

Precision Timing Protocol

Genlock over IP

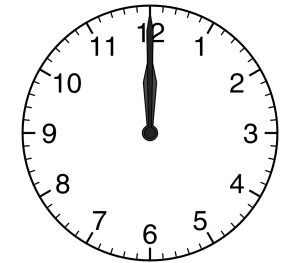
Paul Dengate, Managing Director
OnAir Solutions

IP SHOWCASE THEATRE AT METexpo 17-19 July 2019

What do we mean by “timing”?

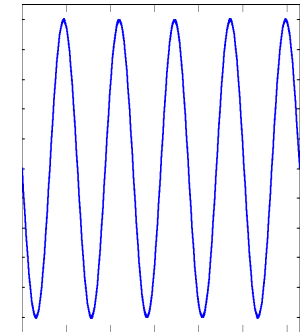
Time of Day (ToD)

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



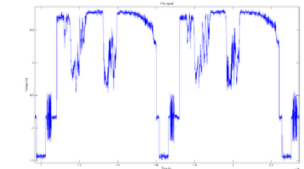
Frequency

- 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

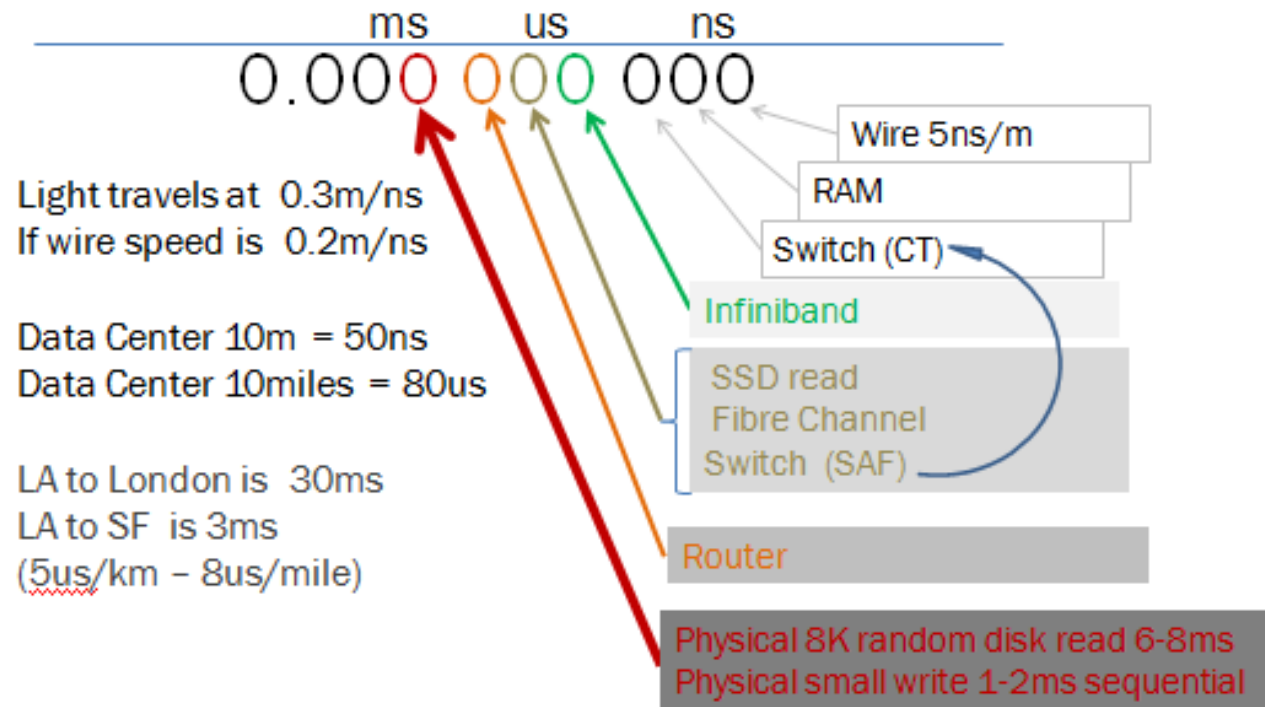
- Alignment – critical for clean video switching



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 - 1 μ s 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 / 1 μ s 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)

MEINBERG LANTIME M3000 timeserver

Reference Time Active Alarms: 0 Critical, 1 Error
Time Service
Network
Alarm

Logged in as: root
Access-Level: Super-User
Firmware-Build: 6.20.014

Main Network Notification Security NTP **PTP** System Statistics Clock NTP-Mon XtraStats Docs & Support Logout

LANTIME - PTP

- PTP V2 Status
- PTP V2 Configuration

Interface 01 (Slot: MRI1): Network **Global** SyncE Misc Outputs

Global:

Operating Mode PTP NTP

Select Profile Custom

PTP Mode Unicast Slave

Hybrid-Mode

Unicast Master Address 1 172.29.9.210

Unicast Master Address 2 0.0.0.0

← Additional master port IP Address

Delay Mechanism E2E

Domain Number 0

Network Protocol UDP/IPv4 (L3)

Timescale PTP Standard (TAI)

Priority1 128

Priority2 128

Announce Interval 1 announce message per second

Sync Interval 16 sync messages per second

HQ-Filter No

Delay Request Interval 16 request messages per second

← Selectable Message rates

Interval Duration [s] 60

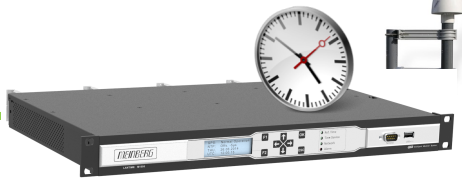
Announce Receipt Timeout 3

IP SHOWCASE THEATRE™

PTP ST2059-2



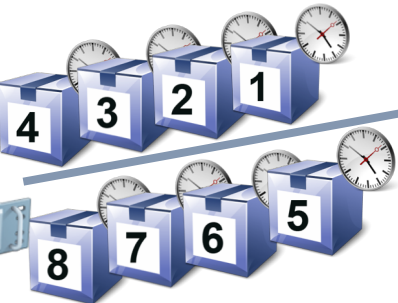
Audio-Transmitter



GNSS

PTP Grandmaster

PTP ST2059-2

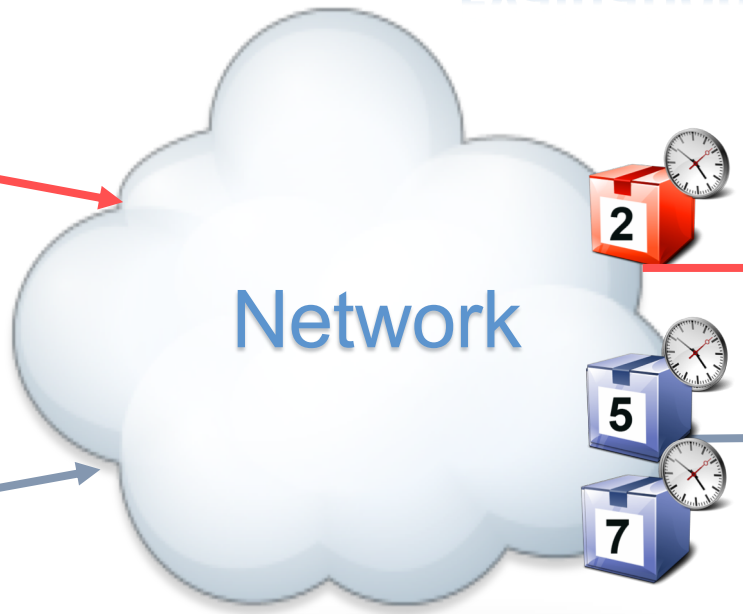


Video-Transmitter

RTP Timestamp Evaluation



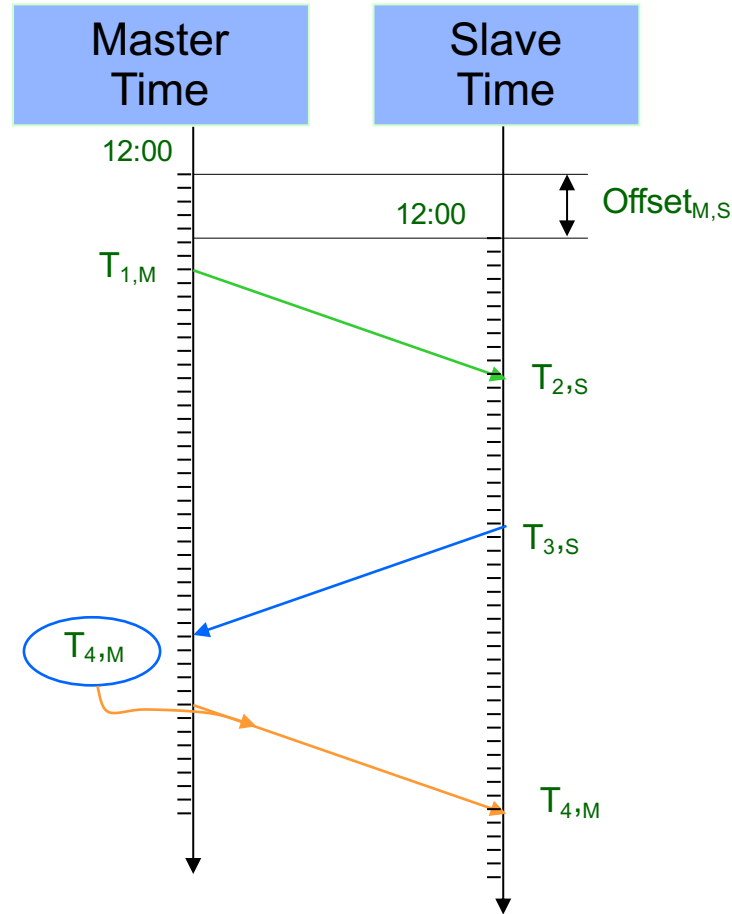
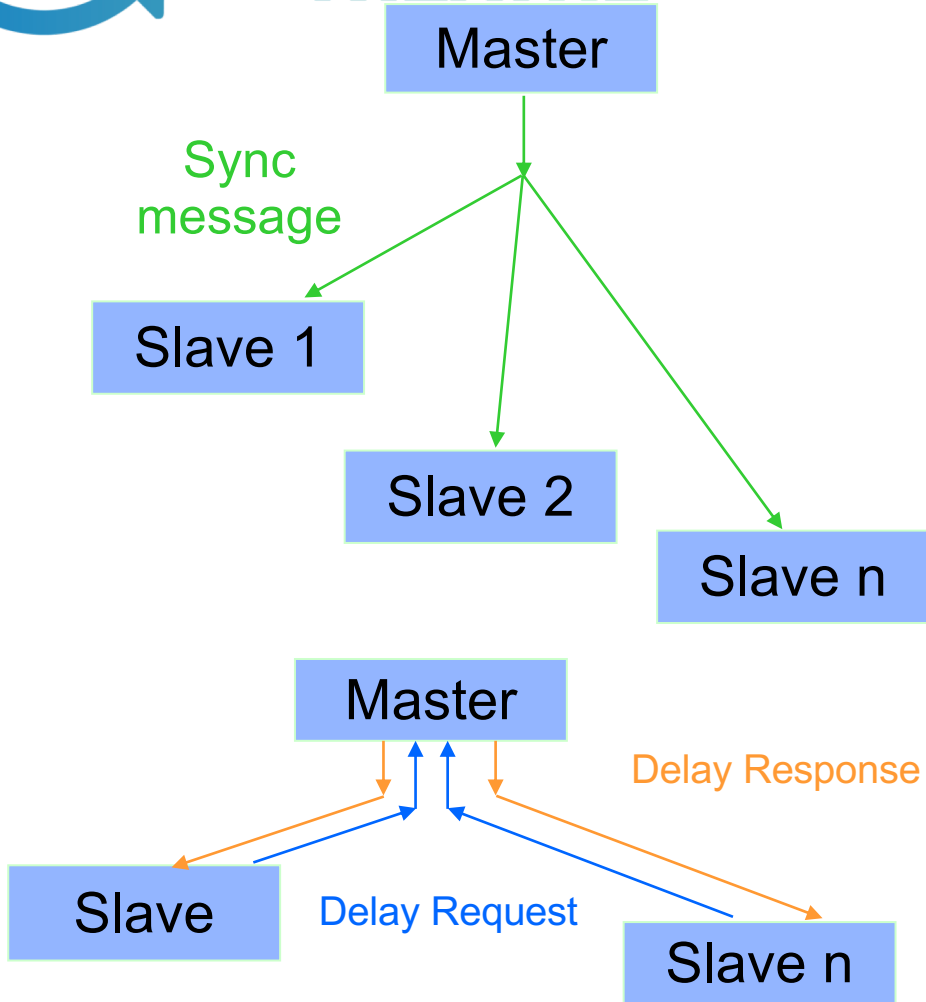
Receiver
AV - Receiver



PTP ST2059-2

SDI Stream





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

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

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

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

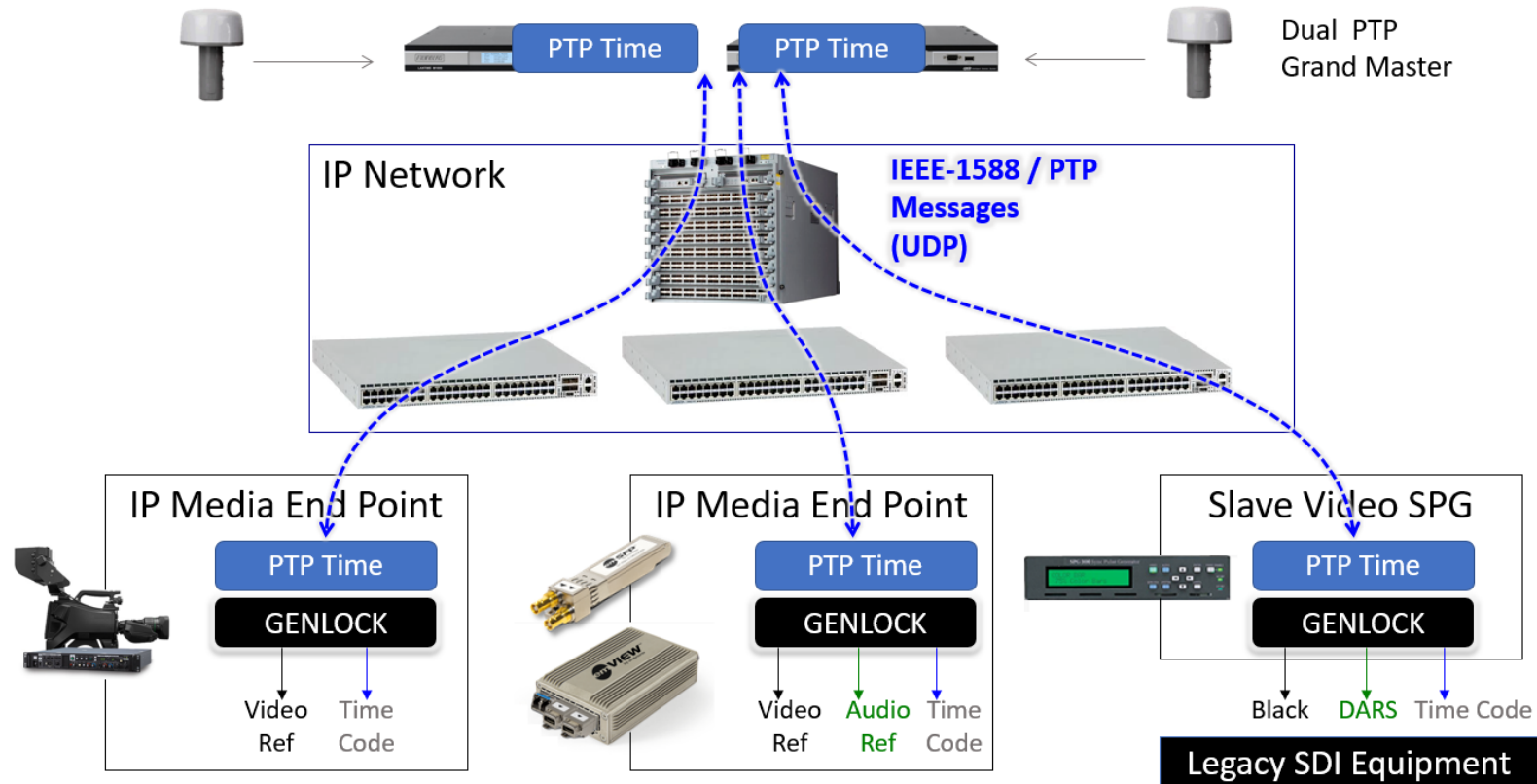
PTP BMCA - *Best Master Clock Algorithm*

- 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

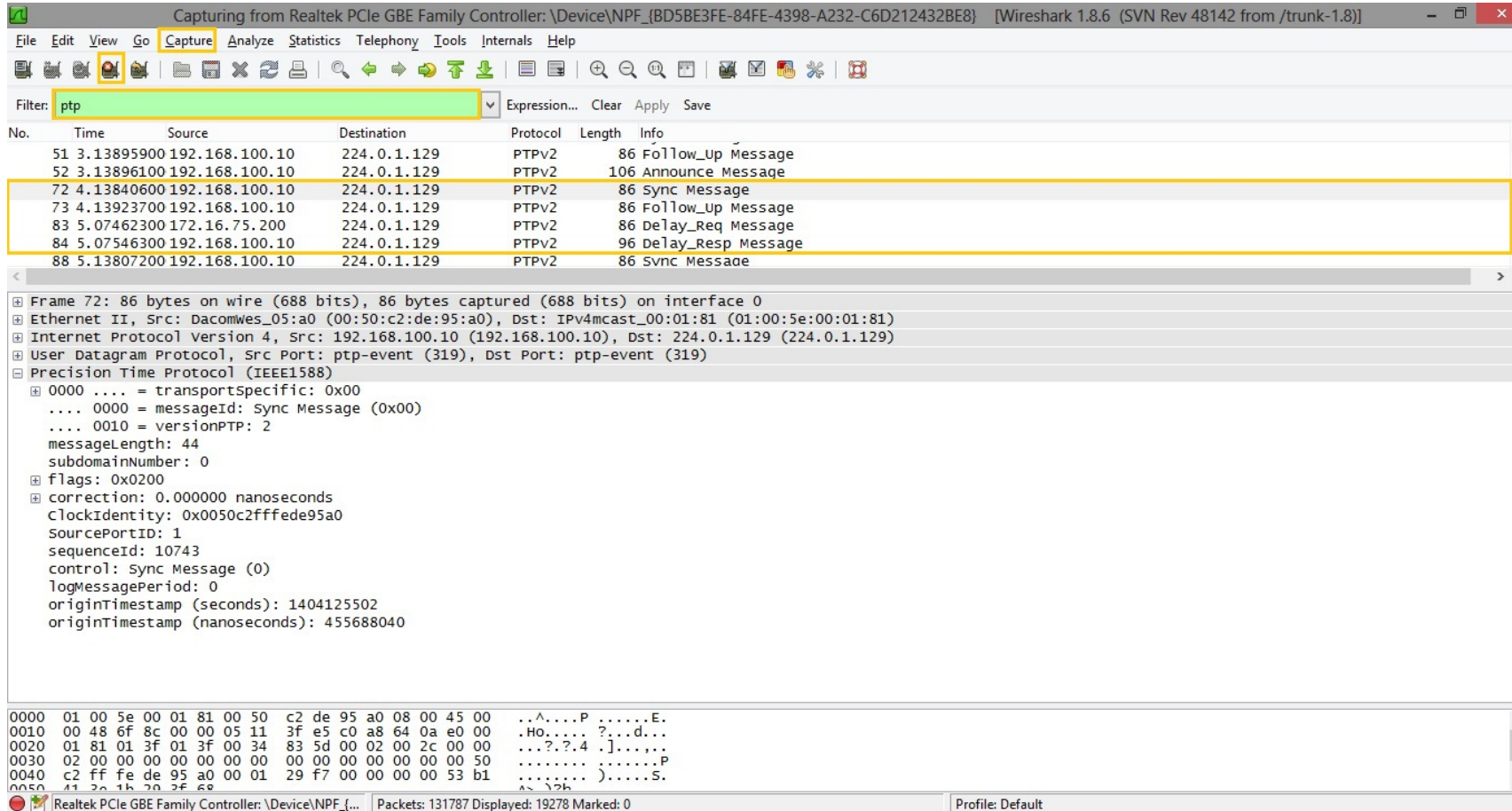
- Non-PTP aware hardware will degrade timing accuracy
- Transparent Clocks calculate time-stamps but aren't masters
- Boundary Clocks provide PTP to clients and can select between multiple Grand Master Clocks for redundancy
- BC can also protect the Grand Master(s) from overload and provide neat timing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

Integrating to a hybrid environment



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

PTP capture in Wireshark



Wireshark interface showing a capture of Precision Time Protocol (PTP) messages. The filter is set to 'ptp'. The packet list shows several messages, with packet 72 highlighted in yellow. The packet details pane shows the structure of the PTP Sync Message.

No.	Time	Source	Destination	Protocol	Length	Info
51	3.13895900	192.168.100.10	224.0.1.129	PTPv2	86	Follow_Up Message
52	3.13896100	192.168.100.10	224.0.1.129	PTPv2	106	Announce Message
72	4.13840600	192.168.100.10	224.0.1.129	PTPv2	86	Sync Message
73	4.13923700	192.168.100.10	224.0.1.129	PTPv2	86	Follow_Up Message
83	5.07462300	172.16.75.200	224.0.1.129	PTPv2	86	Delay_Req Message
84	5.07546300	192.168.100.10	224.0.1.129	PTPv2	96	Delay_Resp Message
88	5.13807200	192.168.100.10	224.0.1.129	PTPv2	86	Svnc Message

Frame 72: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0

- Ethernet II, Src: DacomWes_05:a0 (00:50:c2:de:95:a0), Dst: IPv4mcast_00:01:81 (01:00:5e:00:01:81)
- Internet Protocol Version 4, Src: 192.168.100.10 (192.168.100.10), Dst: 224.0.1.129 (224.0.1.129)
- User Datagram Protocol, Src Port: ptp-event (319), Dst Port: ptp-event (319)
- Precision Time Protocol (IEEE1588)
 - 0000 = transportSpecific: 0x00
 - ... 0000 = messageId: Sync Message (0x00)
 - ... 0010 = versionPTP: 2
 - messageLength: 44
 - subdomainNumber: 0
 - flags: 0x0200
 - correction: 0.000000 nanoseconds
 - ClockIdentity: 0x0050c2fffe95a0
 - SourcePortID: 1
 - sequenceId: 10743
 - control: Sync Message (0)
 - logMessagePeriod: 0
 - originTimestamp (seconds): 1404125502
 - originTimestamp (nanoseconds): 455688040

```

0000  01 00 5e 00 01 81 00 50 c2 de 95 a0 08 00 45 00  ..^...P.....E.
0010  00 48 6f 8c 00 00 05 11 3f e5 c0 a8 64 0a e0 00  .HO...?..d...
0020  01 81 01 3f 01 3f 00 34 83 5d 00 02 00 2c 00 00  ...?.?.4.].....
0030  02 00 00 00 00 00 00 00 00 00 00 00 00 00 50  .....P
0040  c2 ff fe de 95 a0 01 29 f7 00 00 00 00 53 b1  .....).S.
0050  41 20 1b 20 2f e8 8c 20b
    
```




MEINBERG PTP TRACK HOUND v1.0.0

Filters: Interface(s): All | Protocol(s): All | Domain(s): All | Message(s): All | Device(s): All | Control

25k (864 MB)

Messages

No.	Interface	Time	Msg. Type	Dom.	Seq. ID	Source	Destination
4445	eno1	2017-08-24, 10:01:47	PDelay R...	3	33948	172.27.100.124	224.0.0.107
4446	eno1	2017-08-24, 10:01:47	PDelay R...	3	33948	172.27.101.118	224.0.0.107
4447	eno1	2017-08-24, 10:01:47	PDelay R...	3	33948	172.27.101.118	224.0.0.107
4448	eno1	2017-08-24, 10:01:47	Delay Req.	82	19385	172.27.101.142	224.0.1.129
4449	eno1	2017-08-24, 10:01:47	Delay Resp.	82	19385	172.27.82.25	224.0.1.129
4450	eno1	2017-08-24, 10:01:47	Delay Req.	19	26335	172.27.19.63	224.0.1.129
4451	eno1	2017-08-24, 10:01:47	Delay Resp.	19	26335	172.27.19.91	224.0.1.129
4452	eno1	2017-08-24, 10:01:47	Sync	84	4478	172.27.84.153	224.0.1.129
4453	eno1	2017-08-24, 10:01:47	Follow Up	84	4478	172.27.84.153	224.0.1.129
4454	emp150	2017-08-24, 10:01:47	Sync	2	32603	EC:46:70:00:6...	01:80:C2:00:0...
4455	emp150	2017-08-24, 10:01:47	Follow Up	2	32603	EC:46:70:00:6...	01:80:C2:00:0...
4456	eno1	2017-08-24, 10:01:47	Sync	82	58822	172.27.82.25	224.0.1.129
4457	eno1	2017-08-24, 10:01:47	Follow Up	82	58822	172.27.82.25	224.0.1.129
4458	eno1	2017-08-24, 10:01:47	PDelay R...	3	17105	172.27.101.118	224.0.0.107
4459	eno1	2017-08-24, 10:01:47	PDelay R...	3	17105	172.27.100.124	224.0.0.107
4460	eno1	2017-08-24, 10:01:47	PDelay R...	3	17105	172.27.100.124	224.0.0.107
4461	eno1	2017-08-24, 10:01:47	Announce	1	19412	172.27.19.58	224.0.1.129
4462	emp150	2017-08-24, 10:01:47	Sync	2	32604	EC:46:70:00:6...	01:80:C2:00:0...
4463	emp150	2017-08-24, 10:01:47	Follow Up	2	32604	EC:46:70:00:6...	01:80:C2:00:0...
4464	eno1	2017-08-24, 10:01:47	Delay Req.	82	19265	172.27.101.148	224.0.1.129
4465	eno1	2017-08-24, 10:01:47	Delay Resp.	82	19265	172.27.82.25	224.0.1.129

Message Details

Sync
Length: 60 bytes
Protocol: IEEE 802.3
Domain: 2
Sequence ID: 32071
Receive Time: 10:00:48.846655

Ethernet II | PTP | Sync
Correction: 0.000 ns
Clock ID: 0xEC4670FFFE0069A9
Source Port ID: 1
Sequence ID: 32071
Control: Sync (0)
Log Message Period: -3

Devices

Type	Identity	Protocol	Dom.	ANN	SYN	FUP
GM	Meinberg_FFFE009F2E	IPv4	0	34	67	67
GM	Meinberg_FFFE0060C1	IPv4	1	67	133	133
GM	Meinberg_FFFE0069A9	IEEE 802.3	2	67	534	534
GM	Meinberg_FFFE02424E	IPv4	3	66	66	66
Unknown	Meinberg_FFFE0242D	IPv4	3	0	0	0
GM	Meinberg_FFFE00BF4	IPv4	11	67	67	67
GM (5)	Meinberg_FFFE008FC9	IPv4	19	67	67	67
GM	Meinberg_FFFE002435	IEEE 802.3	38	67	67	67
GM (4)	Meinberg_FFFE009CF3	IPv4	82	66	67	67
GM (2)	Meinberg_FFFE009081	IPv4	84	67	67	67
Monitor	Meinberg_FFFE009F28	IPv4	Any	0	0	0
Monitor	Meinberg_FFFE008FB5	IPv4	Any	0	0	0
Monitor	Meinberg_FFFE008FB6	IPv4	Any	0	0	0

Device Details (Grandmaster, Network: eno1, PTPv4, IPv4, Domain 1)

Port Identity: 0xEC4670FFFE0060C1:00001 | Port State: Master
Address: 172.27.19.58 | Delay Mech.: Unknown
Vendor: Meinberg | Ann. Rate: 1/s
Device: - | Sync Rate: 2/s
Management: - | Req. Rate: -
GM Clock Quality: P1 128, CC 6, CA 0x21 (Withn 100 ms), CV 13563, P2 128, SR 0

Events

No.	Time	Identity	Event
73	2017-08-24, 10:01:31.485	Meinberg_FFFE008FB6	State changed from Unknown to Active
72	2017-08-24, 10:01:30.470	Meinberg_FFFE008FB6	Type changed from Unknown to Monitor
71	2017-08-24, 10:01:30.470	Meinberg_FFFE008FB6	New device (Unknown, 172.27.19.93) detected
70	2017-08-24, 10:00:58.875	Meinberg_FFFE009F28	State changed from Unknown to Slave
69	2017-08-24, 10:00:54.935	Meinberg_FFFE006056	State changed from Unknown to Slave
68	2017-08-24, 10:00:54.935	Meinberg_FFFE009EFA	State changed from Unknown to Slave
67	2017-08-24, 10:00:48.748	Meinberg_FFFE006056	Type changed from Unknown to Slave
66	2017-08-24, 10:00:48.748	Meinberg_FFFE006056	New device (Unknown, 172.27.84.152) detected
65	2017-08-24, 10:00:47.895	Meinberg_FFFE009F28	Type changed from Unknown to Slave
64	2017-08-24, 10:00:47.297	Meinberg_FFFE006056	State changed from Unknown to Slave
63	2017-08-24, 10:00:46.402	Meinberg_FFFE009F28	New device (Unknown, 172.27.19.63) detected

Messages

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_FFFE00BF4
433	eno1	2017-08-07, 14:02:47	Follow Up	19	33896	172.27.19.99	224.0.1.129	Meinberg_FFFE00BF4
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_FFFE00BF4
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_FFFE00BF4
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

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/>





- 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



Thank You



OnAir Solutions & Meinberg

Paul.Dengate@onair.com.au

+61 2 8882 7766

