Precision Timing Protocol

Genlock over IP

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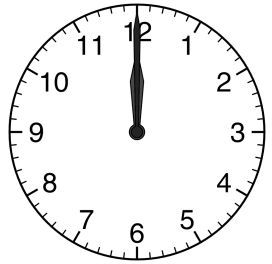
IP SHOWCASE THEATRE AT METexpo 17-19 July 2019

What do we mean by “timing”?

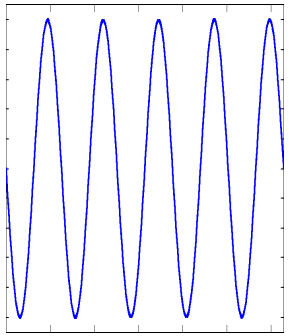
Time of Day (ToD)

- DD-Mmm-YYYY HH:mm:ss
- Traditional broadcast uses LTC and adds a frame counter



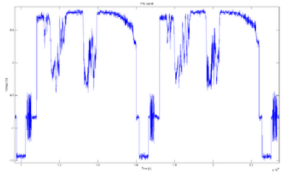
Frequency

- Number of cycles per second
- For broadcast this is the number of frames or fields per second
- Traditionally tied to local power frequency (PAL 50Hz, NTSC 60Hz)



Phase

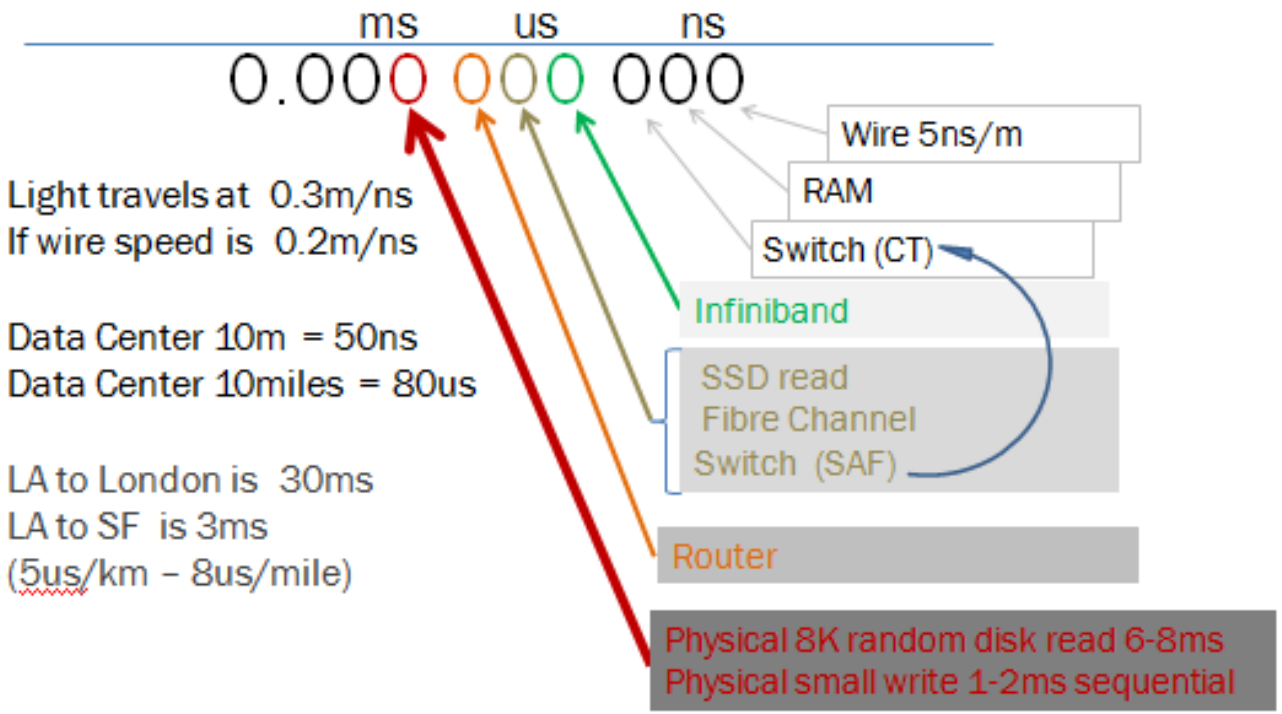
- Alignment – critical for clean video switching



Time for the acronyms

- NTP = **Network Time Protocol**
  - Accurate to around 1ms in ideal conditions (sometime better, often worse)
- GPS = **Global Positioning System**
  - Accuracy to around 40ns
- PTP = **Precision Timing Protocol**
  - Accuracy in the tens of nano seconds with hardware timestamping
  - Dependent on network architecture and hardware
  - Real world local network - 1µs accuracy or better

Orders of Magnitude



http://dboptimizer.com/2011/07/15/time-orders-of-magnitude/

Precision Timing Protocol – what is it?

- An IEEE Standard:
  - **IEEE1588-2002** (PTPv1) – DANTE (in native mode)
  - **IEEE1588-2008** (PTPv2) – AES67 & SMPTE ST 2059
- Used in modern telco, industrial control, power, finance networks
- Accuracy down to tens of nanoseconds using hardware timestamps
- Far exceeds the accuracy of NTP
- Multicast UDP by default, supporting IPv4 & IPv6
- Provides Time of Day, Frequency, Phase (**Genlock over IP**)

Why PTP for Broadcast?

- **Accurate to sub microsecond -** provides the accuracy for broadcasting (500ns between Master and Slave / 1µs between the Slaves)
- **Generic standard** - Customizable via PTP profiles to meet industry specific requirements
- **PTP Profiles for Broadcasters** - SMPTE ST 2059-2 and AES67 Media
- **Network Switches** with boundary or transparent clock functionality allow a robust time distribution over the whole network
- **Easy to setup**

Media over IP Standards

- **IEEE1588-2008 –** Precision Timing Protocol (PTPv2)
- **ST2022-5/6** – SDI over IP
- **ST2059** – Synchronisation of video equipment over IP (using 1588)
- **ST2110-xx** – Separately routable essence streams
- **AES67** – Uncompressed Audio over IP (radio, live audio, A/V)
- **AES-R16-2016** - PTP parameters for AES67 and SMPTE ST 2059-2 interoperability

What are PTP Profiles?

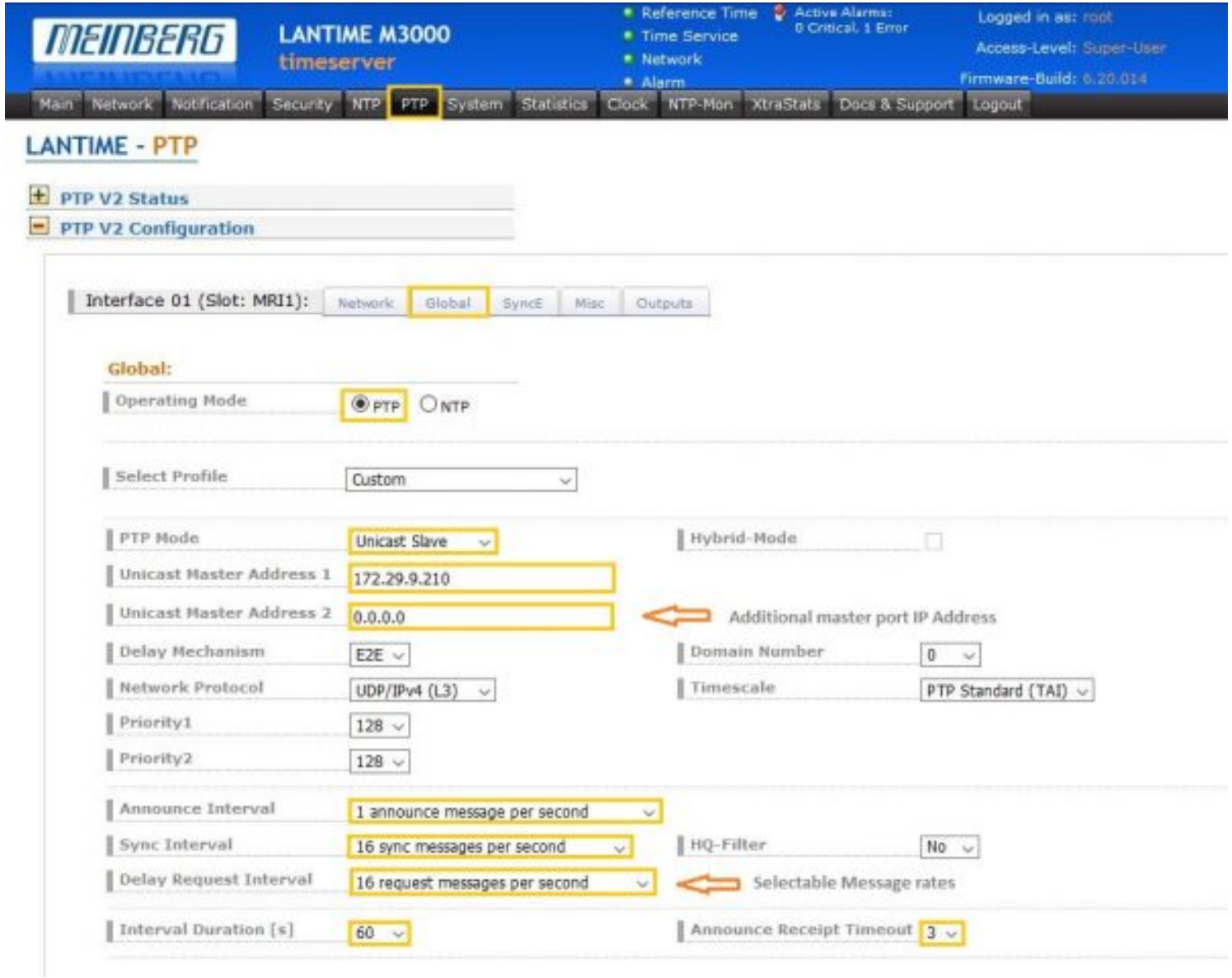
- A collection of parameters for different industries
- Defines Domain number (a group of devices syncing over PTP)
- Defines intervals – announcements, sync requests, delay requests
- Both ST2059 and AES67 support a range of values
- Overlap in values allows for ST2059 & AES67 interop…

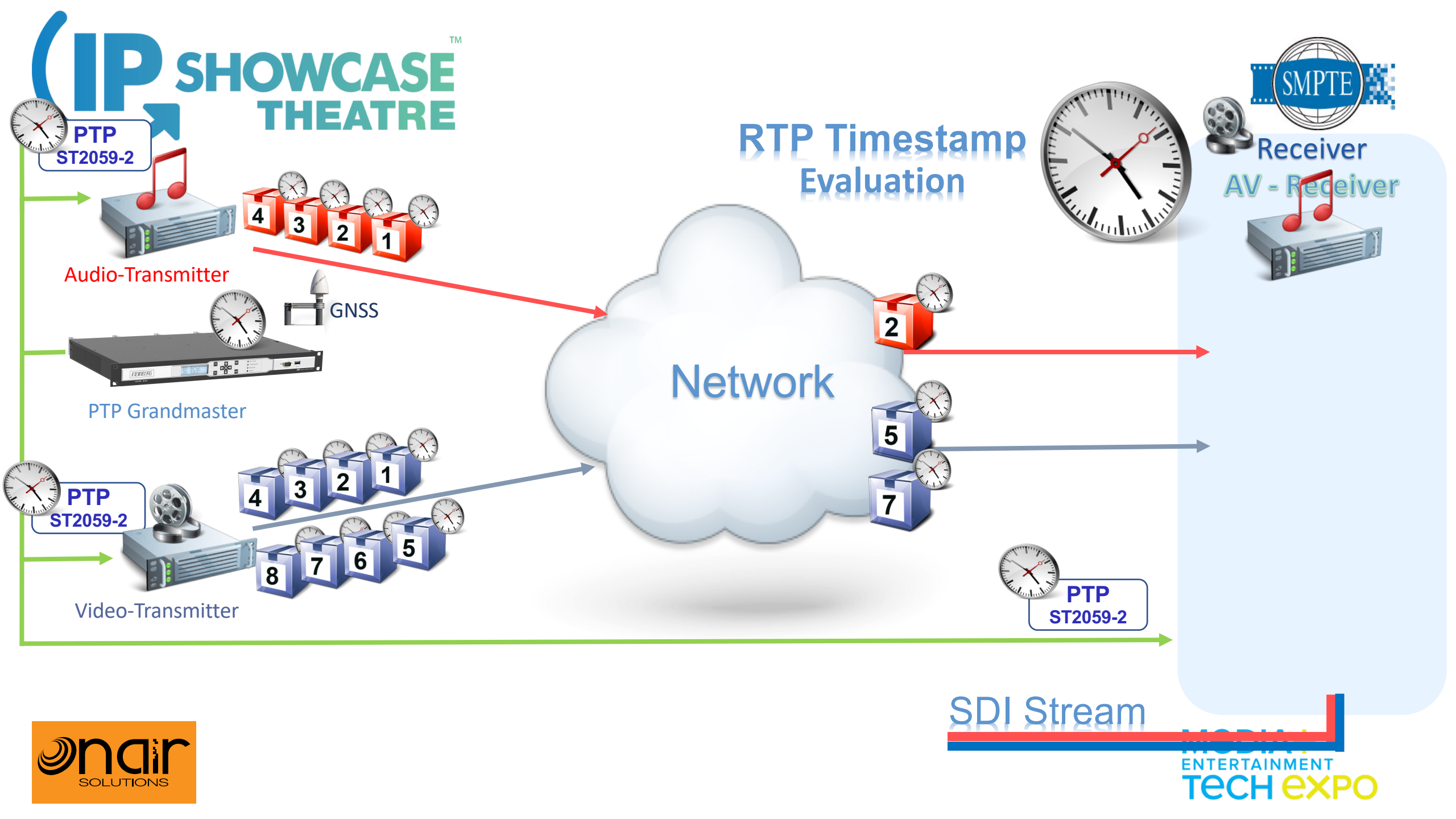
SMPTE 2059 & AES67 Interop

Profile	SM (Synchronization Metadata) TLV	Domain	Priority1	Priority2	Announce Interval	Sync Interval	Delay Request Interval
SMPTE	Yes	Default: 127 Range: 0 through 127	Default: 128 Range: 0 through 255	Default: 128 Range: 0 through 255	Default: 250ms (4/s) Range: -3 to 1 *	Default: 125ms (8/s) Range: -7 to 1 *	Default: 125ms (8/s) Range: -3 to 2 *
AES67	No	Default: 0 Range: 0 through 127	Default: 128 Range: 0 through 255	Default: 128 Range: 0 through 255	Default: 0 (1 sec) Range: 0 to 4 *	Range: -4 to 1	Range: -3 to 2*
AES67+SMPTE	Yes	**Recommended:** 0 Range: 0 through 127	**Recommended:** 128 Range: 0 through 255	**Recommended**: Depends on network	**Recommended:** Default: 250ms (4/s)	**Recommended:** Default: 125ms (8/s)	**Recommended** = Sync Interval

* PTP Parameters are 2^x eg 2^{-3} = 8 per second (125ms)

Configuration

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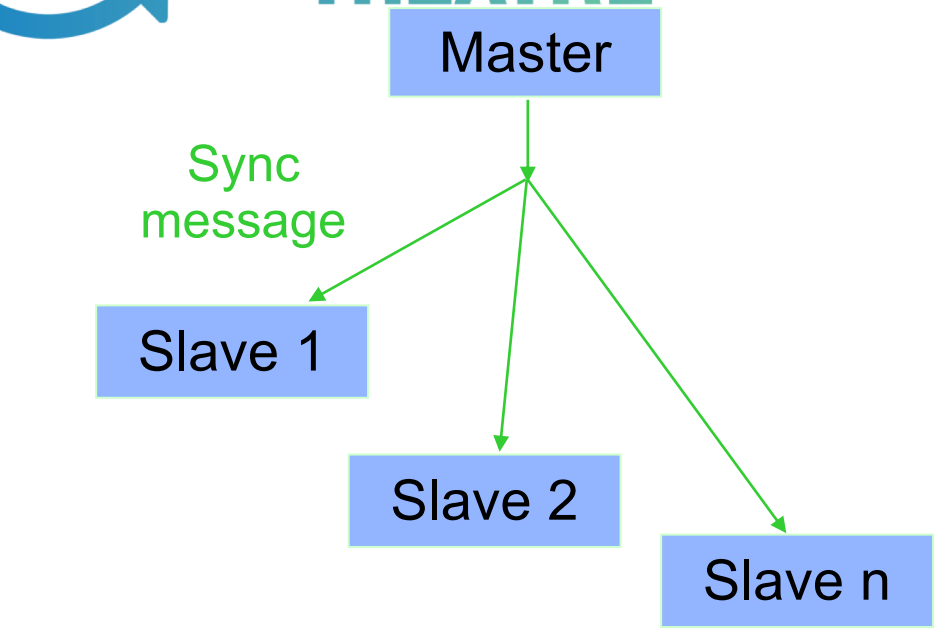
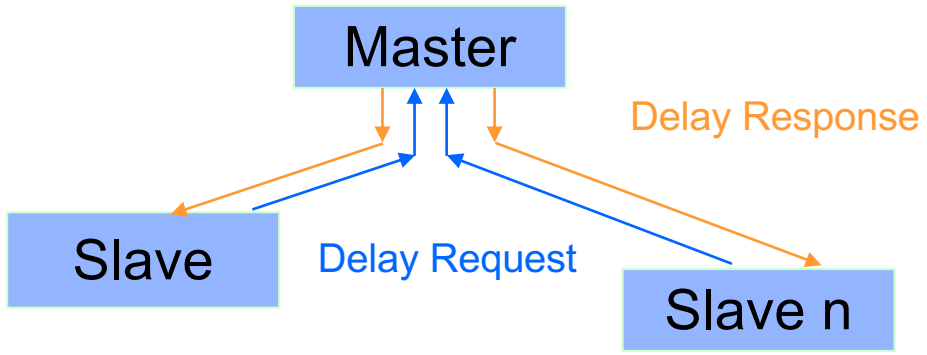
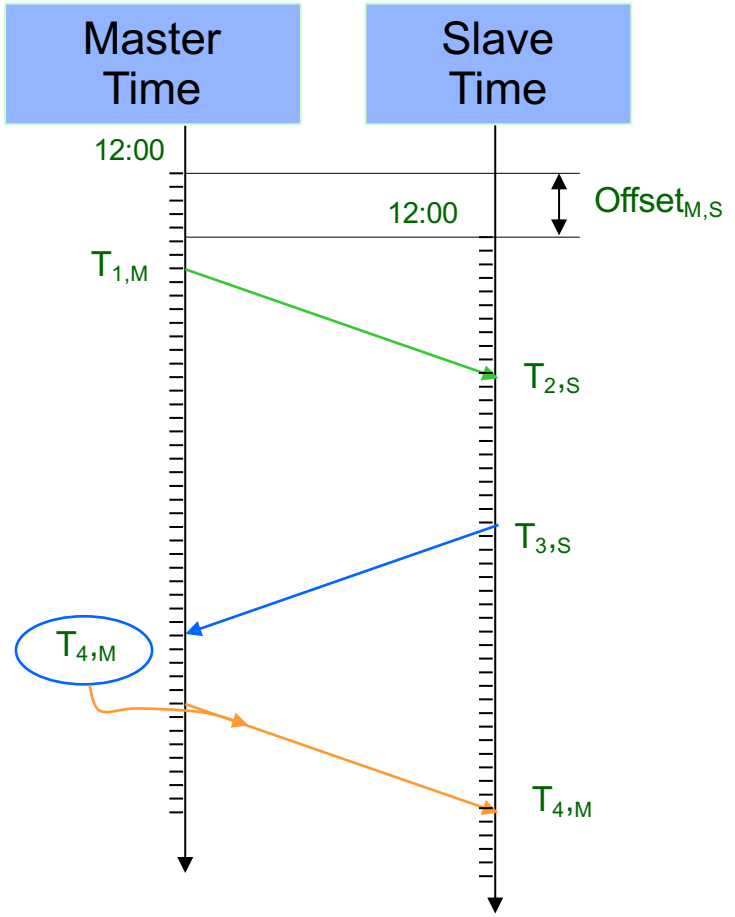
PTP
ST2059-2
Audio-Transmitter
GNSS
PTP Grandmaster
PTP
ST2059-2
Video-Transmitter
Network
RTP Timestamp
Evaluation
SMPTE
Receiver
AV - Receiver
PTP
ST2059-2
SDI Stream
onair
SOLUTIONS
MEDIA
ENTERTAINMENT
TECH EXPO







$$T_{2,S} - T_{1,M} = T_{2,1}$$
$$T_{4,M} - T_{3,S} = T_{4,3}$$

$$Offset = \frac{T_{2,1} - T_{4,2}}{2}$$

$$Delay = \frac{T_{2,1} + T_{4,3}}{2}$$

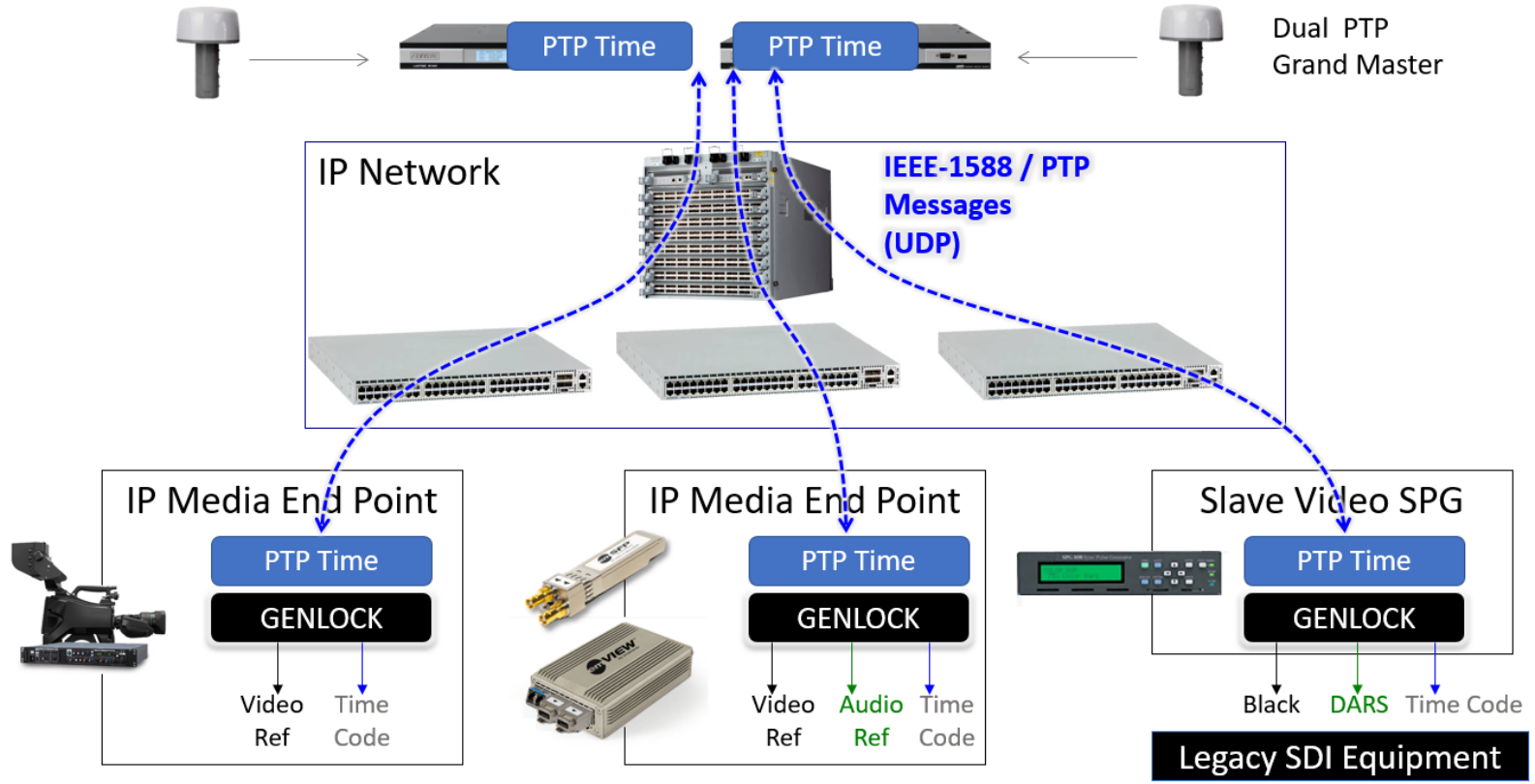
PTP BMCA - *Best Master Clock Algorithm*

- BMCA automatically selects the best clock for you
- Hierarchy of priority for PTPv2 is:
  1. **Priority 1** – user-assigned (smaller numeric values indicate higher priority)
  2. **Class** – each clock is a member of a given class, each class getting its own priority
  3. **Accuracy** – precision between clock and UTC, in nanoseconds (ns)
  4. **Variance** – variability of the clock
  5. **Priority 2** – final-defined priority, defining backup (smaller values indicate higher priority)
  6. **Unique identifier** – MAC address-based selection is used as a tiebreaker
- GPS referenced clocks will win, assuming Priority 1 is appropriate

PTP Aware Networks

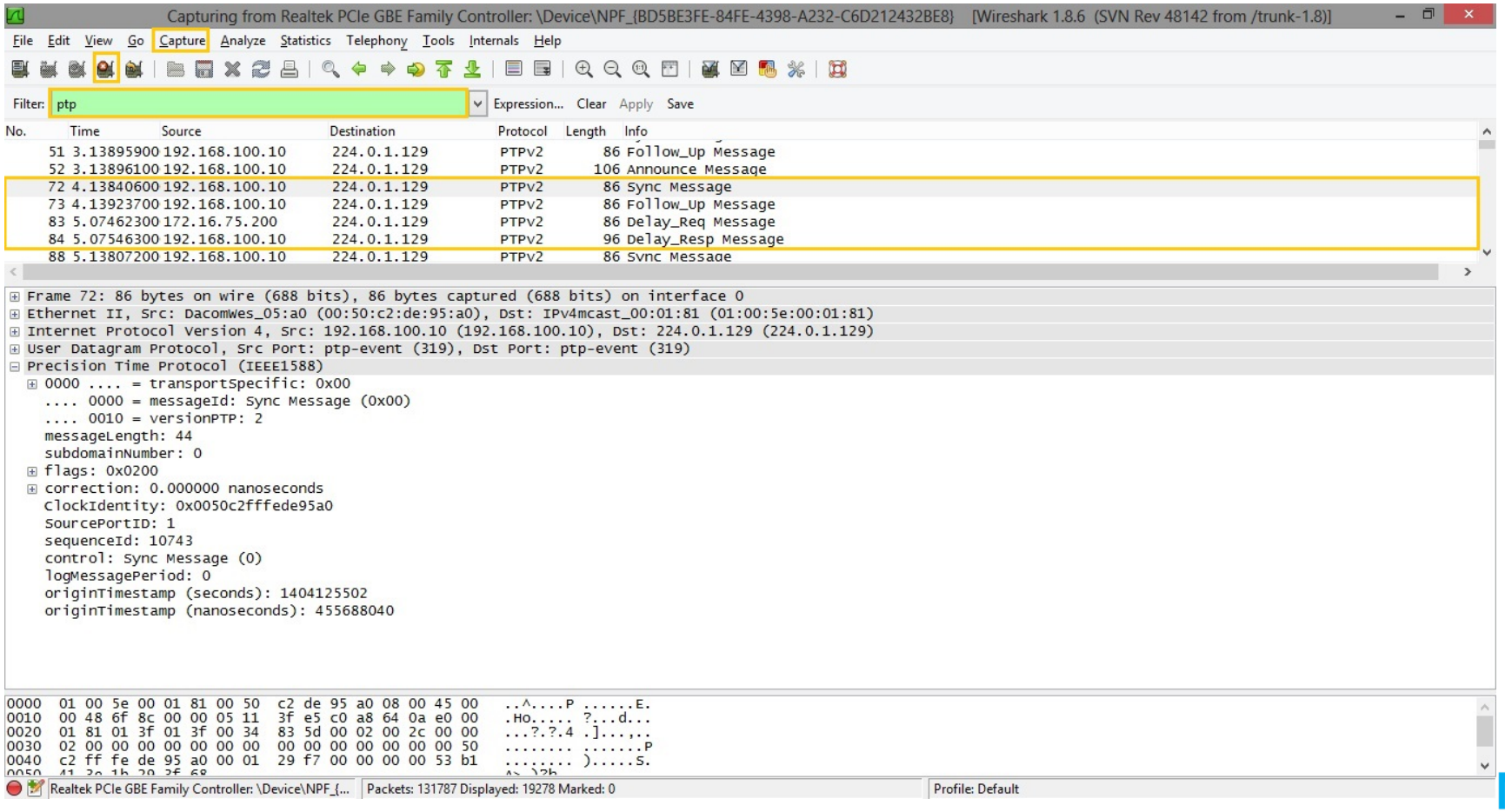
- Non-PTP aware hardware will degrade timing accuracy
- Transparent Clocks calculate time-stamps but aren't masters
- Boundary Clocks provide PTP to clients and can select between multiple Grand Master Clocks for redundancy
- BC can also protect the Grand Master(s) from overload and provide neat timing boundaries
- TC & BC remove the impact of Packet Delay Variation (PDV) / Jitter
- 10x BC can meet an accuracy of ± 1µs (1000ns)

Integrating to a hybrid environment

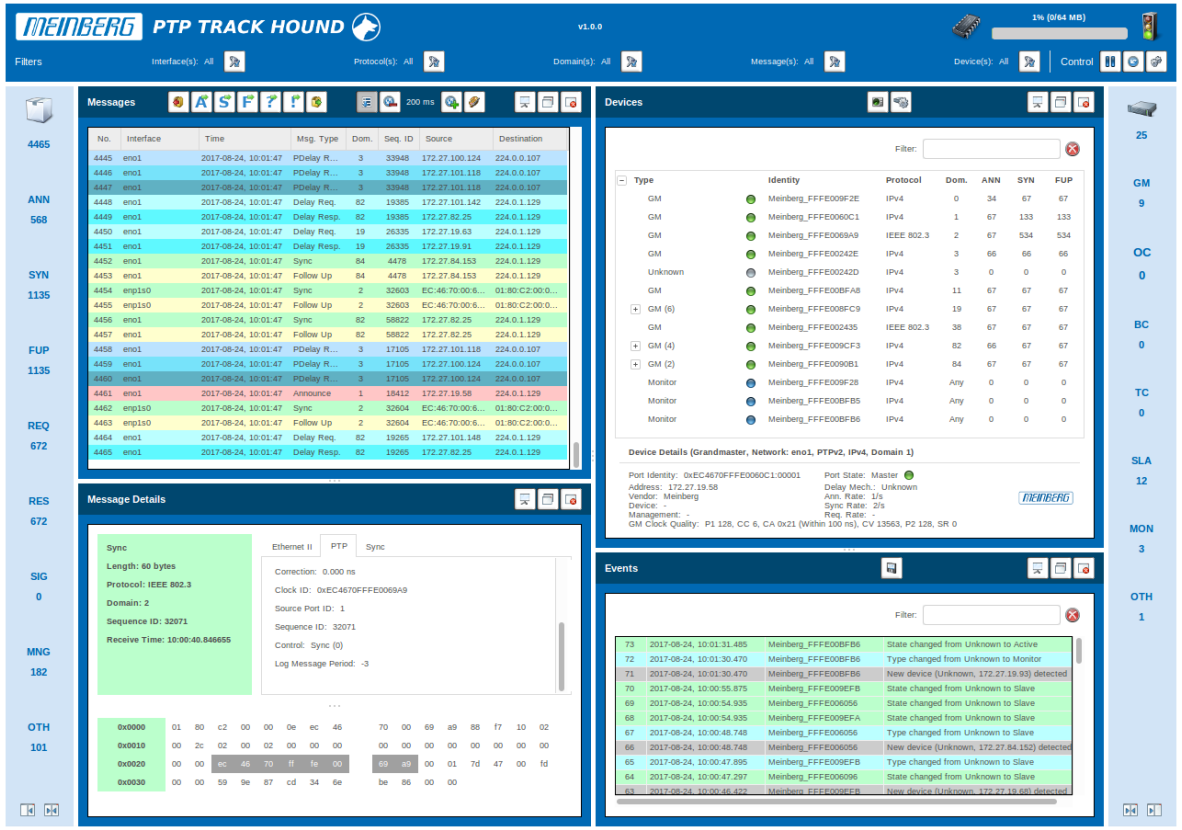


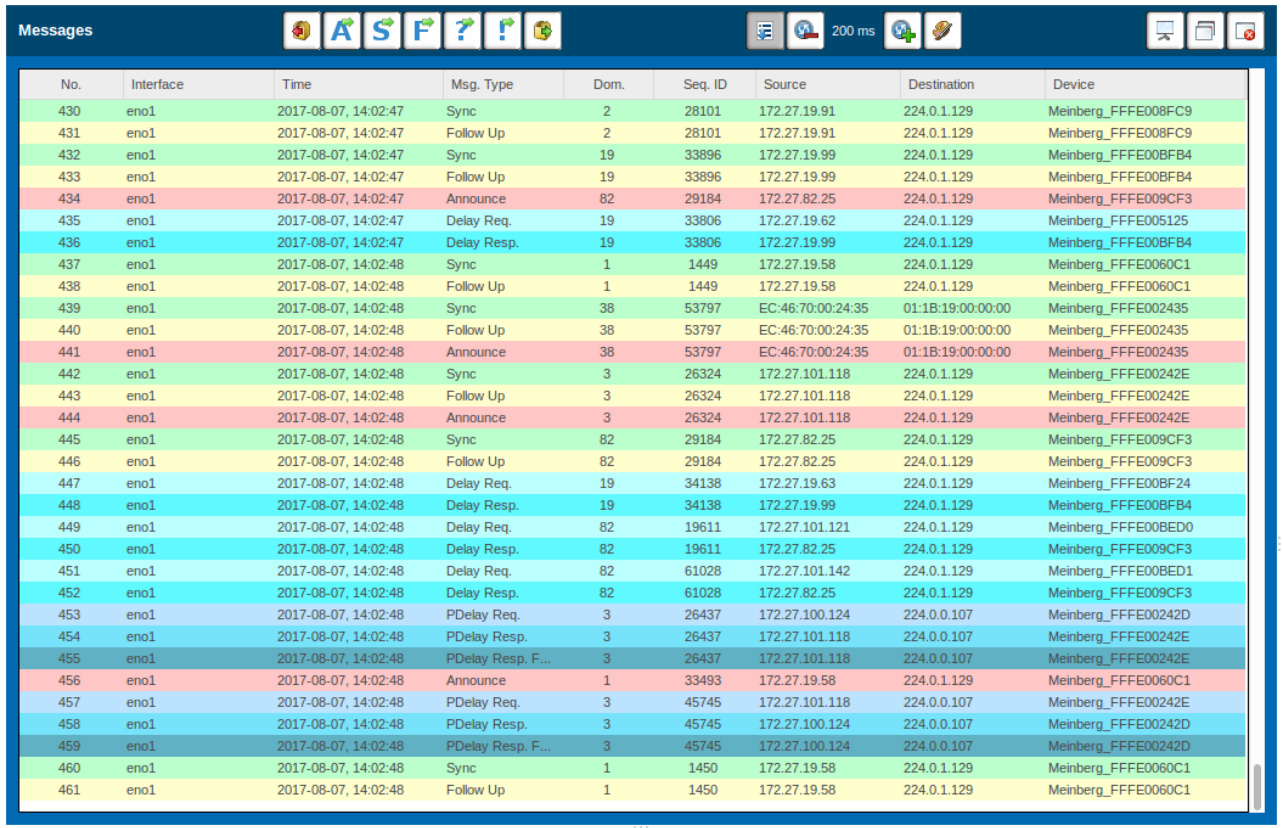
https://www.embrionix.com/resource/transparent_boundary_clock_ST2059_in_broadcast

PTP capture in Wireshark



PTP Track Hound





No.	Interface	Time	Msg. Type	Dom.	Seq. ID	Source	Destination	Device
430	eno1	2017-08-07, 14:02:47	Sync	2	28101	172.27.19.91	224.0.1.129	Meinberg_FFFE008FC9
431	eno1	2017-08-07, 14:02:47	Follow Up	2	28101	172.27.19.91	224.0.1.129	Meinberg_FFFE008FC9
432	eno1	2017-08-07, 14:02:47	Sync	19	33896	172.27.19.99	224.0.1.129	Meinberg_FFFE00BFB4
433	eno1	2017-08-07, 14:02:47	Follow Up	19	33896	172.27.19.99	224.0.1.129	Meinberg_FFFE00BFB4
434	eno1	2017-08-07, 14:02:47	Announce	82	29184	172.27.82.25	224.0.1.129	Meinberg_FFFE009CF3
435	eno1	2017-08-07, 14:02:47	Delay Req.	19	33806	172.27.19.62	224.0.1.129	Meinberg_FFFE005125
436	eno1	2017-08-07, 14:02:47	Delay Resp.	19	33806	172.27.19.99	224.0.1.129	Meinberg_FFFE00BFB4
437	eno1	2017-08-07, 14:02:48	Sync	1	1449	172.27.19.58	224.0.1.129	Meinberg_FFFE0060C1
438	eno1	2017-08-07, 14:02:48	Follow Up	1	1449	172.27.19.58	224.0.1.129	Meinberg_FFFE0060C1
439	eno1	2017-08-07, 14:02:48	Sync	38	53797	EC:46:70:00:24:35	01:1B:19:00:00:00	Meinberg_FFFE002435
440	eno1	2017-08-07, 14:02:48	Follow Up	38	53797	EC:46:70:00:24:35	01:1B:19:00:00:00	Meinberg_FFFE002435
441	eno1	2017-08-07, 14:02:48	Announce	38	53797	EC:46:70:00:24:35	01:1B:19:00:00:00	Meinberg_FFFE002435
442	eno1	2017-08-07, 14:02:48	Sync	3	26324	172.27.101.118	224.0.1.129	Meinberg_FFFE00242E
443	eno1	2017-08-07, 14:02:48	Follow Up	3	26324	172.27.101.118	224.0.1.129	Meinberg_FFFE00242E
444	eno1	2017-08-07, 14:02:48	Announce	3	26324	172.27.101.118	224.0.1.129	Meinberg_FFFE00242E
445	eno1	2017-08-07, 14:02:48	Sync	82	29184	172.27.82.25	224.0.1.129	Meinberg_FFFE009CF3
446	eno1	2017-08-07, 14:02:48	Follow Up	82	29184	172.27.82.25	224.0.1.129	Meinberg_FFFE009CF3
447	eno1	2017-08-07, 14:02:48	Delay Req.	19	34138	172.27.19.63	224.0.1.129	Meinberg_FFFE00BF24
448	eno1	2017-08-07, 14:02:48	Delay Resp.	19	34138	172.27.19.99	224.0.1.129	Meinberg_FFFE00BFB4
449	eno1	2017-08-07, 14:02:48	Delay Req.	82	19611	172.27.101.121	224.0.1.129	Meinberg_FFFE00BED0
450	eno1	2017-08-07, 14:02:48	Delay Resp.	82	19611	172.27.82.25	224.0.1.129	Meinberg_FFFE009CF3
451	eno1	2017-08-07, 14:02:48	Delay Req.	82	61028	172.27.101.142	224.0.1.129	Meinberg_FFFE00BED1
452	eno1	2017-08-07, 14:02:48	Delay Resp.	82	61028	172.27.82.25	224.0.1.129	Meinberg_FFFE009CF3
453	eno1	2017-08-07, 14:02:48	PDelay Req.	3	26437	172.27.100.124	224.0.0.107	Meinberg_FFFE00242D
454	eno1	2017-08-07, 14:02:48	PDelay Resp.	3	26437	172.27.101.118	224.0.0.107	Meinberg_FFFE00242E
455	eno1	2017-08-07, 14:02:48	PDelay Resp. F...	3	26437	172.27.101.118	224.0.0.107	Meinberg_FFFE00242E
456	eno1	2017-08-07, 14:02:48	Announce	1	33493	172.27.19.58	224.0.1.129	Meinberg_FFFE0060C1
457	eno1	2017-08-07, 14:02:48	PDelay Req.	3	45745	172.27.101.118	224.0.0.107	Meinberg_FFFE00242E
458	eno1	2017-08-07, 14:02:48	PDelay Resp.	3	45745	172.27.100.124	224.0.0.107	Meinberg_FFFE00242D
459	eno1	2017-08-07, 14:02:48	PDelay Resp. F...	3	45745	172.27.100.124	224.0.0.107	Meinberg_FFFE00242D
460	eno1	2017-08-07, 14:02:48	Sync	1	1450	172.27.19.58	224.0.1.129	Meinberg_FFFE0060C1
461	eno1	2017-08-07, 14:02:48	Follow Up	1	1450	172.27.19.58	224.0.1.129	Meinberg_FFFE0060C1

https://www.ptptrackhound.com/

PTP Redundancy

- Best Master Clock Algorithm (BMCA) looks after selection of master
- GPS – dual, diverse antennae
- Redundant dual-receiver frame or 2x independent frames
- PTP card per media network

PTP Security

- A rogue PTP Grandmaster could be added with higher priority
- Best Master Clock Algorithm doesn't protect you
- PTP can provide "master list" but this isn't used in SMPTE 2059
- Some switch vendors are adding whitelisting of Grandmasters
- Think about GPS jamming and spoofing

Resources

- https://en.wikipedia.org/wiki/Precision_Time_Protocol
- https://blog.meinbergglobal.com/
- http://www.aes.org/standards/blog/2016/5/aes-r16-2016-report-on-ptp-parameters
- https://www.meinberg.academy/

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SMPTE

- Sync Core with Multiple Reference Input
- Automatic Reference Changeover
- Future-Proofed (expandable)
- Unmatched Scalability
- Highest Redundancy

- Most powerful PTP implementation on the market today
- Enable easy transition from SDI to IP
- Make use of our long-term experience in PTP from other industries

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