Introduction to White Rabbit and to the Workshop

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European Organisation for Nuclear Research (CERN)

11th White Rabbit Workshop

6 October 2021
Outline

1. Introduction to White Rabbit
2. The White Rabbit Ecosystem and Community
3. This Workshop
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2. The White Rabbit Ecosystem and Community
3. This Workshop
What is White Rabbit?

- Initiated to renovate CERN’s and GSI’s accelerator timing systems
- **Based on well-established standards**
  - Ethernet (IEEE 802.3)
  - Bridged Local Area Network (IEEE 802.1Q)
  - Precision Time Protocol (IEEE 1588)
- **Extends standards** to meet new requirements and provides
  - Sub-ns synchronisation
  - Deterministic data transfer
- Initial specs: links ≤10 km & ≤2000 nodes
- **Open Source and commercially available**
White Rabbit technology - sub-ns synchronisation

Based on

- IEEE 1588 Precision Time Protocol on Gigabit Ethernet over fibre
White Rabbit technology - sub-ns synchronisation

Based on
- IEEE 1588 Precision Time Protocol on Gigabit Ethernet over fibre

Enhanced with
- Layer 1 syntonisation
- Digital Dual Mixer Time Difference (DDMTD)
- Link delay model
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: \( OFM = t_2 - (t_1 + \delta_{ms}) \)
**Precision Time Protocol (IEEE 1588)**

- Frame-based synchronisation protocol
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  - offset from master: \( OFM = t_2 - (t_1 + \delta_{ms}) \)
- Hierarchical network
Precision Time Protocol (IEEE 1588)

- Frame-based synchronisation protocol
- Simple calculations:
  - link delay: \( \delta_{\text{ms}} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2} \)
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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
Link delay model

- Correction of Round Trip Time (RTT) for asymmetries

\[ \delta_{ms} = 1 + \alpha_2 + \alpha (RTT - \sum \Delta - \sum \epsilon) \]

Accurate offset from master (OFM):

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

RTT = \( t_4 - t_1 - (t_3 - t_2) \)
Link delay model

- Correction of Round Trip Time (RTT) for asymmetries
- Asymmetry sources: FPGA, PCB, SFP electrics/optics, chromatic dispersion

\[ \text{Link delay model:} \]

- Fixed delays – calibrated/measured
- Variable delays – evaluated online with:

\[ \alpha = \nu \left( \lambda_s - \lambda_m \right) - 1 = \delta_{ms} - \delta_{sm} \]

Accurate offset from master (OFM):

\[ \delta_{ms} = 1 + \alpha \left( RTT - \sum \Delta - \sum \epsilon \right) \]

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

Sources of asymmetry:

- Fiber (single strand)
  - \( \lambda_M = 1490\text{nm} \)
  - \( \lambda_S = 1310\text{nm} \)
Correction of Round Trip Time (RTT) for asymmetries

Asymmetry sources: FPGA, PCB, SFP electrics/optics, chromatic dispersion

Link delay model:
- Fixed delays – calibrated/measured
- Variable delays – evaluated online with:
  \[
  \alpha = \frac{\nu_g(\lambda_s)}{\nu_g(\lambda_m)} - 1 = \frac{\delta_{ms} - \delta_{sm}}{\delta_{sm}}
  \]
Correction of Round Trip Time (RTT) for asymmetries

Asymmetry sources: FPGA, PCB, SFP electrics/optics, chromatic dispersion

Link delay model:
- **Fixed delays** – calibrated/measured
- **Variable delays** – evaluated online with:
  \[
  \alpha = \frac{\nu_g(\lambda_s)}{\nu_g(\lambda_m)} - 1 = \frac{\delta_{ms} - \delta_{sm}}{\delta_{sm}}
  \]

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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### Dispelling the commercial vs open myth

<table>
<thead>
<tr>
<th></th>
<th>Commercial</th>
<th>Non-commercial</th>
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</thead>
<tbody>
<tr>
<td>Open</td>
<td><strong>Winning combination. Best of both worlds.</strong></td>
<td>Whole support burden falls on developers. Not scalable.</td>
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<tr>
<td>Proprietary</td>
<td>Vendor lock-in.</td>
<td>Dedicated non-reusable projects.</td>
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Javier Serrano | CERN BE-CEM-EDL | White Rabbit | 10/17
Like *Open Core* but

- Entities in charge of core and of periphery are not the same: no conflict of interest.
- Public institutions only concerned with core. Private companies in the periphery and also in core when appropriate.
The commons as ground to build upon
The time dimension

Proprietary extensions

Public Core

Some extensions get integrated into the “platform”

Proprietary extensions

Public Core
An efficient public/private partnership

Most contributions paid with public money are published under an open-source licence. See https://ohwr.org/project/ohr-meta/wikis/Documents/oshw-in-public-institutions.
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This Workshop

- Very informal event. Please mute your mic when not speaking.
- Speakers:
  - Please upload your slides to https://ohwr.org/project/white-rabbit/wikis/Oct2021Meeting if you have the rights or send them to me so I do it.
  - You are in charge of your time slot.
You can stay in touch after the event through the white-rabbit-dev forum: https://forums.ohwr.org/c/white-rabbit-dev. Discourse can be used in mailing list mode (all categories) or you can watch a certain category (e.g. white-rabbit-dev) and get notified every time somebody posts.

Special discussion session tomorrow at 16:30 CEST about the future of WR. Please read the WR Collaboration proposal draft beforehand if you can.