The White Rabbit Collaboration in a nutshell

Projects! Some examples:

- Ongoing: collaboration with GMV and IQD on hold-over.
- Quantum: see e.g. CERN's Quantum Tech Initiative at https://quantum.cern
- Under discussion: robust, long-distance WR for smart grids

An experiment in public-private partnerships

Getting the best of both worlds

- Dissemination according to our Open Science mandate
- Impact and sustainability

Economics

- Companies can add value of top of WR and monetise products based on those developments
- They decide what they contribute as open source and what they keep proprietary

WRC members in 2024

White Rabbit Collaboration

White Rabbit
COLLABORATION

Join us! For more details, see
https://www.white-rabbit.tech

Outline

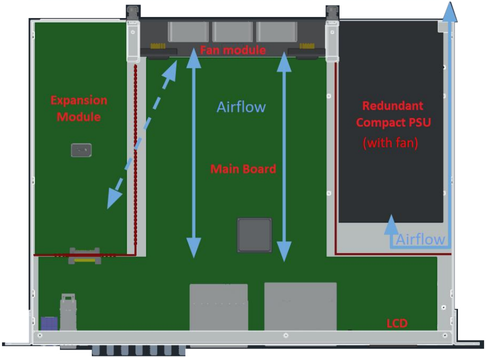
Plans

WR Switch v4

- GbE and 10GbE support
- Redundant and serviceable fans and power supplies
- Based on Xilinx/AMD Zynq UltraScale+ System-on-Chip (SoC)
- Expansion board slot for enhancements (low phase noise, hold-over. . .)

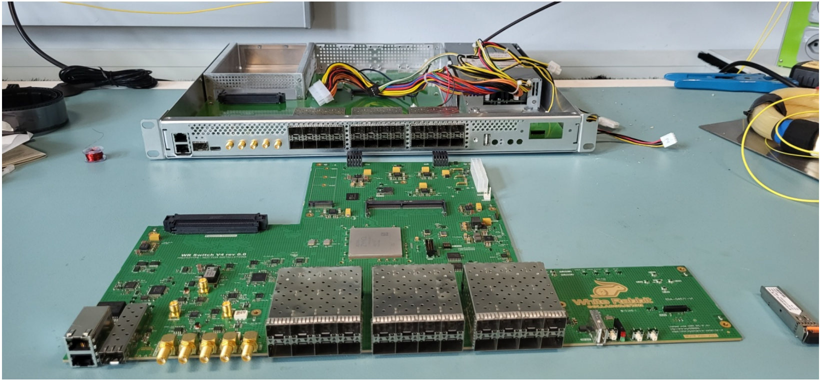
See https://ohwr.org/project/wr-switch-hw-v4/wikis for more details.

WR Switch v4

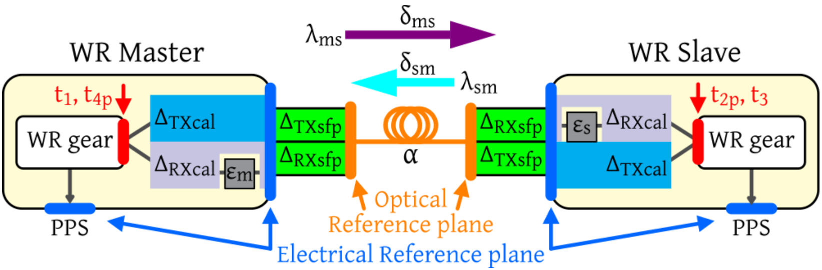


Prototyping stage, v3 functionality before the end of the year.

WR Switch v4



Standardisation++



Courtesy Henk Peek and Peter Jansweijer

Standardisation++ (P. Jansweijer, M. Lipiński)

Amendments to IEEE 1588-2019

- Absolute calibration
- In-situ calibration of asymmetry

Within the SNIA SFF working group

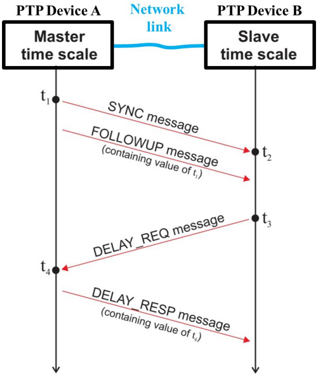
Storage of calibration parameters in SFP EEPROM

Possibilities for collaboration: non-exhaustive list

- Telecom: support for G.8275.1 PTP profile, higher rate for PTP frames, improvements in BMCA, ESMC support, live reconfiguration... See presentation of Marek Brawański at the 13th WR Workshop.
- Quantum: both QKD and entangled qubits
- Monitoring and logging of important parameters and events with time stamps
- Automation of calibration of port delays and fibre asymmetry
- Robustness: hardware and system-wide (clock ensemble). Redundancy and seamless switch-over ($<$1ns jump)
- Best practices for long-distance WR, in combination or not with weak signals for quantum networking
- Testing and qualification laboratory
- Other?

Backup slides

Precision Time Protocol (IEEE 1588)



- Frame-based synchronisation protocol
- Simple calculations:
  - link delay: $\delta_{ms} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2}$
  - offset from master: $OFM = t_2 - (t_1 + \delta_{ms})$

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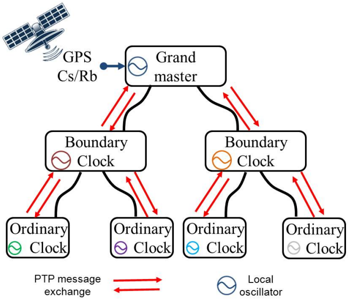

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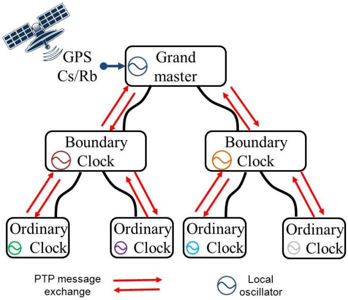

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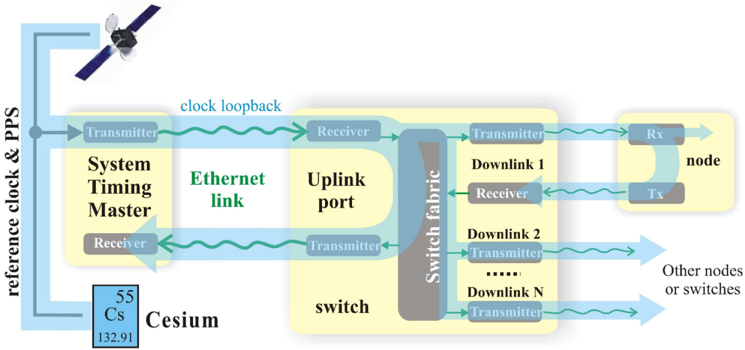
- Hierarchical network
- Shortcomings of traditional PTP:
  - devices have free-running oscillators
  - frequency drift compensation traffic can compromise determinism of other messages
  - assumes symmetry of medium
  - resolution of timestamps

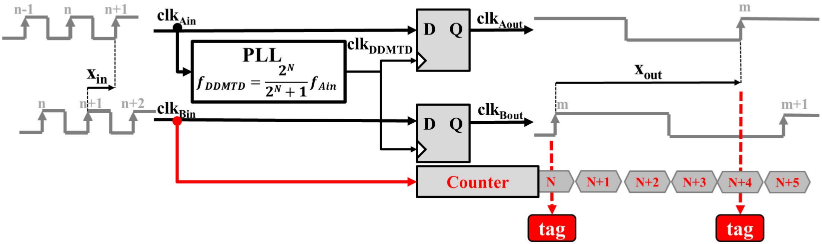
Layer 1 Syntonisation

- Clock is encoded in the Ethernet carrier and recovered by the receiver chip
- All network devices use the same physical layer clock
- Clock loopback allows phase detection to enhance precision of timestamps



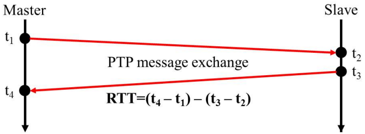
Digital Dual Mixer Time Difference (DDMTD)

- Precise phase measurements in FPGA
- WR parameters:
  - $clk_{in} = 62.5$ MHz
  - $clk_{DDMTD} = 62.496185$ MHz (N=14)
  - $clk_{out} = 3.814$ kHz
- Theoretical resolution of 0.977 ps



Link delay model

- Correction of Round Trip Time (RTT) for asymmetries



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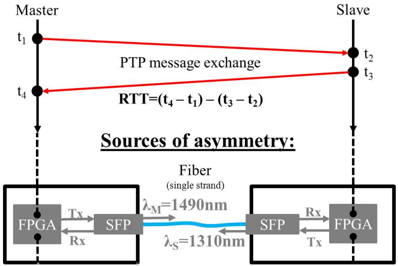

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  - **Fixed delays** – calibrated/measured
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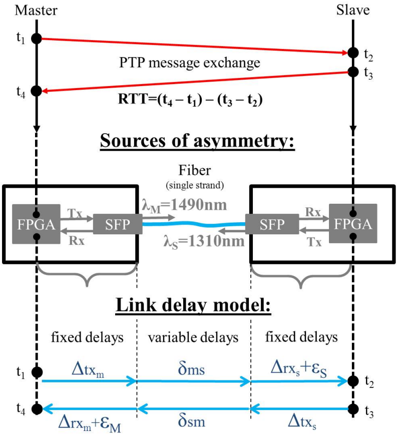
$$\alpha = \frac{\nu_g(\lambda_s)}{\nu_g(\lambda_m)} - 1 = \frac{\delta_{ms} - \delta_{sm}}{\delta_{sm}}$$



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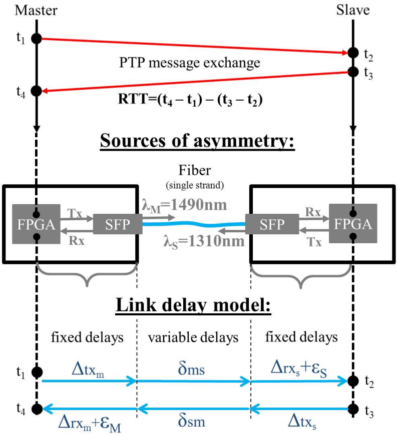
- Accurate offset from master (OFM):

$$\delta_{ms} = \frac{1+\alpha}{2+\alpha}\left(RTT - \sum \Delta - \sum \epsilon\right)$$

$$OFM = t_2 - (t_1 + \delta_{ms} + \Delta_{txm} + \Delta_{rxs} + \epsilon_S)$$



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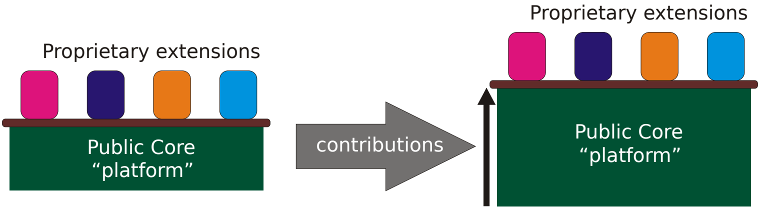
WR and open source

	Commercial	Non-commercial
Open	**Winning combination. Best of both worlds.**	Whole support burden falls on developers. Not scalable.
Proprietary	Vendor lock-in.	Dedicated non-reusable projects.

Public-private partnerships



Public-private partnerships