CELEBRATING 10 YEARS RAVENNA AES67 & ST 2110 built-in

RAVENNA 2020 Webinar Series

(The "Remote" Sessions)

Update on IEEE 1588-2019
&
PTP in WAN Applications

Tue, Nov 24, 2020
15:00 h (CET)

Presenter: Andreas Hildebrand, ALC NetworX
Daniel Boldt, Meinberg

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ALC NetworX

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*)

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Daniel Boldt, Head of Software Development, Meinberg

- Diploma in Media Technology (Thesis done at ZDF, German television)
- 20 years experience with the development of synchronization products
- Main Topics: IEEE 1588, NTP, LANTIME and microSync Firmware platforms

MEINBERG

The Synchronization Experts.

MEINBERG, Bad Pyrmont / Germany

- established 1979
- Full-Depth Manufacturer of Time and Frequency Synchronization Equipment (R&D, Production, Sales & Marketing at a single location)
- Time and Sync solutions for all industries (Broadcast, Power, Telecom, Finance, etc..)
- Acquired PTP technology supplier Oregano Systems (Vienna) in 2019
- Active in various standardization bodies (IEEE, ITU, SMPTE, IETF,…)

Andreas:

- What’s new in IEEE 1588-2019 (PTP v2.1)?
- ***Must-have or deal-breaker?***

Daniel:

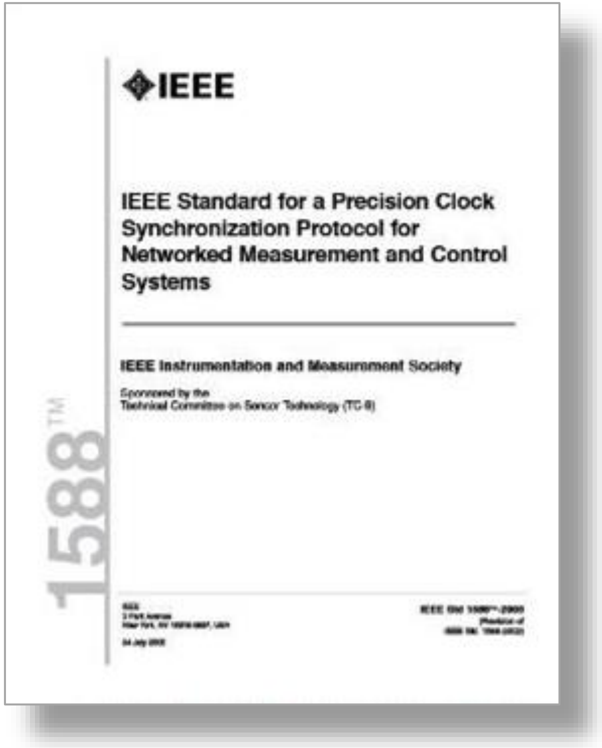
- Transporting PTP over WAN – the challenges
- Possible solutions
- Real-life PTP-over-WAN example

PTP – An IEEE Standard

- Precision Time Protocol ("PTP") - a standard (IEEE 1588) which describes a protocol for transferring time accurately through data networks

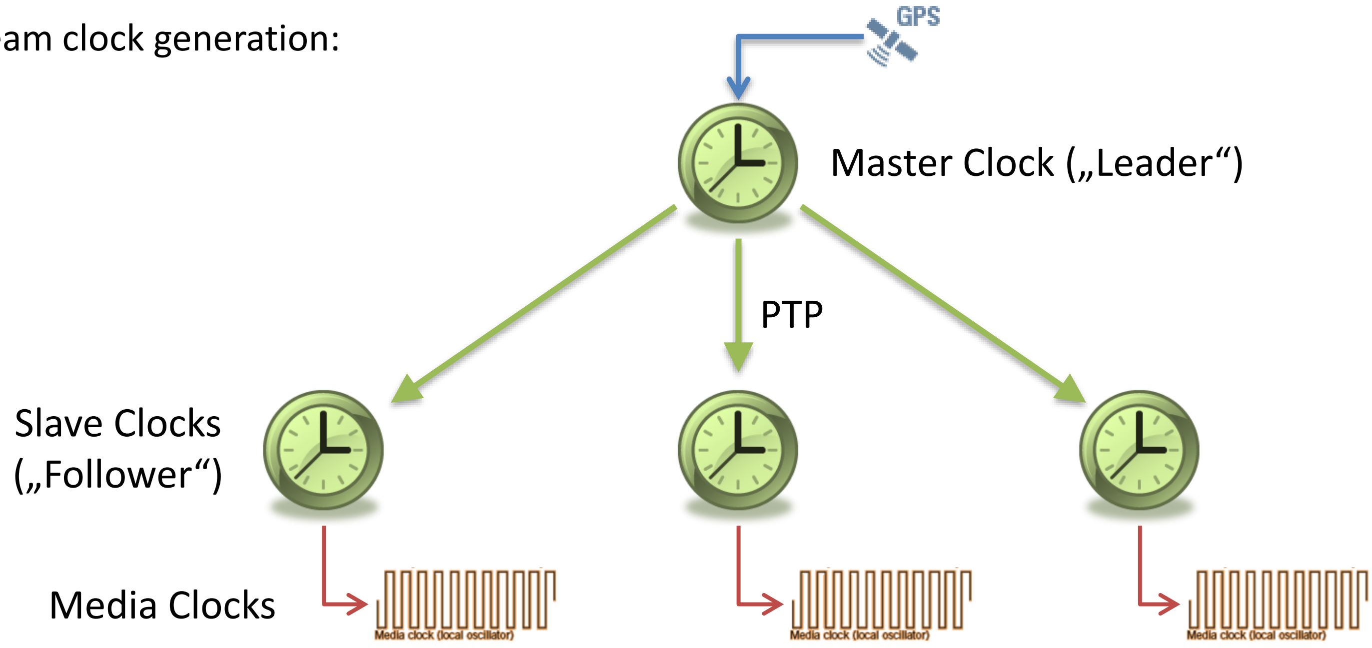
- Accurate (sub-µs) time and frequency transfer
- Highly generic standard
- Customizable via PTP profiles
- Already widely used in time-sensitive Ethernet-based applications
  - Telecom, Power, Finance, Test & Measurement, Industrial Automation, …

- First version: IEEE 1588-2002 (PTP v1)
- Most common version: IEEE 1588-2008 (PTP v2)
- Latest version: IEEE 1588-2019 (PTP v2.1) – published in 2020



PTP v2.0 – The basis for RAVENNA / AES67 & SMPTE ST 2110

- Media & stream clock generation:



AES67 PTP Media profile & SMPTE ST 2059-2 PTP profile

"**AES67 Media profile**" (Annex to AES67)

- Normative, but optional (PTP Default profile req'd)
- Reduced msg intervals for improved startup and accuracy
- Physical clock requirements (AES11)
- Add'l clock classes (to signal AES11 DARS grade)

Overview on message rates:*

Parameter	Default	Minimum	Maximum
Domain number	0	0	127
Announce interval	2 s	1 s	16 s
Sync interval	125 ms	$^{1}/_{16}$ s	2 s
Delay request interval	1	125 ms	32 x Sync interval

SMPTE ST 2059-2 - "**SMPTE PTP Profile**"

- Normative, mandatory for SMPTE ST 2110
- Further reduced msg intervals for improved startup and accuracy
- Specific PTP rules and clock constraints required by SMPTE application
- SMPTE-specific TLV metadata

Parameter	Default	Minimum	Maximum
Domain number	127	0	127
Announce interval	250 ms (1 s)*	125 ms	2 s
Sync interval	125 ms	$^{1}/_{128}$ s	500 ms
Delay request interval	Sync interval	Sync interval	32 x Sync interval

* **AES-R16-2016** summarizes differences & commonalities between ST 2059 / AES67 & PTP Default profiles

PTP Compatibility

Year	Version number	Backward compatible
2002	1	N/A
2008	2	No
2019	2.1	

PTP v2.1 – will it break RAVENNA / AES67 & SMPTE ST 2110 / ST 2059?

PTP Compatibility

Year	Version number	Backward compatible
2002	1	N/A
2008	2	No
2019	2.1	Yes, with v2

"DON'T PANIC!"

From the Bylaws of the IEEE 1588 Working Group:

"The working group shall ensure that the resulting draft has the highest degree of backward compatibility possible with the previous edition of IEEE 1588…"

Backward compatibility means:

- PTP v2.1 devices* work in PTP v2.0 networks and won't compromise it (**Leaders* as well as *Followers*)
- PTP v2.1 features are optional
- PTP v2.0 features work as before

PTP v2.1 – what's new?

- Enhancements and changes to
  - make the standard clearer
  - add flexibility to the protocol
  - add robustness to the protocol
  - increase accuracy
- Some of these features were taken from existing PTP profiles

PTP v2.1 – adding flexibility

- Mixed multicast / unicast operation
  - Announce and Sync messages are multicast, DelayRequest and DelayResponse are unicast
  - Better scalability in larger systems with E2E synchronization
  - New TLV in Announce to inform about Master clock unicast address (for DelayRequests)
  - New multicast message to inform about Slave clock unicast address (for DelayResponse)
- Modular Transparent Clocks
  - TCs can now be built in a blade server or SFP architecture
  - “Stepness” now a port property (instead a clock property)
  - Addresses potential issues with mixed 1 / 2 step operation
- Special PTP ports
  - interfacing to network technologies which have their own built-in timing mechanism, e.g. EPON or WiFi

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PTP v2.1 – adding robustness

- Profile isolation
  - Running multiple (incompatible) profiles on the same network
  - Could be solved in PTP v2.0 by assigning different domain numbers (but tedious and error-prone)
  - PTP v2.1 introduces profiled ID assigned to SDOs (SdoID)
  - Fully backward-compatible by using previously reserved fields in PTP message header

Bits								Octets	Offset
7	6	5	4	3	2	1	0		
transportSpecific				messageType				1	0
reserved				versionPTP				1	1
messageLength								2	2
domainNumber								1	4
reserved								1	5
flagField								2	6
correctionField								8	8
reserved								4	16
sourcePortIdentity								10	20
sequenceId								2	30
controlField								1	32
logMessageInterval								1	33

Common Message Header PTP v2.0

Bits								Octets	Offset
7	6	5	4	3	2	1	0		
majorSdoId				messageType				1	0
minorVersionPTP				versionPTP				1	1
messageLength								2	2
domainNumber								1	4
minorSdoId								1	5
flagField								2	6
correctionField								8	8
messageTypeSpecific								4	16
sourcePortIdentity								10	20
sequenceId								2	30
controlField								1	32
logMessageInterval								1	33

Common Message Header PTP v2.1

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PTP v2.1 – adding robustness

- Profile isolation
  - Running multiple (incompatible) profiles on the same network
- Inter-domain interactions
  - Running multiple domains on the same network to increase robustness (requires multi domain OC)

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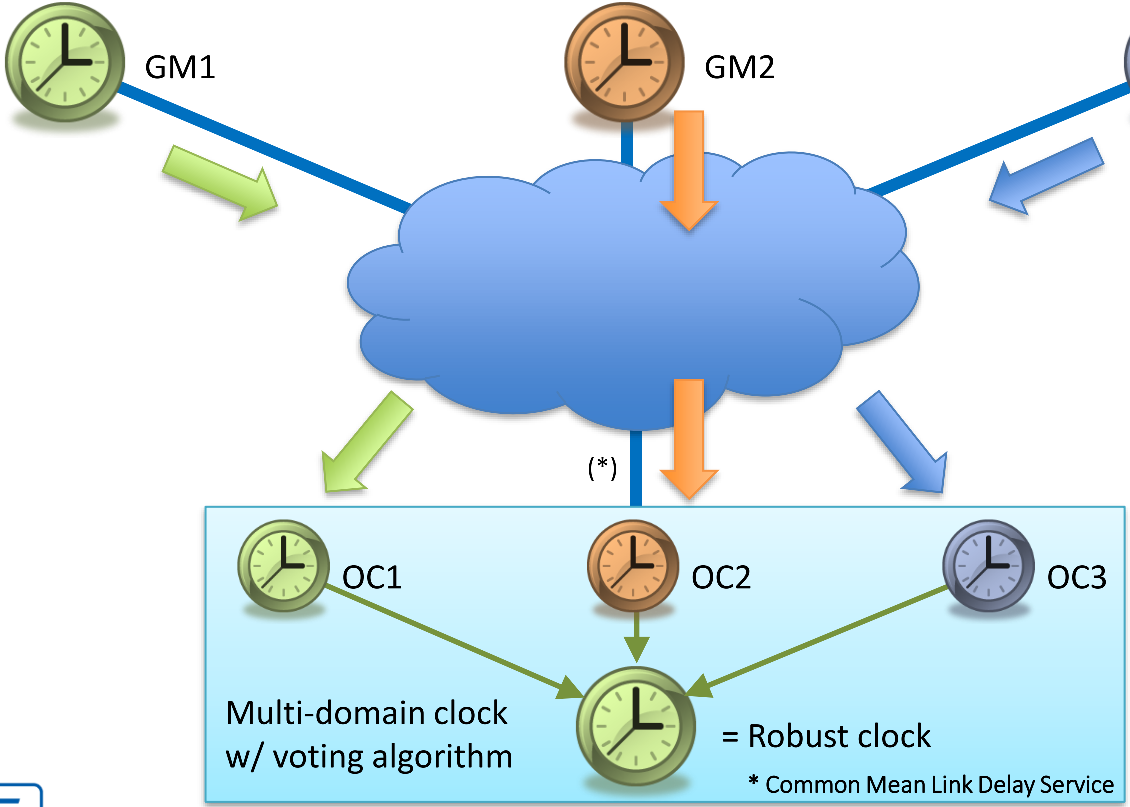
PTP v2.1 – inter-domain interaction



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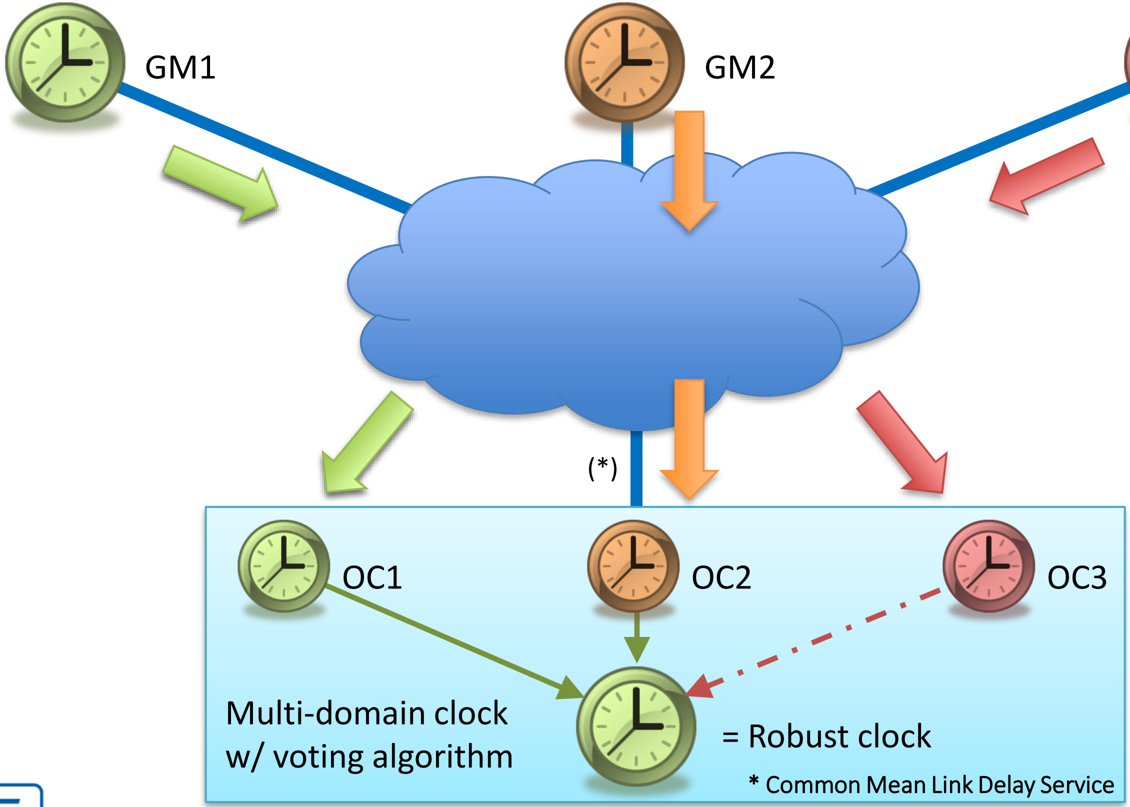
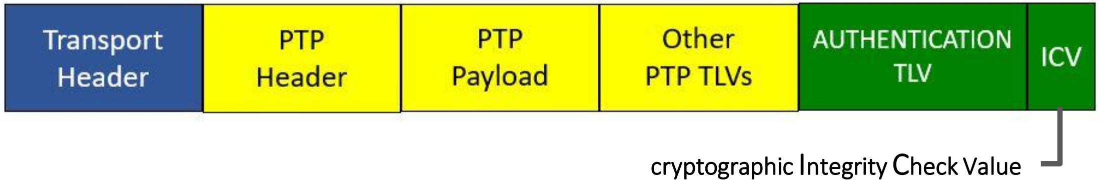
PTP v2.1 – inter-domain interaction



PTP v2.1 – adding robustness

- Profile isolation
  - Running multiple (incompatible) profiles on the same network
- Inter-domain interactions
  - Running multiple domains on the same network to increase robustness (requires multi domain OC)
- Security
  - Addition of security guidelines
  - Definition of an AUTHENTIFICATION TLV for messages, adding source integrity checking



PTP v2.1 – adding robustness

- Profile isolation
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- Security
  - Addition of security guidelines
  - Definition of an AUTHENTIFICATION TLV for messages, adding source integrity checking
- Standard performance metrics
  - Definition of a standard format for performance statistics
    - average / min / max / standard dev values of
    - offset from master + various delay metrics
    - message reception counters
    - for 15 minute intervals within 24 h

PTP v2.1 – adding robustness

- Profile isolation
  - Running multiple (incompatible) profiles on the same network
- Inter-domain interactions
  - Running multiple domains on the same network to increase robustness (requires multi domain OC)
- Security
  - Addition of security guidelines
  - Definition of an AUTHENTIFICATION TLV for messages, adding source integrity checking
- Standard performance metrics
  - Definition of a standard format for performance statistics
- Slave port monitoring
  - Definition of TLVs to support active slave port monitoring
    - Slave RX Sync Timing Data TLV
    - Slave RX Sync Computed Data TLV
    - Slave TX Event Timestamps TLV

PTP v2.1 – increasing accuracy

- Originating from the “White Rabbit” project (CERN)
- Targeting at achieving sub-nanoseconds accuracy
- Optional extensions to the “core” IEEE 1588 Std
  - Manual Port Configuration
    - Static configuration of port states (master / slave / disabled), bypassing BMCA
    - Quick start of network timing system, no dynamic changes of link delays
    - No automatic reconfiguration in case of any failure (i.e. no GM backup)
  - Physical layer (L1) syntonization
    - Syntonization between PTP clock layer and network L1 clock layer (i.e. SyncE) by referencing PTP clock to L1 clock
  - Configurable timestamp correction + asymmetry calibration
    - Ability to configure ingress + egress latencies
    - Including calibration of PHY asymmetry for different media (i.e. bidirectional fiber)
  - High Accuracy Default PTP Profile
    - Defining all necessary operating parameters and requirements to achieve sub-nanoseconds accuracy

PTP v2.1 – Summary of new features

- **More flexibility**
  - Mixed multicast/unicast
  - Modular TCs (e.g. Special SFPs)
  - Special ports (Timing transfer)

- **Improved robustness**
  - Profile Isolation
  - Interdomain interactions
  - Security TLV
  - Standard metrics
  - Slave port monitoring

- **Increased Accuracy**
  - Manual port configuration
  - Layer-1 syntonization
  - Calibration
  - HA profile

Backwards compatibility to V2 remains!
A PTPv2 Slave will sync to a v2.1 master!

PTP v2.1 – a "must-have" for RAVENNA / AES67 & SMPTE ST 2110?

- All standards / profiles (and their upcoming revisions) are still referring to IEEE 1588-2008
- None of these are "broken" by continuing to reference to PTP v2.0.
- Current and future systems can rely on accurate and reliable operation as provided by PTP v2.0.

- Most useful features of PTP v2.1:
  - Mixed Multicast/Unicast operation – for large network environments
  - Modular Transparent clocks – for setting up cloud environments with tight synchronization
  - Profile isolation – for running different PTP profiles (i.e. ST 2059 and AES67)
  - Inter-domain interactions – for building networks with higher reliability and robustness
  - Security – protecting networks from malicious message insertion
  - Slave port monitoring (together w/ standard performance metrics) – more reliable operation status
  - Special PTP ports – might be useful in certain WAN applications

How to evolve towards PTP v2.1

- The “engineering” way (system planning)
  - PTP v2.1 devices can be added safely to the network without breaking operation
  - New features or improvements can added / enabled as needed / supported
- The “standards” way (by AES67 / ST 2110 & ST 2059 DGs):
  - Careful evaluation of useful features
  - Introduction of selected features into upcoming revisions
  - Trying to preserve backwards compatibility wherever possible

Summary

- PTP v2.1 introduces new (optional) features on
  - flexibility
  - robustness
  - accuracy

  which may partly be beneficial for media system environments.

- All enhancements of PTP v2.1 are fully backwards-compatible with PTP v2.0.

- RAVENNA / AES67 & SMPTE ST 2110 are not broken by continuing to reference PTP v2.0; current and future systems can rely on accurate and reliable operation as provided by PTP v2.0.

IEEE Std 1588-2019 (PTP v2.1) is neither a must-have nor a deal-breaker.

PTP in WAN Applications

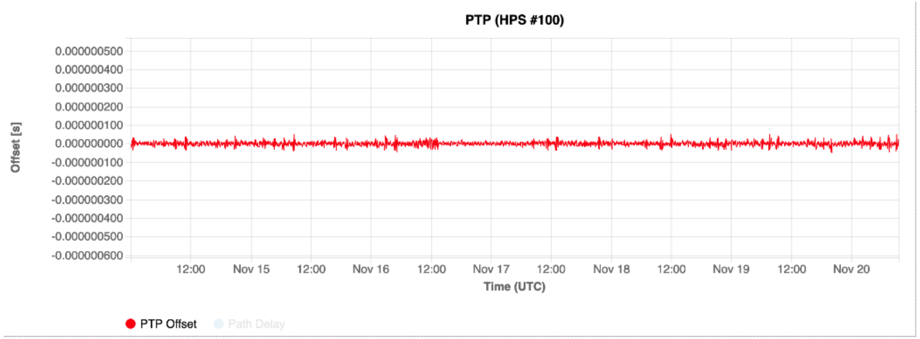
Daniel Boldt

The Synchronization Experts.

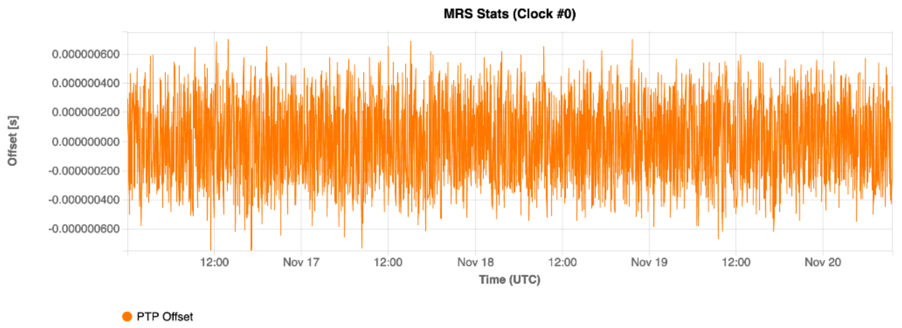
Challenges when transporting PTP over WAN connections:

1) Unpredictable „Packet Delay Variation - PDV“
-> „Packet Jitter“ that affects Slave accuracy and stability („Dynamic Time error“ - dTE)

low PDV („ptp-aware“ connection):



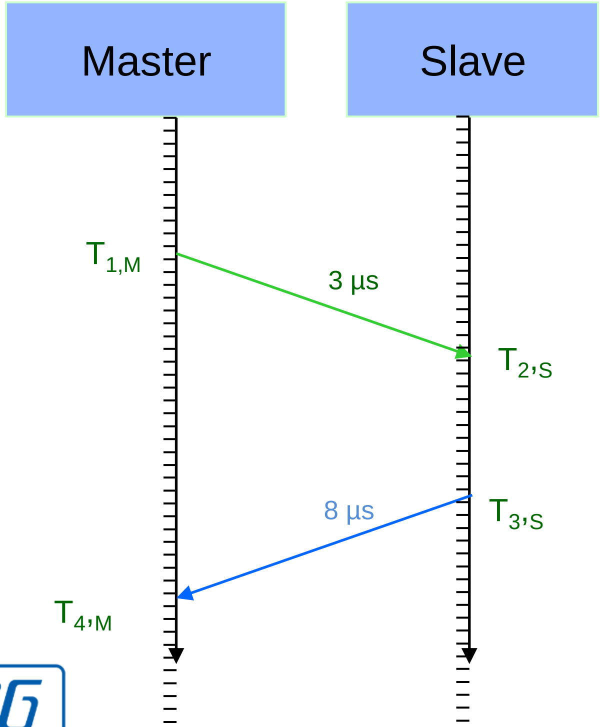
high PDV („non-ptp-aware“ connection)



Reason for packet delay variation:

- Queueing delays in non ptp-aware network equipment
- Amount of delay depends on switch performance and traffic load
- PTP packet needs to „wait“ before leaving the switch in case a larger packet is sent out just before

2) Asymmetry between Receive and Transmit path



M2S delay = 3 µs
S2M delay = 8 µs

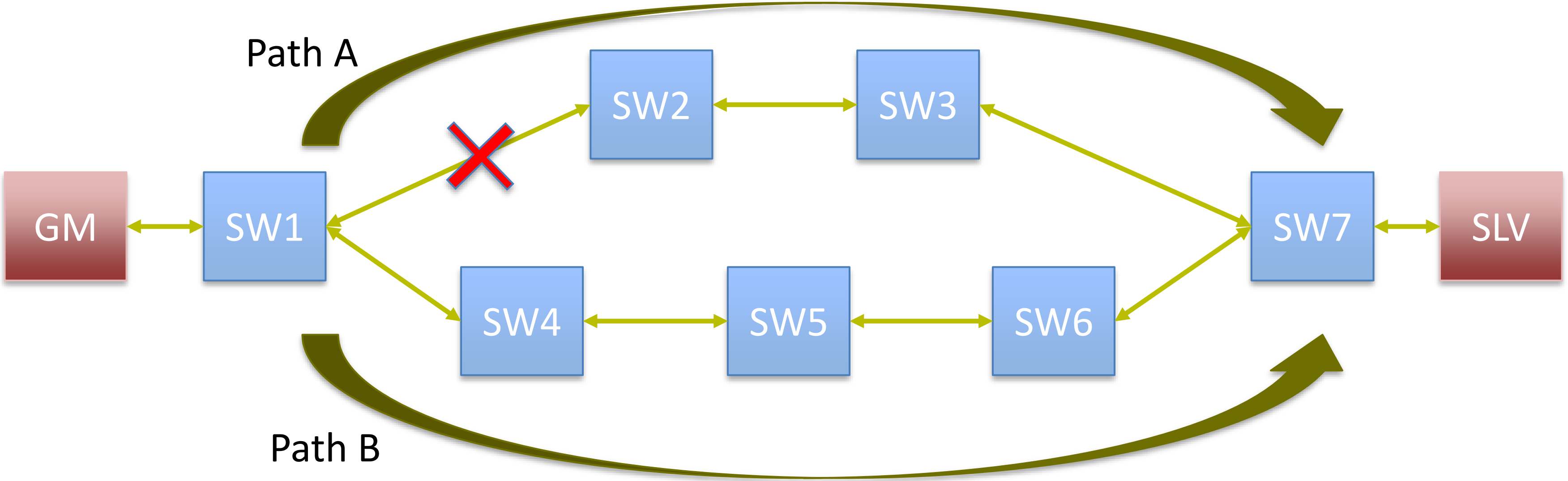
One example:
Link Speed conversion 1GB -> 100 Mbit
„Store-and-forward“ vs. „Cut-through“

Round Trip Delay = 11 µs
calculated One-Way Delay = 5.5 µs

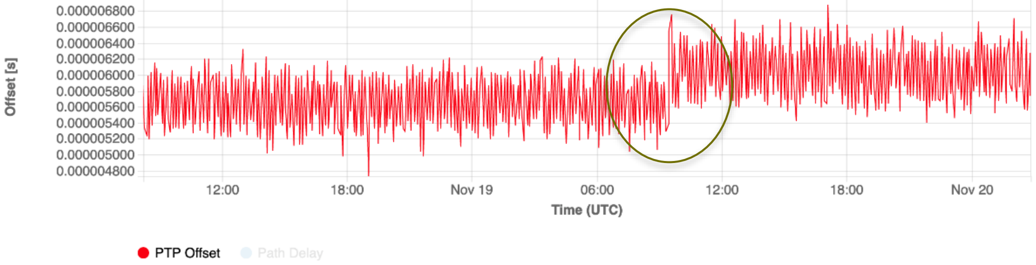
Real Delay: 3 µs

Results in Constant Time Error (cTE) of 2.5 µs time offset in end node

3) Network Path Re-Arrangements



Different path asymmetries lead to time offset steps

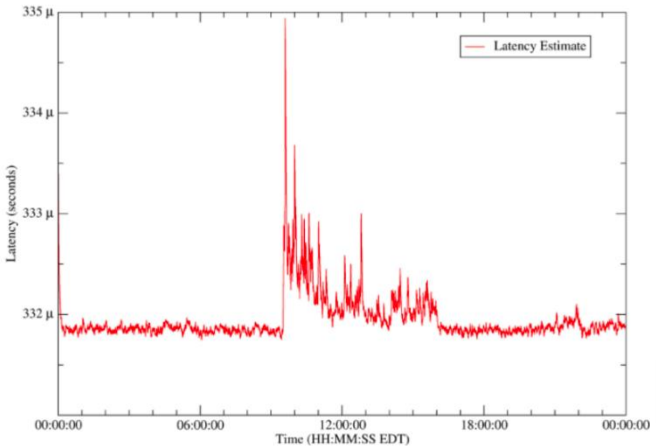


Solutions for the Infrastructure (if possible):

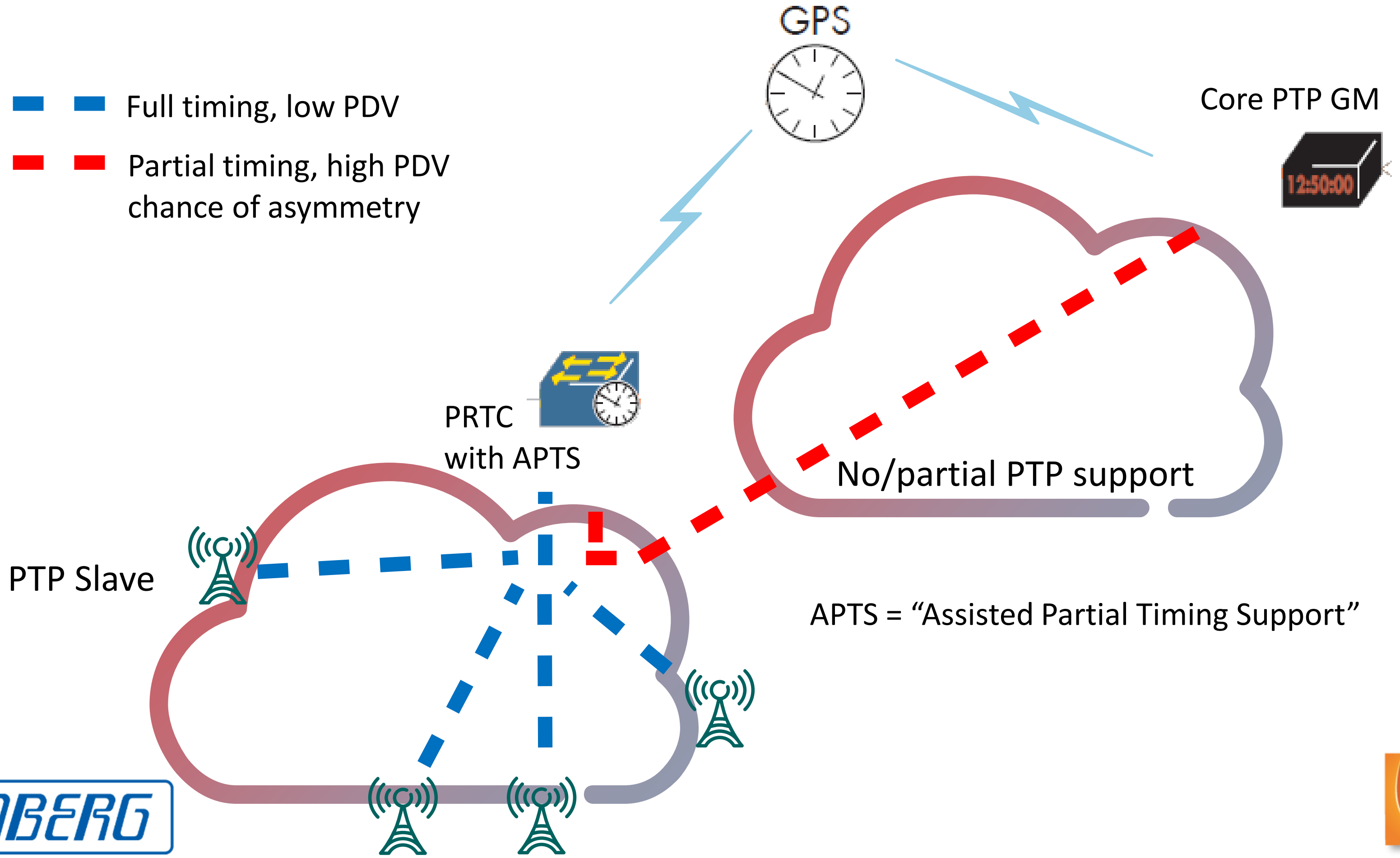
- PTP-enabled Switches/Routers (BCs or TCs)
- Dedicated Wavelength in DWDM systems
- Dark Fibre connection (often not possible or expensive)

Solutions for PTP Slave Systems:

- High-Quality oscillator to allow long-term PTP statistics and analysis while maintaining stability
- Advanced adaptive PTP filter mechanisms
- Asymmetry Step detection (for path re-arrangements)
- Automatic link asymmetry calibration with reference
- Gateway clock („Edge Grandmaster“) provides „clean“ PTP Master signal to local PTP clients at remote site



PTP in WAN Applications

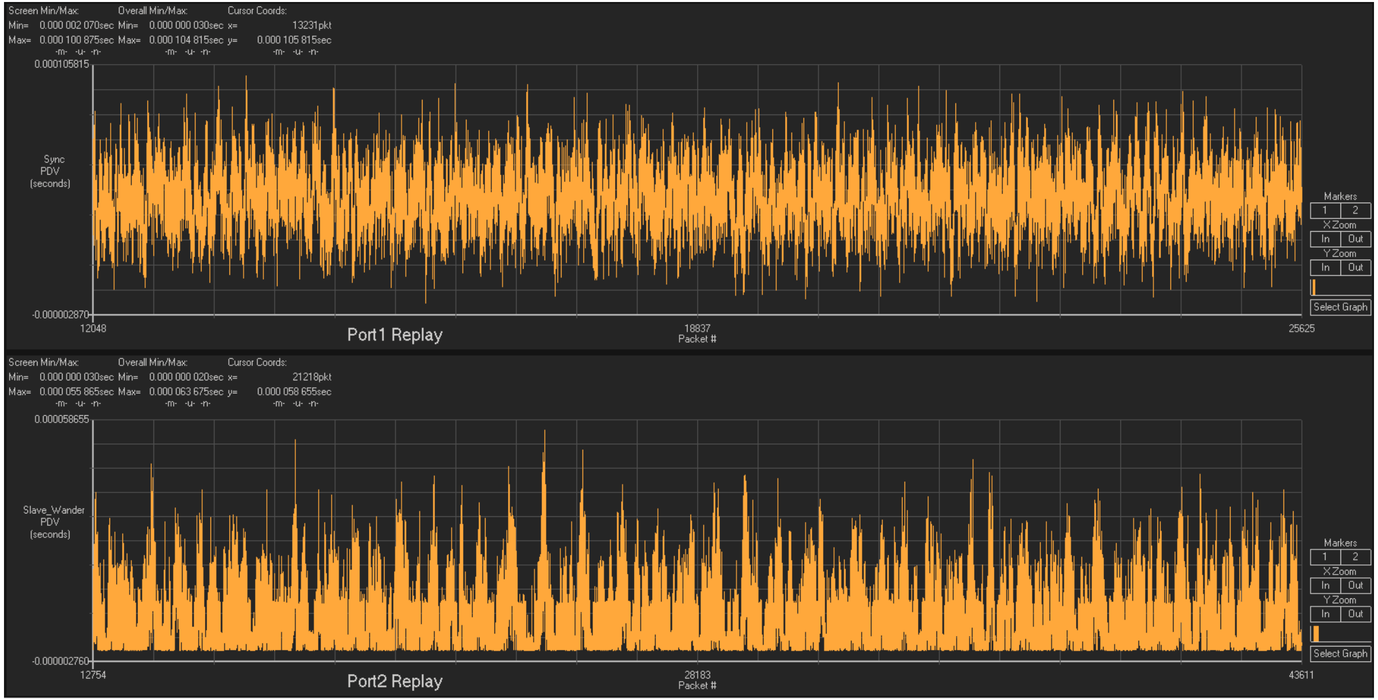


Mitigating
Packet delay variation:

Master → Slave
approx. 100 µs jitter

Slave → Master:
approx. 60 µs jitter

Resulting Asymmetry:
approx. 8 µs



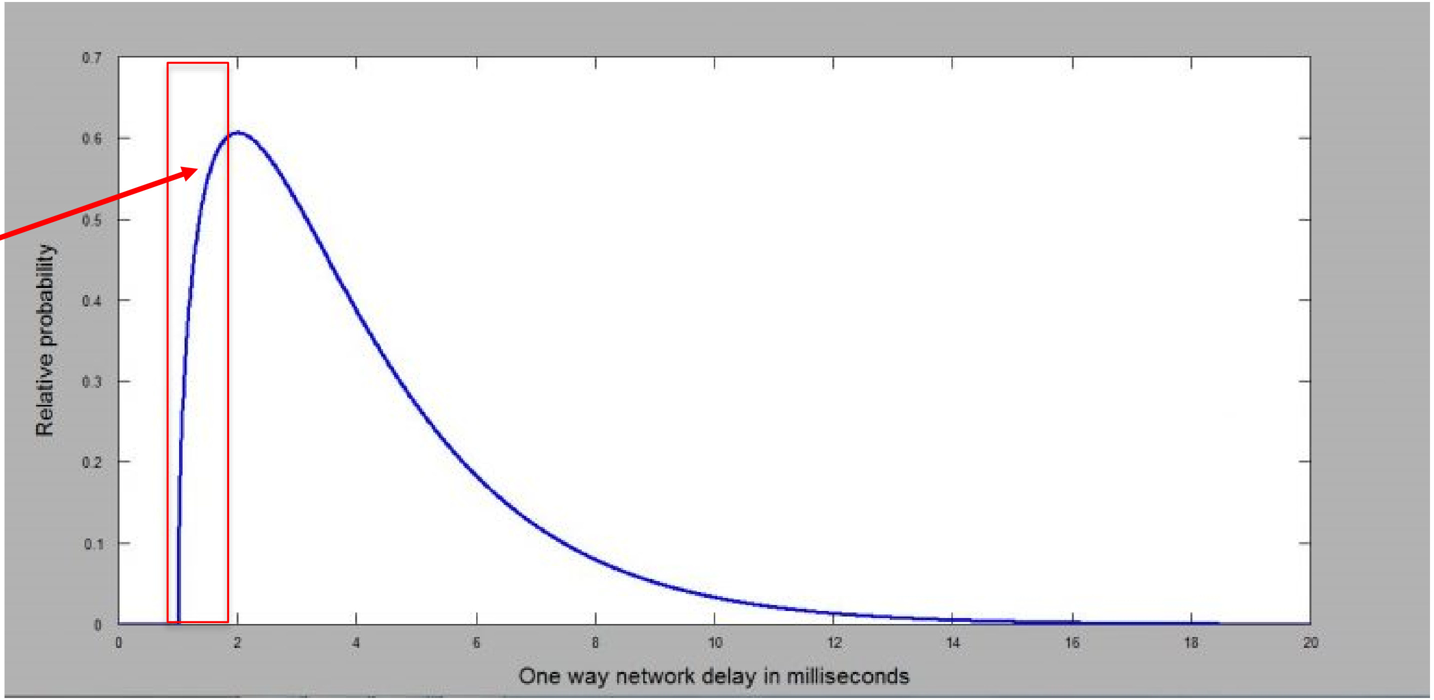
Calnex Paragon-X used as Impairment generator

One-Way Delays measured over the network (M2S and S2M)

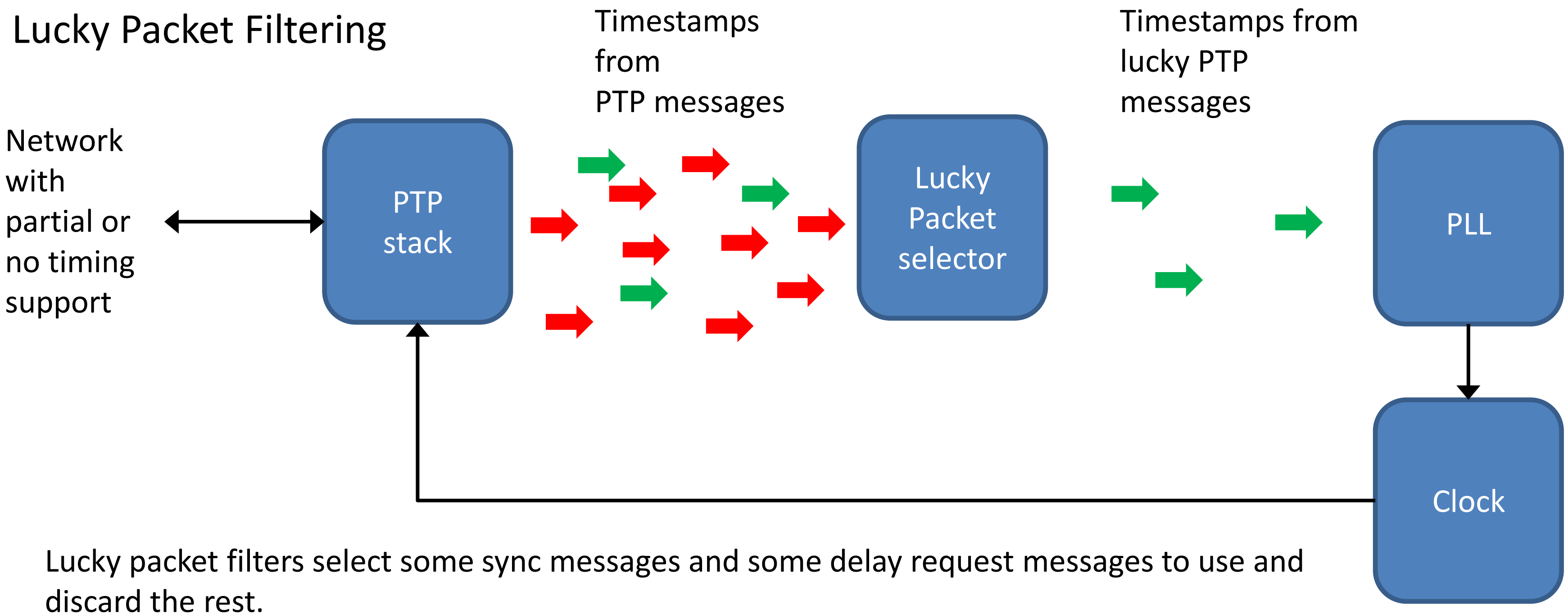
Select the „Lucky Packets“
→ fastest packets with the lowest delays

Lucky Packet Filter will reduce Packet Delay Variation dramatically

→ Better Slave Stability



Lucky Packet Filtering



- Lucky packet filters select some sync messages and some delay request messages to use and discard the rest.
    - Sync messages with the lowest Master-to-Slave time (t2-t1)
    - Delay request messages with lowest Slave-to-Master time difference (t4-t3)
    - These messages assumed to have little or no queuing delay

3-day Test with impairments:

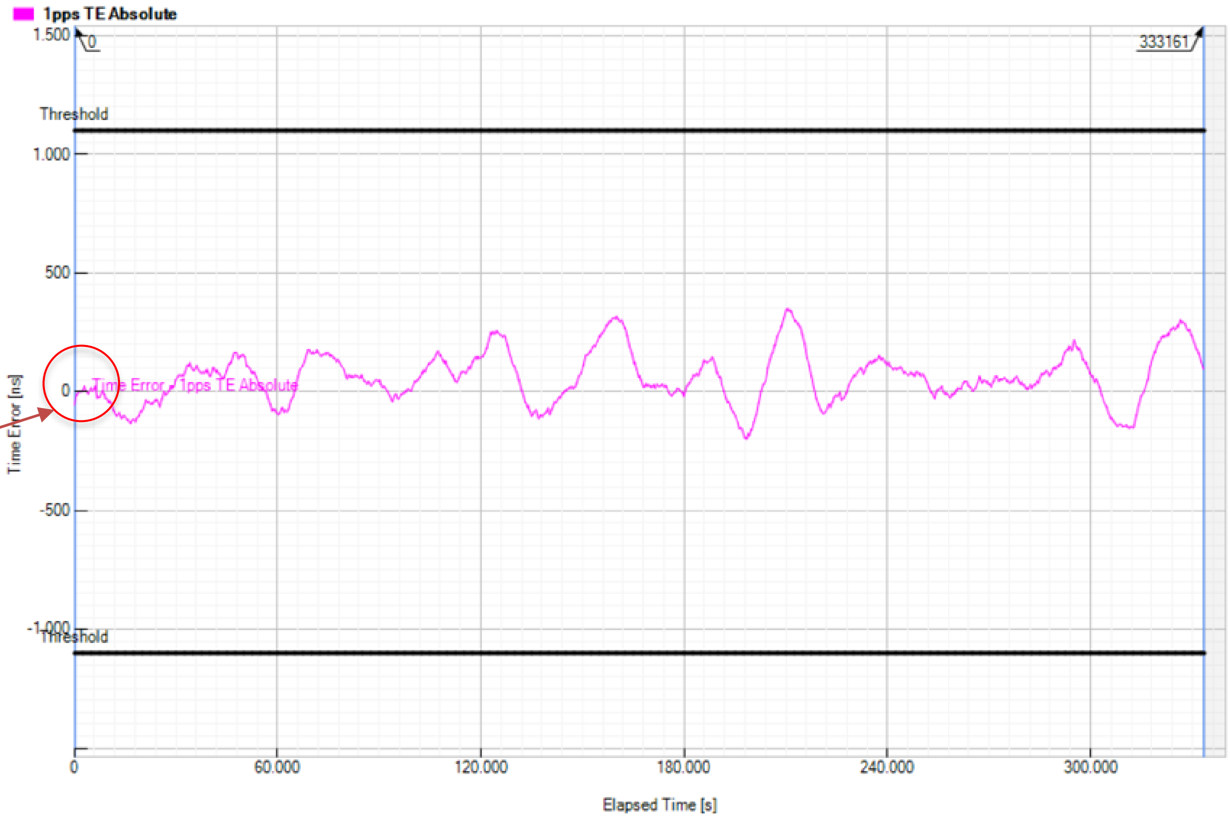
Master → Slave
100 µs jitter
Slave → Master:
60 µs jitter

64 PTP packets/s

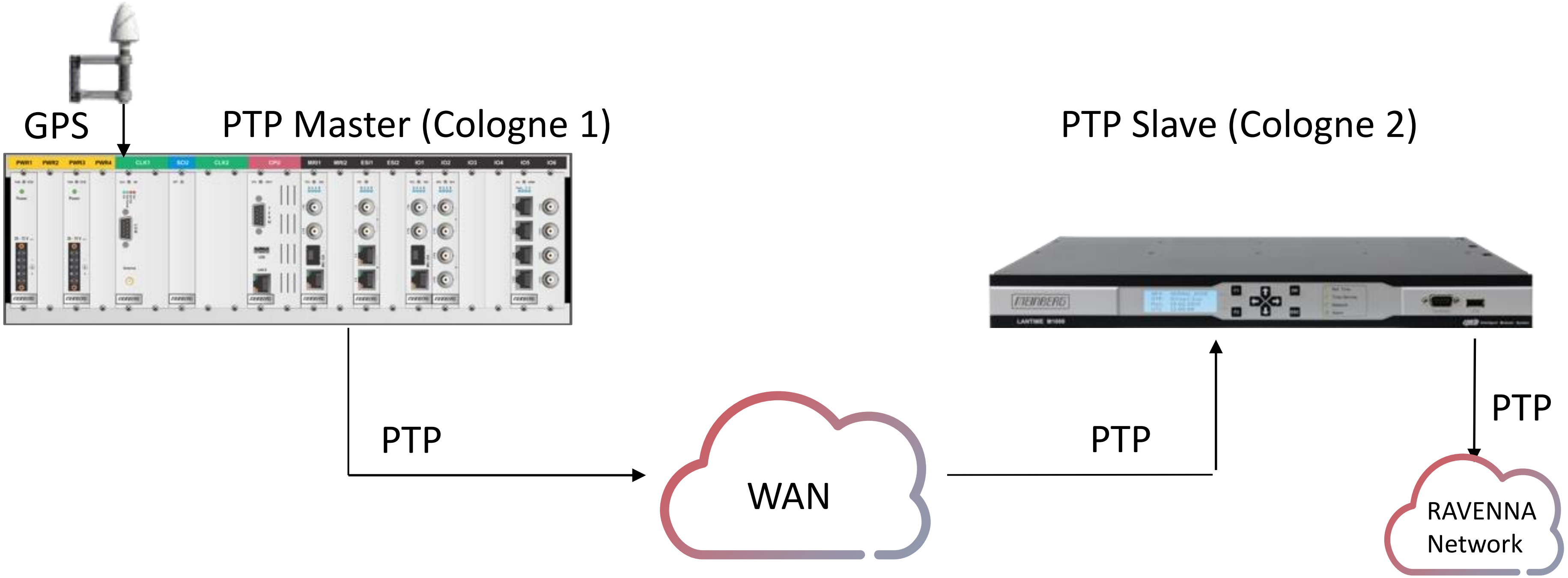
GPS assistance at startup for asymmetry calibration

Lucky Packet Pre-Filter reduced offset variation to **+-5µs**

HQ Clock filter reduced jitter again down to **+-300ns**



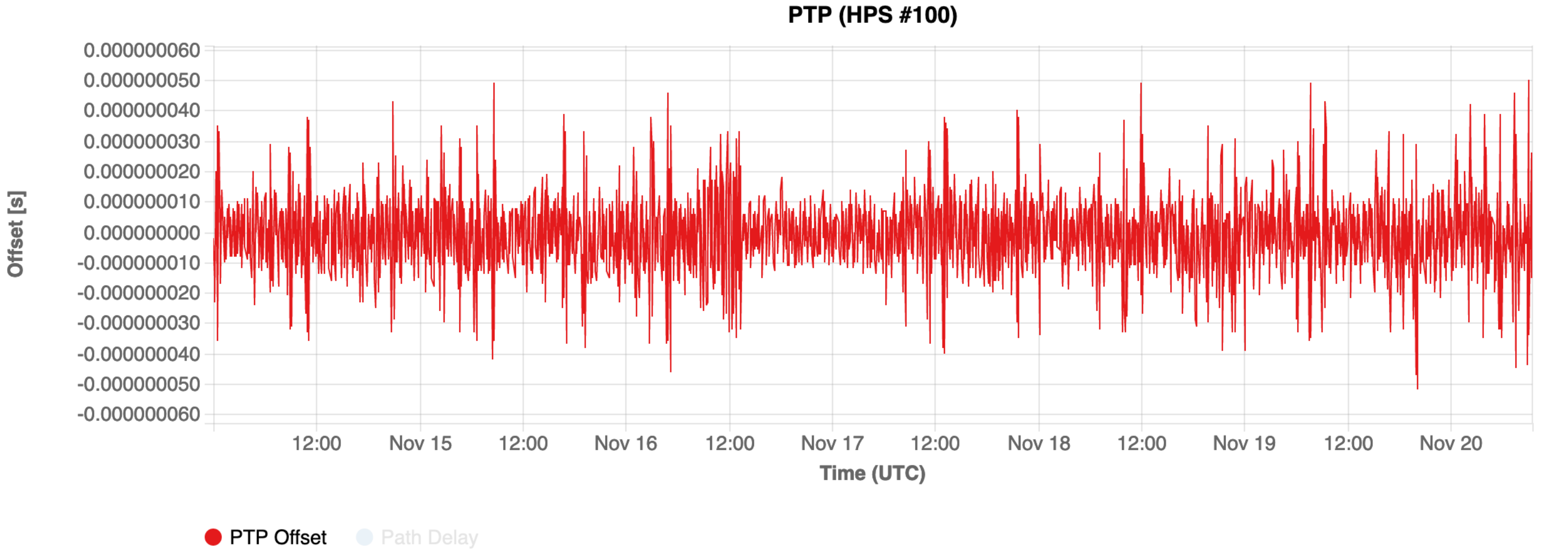
Real Life Example WDR – Remote Studio synchronization: two sites in Cologne



PTP Default Profile with 16pkt/s
PTP-aware switches and dark fibre
link (10 km distance)

Real Life Example WDR – Remote Studio synchronization two sites in Cologne

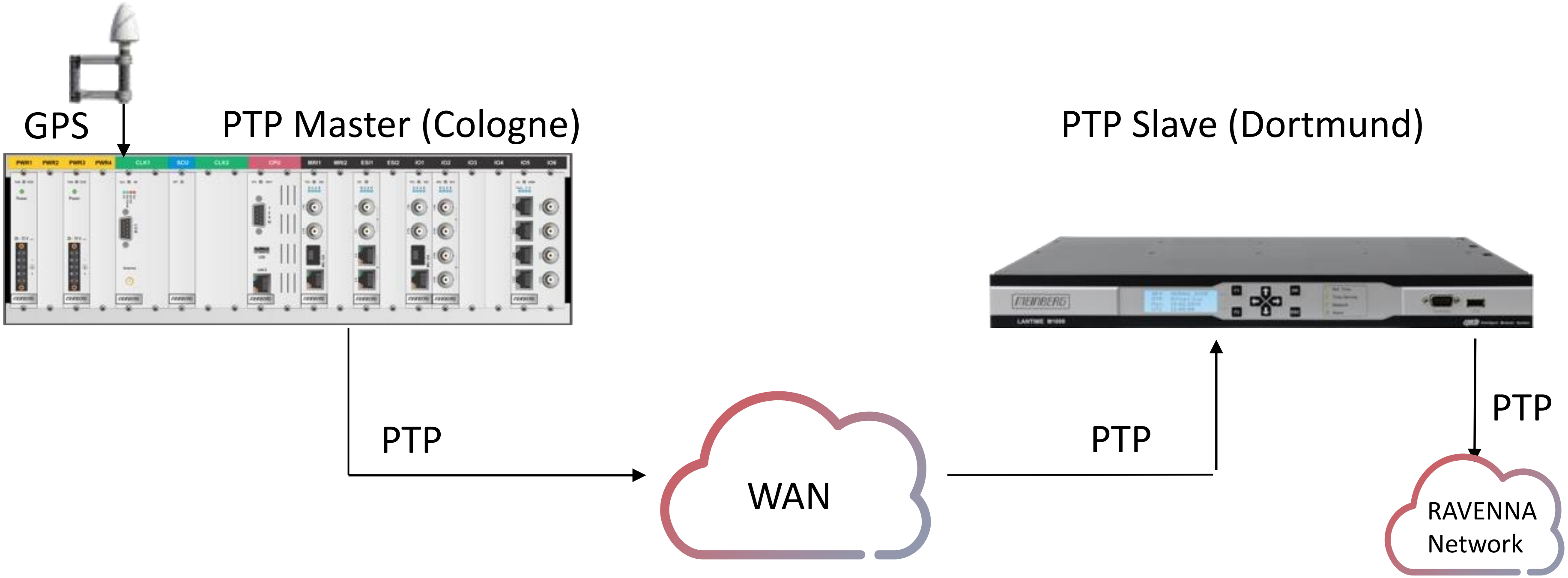
PTP input after
Lucky packet
Filter
(<+-50ns)



GNSS grade synchronization via high quality long-range fibre connection

PTP in WAN Applications

Real Life Example WDR – Remote Studio synchronization Cologne - Dortmund



PTP Default Profile with 16pkt/s
MPLS PTP-unaware network

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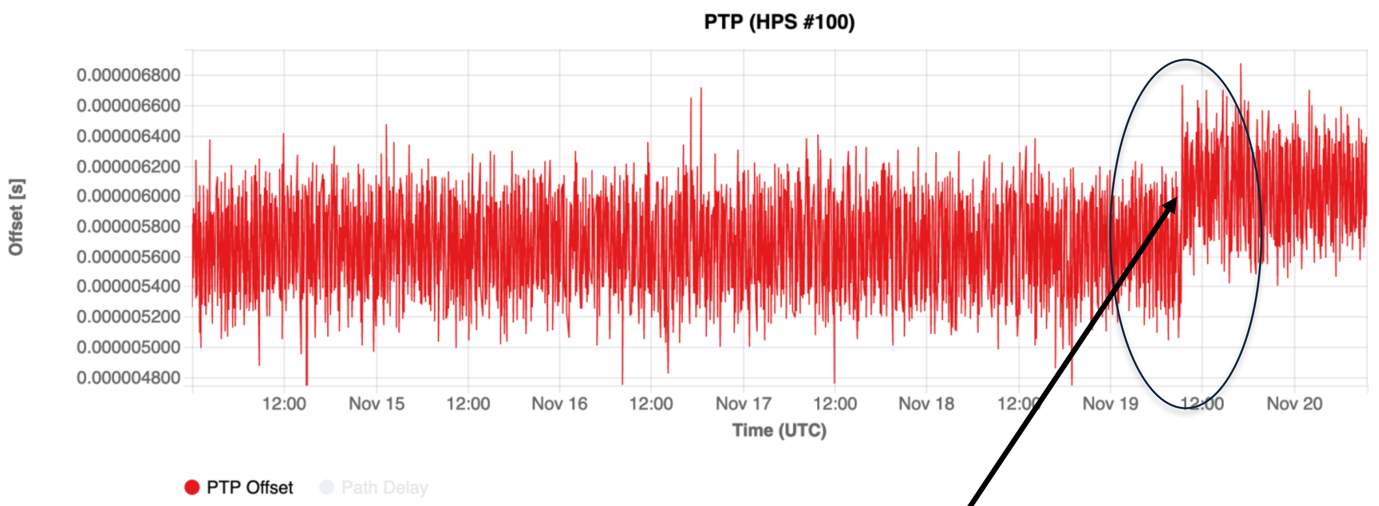
Real Life Example WDR – Remote Studio synchronization Cologne - Dortmund

PTP input after
Lucky packet
Filter
(<+-500ns)



Small offset jump (300ns) on Nov. 19th due to network path re-arrangement
Mitigated by „Asymmetry Step Detection“ in Clock

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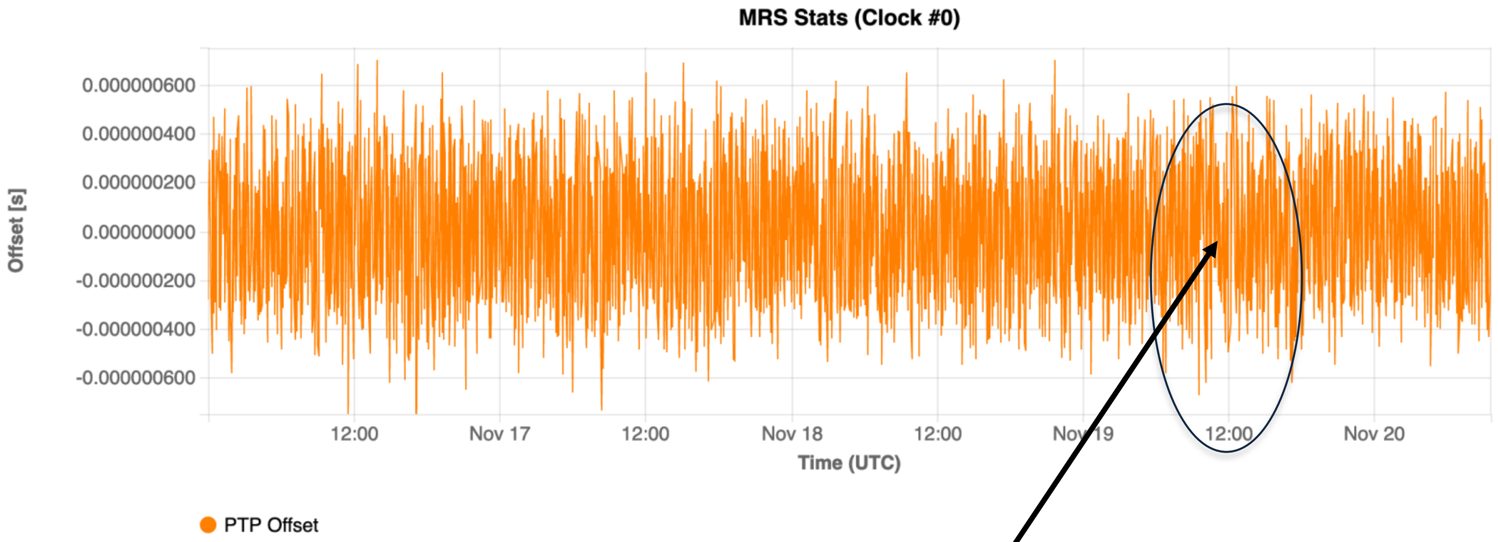
Real Life Example WDR – Remote Studio synchronization Cologne - Dortmund

PTP clock inputs after Asymmetry step detection



Offset jump of input compensated

Output accuracy of clock:
< 100 ns

Target accuracy at remote site sufficient for RAVENNA network
GPS antenna not required!

Questions?

More answers…

RAVENNA / AES67 / SMPTE ST 2110 Resources:

www.ravenna-network.com/resources

PTP Resources:

www.meinbergglobal.com/english/info

blog.meinbergglobal.com

You‘ve made it!

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