NASPI Work Group Meeting
Gaithersburg, MD
March 23, 2017

ultra-accurate time and frequency synchronization

Allied Partners

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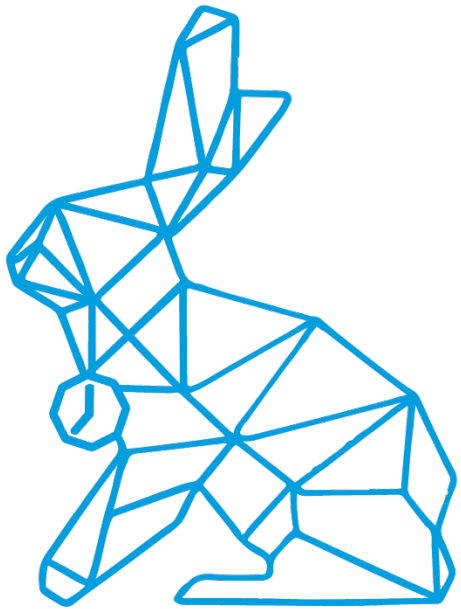
Time Synchronization as a first-order concept

You take care of it, or you will pay for it!

White Rabbit Technology

An extension of Ethernet.

- Born at CERN
- Synchronization: **Sync-E & PTP (IEEE-1588v2)**
- Accurate timestamps
- Thousand of nodes
- Distance range over 80 km; with amplifiers, longer distances possible
- Robustness & redundancy
- Self-calibration over long distances
- Candidate for PTP IEEE-1588 v3 (high-accuracy profile released by 2018)



How White Rabbit works

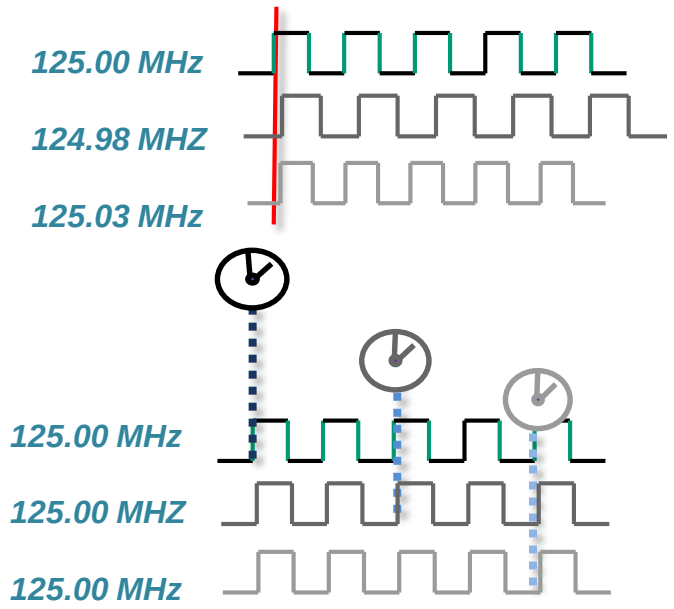
Synchronization: **Sync-E & PTP (IEEE-1588v2)**

Small differences in the node/switch individual clocks. →

Sync-E

Common notion of frequency!! →

SYNTONIZATION VIA SYNC-E

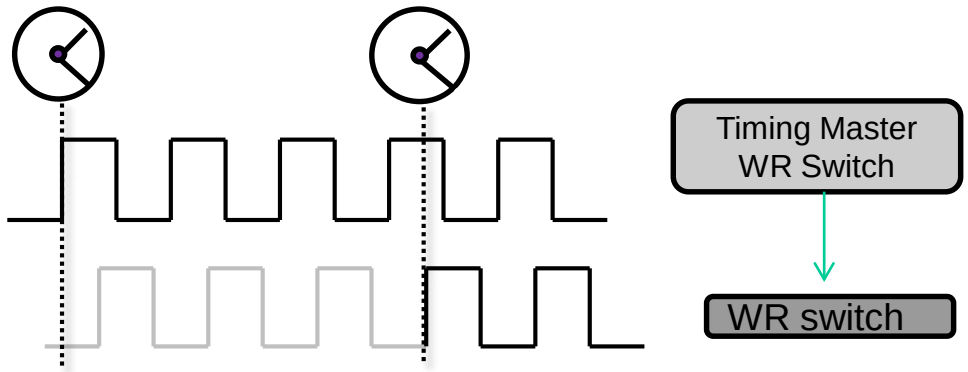


OFFSET ADJUSTMENT WITH ENHANCED PTP

Synchronization: **Sync-E & PTP (IEEE-1588v2)**

Temperature and distance affect correction

DDMTD: digital dual mixer time difference



Capable of measuring time differences between two digital clock signals with very fine resolution (sub-picosecond).

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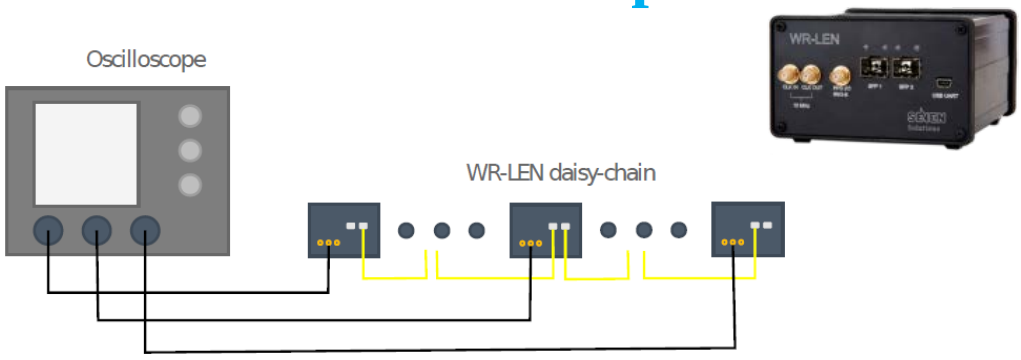
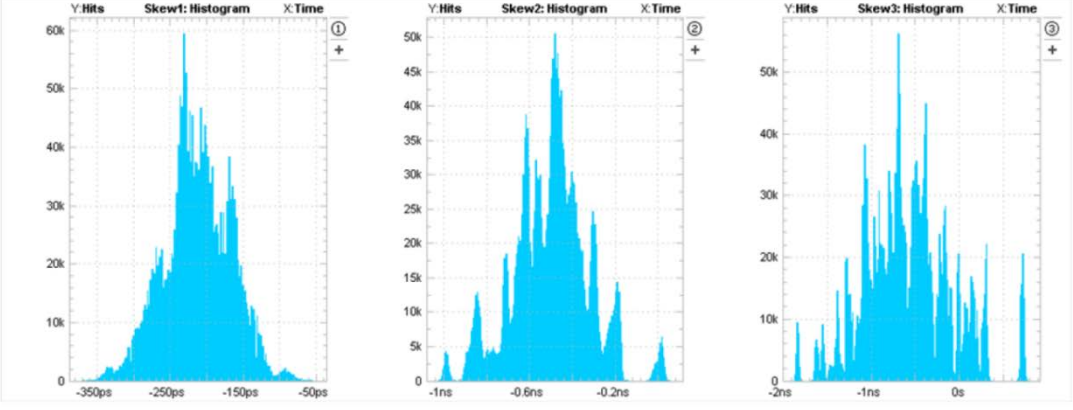
Time transfer over 18 hops



Synchronization results along a WR-LEN daisy chain.

- Experiment with 90% of bandwidth utilization.
- Using default device configuration (non parameter tuning).

Left Plot (node 10th)
Middle Plot (node 15th)
Right Plot (node 18th)



Description	Mean	RMS	Peak-to-Peak
Skew Master to 10th node	-212.51 ps	45.65 ps	312.50 ps
Skew Master to 15th node	-500.66 ps	174.50 ps	1.07 ns
Skew Master to 18th node	-573.45 ps	490.17 ps	2.65 ns

Long-Distance Project Examples

Long-distance WR projects include…

United kingdom:

- 110km bidirectional with Skylane 1550 120km (32dB)
- 330km with Skylane DWDM 120km and waveready 219 EDFA amplifiers

South Africa (SKA):

- 64km in the outdoor with SFP AXCEN 3254_05D1

Finland (MIKES):

- >1000km with Coriant hiT7300, "2,5Gbps alienwave" 196.000THz http://www.ohwr.org/projects/white-rabbit/wiki/Mikes

Application Cases

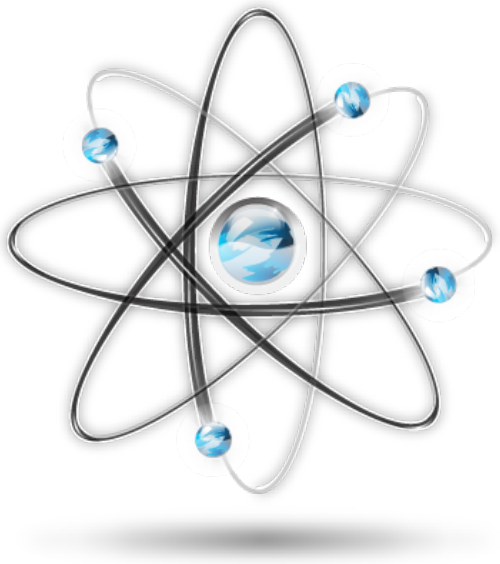




Scientific Facilities

- Modern large-scale scientific facilities require timing distribution systems with extremely high timing stability to synchronize radio frequency (RF) and optical sources across hundreds of meters to several kilometers.

- Facilities such as particle accelerators and phased-array antennas for radio-astronomy require extremely high timing accuracy between multiple remotely located equipment and source/sensors devices.



Metrology

- Long distance optical fiber links
- National metrology labs time, frequency and optical pattern distribution
- Applications:
  - Metrology calibration, certification, etc.
  - Legal timestamps for finance, bank, etc.

Global explosion of commercial applications!

High-Frequency Trading

- A massive number of transactions are being made every millisecond by very diverse finance institutions worldwide.
- Accurate time-stamping of these transactions is critical to coherently manage them all and also in order to be able to detect abuse actions.
- MiFID (II) new directive starts in 2017 including new timing demands.
- WR offers an efficient solution for time support of latency control, key for verifying network quality.
- The reliable WR timestamp makes possible the legal certification of financial transactions.

4G/5G Networks

- Ethernet is becoming the main technology for data and also for voice (IP) in mobile telecom infrastructures.
- Data transmission at different antennas and nodes need to be highly synchronized to optimize the bandwidth and increase quality.

The better the distributed clocks' synchrony, the better the quality and bandwidth.

Synchronization Accuracy Requirements for Telecom

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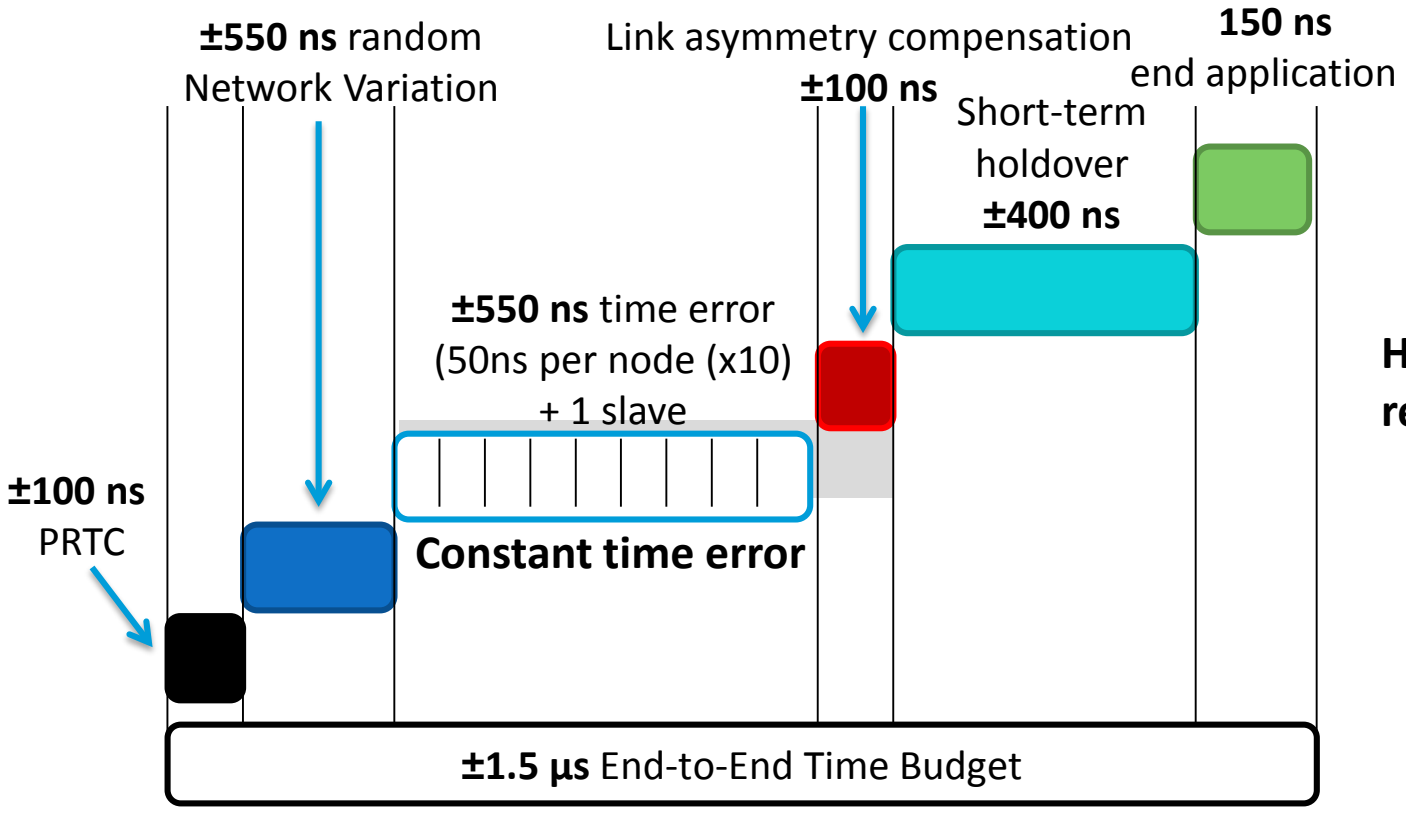
Application	Frequency / Air Interface	Time/ Phase	Why you need to comply	Impact of non compliance
LTE-FDD	16 ppb / 50 ppb	-	Call initiation	Call interference, dropped calls
LTE-TDD	16 ppb / 50 ppb	± 1.5 µs	Time slot alignment	Packet loss/ collisions Spectral efficiency
LTE MBSFN (TDD/FDD)	16 ppb / 50 ppb	± 500 ns	Proper time alignment of video signal decoding from multiple base transceiver stations	Video broadcast interruption
LTE-A (TDD/FDD) / COMP/MIMO	16 ppb / 50 ppb	± 500 ns	Coordination from signals to/from multiple base stations	Poor signal quality at edge cells Location-based services accuracy Lower data speeds

Even more astringent requirements: 130 ns for 5G. And even more demanding requirements are currently being defined.

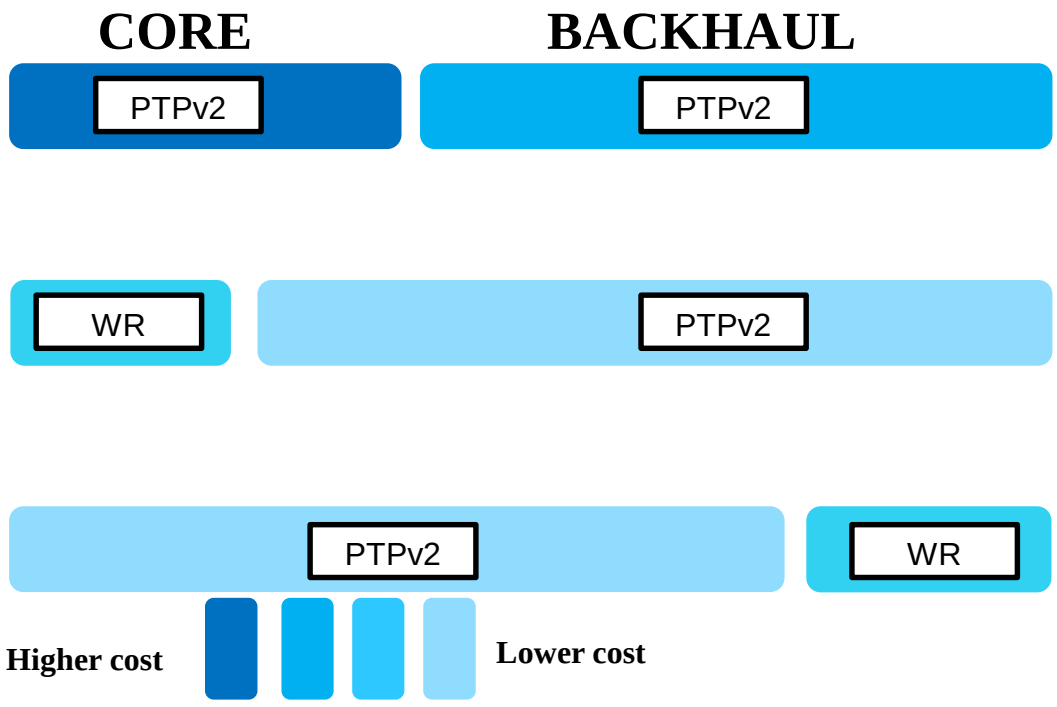
The Time Budget Concept

- You have to limit the time budget (synchronization error) associated to each element in the Mobile network.



How can we achieve LTE-A requirement of 500 ns?

Optimizing the time budget



Current approach: EXPENSIVE
PTPv2 approach used for the entire network.
High end equipment and complex verification

Upgrade to White Rabbit at CORE: COST-EFFECTIVE
The shorter timing footprint of White Rabbit time transfer solution allows using legacy/simpler equipment at the backhaul

Upgrade White Rabbit at BACKHAUL: COST-EFFECTIVE
Keeping the core, ideal approach for new backhaul deployments

GEO-positioning

- Real-Time-Locating-Systems (RTLS) represent an emergent market estimated to be 350 Million Dollars in 2014 with a growth of 10% in 2015 (IDTechex. 2014).
- Thanks to Seven Solutions timing equipment, it is possible to backup or improve existent GPS systems as well as RFID signals.
- Our solutions enable accurate ToA or TDoA techniques to achieve cm-range accuracy using UWB, Mobile or WIFI signals.

Critical infrastructure

Essential infrastructure for the functioning of a society and economy, including:

- Electricity generation, transmission and distribution.
- Gas production, transport and distribution.
- Oil and products production, transport and distribution.
- Heating (e.g. natural gas, fuel oil, district heating).
- Transportation systems (fuel supply, railway network, airports, inland shipping).
- Security services.

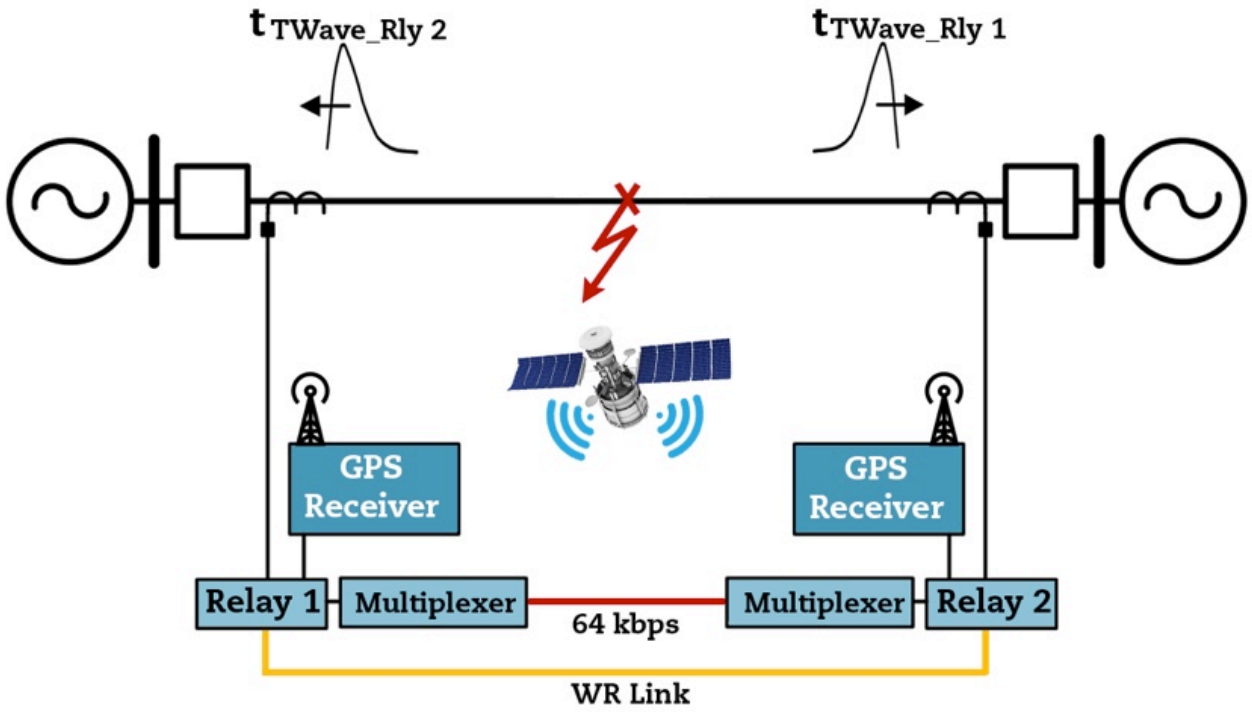
At least 17 of 21 types of infrastructures classified as critical by government authorities require timing information

Smart Grid

For continuous Smart Grid monitoring and forensic analysis, it is mandatory to know what is happening, when and where.

- **Global Time is critical**. Individual independent clocks are no longer valid. The whole system needs to have a common notion of time.
- **GPS independence** provides greater resiliency
- **Key grid elements**: WAMS, PMUs, relays, etc.
- Ultra-accurate time for sequence of events enables applications like **Travelling Wave Fault Location**,

Traveling Wave Fault Location



- **1ns = 1 foot** fault location accuracy
- **WR accuracy exceeds that of 1588v2** at long distances over several hops
- **Self-calibration** reduces engineering overhead and increases accuracy
- **Ultra-accurate time stamps** across gird aids in forensic analysis
- **GPS independent and resilient**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