WR-based Control and Timing @ CERN

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Outline

1. Why WR @ CERN?

2. CERN Control System

3. WR-based Control System
Why White Rabbit?

- White Rabbit started within renovation effort of General Machine Timing (GMT) – the current control and timing system at CERN
- GMT works great but has some disadvantages:
  - Based on RS-422, low speed (500kbps)
  - Unidirectional communication (controller → end stations)
  - Separate network required for end station → controller communication
  - Custom design, complicated maintenance
- White Rabbit is meant to solve these problems
Why WR @ CERN?

- **CERN Control System**
- **WR-based Control System**

CERN

- 6 accelerators
- LHC: 27km perimeter
- Thousands of devices to be controlled and synchronized
- A huge real-time distributed system

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**CERN's accelerator complex**

- ALICE
- ATLAS
- CMS
- LHC (2008, 27 km)
- SPS (1970, 1 km)
- CNGS (2003, Gran Sasso)
- East Area
- PS (1950, 629 m)
- LEIR (2005, 78 m)
- ISOLDE (1980)
- Booster (1970, 1 km)
- AD (1994, 1991)
- TT10
- TT11
- TT80
- TT40
- TT2
- n-Toff
- LINAC 2
- LINAC 3
- LHCb
- Neutrons
- Protons
- Antiprotons
- Proton/antiproton conversion
- Neutrinos
- Electrons
**Events** – points in time at which actions are triggered
- Each event is identified by an **ID**
Devices are subscribed to events
Each device "knows" what to do on particular event
Each event (ID) has a trigger time associated
A set of events is sent as a single Control Message (CM)
CM is broadcast to all the end devices (nodes)
A simplified explanation of CERN control system (4)

Granularity Window:

- Controller-input to node-output (i.e. pulse)
- Maximum bound latency \textbf{guaranteed} by the system
- Processing and network latency included
A simplified explanation of CERN control system (5)

- 4 accelerator networks
- Separate **Data Master (DM)** for each network
- LIC Data Master communicates with other DMs and control devices in their networks
- Broadcast of **Control Messages** within network(s)
Why WR @ CERN ?

CERN Control System

WR-based Control System

WR-based Control System

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Accelerator Networks

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Accelerator and Auxiliary Networks
Traffic distribution

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CCR (Prevessin)

Data Masters (WR Nodes)

LHC (node)

LIC (node)

AD (node)

REX (node)

Timing Masters

Time source

WR Network Backbone

CCR (Prevessin)

ISOLDE

LHC Network

LIC Network (Meyrin)

Node

Node

Node

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Traffic distribution: VLANs + multicast

Per-accelerator VLANs

- VL001
- VL002
- VL003
- VL004

DM-to-DM VLANs

- VL212
- VL223
- VL224

Shared accelerator VLANs

- VL121
- VL123
- VL124

Abbreviations:

- SW — White Rabbit SWitch
- AD — Antiproton Decelerator
- LHC — Large Hadron Collider
- ISOLDE — Isotrope Separator OnLine DEvice
- LIC — LHC Injection Chain
- REX — The Radioactive beam Experiment
- DM — Data Master
- @ ISOLDE

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Time Distribution

Data Masters (WR Nodes)

LHC (node)  LIC (node)  AD (node)  REX (node)

Timing Masters

SW  SW  SW  SW  SW

Abbreviations

SW – White Rabbit Switch
LHC – Large Hadron Collider
LIC – LHC Injection Chain
AD – Antiproton Decelerator
ISOLDE – Isotrope Separator OnLine Device
REX – The Radioactive beam Experiment @ ISOLDE

Timing over WRPTP (fiber/copper cable):

active  backup

Timing source fanout (dedicated cable):
Network Layers

Data Masters (WR Nodes)

Layer 0

Layer 1
2 SWs

Layer 2
16 SWs

Layer 3
128–256 SWs

Layer 4
2048–4096 SWs

Abbreviations

SW  – White Rabbit SWitch
LHC  – Large Hadron Collider
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REX  – The Radioactive beam Experiment @ ISOLDE
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WR-based Control System

Data Masters

CCR (Prevessin)

LHC (node)

LIC (node)

AD (node)

REX (node)

Data Masters (WR Nodes)

Time source

Timing Masters

WR Network Backbone

LHC Network

SW

SW

SW

SW

SW

SW

SW

SW

SW

SW

SW

SW

SW

SW

LIC Network (Meyrin)

Node

Node

Node

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Multicast for redundant controllers (Data Masters)

- Broadcast (unregistered multicast) communication: DM-to-nodes
- Multicast communication: nodes-to-DM
- Multicast address used for Data Masters (DM-A and DM-B)
- Seamless switch over between DMs: time-triggered synchronous reconfiguration of 1-Layer switches
- Nodes send data to multicast address: both DMs receive data
- No need for network reconfiguration when switching/changing DMs
Conclusions

- It is a collections of ideas possibly used in future for real design
- It is useful reference when implementing WR switch features
- It is strongly influenced by the legacy system and migration prospectives
- Key ideas
  - Fully redundant backbone
  - Distribute redundancy to different locations across the complex
  - Separate logically Accelerator Networks with VLANs
  - Design stuff such that even the craziest ideas are an option
Thank you