# Outline

1. Overview
2. BTrain
3. OASIS Trigger Distribution
4. Conclusions
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Introduction

- White Rabbit is an Ethernet-based network.
- It provides sub-ns synchronisation between connected nodes.
- It is deterministic (upper-bound latency).
- Many novel applications possible using these features.
Layout of the WR backbone in CCR

Version 1, state on 2021-07-02, updated Maciej Lipinski
WR Application Taxonomy

- Time and frequency transfer $\rightarrow$ National time labs, ...
- Time-based control $\rightarrow$ GSI, ...
- Precise timestamping $\rightarrow$ LHAASO, KM3NET, ...
- Trigger distribution $\rightarrow$ LIST, OASIS, ...
- Fixed-latency data transfer $\rightarrow$ BTrain, ...
- Radio frequency transfer $\rightarrow$ ESRF, SPS LLRF, ...
A Few Words about Radio Frequency Transfer

Feedback frequency (equal to RF input when locked)

RF input

Phase detector

PI control

DDS

Encode packets

125 MHz reference
TAI time

Master

Receiver

White Rabbit network

Decode packets

Apply control words

125 MHz reference
TAI time

 DDS

RF output
A Few Words about Radio Frequency Transfer
A Few Words about Radio Frequency Transfer

To be covered in next presentation.
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Synchrotron Operation

Coordination required between:

- $f(t)$ - RF in accelerating cavities.
- $B(t)$ - Magnetic field in bending magnets.
- $I(t)$ - Current provided by power converters.
- Beam instrumentation.

Coordination provided by the BTrain system.
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Coordination provided by the BTrain system.
What is BTrain

- **Magnetic field** measurement (B value) drives everyone else.
- Two wires, each with a **train of pulses**.
- Each pulse marks an increase/decrease in B.
- 1μs pulse width, max 500KHz repetition rate.
- Fixed increase/decrease of B per pulse (0.1G).
Why Renovate it?

- Obsolete equipment.
- Higher resolution required (0.05G).
- Much faster increase/decrease rates required.
- Limited diagnostics.
Fixed Latency Data Transfer over WR

Very important for a closed-loop control system such as BTrain.
BTrain over WR

- Fixed latency distribution of multiple B values.
- Also delivers the control current value (via different VLAN).
- Resolution down to 100μG.
- Allows any increase/decrease rate.
- Extensive diagnostics.
WR Streamers

- HDL modules used by BTrain to send/receive frames.
- Can be found in the `wr-cores` repository.
- May be attached to the WR PTP core.
- Data Transfer Layer: FIFO over WR.
- Diagnostics on latency and tx/rx/lost frames.
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What is OASIS?

Open Analogue Signal Information System

- A distributed oscilloscope.
- Monitor and correlate signals across the CERN accelerator complex.
- 5000+ analogue signals.
- 500+ multiplexed digitisers.
- 250+ triggers.
- Accessible in the form of a virtual scope GUI.
OASIS WRTD

- Ongoing project to renovate the OASIS trigger distribution.
- New approach based on White Rabbit Trigger Distribution.
- Deprecate obsolete hardware.
- Improve performance and scalability.
- Full deployment will involve 30 WR switches.
How OASIS WRTD Works

- Replicate a trigger pulse at destination(s) with **fixed latency**.
- **Increase pre-trigger** acquisition buffer accordingly.
- **Roll back** the buffer to the moment of the original trigger.
Current state of OASIS trigger distribution

- **Timing events** converted to triggers by timing receivers (CTRs).
- Triggers multiplexed by CTCs.
- Triggers resynced **statically** by CTRs and **dynamically** by CTCs.
- **Dedicated** CTC output channel and **long** trigger cable per digitiser.
OASIS WRTD: phase I

- CTCs and CTRs remain, to generate and resync triggers.
- Some CTC outputs selectively repurposed to drive TDCs.
- Digitisers at the other end triggered by FDs (or directly).
- Fixed latency set to 400μs during testing.
During a new connection request, OASIS server checks if the trigger is already generated for another digitiser.

- If yes, it finds the correct FD/WR-DAQ and programs it.
- If not, it first reserves a CTC output and programs the TDC as well.
OASIS WRTD: phase II

- Full deployment, no more CTCs.
- CTR outputs digitised directly by TDCs.
- Triggers still resynced statically by CTRs.
- Triggers resynced dynamically by new devices.
OASIS WRTD: phase III

- No more TDCs to digitise triggers.
- Produce WRTD events directly from the timing system.
Lab Test Setup
Demo Time
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Summary

- Many interesting applications possible with an Ethernet-based network augmented with sub-ns synchronisation and deterministic latency.
- CERN is increasing its operational use of WR in time-critical applications.
- When deploying multiple WR applications, it is important to put in place a WR network backbone.
- Use VLANs to share timing but isolate data traffic.
- WR has been very successful at CERN so far, more applications to come!
Thank you for your attention!