WR technology introduction

23rd March 2023

SAFRAN

ELECTRONICS & DEFENSE

Fermilab Workshop

23rd March 2023

SAFRAN

Agenda

01

Introduction to the technology

02

System structure

03

Pre-calibration

04

WR in the market and general tips

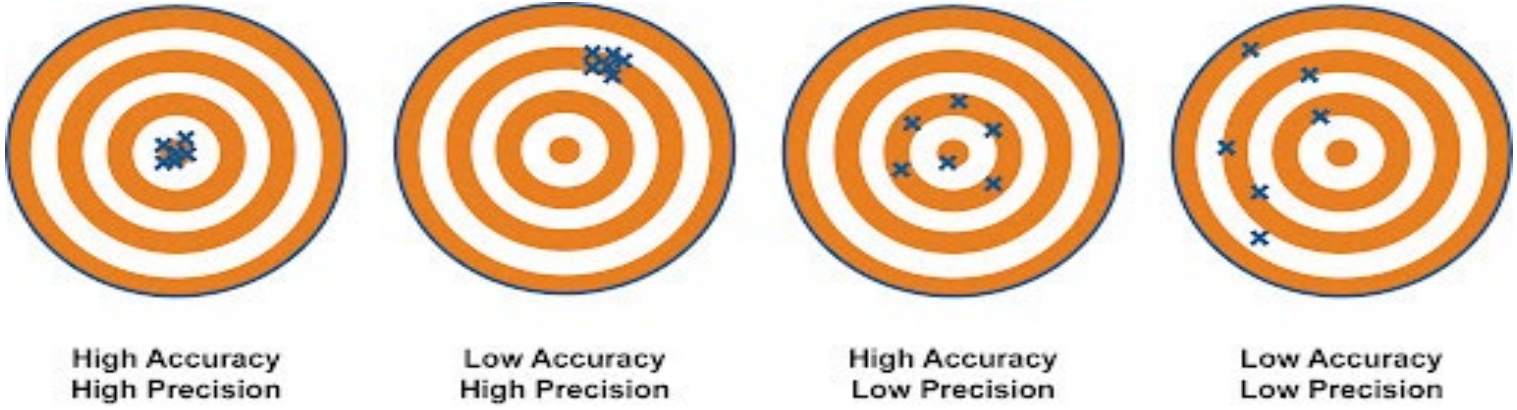
01

Introduction to the technology

SAFRAN

Introduction

- **Accuracy**
  - Relationship between the result and the correct value
- **Precision**
  - The degree of repeatability of different results of the time



White Rabbit goals

Born at CERN, Next IEEE-1588-2019 HA standard
Stable and validated ecosystem

Easy to integrate into existing telecom networks
(Ethernet, PTPv2)

Scalable
to long distances and number of nodes

Highly accurate
Sub-ns performance. Time transfer without impact in time error budget

Dependable
No GPS vulnerabilities. Performance is not affected by data traffic

Cost-effective
Easy to deploy, self-calibration

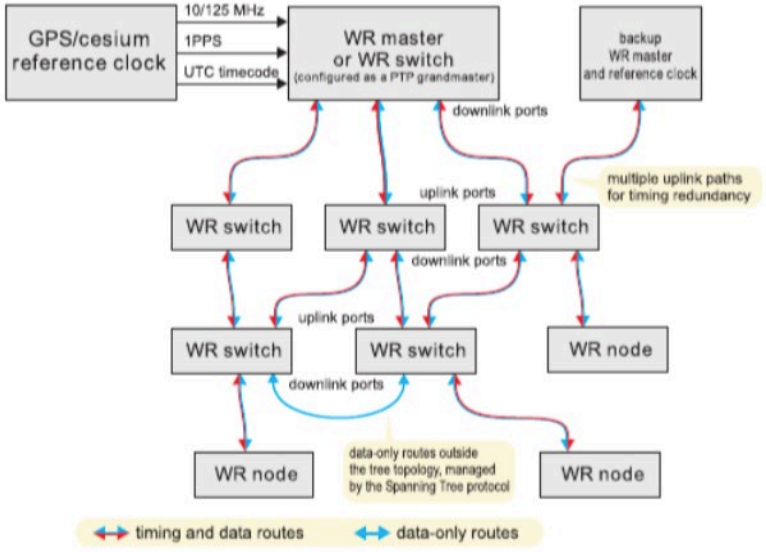
New applications
Mobile-based cm-range indoor/outdoor positioning as GPS alternative
Support Blockchain scalability

02

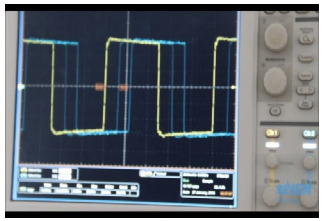
System structure

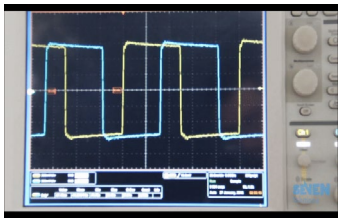
SAFRAN

WR basic hierarchy: GM, BC & Slaves

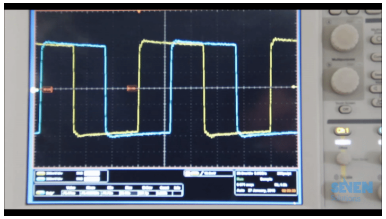


Syntonization – Sync E





Synchronization – Enhanced PTP

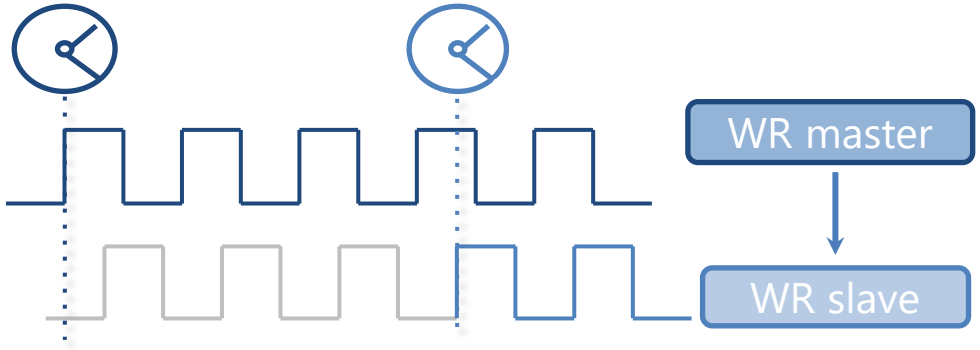


- Frequency is the time ruler. PPS provide just initial phase relationship: PPS - 10MHz signals may drift
- All devices must be WR-compliant for sub-nanosecond accuracy. However, other PTPv2 or just Ethernet devices can be connected to the network without achieving WR synchronization performance
- Boundary clock behavior. Scalability driven by the number of ports

Synchronization: L1 syntonization & PTP (IEEE-1588v2)

White Rabbit measures the offset between devices taking into account fixed and dynamic variations due to weather conditions using picosecond level accurate timestamps

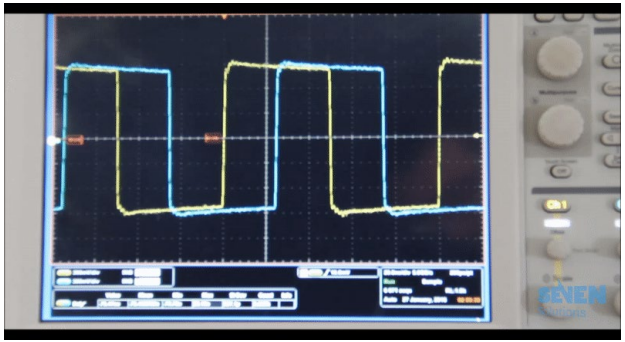
Timestamp generation based on frequency mixing techniques: Clock phase measurement



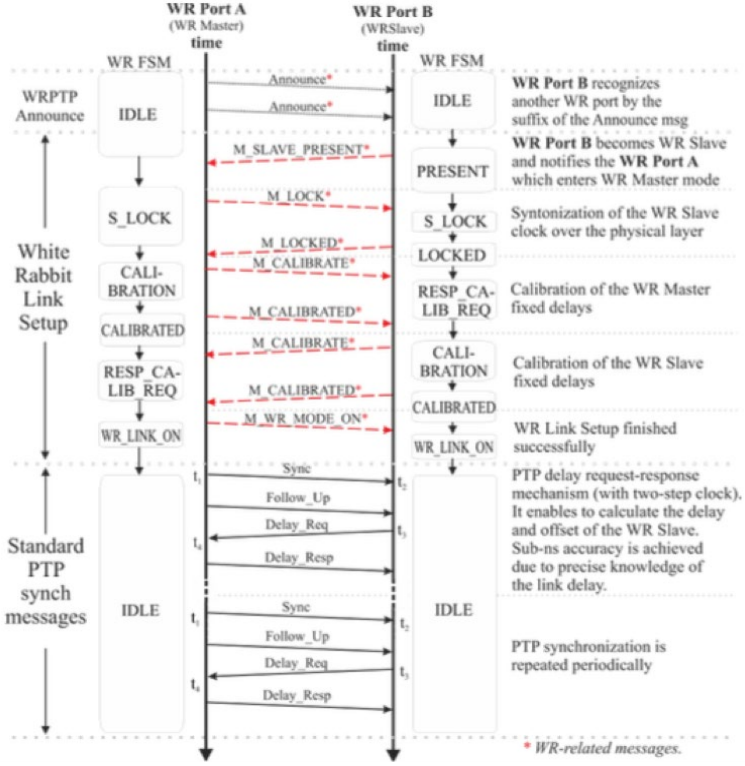
The timestamps are capable of measuring time difference and phases of two digital clock signals with very fine resolution (sub-picosecond) and they are used to adjust the received and generated clock offset

Time transfer: WR-PTP

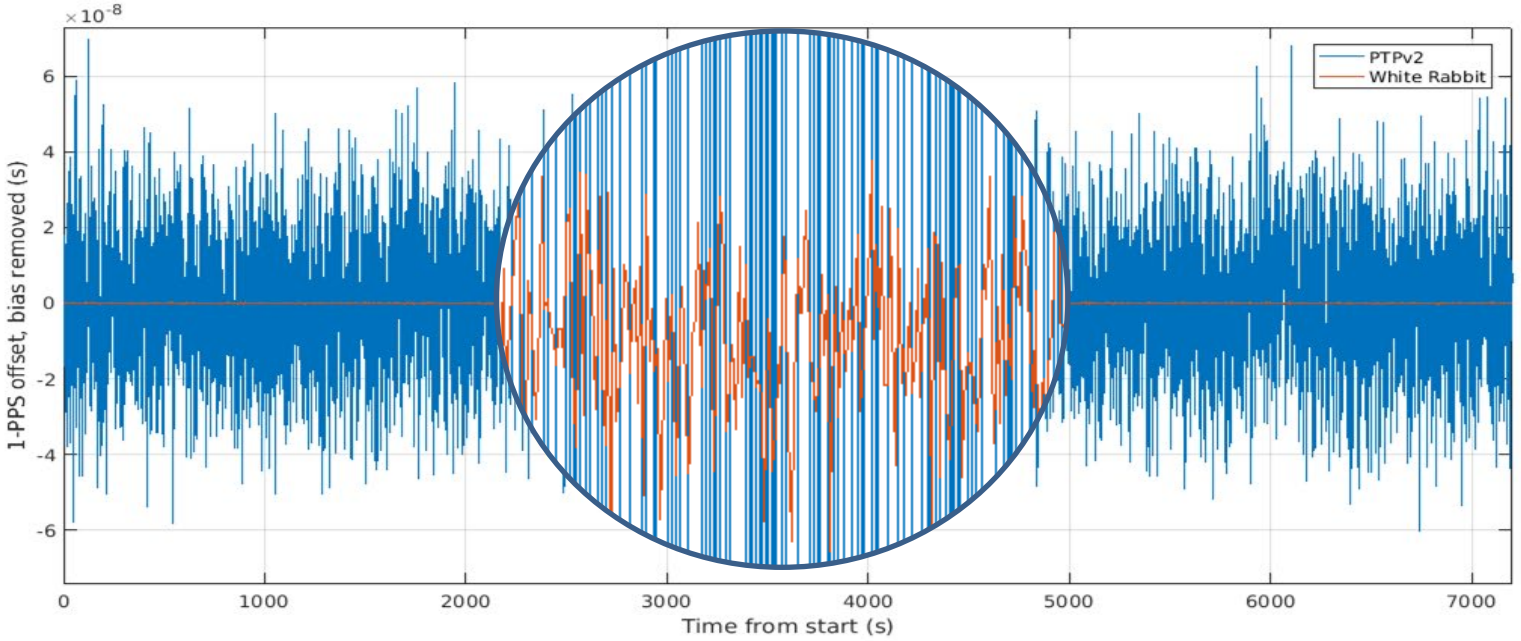
White Rabbit uses the information collected by the exchange of timestamped packets for correcting the constant offset between nodes



The information from the calibration is also important for compensating the static offset between nodes



WR vs PTP accuracy



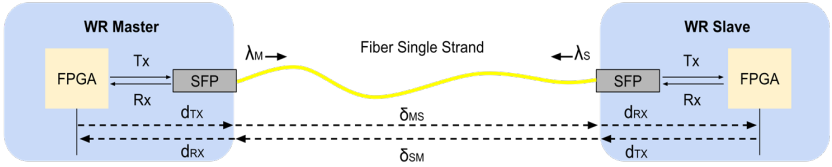
03

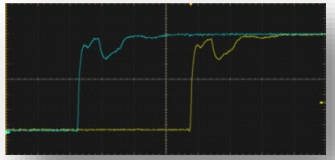
Pre-calibration

SAFRAN

Pre-calibration

- **White Rabbit uses single fiber WDM (typically BiDi SFP 1310/1490 nm and single-mode fiber G652) to avoid link asymmetries caused by different propagation velocities on the downstream and upstream links**
  - BiDi SFPs use different wavelengths tx and rx, which means slight disparities in propagation of speed
  - The propagation speed difference for each wavelength in the fiber is calibrated and it is automatically compensated for the actual fiber
  - Fixed delays caused by the SFPs and internal offsets are calibrated and removed
  - Temperature changes are dynamically compensated.
  - Plug & play: do not require calibration in the field for bidirectional fibers of <10Km with devices and supported SFPs
  - Any new design, FPGA firmware modification, new (unsupported) SFPs may require equipment recalibration



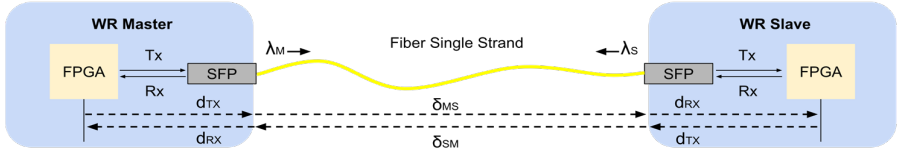


$$\text{delay}_{MS} \neq \frac{RTT}{2}$$

Asymmetry translates into PPS misalignment between master and slave

Pre-calibration

- **Large distance links may require remote support calibration, especially for two fiber deployment or if the devices in the optical paths are unknown (for other cases is just about optical fiber-wavelengths calibration - α)**
- **Coefficient of asymmetry of the optical fiber (α)**
  - It describes the asymmetry of the fiber (difference in the propagation time between master and slave (m-s/s-m)
  - It can include the asymmetry due to:
    - Different speed of propagation in the fiber because of the wavelength
    - Using two fibers with different lengths
  - If additional elements are introduced in the "optical path" (amplifiers, DCMs, transponders, etc…) that produce additional asymmetry, they can be modeled as part of this coefficient
  - $\alpha = \frac{\delta_{MS}}{\delta_{SM}} - 1$



Wavelength asymmetry can reach more than 100 ns of offset, depending on the selected wavelengths channels!

04

WR in the market and general tips

SAFRAN

WR vs other technologies

White Rabbit

- Sub nanosecond accuracy and precision
- Inter- and intra- datacenter sync
- In-built failover
- Extremely scalable
- Pre-calibrated

- Dedicated infrastructure required

PTP

- Tens of nanosecond accuracy
- Can share existing network
- Standard and widely accepted at industrial level

- Susceptible to accuracy variations during high traffic patterns
- Many different implementations / tuning parameters
- Dedicated HW required

GNSS / GPS

- Highly available
- Tens of nanoseconds accuracy

- Limited distribution capabilities
- Susceptible to outages
- Custom cabling and infrastructure
- Not possible in all locations

NTP

- Globally available and free reference services over the Internet

- Low levels of accuracy and precision (microseconds)

WR FAQ

- **Reduced bandwidth used: <10 packets/s**
- **Bidirectional SFPs are the preferred choice. Two-fiber DWDM SFPs require calibration.**
- **WR can be used for phase-constant RF (frequency) distribution (RoE) applications.**
- **WR is non-standard profile. It is very close to the IEEE-1588-2019 High Accuracy profile (this is in fact based on WR as pre-standard). Our devices can provide other IEEE-1588v2 profiles for last-hop interoperability with accuracy equals to direct PTP grandmaster connection.**
- **Only for large distance links (+10Km), a one-time calibration is needed. Recalibration is required is network is modified.**
- **Data can be managed with WR without impacting the performance, but devices are not by default ready to handle high volume of data so most of the deployments use an independent WR network.**
  - There are some facilities with static routing topologies where customized equipment have been used to fully integrate the timing and data network, but this required NRE work to work properly.

POWERED BY TRUST