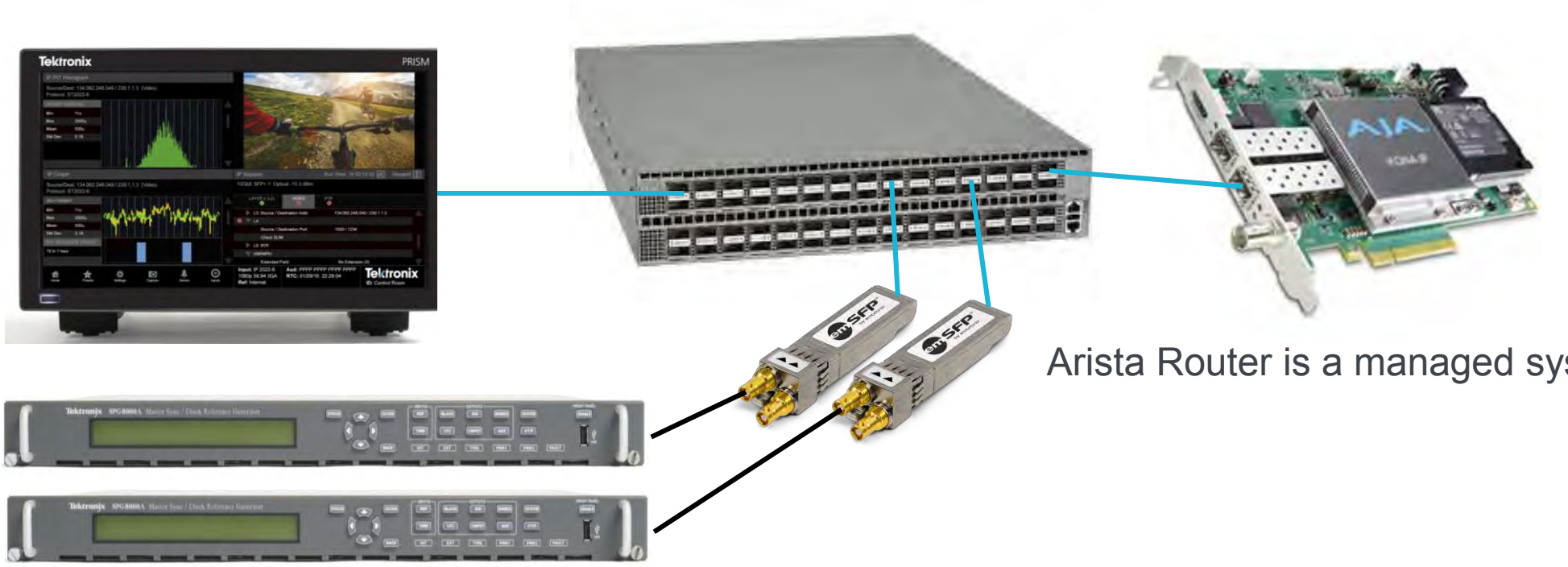
Plugged directly into a CG



Multicast and IGMP

- Multicast is used to send a packet from one host to a selected group of hosts
  - Members of the group could be present anywhere on the network.
  - Members join and leave the group and indicate this to the routers
  - Senders and receivers are distinct i.e. a sender need not be a member
    * Multicast addresses are in the range 224.0.0.0 through 239.255.255.255
- IGMP is used to manage membership of multicast groups
  - Who wants to watch which content ? - Multicast Join request
  - Who is watching which content ? - Host Membership query

Managed system



Arista Router is a managed system

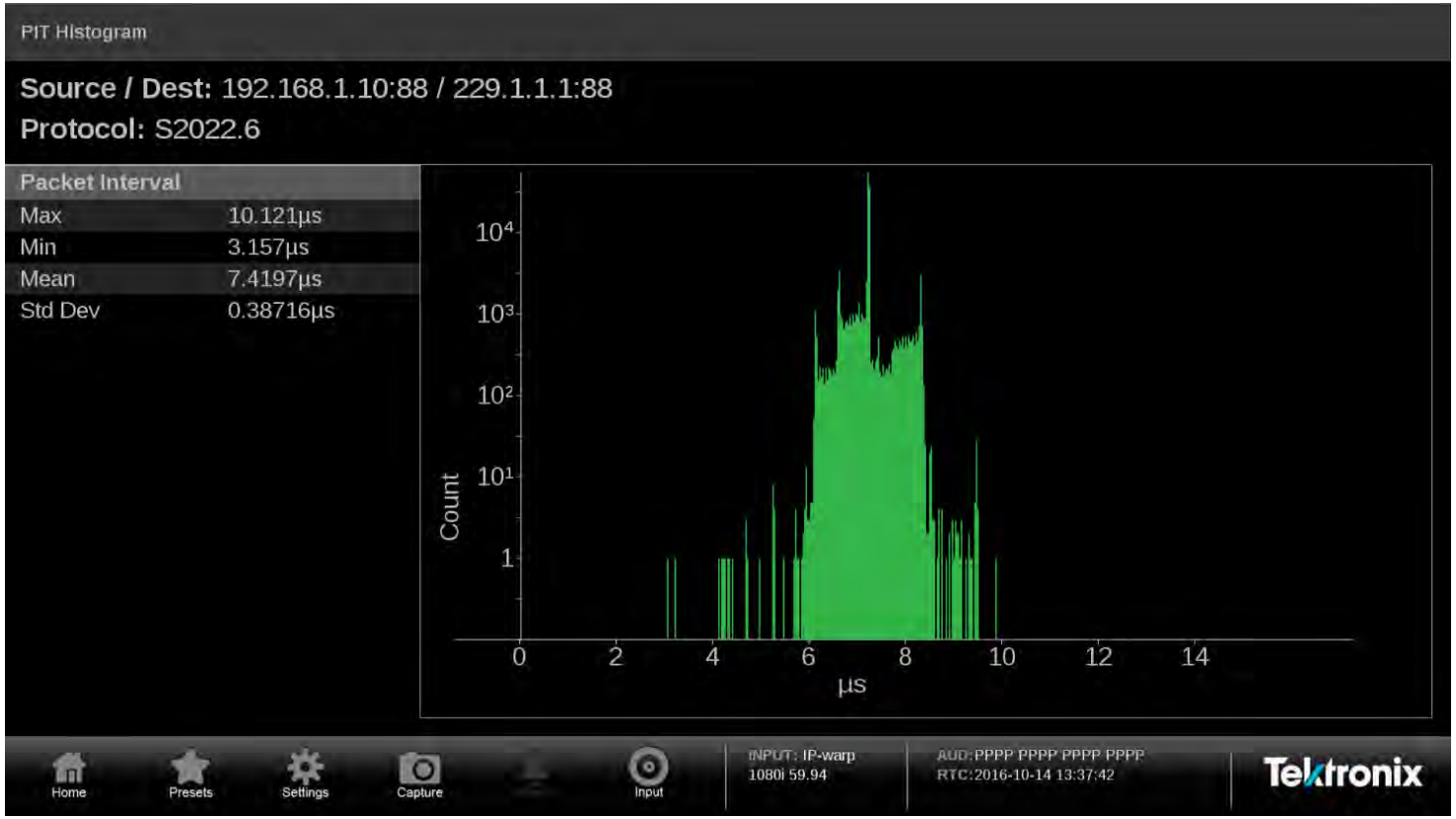
The Prism or any other Device needs to send a join command in order to see a stream.

Troubleshooting Technique
Mirror a Device's Port with the Prism's Port

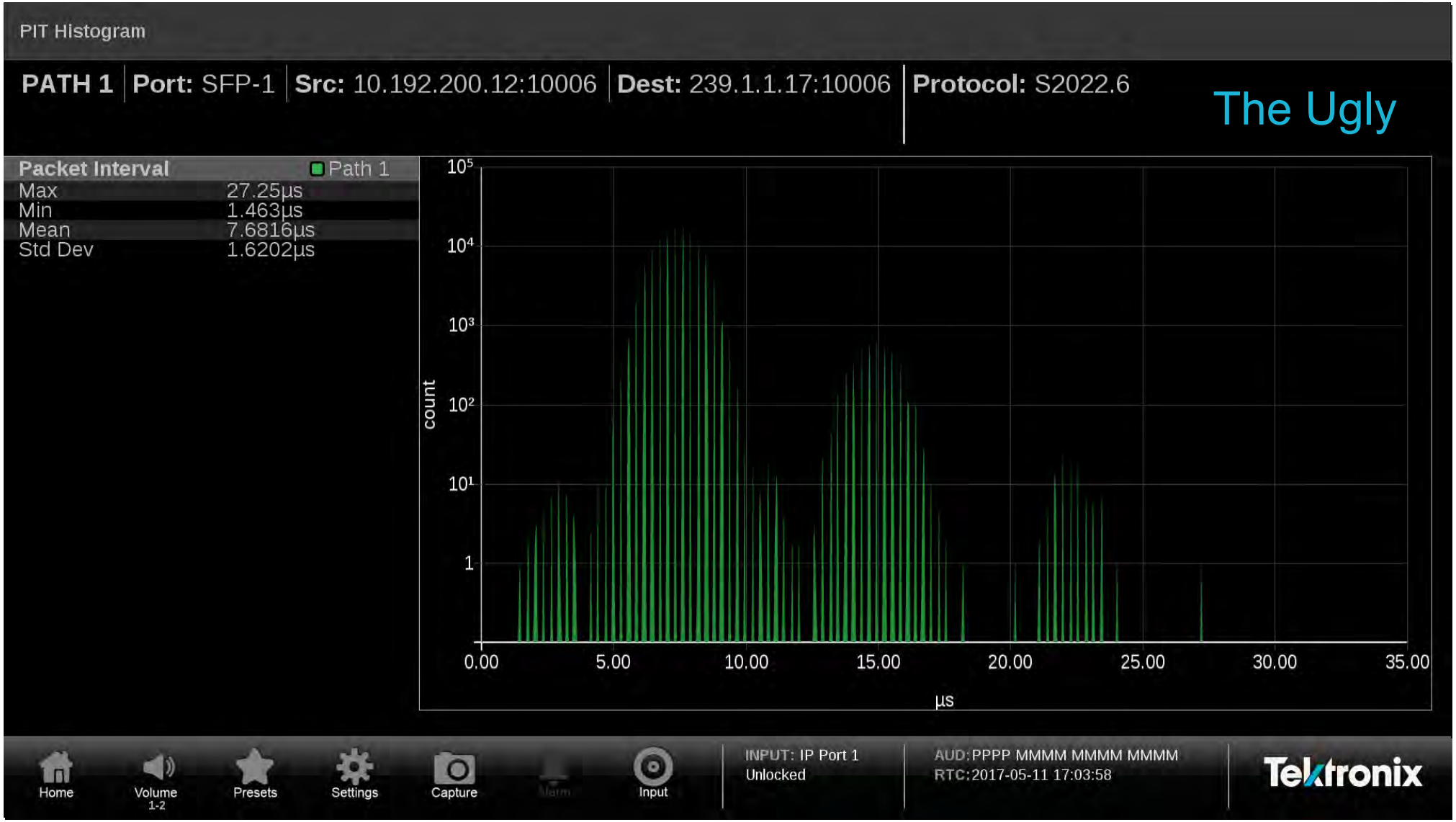
PIT Histogram (ST2022-6)

“QUICKNESS TO TROUBLE SHOOT AND RESOLVE PROBLEMS”

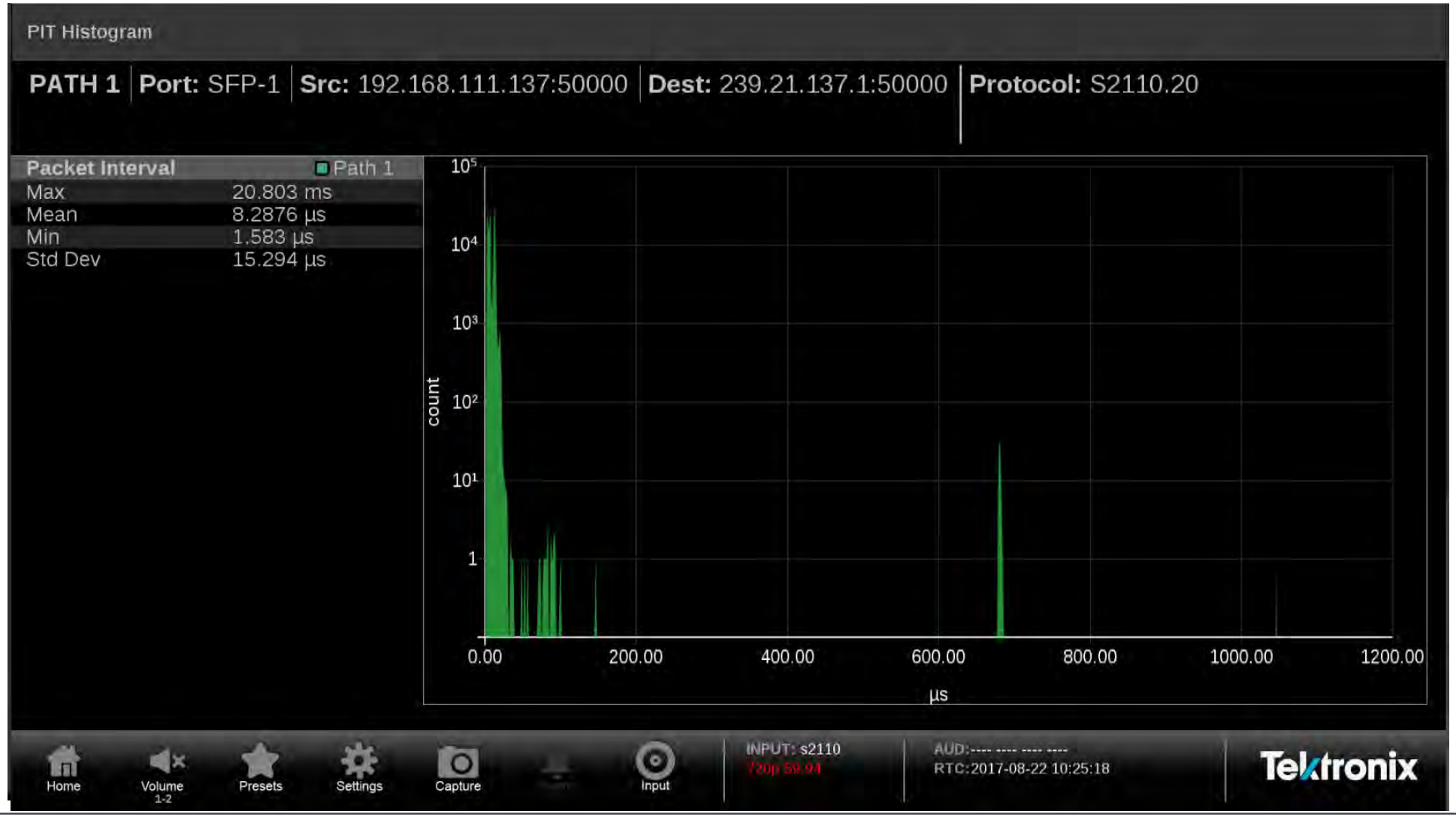
- “Ensure the healthiness of entire IP system”
  - Burst events at too short / long PIT could cause buffer over / under flow



PIT Histogram (ST2022-6)



PIT Histogram (ST2110)

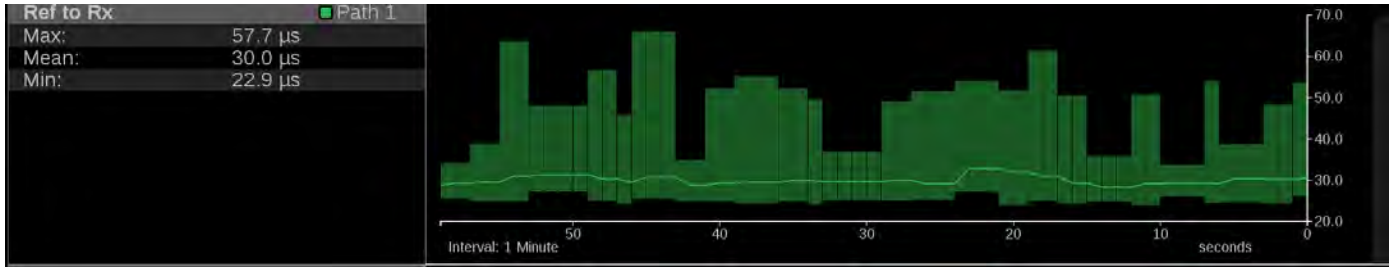


ST2110

Tools not widely Implemented

ST2110-10

- Specifies how PTP (SMPTE 2059) timing is used for ST2110
- Specifies the RTP timestamp calculations for Video, Audio, and ANC signals



- Specifies general requirements of the IP streams
- Specifies using the ***Session Description Protocol (SDP)***

Session Description Protocol

- All streams have SDP (session description protocol) defined
- SDP is from RFC 4566, originally used for managing video and audio over IP networks (telecom)
- SDP description for a stream tells receiver what it is getting
  - Definitions for each ST2110 stream are defined in

    SMPTE 2110-10 spec

Session Description Protocol

An Example SDP File:

```
v=0
o=- 1472821477 1472821477 IN IP4 172.29.226.31
s=IP Studio Stream
t=0 0
m=video 5000 RTP/AVP 103
c=IN IP4 232.25.176.223/32
a=source-filter:incl IN IP4 232.25.176.223 172.29.226.31
a=rtpmap:103 raw/90000
a=fmtp:103 sampling=YCbCr-4:2:2; width=1920; height=1080; depth=10;
interlace=1; colorimetry=BT709-2
a=extmap:1 urn:x-nmos:rtp-hdrext:sync-timestamp
a=extmap:2 urn:x-nmos:rtp-hdrext:origin-timestamp
a=extmap:4 urn:x-nmos:rtp-hdrext:flow-id
a=extmap:5 urn:x-nmos:rtp-hdrext:source-id
a=extmap:7 urn:x-nmos:rtp-hdrext:grain-flags
a=extmap:6 urn:x-nmos:rtp-hdrext:grain-duration
```

Payload Type

Video Format

Session Description Protocol

ST2110-21: Video Timing

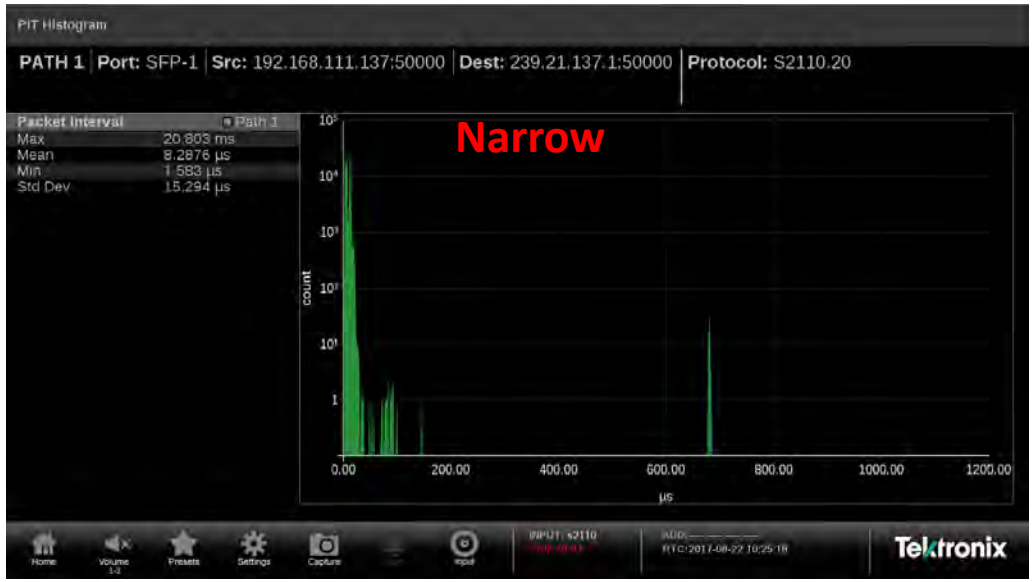
Needs to be Supported

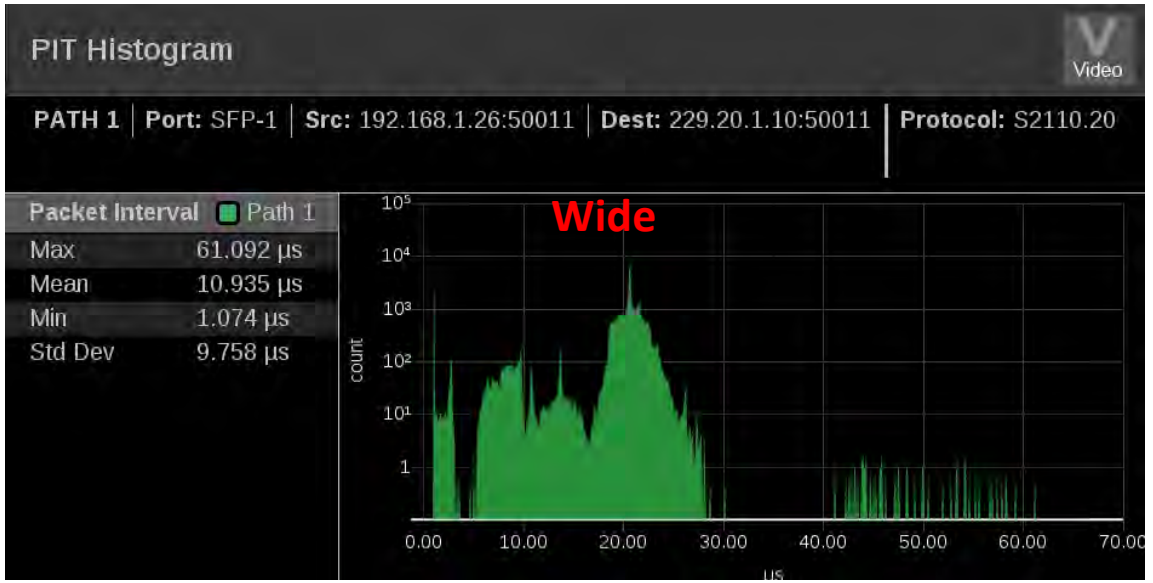
ST2110-21: Video Timing

- Describes required transmitter performance for streams
    - Packet pacing
    - Bursts
    - Gaps
- Considers expected network behavior and link/fabric loading
- Accommodates SDI-like HW sources (with V and H blanking gaps) **gapped mode**.
- Accommodates full-frame-time rasters (no gaps): **linear mode**
- Accommodates software senders: **wide linear**

ST2110-21: video timing-transmission

- **‘Narrow’** transmission for SDI like sources, i.e. **Hardware Sources**
- **‘Wide’** transmission intended for support of **software-based signal sources**





ST2110-21: video timing-transmission

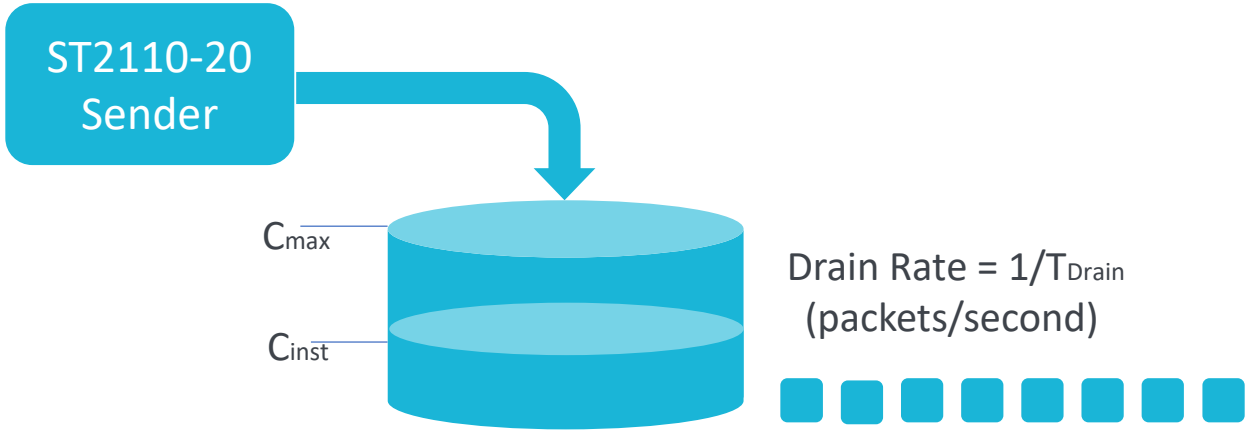
- '**Narrow**' transmission for SDI like sources, i.e. **Hardware Sources**
- **'Wide'** transmission intended for support of **software-based signal sources**

N sender is supported by both **W and N receivers**

W sender is supported by only **W receivers**

S2110-21: Transmission Traffic Shape Models

- Network Compatibility Model: Tested directly at the output of the sender, packets from the sender enter a buffer that drains every Tdrain seconds if a packet is available.
- Cinst represents the instantaneous number of packets in the buffer.
- Cmax represents the max value the buffer cannot exceed.



S2110-21: Buffer Models

- For VRXFull, 8 packets is the minimum for narrow senders, which is approximately 2 lines of data in 4:2:2, 1920*1080.
- For VRXFull, 720 packets is the minimum for wide senders, which is approximately 20% of a frame at 4:2:2, 1920*1080.

ST2110-30: audio

Make sure it equipment will support you design

ST2110-30: audio

- AES67 format used to send uncompressed PCM audio
- Full implementation of AES67 not supported
  - 48KHz, 96KHz
  - 24 bit linear encoding
- Check Audio level Support of Devices in the System

ST2110-30: audio

- *Level A:
  - Reception of 48 kHz streams with from 1 to 8 channels at packet times of 1 ms
- Level AX:
  - Reception of 48 kHz streams with from 1 to 8 audio channels at packet times of 1 ms.
  - Reception of 96 kHz streams with from 1 to 4 channels at packet times of 1ms

ST2110-30: audio

- *Level B:
  - Reception of 48 kHz streams with
  - from 1 to 8 channels at packet times of 1 ms
    or 1 to 8 channels at packet times of 125 µs
- Level BX:
  - Reception of 48 kHz streams with from 1 to 8 channels at packet times of 1 ms or 1 to 8 channels at packet times of 125 µs.
  - Reception of 96 kHz streams with
    from 1 to 4 channels at packet times of 1ms
    or 1 to 8 channels at packet times of 125 µs.

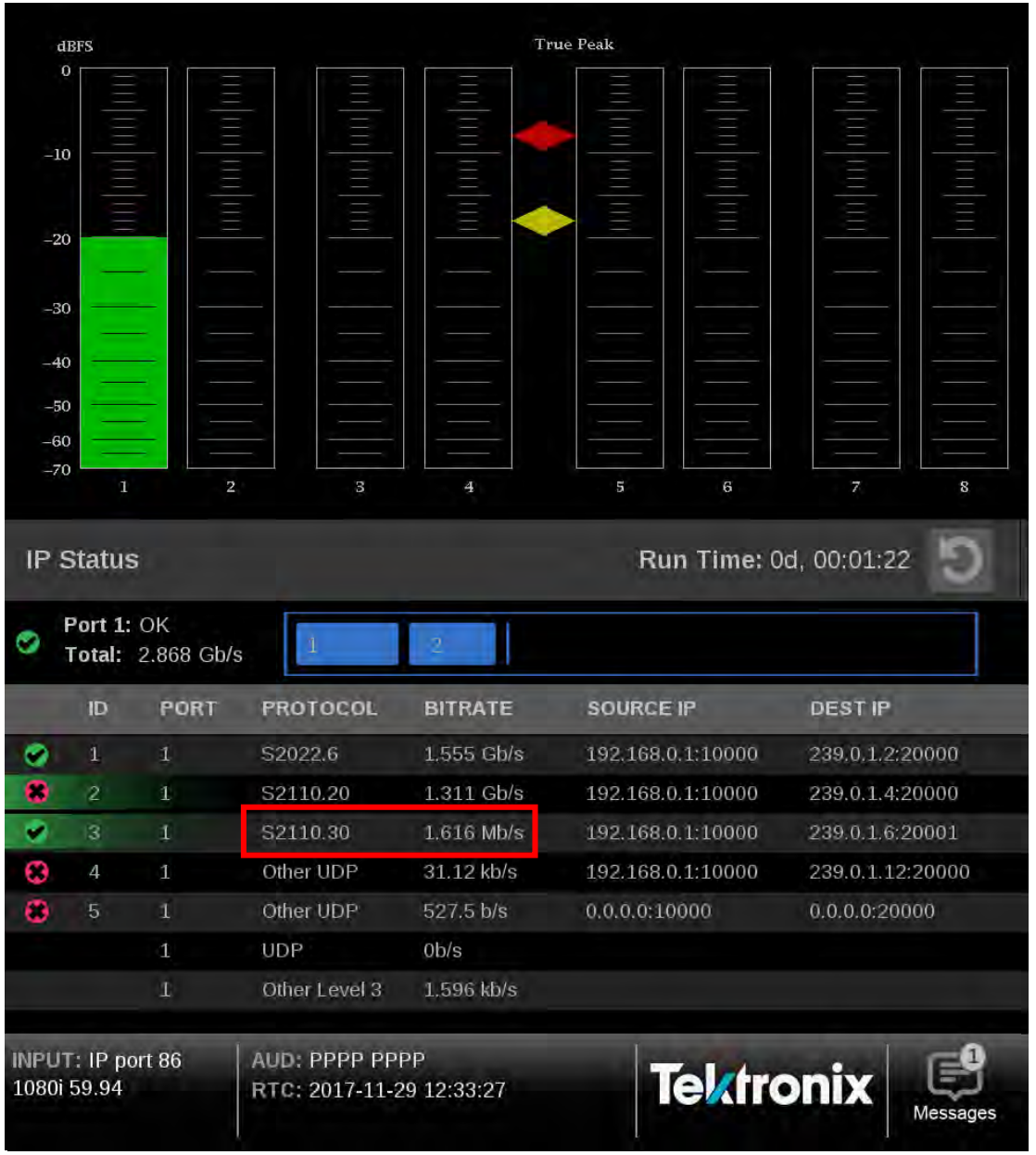
ST2110-30: audio

- Level C:
  - Reception of 48 kHz streams with
  - from 1 to 8 channels at packet times of 1 ms
    or 1 to 64 channels at packet times of 125 µs
- Level CX:
  - Reception of 48 kHz streams with from 1 to 8 channels at packet times of 1 ms or 1 to 64 channels at packet times of 125 µs.
  - Reception of 96 kHz streams with
    from 1 to 4 channels at packet times of 1ms
    or 1 to 32 channels at packet times of 125 µs.

2110-30 Bit Rate

WILL INDICATE THE NUMBER OF CHANNELS

Channels	Bit Rate
1	1.616 Mb/s
2	2.768 Mb/s
3	3.92 Mb/s
4	5.072 Mb/s
5	6.224 Mb/s
6	7.376 Mb/s
7	8.528 Mb/s
8	9.68 Mb/s



- 48kHz sampling support is required for all devices
- Support for 1ms packet time is required for all devices
- Support 1..8 channels per stream is required for all devices

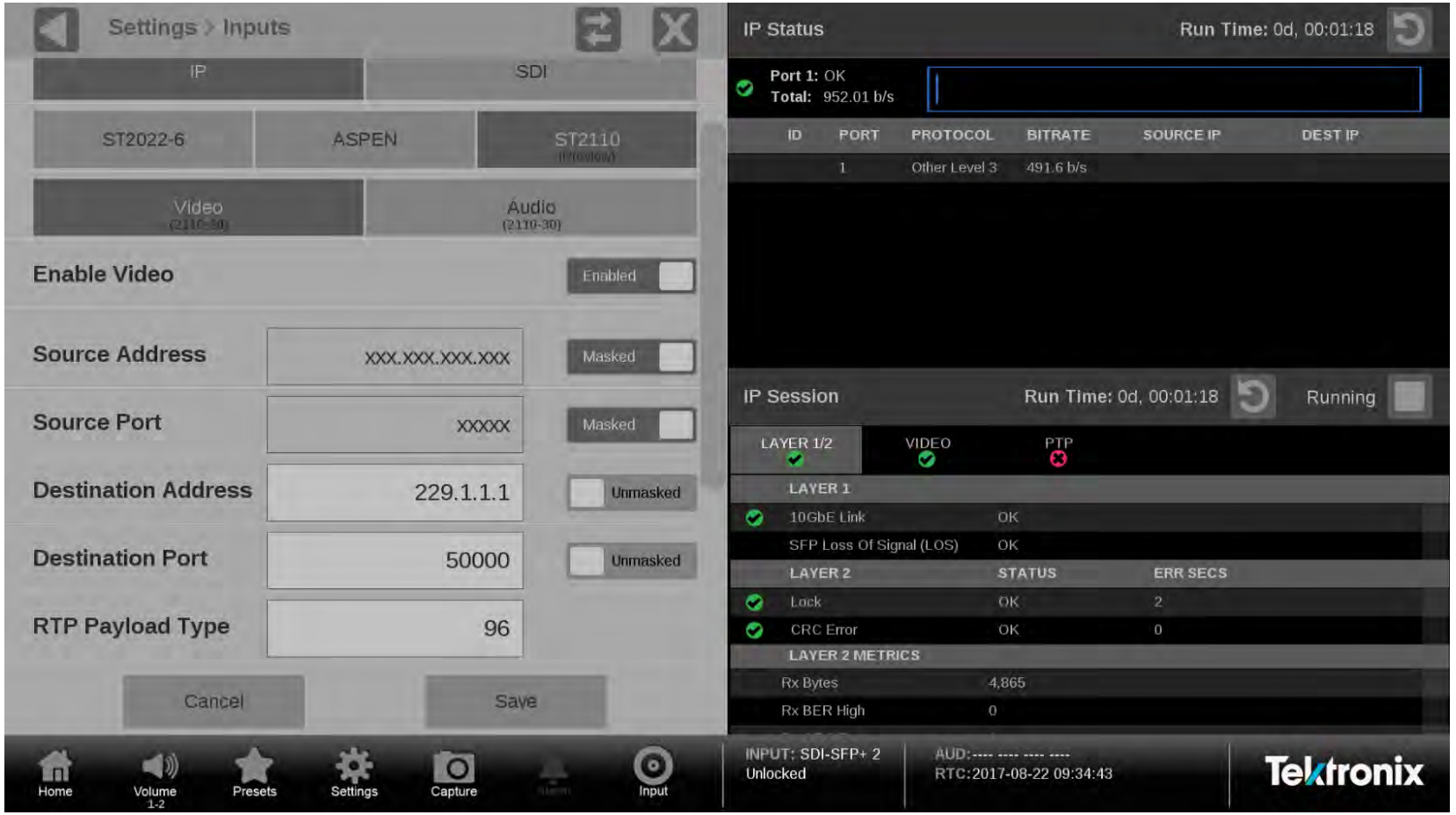
AMWA and NMOS

AMWA and NMOS

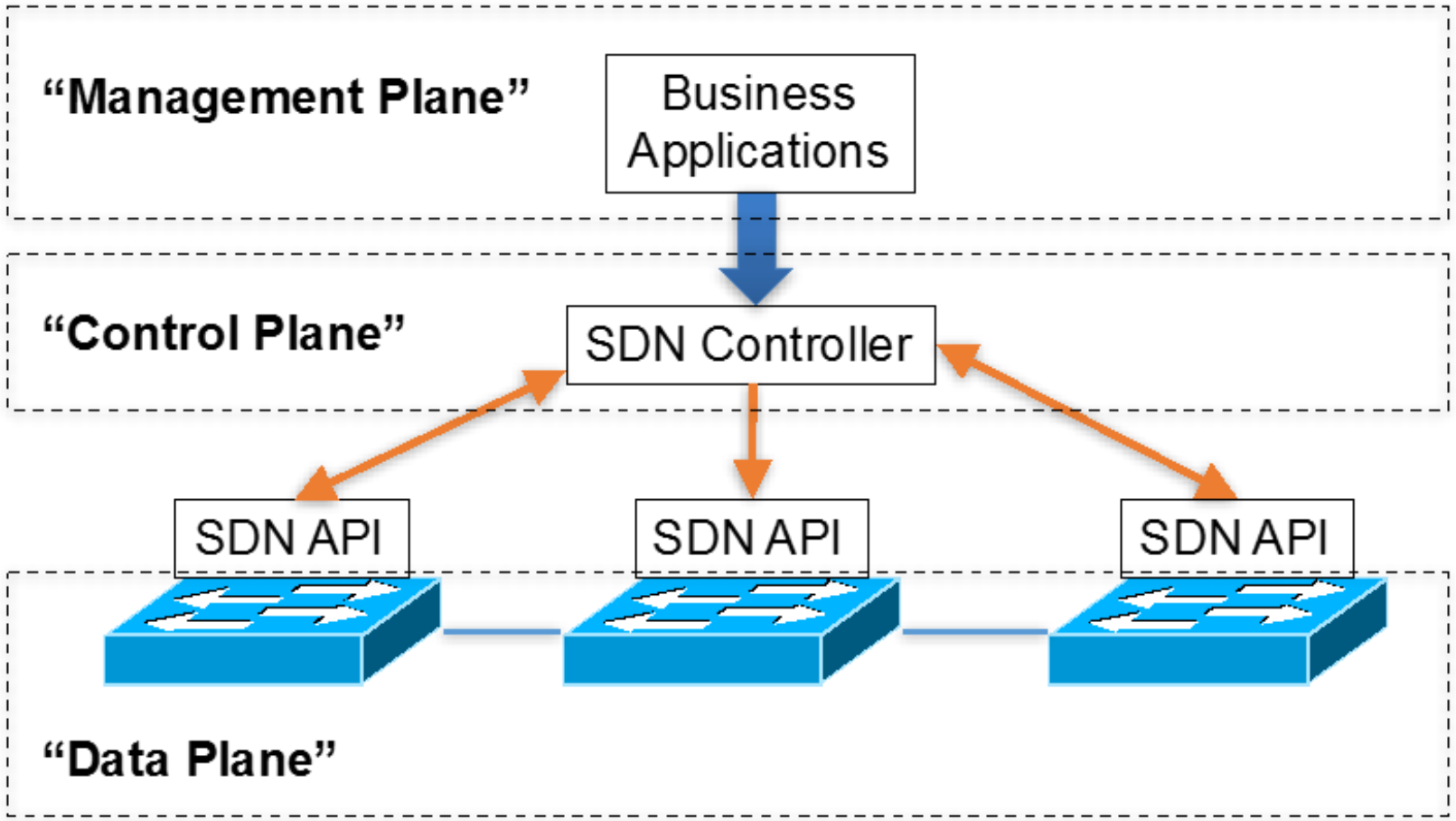
- Advanced Media Workflow Association
  - “The AMWA is an open, community-driven forum, advancing business-driven solutions for Networked Media workflows.”
  - http://www.amwa.tv
  - https://github.com/AMWA-TV
  - BBC, Fox, Ericsson, PBS, AJA, Arista, AVID, Cisco, Dalet, enbrionix, evertz, Grass Valley, Harmonic, Nevion, Panasonic, Macnica, Sony, SAM, Tektronix, Streampunk, Coveloz
- Networked Media Open **Specifications (not a Standard)**
  - http://www.nmos.tv
  - https://github.com/AMWA-TV/nmos
  - “NMOS is a family name for specifications produced by the Advanced Media Workflow Association related to networked media for professional applications.”

Overall Goals

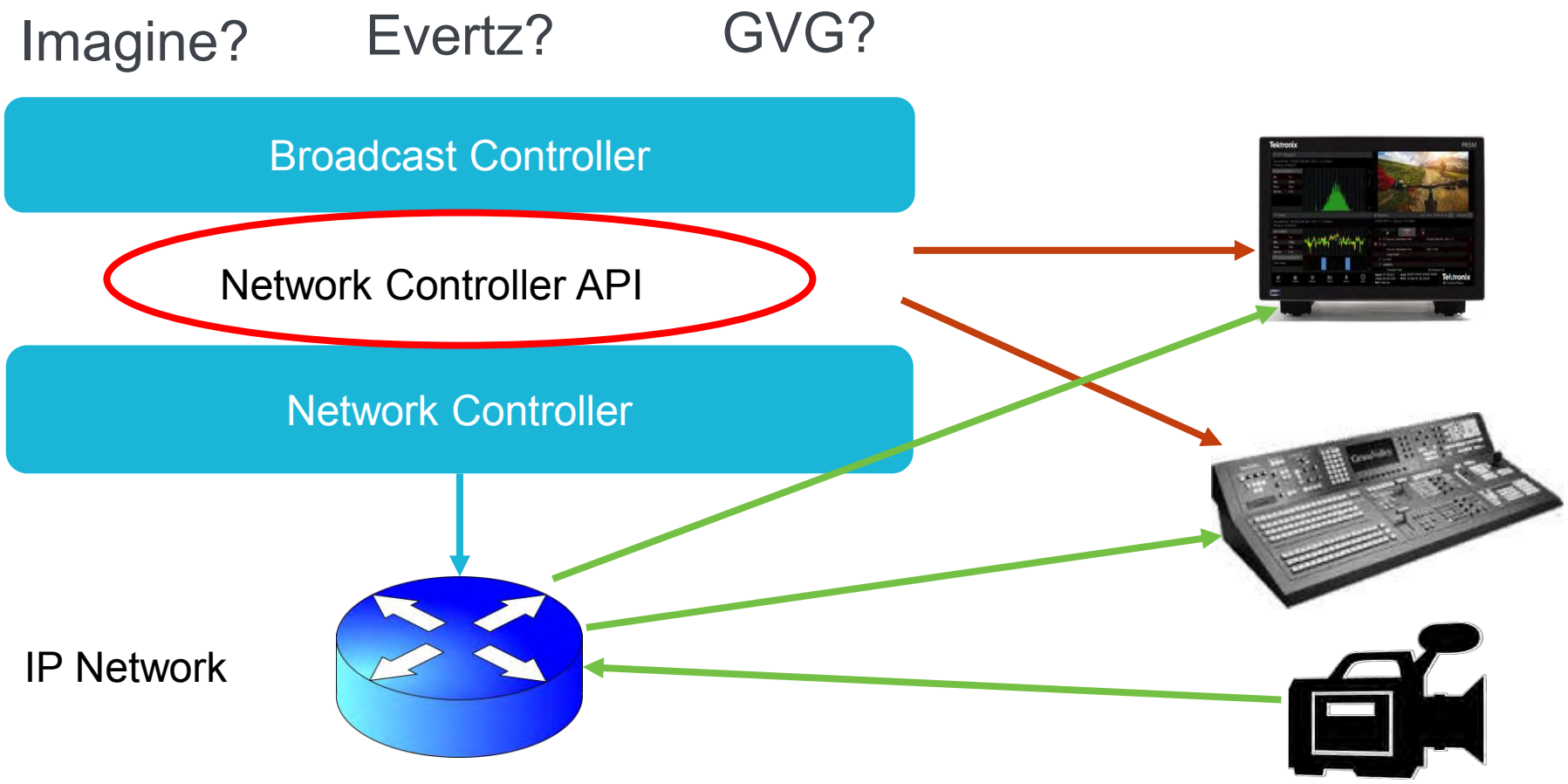
- Simplifying this:



Software Defined Network



NMOS is the Heart of SDN



Getting Documentation

- High Level Documentation and diagrams accompany the formal RAML definitions of NMOS Standards on AMWA's Github account in the "docs" directory (and its very good):
  - IS-04 Discovery / Registration:
    - https://github.com/AMWA-TV/nmos-discovery-registration/tree/master/docs
  - IS-05 Connection Management:
    - https://github.com/AMWA-TV/nmos-device-connection-management/tree/master/docs
  - IS-06 Network Control (In-progress):
    - https://github.com/AMWA-TV/nmos-network-control

Specifications of Interest:

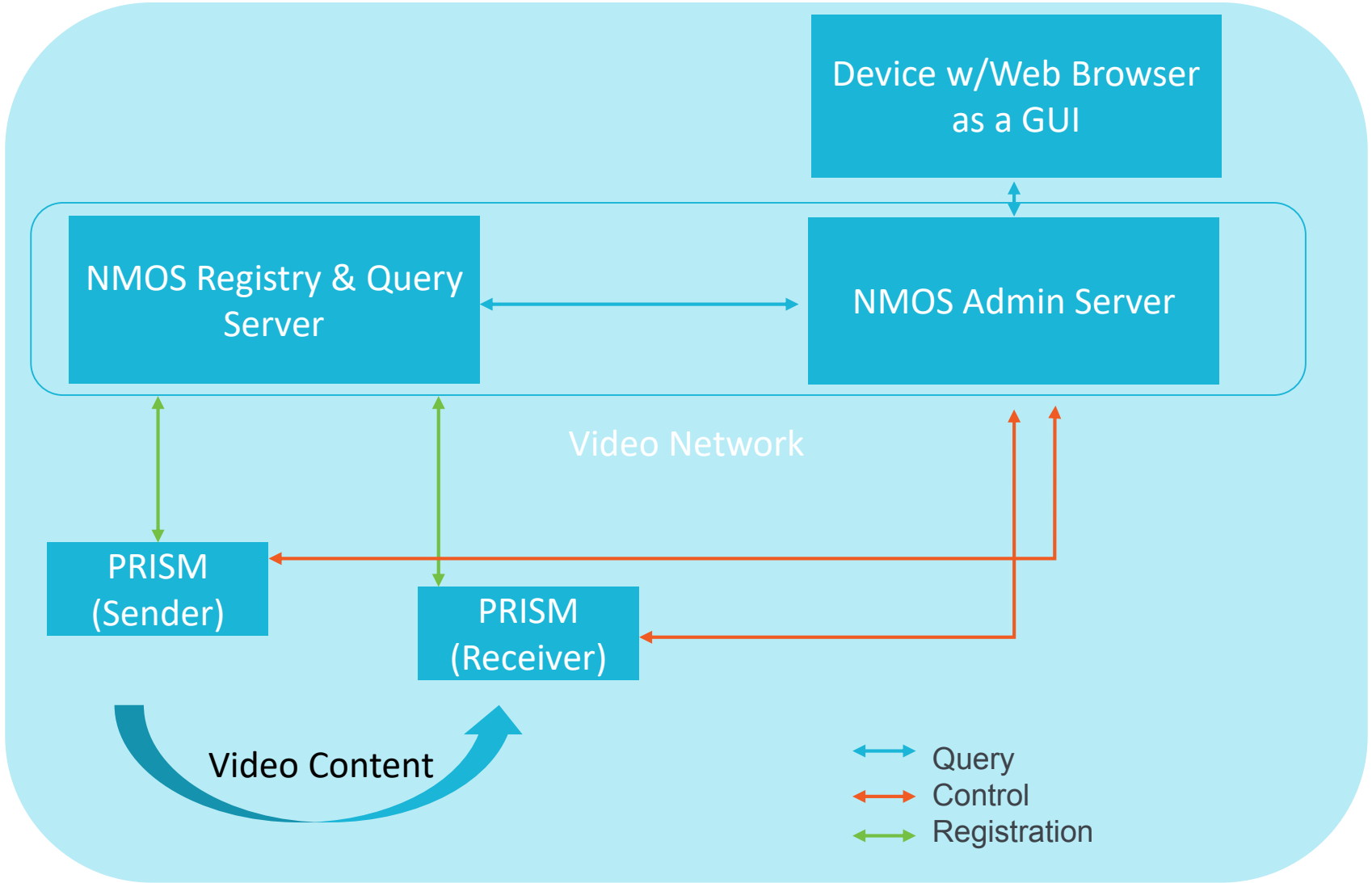
- IS-04 – Discovery and Registration
  - Finding NMOS Devices on the Network
  - Describing their capabilities
  - Advertising the locations of other (IS-05) APIs
- IS-05 – Device Connection Management
  - HTTP APIs for telling senders where to send content
  - HTTP APIs for telling receivers where to get content
  - Trading SDP Files from Senders to Receivers
- IS-06 - Network Control (In-progress)
  - Describe Network Topology
  - Allocate Bandwidth to streams

What NMOS is and isn't :

- Is a mechanism to:
  - Find sources / senders
  - Make / break connections
  - Report connection status
  - Eliminate need for UI on senders / receivers
  - Allow 3rd party management UI through standardized, unified API

- Is not a mechanism to:
  - Encode / Encapsulate video, audio (payload agnostic)
  - Actively sniff out non-NMOS devices

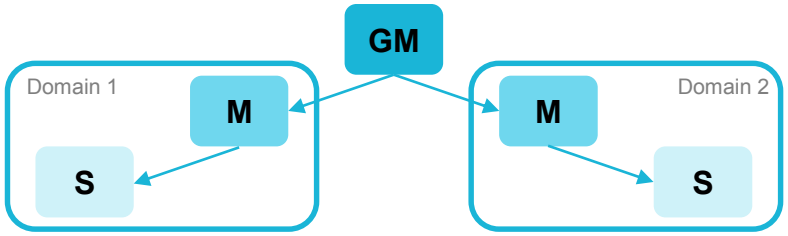
Plugging into a simple NMOS Network



Precision Time Protocol (PTP) System Timing

PTP Terms and Definitions

- **PTP Domain**
  - Logical grouping of clocks that are synchronised to each other using PTP, but may not be synchronised to other clocks in another domain
- **Grandmaster Clock**
  - Ultimate source of time for clock synchronisation using PTP
    - In broadcast applications, these are usually synchronised to GPS, GLONASS or both
- **Master Clock**
  - A clock that is the source of time to which all other clocks in that domain are synchronised
- **Slave Clock**
  - A clock that is synchronised to another clock



Relevant Standards

IEEE 1588-2008 (PTP V2)

- Standard for a Precision Clock Synchronisation Protocol for Networked Measurement and Control Systems

SMPTE ST 2059-1 2015 (PTP V2)

- Generation and Alignment of Interface Signals to the SMPTE Epoch

SMPTE ST 2059-2 2015 (PTP V2)

- Profile for Use of IEEE-1588 Precision Time Protocol in Professional Broadcast Applications

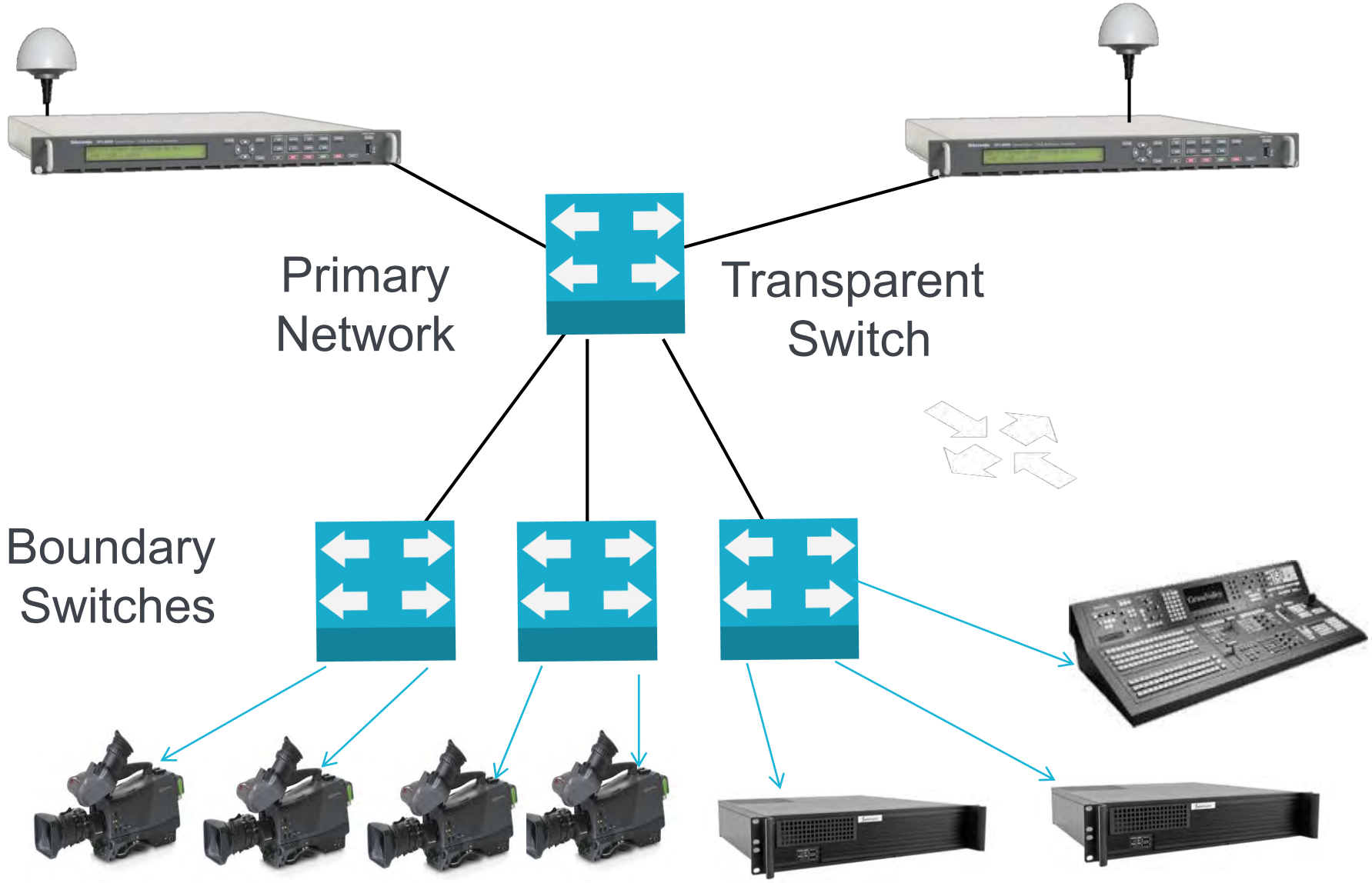
AES67-2015 (PTP V2)

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

DANTE (PTP V1) (DIGITAL AUDIO NETWORK THROUGH ETHERNET)

- Proprietary system used in digital audio over a standard Ethernet network Developed in 2006 by Audinate

Every Device in the PTP Network will need to be configured

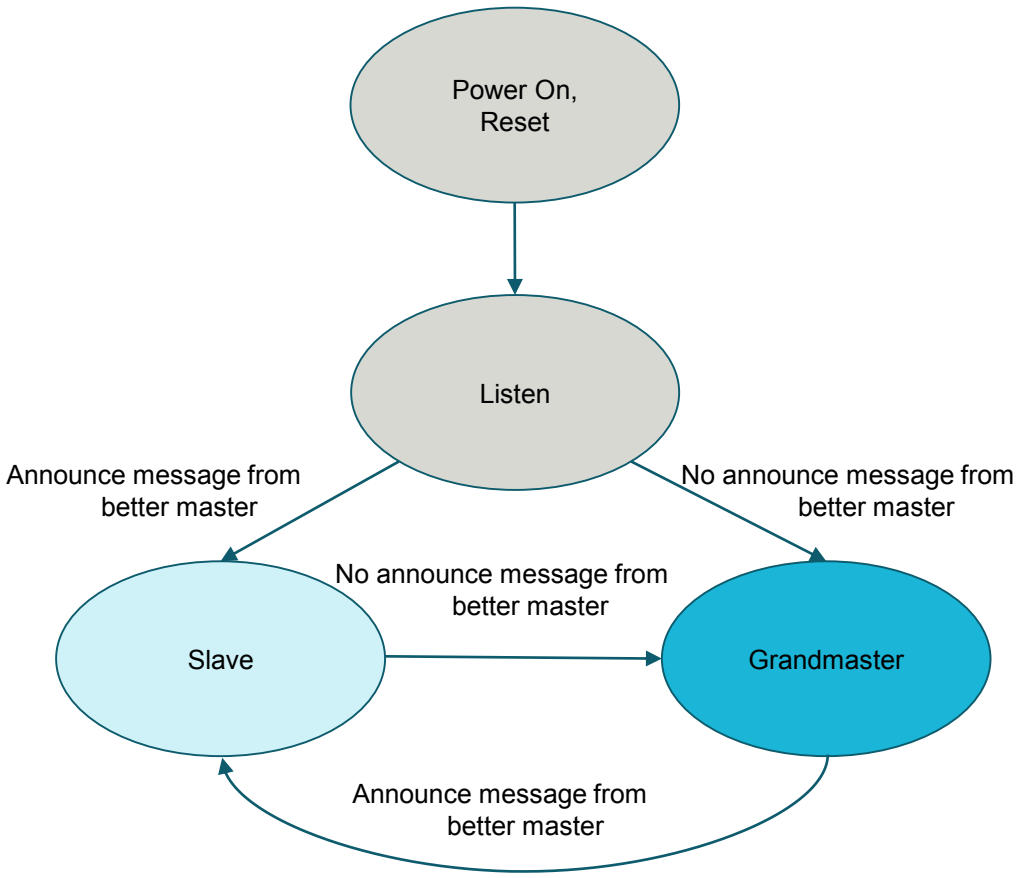


PTP Clocks

BEST MASTER CLOCK ALGORITHM (BMCA)

- BMCA runs on all devices
- Master based on several parameters
  - Priority 1 defaultDS.priority1 Default Value 128
    - Lowest value wins (Range 0-255)
  - Clock Class
  - Clock Accuracy
  - Clock Variance

  } How good is my clock
  - Priority 2 defaultDS.priority2 Default Value 128
    - Lowest value wins (Range 0-255)
- Final tie breaker
  - Clock ID usually MAC address



Determining Master/Slave Clock State

PTP Message Types

ANNOUNCE

- Used to **establish the synchronization hierarchy**
- Provides the clock status and clock criteria used to determine **which clock becomes the Grandmaster**

SYNC AND FOLLOW UP

- Transmitted by the Grandmaster and **used by the Slaves to derive the time**

DELAY REQUEST

- Request for timing information sent from Slave to the Grandmaster in order to **determine the propagation delay between the Slave and the Grandmaster**

DELAY RESPONSE

- **Time of receipt of the Delay Request message sent by the Grandmaster back to the Slave**

Synchronization Message Exchange

Used by Ordinary and Boundary Clocks

Primar Master Time

T-ms $(t_2 - t_1)$

t_1

t_1, t_2

T-sm $(t_4 - t_3)$

t_4

$$\text{Delay} = \frac{(t_2 - t_1) + (t_4 - t_3)}{2}$$

PTP Clock Types - 2

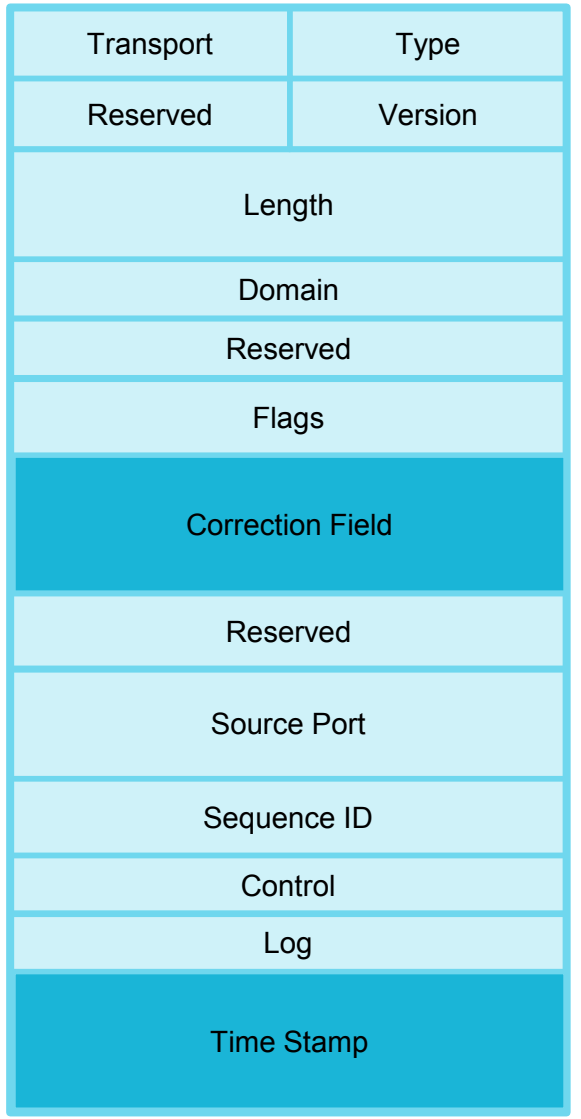
TRANSPARENT CLOCK

- **Accounts for queueing delays** in switches or routers
- **Hardware time stamps** Sync and Delay Request messages on arrival and departure and adds the difference to a **correction field in the message header**

BOUNDARY CLOCK

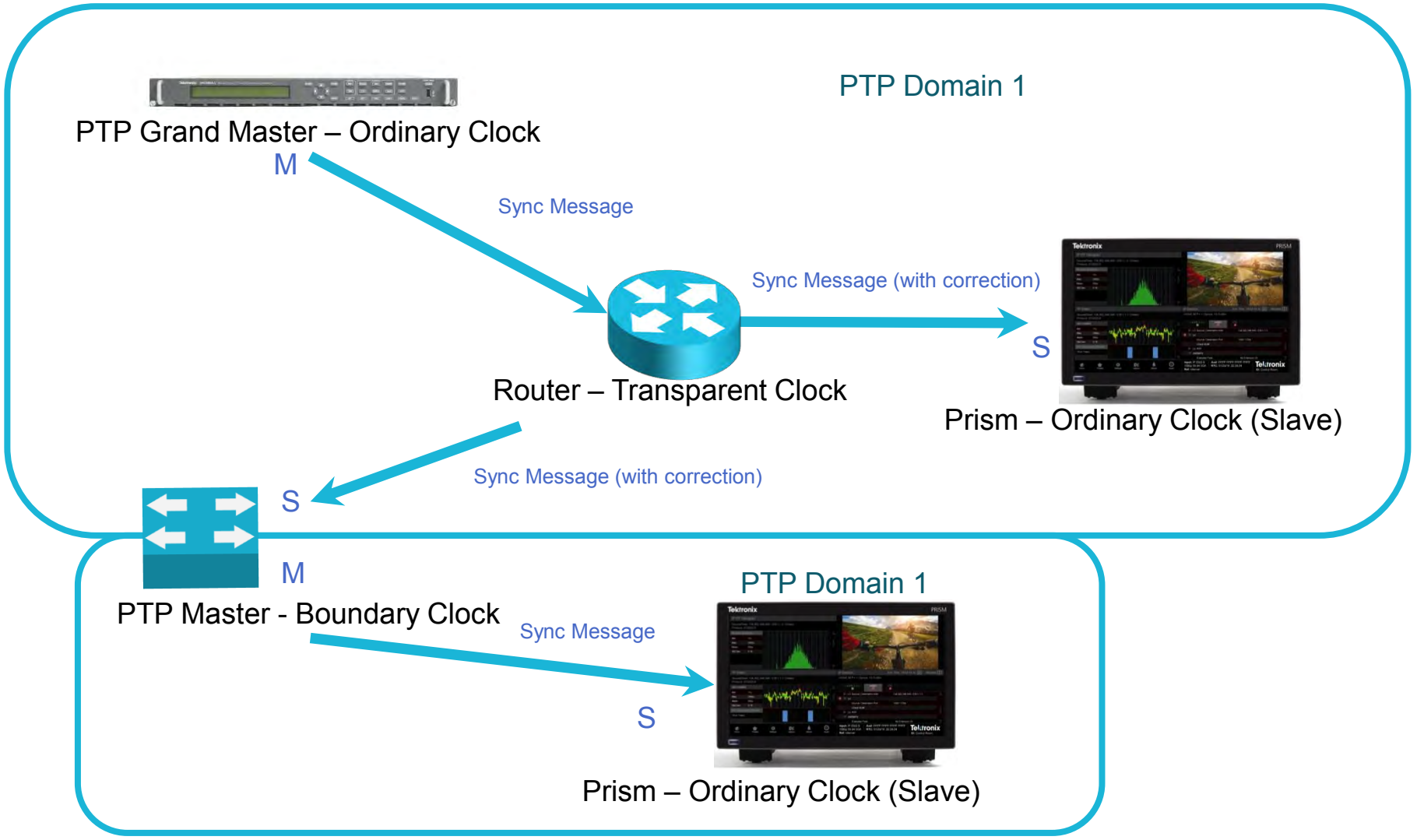
- Receives time from a Master on one Slave port
- Provides Multiple Master (not Grandmaster) **ports to downstream Slaves in a domain**
- **Removes the effect of its own queue**

Switches/Routers in a PTP network must be PTP aware
(Must be either a Transparent Clock or a Boundary Clock)



Sync/Delay Request Message Format

PTP Clock Types In A Network



PTP Network

QUESTION TO ASK

- **Does the IP Switch support the SMPTE Profile (ST2059)**
  - Can it be a Boundary Clock
    - Receives time from a Master on one Slave port
    - Provides Multiple Master (not Grandmaster) ports to downstream Slaves in a domain
    - Removes the effect of its own queue
- **What Domain should be used?**
  - Range is from 0 to 127
  - Dante uses PTP Version 1 which is not compatible with V2
    - Some Dante devices can act as a Boundary Clock for PTP V1 when in the AES mode
    - Some Dante devices can only use domain 0
    - Default Values for ST2059-2 =127
    - Default Values for AES and IEEE1588 = 0

PTP ST 2059-2 Interoperability (AES-R16-2016)

Interoperability between Default, AES and SMPTE Profiles	Min	Max	Proposed	Further info
Domain Number	0	127	0	Must be same for all ports
Log Announce Interval*	0	1	1	Must be same for all ports
Announce Receipt Timeout	2	10	3	Must be same for all ports
Log Sync Interval*	-1	-1	-1	

Interoperability between AES and SMPTE Profiles	Min	Max	Proposed	Further info
Domain Number	0	127	0	Must be same for all ports
Log Announce Interval*	0	1	0	Must be same for all ports
Announce Receipt Timeout	2	10	3	Must be same for all ports
Log Sync Interval*	-4	-1	-3	

*The value of the parameter is the logarithm to base 2

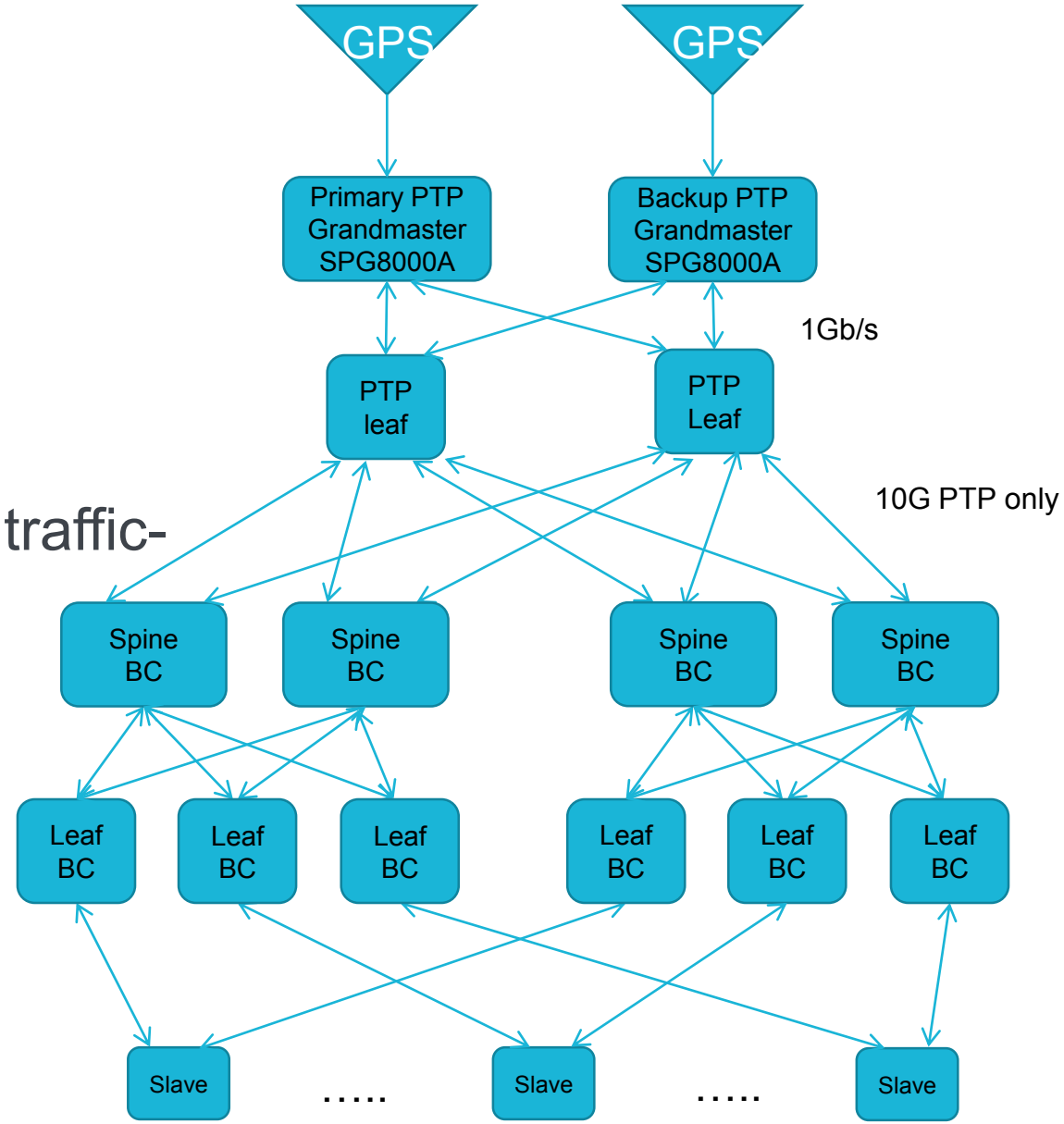
Choosing Your Grandmaster Clock (GM)

THE KEY HERE IS YOU CHOOSE THE GM, DON'T LET IT BE CHOSEN FOR YOU

- **Each Domain needs a Grandmaster Clock**
- **Priority 1 is used to select the devices you want to be able to be the GM**
  - Lowest Value wins (Range 0 - 255)
  - Make the Priority 1 value very low for the GM devices.
  - If Priority 1 is zero then there is less chance of a rogue device becoming the GM
  - Remember if all the BMCA values are equal then the MAC address is used to pick the GM
- **Clock class, accuracy and variance are quality of lock values**
  - Which will select the best and most stable PTP source
  - Selects from the devices with the lowest Priority 1 value.
  - If all the quality values are equal then Priority 2 will select the GM.
- **Priority 2 is used to select which of the devices with the lowest Priority 1 value you would prefer to be the GM**
  - Lowest Value win (Range 0 - 255)
  - Also making the Priority 2 value low would be safer

Leaf Spine

- Redundant System
- PTP Leaf
- Single output master OK
- PTP leaf should not see video traffic-
  - need to block out video



PTP message congestion

- **Multicast**
  - **All messages go from all devices to all devices**
  - Large load for slaves – 1000 slaves @ 8 Hz rate -> 16020 message/sec
  - Larger load for Switch, scales with N squared -> 16,017,000 message per sec
- **Mixed- Not many devices support yet**
  - **Delay Request and Response are unicast – so route explicitly**
  - Slave load for 1000 slaves at 8 Hz rate -> 36 message a sec
  - Switch load is 36,000 per sec.
  - Mixed with Negation– Preferred -Master Regulates Rate/Load – 250 Sec Duration of Session then slave needs to ask again
- **Unicast- Master Needs to Know all Slaves**
  - Announce, Sync and Follow up are routed explicitly instead of common. So larger load on master.
  - Same load on Slaves
  - Similar load on Switch – depending on effort for multicast vs unicast

Verifying Video Lock in the IP world

JUST LIKE BASEBAND VIDEO YOU NEED THE SIGNALS TO SYNCHRONIZED TO A COMMON REFERENCE

Many challenges still lie ahead

IT'S NOT FOR THE FAINT OF HEART

- Manufacturers ST2110 products are getting more stable
  - The implementation of the standards is improving
- As we start to deploy NMOS servers then control will become easier
- The user and the market will need help define audio interoperability
  - Number of Channels pre Streams
- Future System will be 25g instead of 10g. (To support 4K)
- PTP with Boundary Clock for best results.
  - Check configuration
- Once we move to an IP based system, it will open future possibilities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