WRXI: Distributed Instrumentation over White Rabbit

White Rabbit eXtensions for Instrumentation

Dimitris Lampridis

CERN, BE-CO-HT

1st White Rabbit Tutorial Workshop
7 October 2017
Introduction
Introduction
White Rabbit eXtensions for Instrumentation

- A communication protocol for distributed instrumentation over a White Rabbit (WR) network
White Rabbit eXtensions for Instrumentation

- A communication protocol for distributed instrumentation over a White Rabbit (WR) network
- Augments WR with complex event scheduling, timestamping and real-time message exchanging across the network
White Rabbit eXtensions for Instrumentation

- A communication protocol for distributed instrumentation over a White Rabbit (WR) network
- Augments WR with complex event scheduling, timestamping and real-time message exchanging across the network
- Provides auto-detection of attached nodes
**White Rabbit eXtensions for Instrumentation**

- A communication protocol for distributed instrumentation over a White Rabbit (WR) network
- Augments WR with complex event scheduling, timestamping and real-time message exchanging across the network
- Provides auto-detection of attached nodes
- Designed in an application-agnostic way, so that it can be adopted and re-used by others
- Fully open design and implementation
We want an external event (injected into our network via an FMC-TDC) to arm an FMC-ADC digitizer, configured for internal triggering.

We also want another non-WRXI digitizer (attached to our network via an FMC-Delay) to trigger 30 us after the FMC-ADC.
1 configure FMC-TDC: broadcast msg#1 upon reception of external TTL pulse
1. configure FMC-TDC: broadcast msg#1 upon reception of external TTL pulse

2. configure FMC-ADC: listen for msg#1 and arm
WRXI Example

1. configure FMC-TDC: broadcast msg#1 upon reception of external TTL pulse
2. configure FMC-ADC: listen for msg#1 and arm
3. configure FMC-ADC: broadcast msg#2 on internal trigger
configure FMC-TDC: broadcast msg#1 upon reception of external TTL pulse

configure FMC-ADC: listen for msg#1 and arm

configure FMC-ADC: broadcast msg#2 on internal trigger

configure FMC-Delay: listen for msg#2 and generate pulse 30 us after the recorded timestamp
WRXI Example

1. configure FMC-TDC: broadcast msg#1 upon reception of external TTL pulse
2. configure FMC-ADC: listen for msg#1 and arm
3. configure FMC-ADC: broadcast msg#2 on internal trigger
4. configure FMC-Delay: listen for msg#2 and generate pulse 30 us after the recorded timestamp
5. Execute
WRXI Example

1. configure FMC-TDC: broadcast `msg#1` upon reception of external TTL pulse
2. configure FMC-ADC: listen for `msg#1` and arm
3. configure FMC-ADC: broadcast `msg#2` on internal trigger
4. configure FMC-Delay: listen for `msg#2` and generate pulse 30 us after the recorded timestamp
5. Execute
6. Retrieve data
Nearest existing solution: LXI

Nearest existing solution is **LXI**

- Designed for instrumentation
- Works over Ethernet
- Plug & Play
- Has extensions for synchronisation, timestamping and message exchanging
LXI Event Messages

<table>
<thead>
<tr>
<th>HW Detect</th>
<th>Domain</th>
<th>Event ID</th>
<th>Sequence</th>
<th>Timestamp</th>
<th>Epoch</th>
<th>Flags</th>
<th>Data Field(s)</th>
<th>Zero</th>
</tr>
</thead>
</table>

UDP multicast (registered address 224.0.23.159)

Each message has:

- an event ID (16 reserved by LXI)
- a sequence counter
- a timestamp of the event generation
- Zero or more “TLV” data fields

LXI standard already defines most common types: int, float, ASCII, XML, JSON, …
LXI Discovery and Identification

- XML identification via GET at:
  http://<hostname>:80/lxi/identification

- Service discovery based on mDNS and DNS-SD
  (a.k.a. Bonjour, Avahi, etc.)
Proposed Approach (revisited)

Aim for LXI compatibility:
- use LXI Event messages over UDP multicast
- respect message contents
- support the 16 basic event IDs
- maybe follow LXI plug-n-play
- cherry-pick from the rest
- don’t block other LXI functions
Adoption of WR outside of CERN

- Ever-increasing list of WR users
- But also, list of companies producing WR hardware
Adoption of WR outside of CERN

Struck SIS8300 (DE)

The SIS8300-x digitizer board family is in use for LLRF, BPM and controls applications in several accelerators. The brand new SIS8300-KU is targeted at users who would like to develop or customize firmware with the Xilinx Vivado toolchain. The higher MGT speeds of the Ultrascale family result in performance improvements on the PCIe, memory and link side.

Central Design Parameters
- 4 lane PCI Express Gen3 Connectivity
- 10 Channels 125 MS/s 16-bit ADC
- 10 MS/s to 125 MS/s Per Channel Sampling Speed
- AC or DC Input Stage
- Internal, Front Panel, RTM and Backplane Clock Sources
- Two 16-bit 250 MS/s DACs for Fast Feedback Implementation
- High Precision Clock Distribution Circuitry
- Programmable Delay of Dual Channel Digitizer Groups
- Multi Gigabit Link Port Implementation to Backplane
- Twin SFP+ Card Cage for High Speed System Interconnects
- White Rabbit Clock Option for SFP+ Ports
- Two RJ45 Connectors (One Clock + 3 Data or 4 Data In/Out)
- XCKU040-1FFVA1156C Kintex Ultrascale FPGA
- 2 GByte DDR4 Memory (flexible partitioning scheme)
- Dual boot
- MMC1.0 under DESY license LV91
- In Field Firmware Upgrade Support
- Zone 3 class A1.0, A1.0C or A1.1CO Compatible
Adoption of WR outside of CERN

SP Devices ADQ7DC (SE)

Large scale integration with Micro-TCA.4 (–MTCA)

- Large scale integration
- Robust mechanical solution
- 10 GbE and **White Rabbit support**

The Micro-TCA.4 form factor is intended for integration into a chassis for modular instrumentation or large scale data acquisition. Chassis trigger and clock reference are supported for easy integration.

The ADQ7DC–MTCA primarily uses the PCIe Gen3x4 interface in the backplane for control and data transfer. The –MTCA form factor also includes the 10GbE, USB 3.0 and 1GbE interfaces.
Adoption of WR outside of CERN

N.A.T. MCH (DE)

NEW NATIVE-R9
White-Rabbit-Support

- Available Chassis
  - NATIVE-R2
  - NATIVE-R9

- White Rabbit Support
  - optional
  - set of registers
  - connect reserved clock pins to
    - bus for Triggers, Clocks, Interlocks

old NATIVE-R9
Adoption of WR outside of CERN

Sundance PXIe700 (UK)

PXIe700 is a powerful, flexible and expandable PXIe module fully compatible with PXI™-5 and ANSI-Vita-57.1 FMC carrier standards. PXIe is the platform of choice for the test, measurement and instrumentation market. The presence of an FMC site gives the ability to add different functionalities through the many available FMCs from various vendors.

The host interface is via x4 Gen2 PCIe. The PCIe interface is hard coded in the FPGA and with the latest Xilinx tools the support avoids any licensing costs. If more powerful Gen3 or DMA support is required, then suitable cores can be purchased from Sundance DSP or third parties. The on-board FLASH can be used to store up to 3 bit streams for configuring the FPGA through the driver from the host. A JTAG interface is also available for reconfiguring the FPGA from host during development and debugging via ChipScope.

PXIe700 supports White Rabbit developed by CERN and a European consortium of companies and universities. It is a fully deterministic Ethernet-based network for general purpose data transfer and sub-nanosecond accuracy synchronization. The IP core for this feature is freely available from the consortium web site.
Adoption of WR outside of CERN

- All of these instruments have WR interfaces
- Capable of sub-ns time synchronization within a WR network
- Lack common protocol for communication and exchange of events between them
- WRXI aims at providing this common “language” for WR-enabled instruments
Call to Action

- All interested parties are welcome to join the effort.
  - R&D partners
  - Users wishing to help shape the requirements
  - Equipment producers who would like to develop WRXI-compatible products
  - …

- Please contact us if you wish to be part of and contribute to the development of WRXI.
Call to Action

- All interested parties are welcome to join the effort.
  - R&D partners
  - Users wishing to help shape the requirements
  - Equipment producers who would like to develop WRXI-compatible products
  - ...

- Please contact us if you wish to be part of and contribute to the development of WRXI.

Thank you for your attention!

https://www.ohwr.org/projects/wrxi