The White Rabbit Fieldbus

E.Gousiou (BE/CO/HT) **on behalf of the White Rabbit team**

Outline

- Introduction to WR & Technology Overview

- Implementation & Support

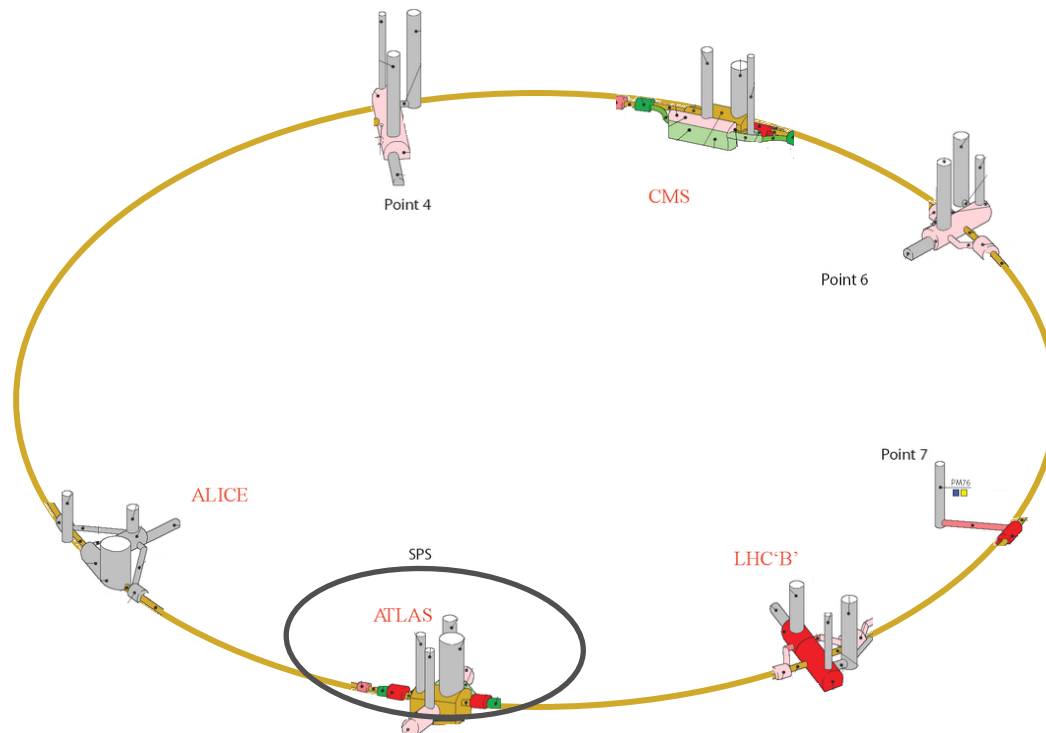- Cost Analysis

- Conclusions

Outline

Real Time Systems

o **Real-time communication systems** require the execution of operations with **tight time constraints**

o **Large distances** between nodes give long transmission delays

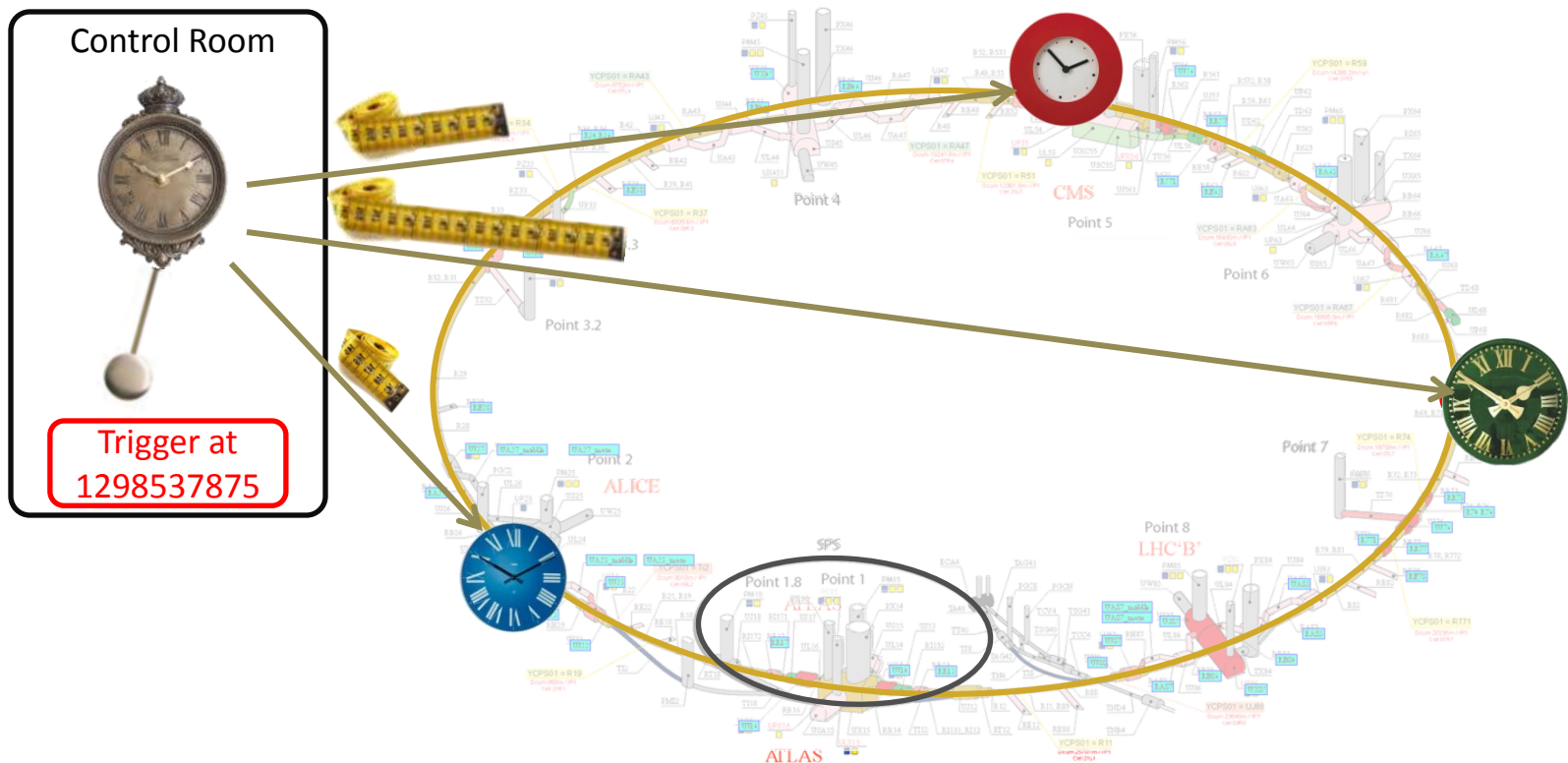o **Dynamic changes** to the number of nodes is not easy

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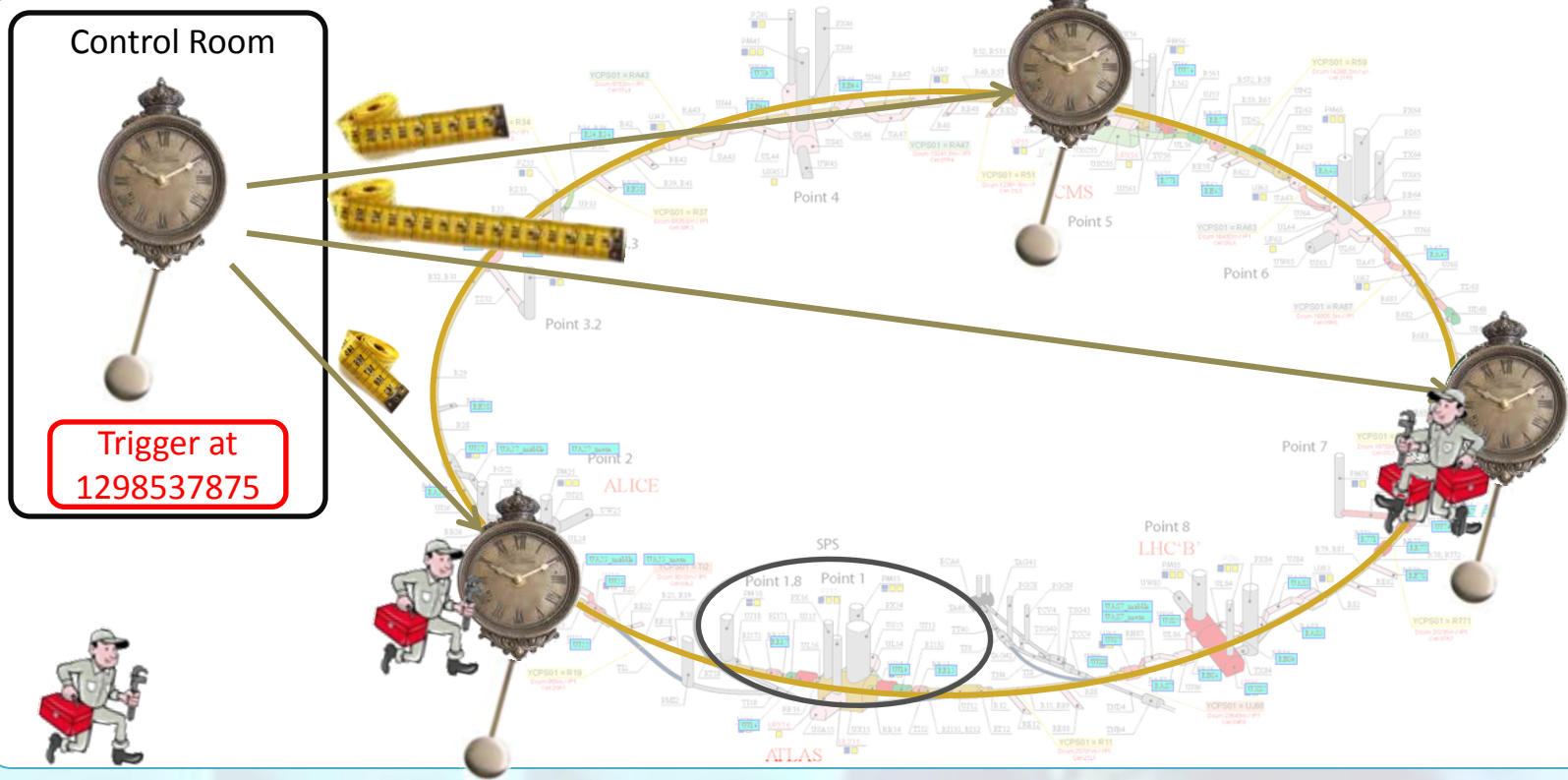o **Dynamic changes** to the number of nodes is not easy

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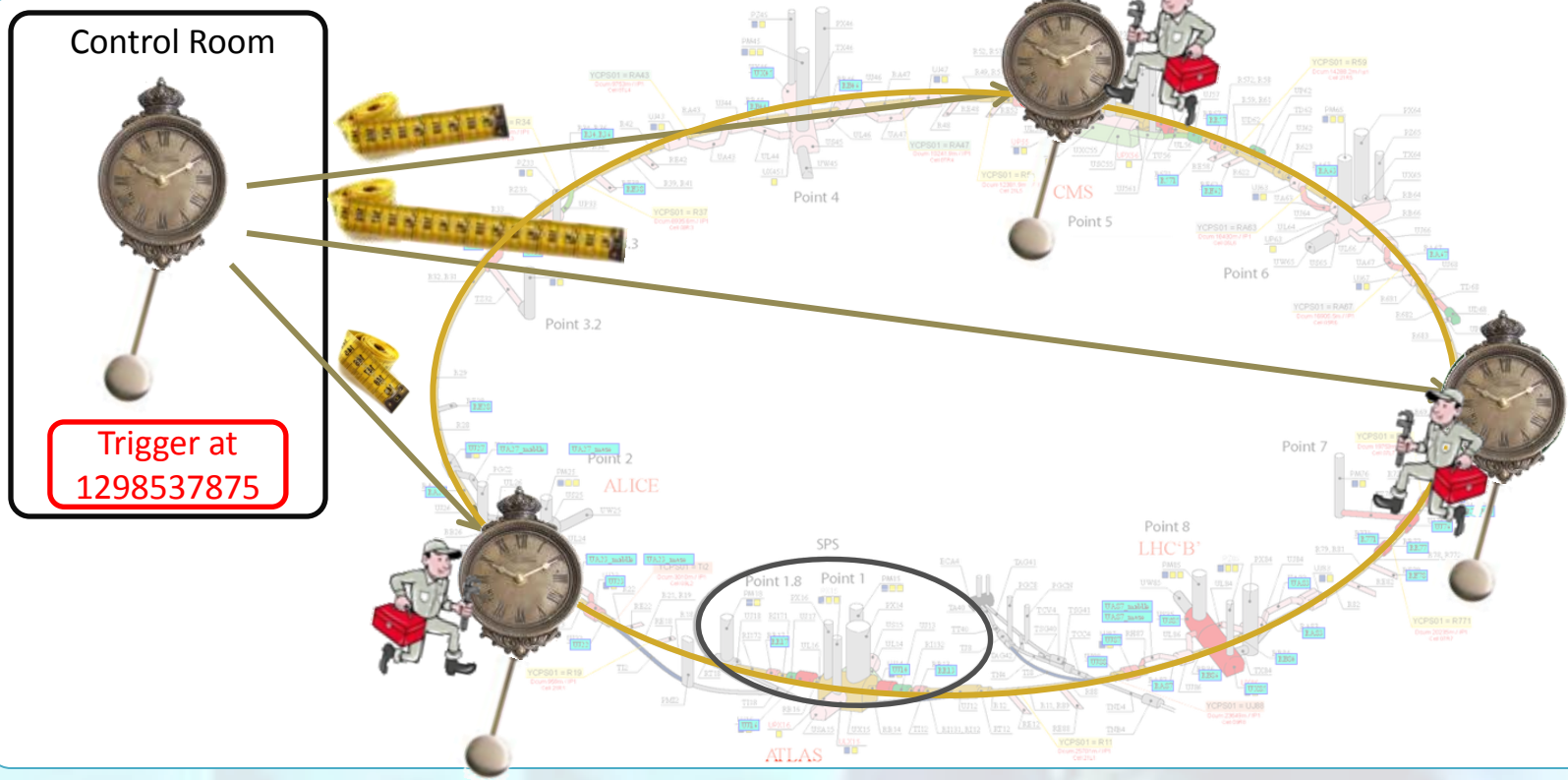
Trigger at
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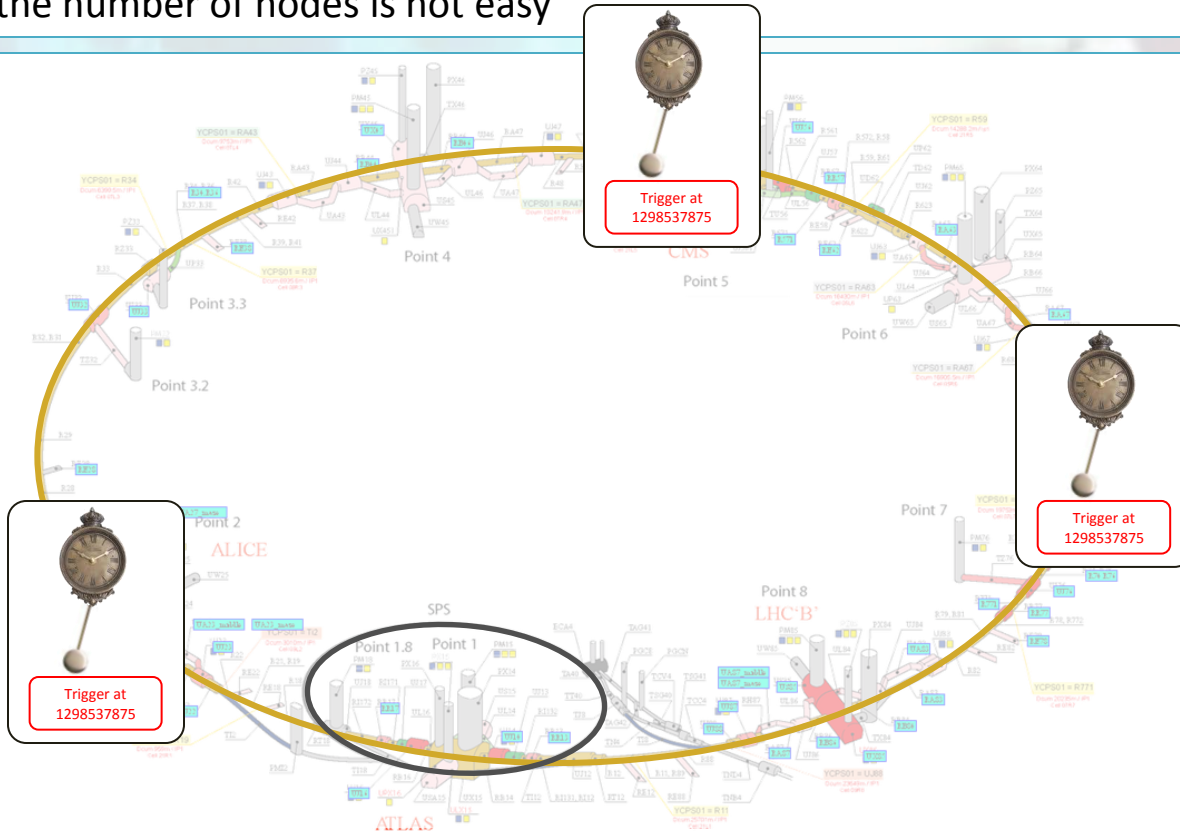
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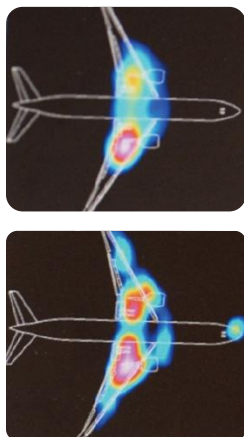

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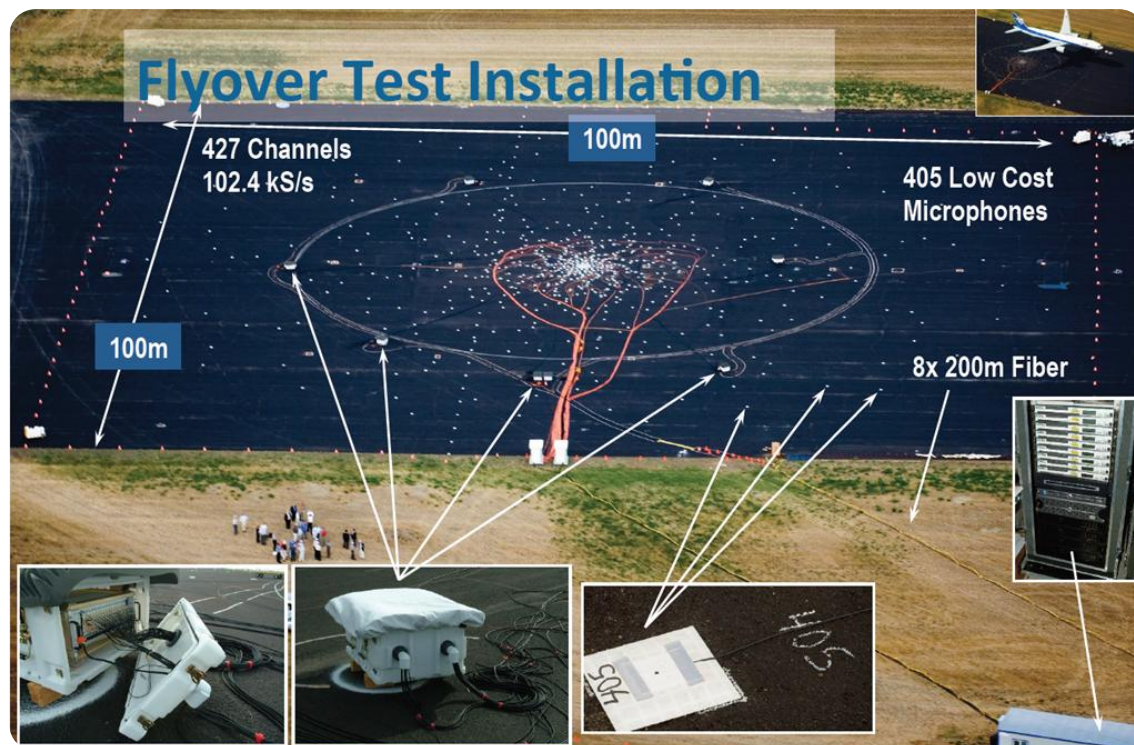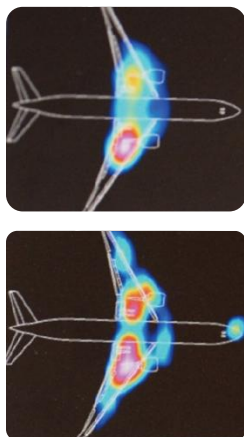
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Measures for Aircraft Noise Emissions Reduction

From NI presentation at …

Flyover Test Installation

427 Channels
102.4 kS/s

100m

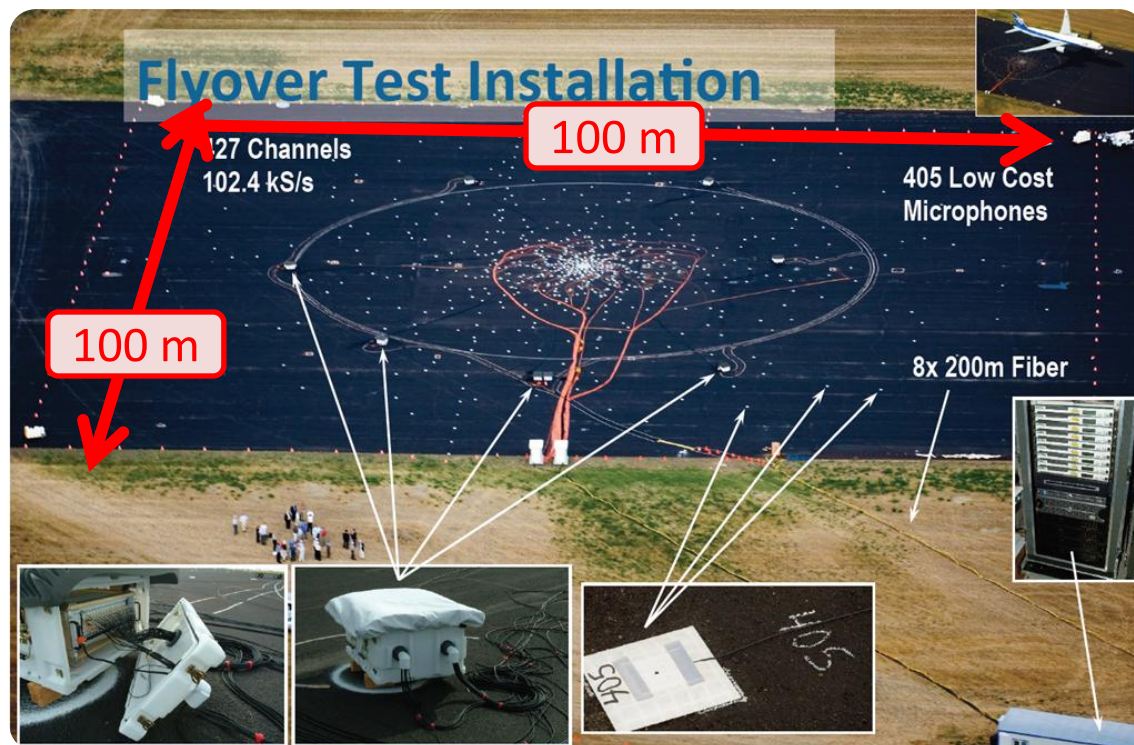405 Low Cost Microphones

100m

8x 200m Fiber

Real Time Systems

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102.4 kS/s

100 m

100 m

405 Low Cost Microphones

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Real Time Systems

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EISCAT: The most sophisticated Imaging Radar ever

With White Rabbit a farm of sensors extended over several kms is possible

From NI presentation at …
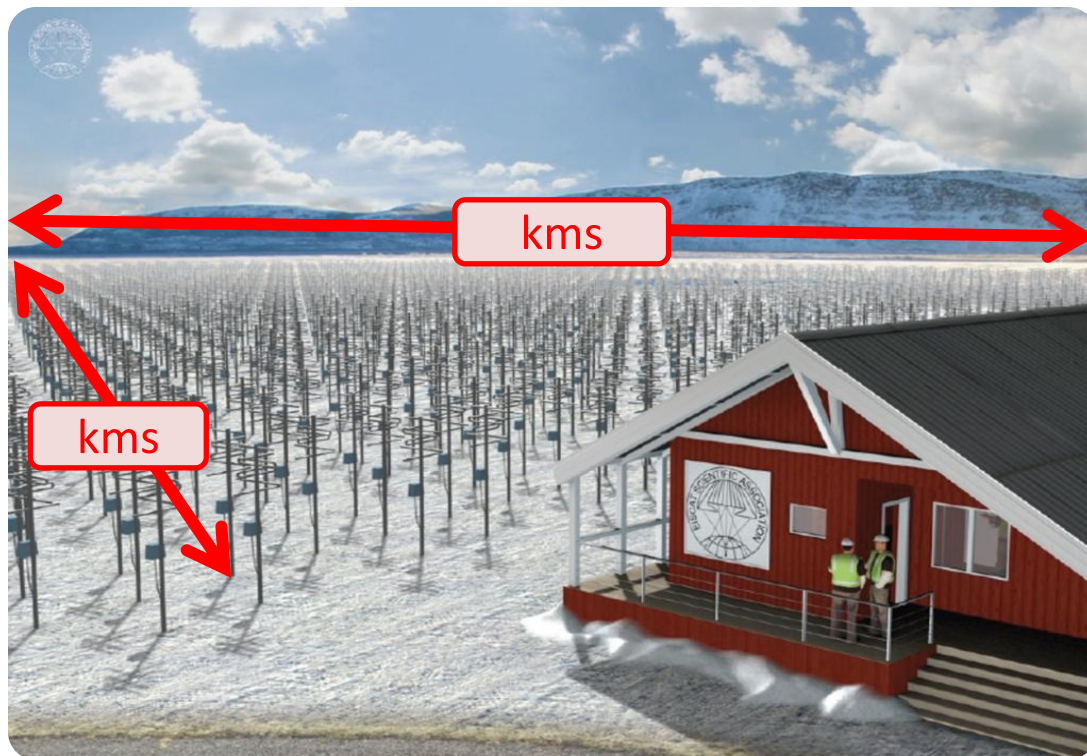
What is White Rabbit

White Rabbit is:

Ethernet

+ Determinism & Reliability

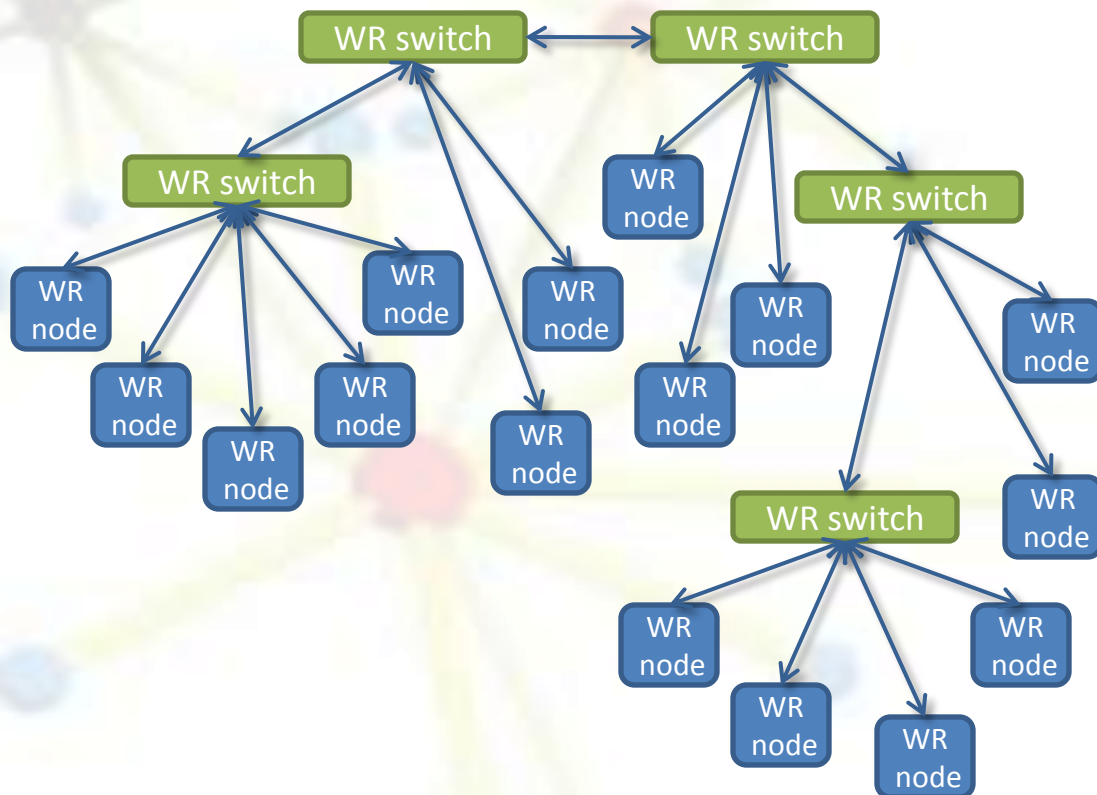**+** Synchronization

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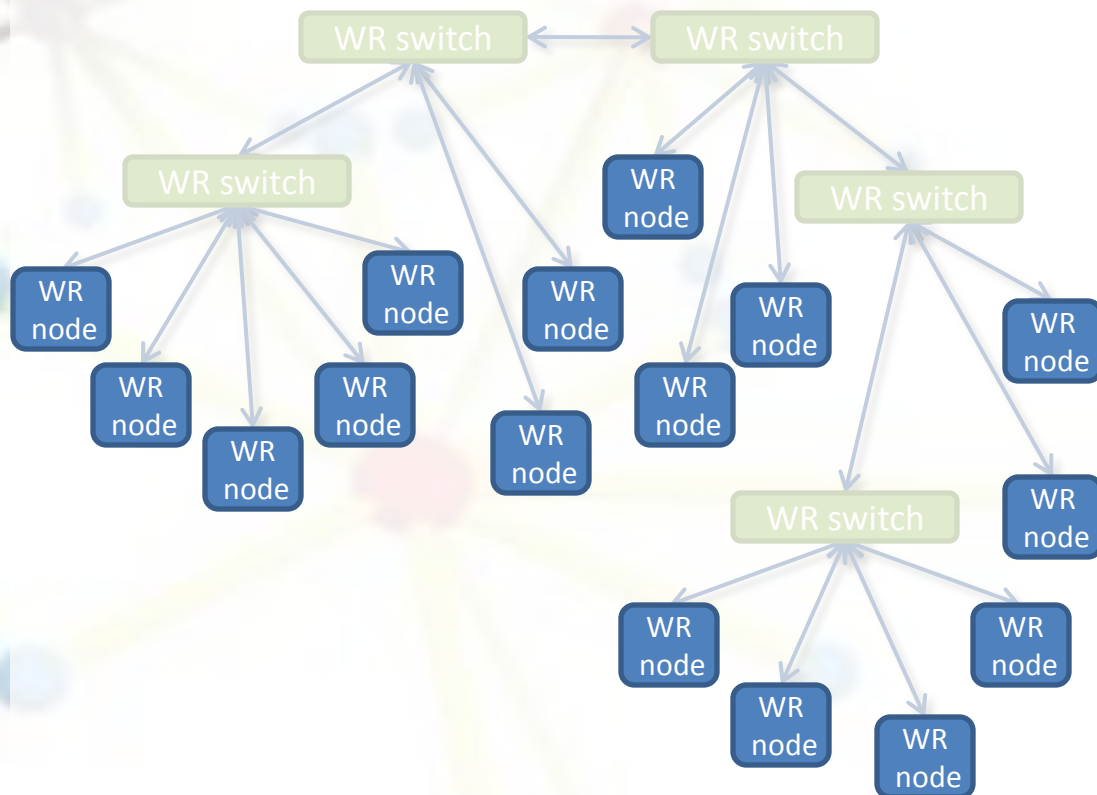
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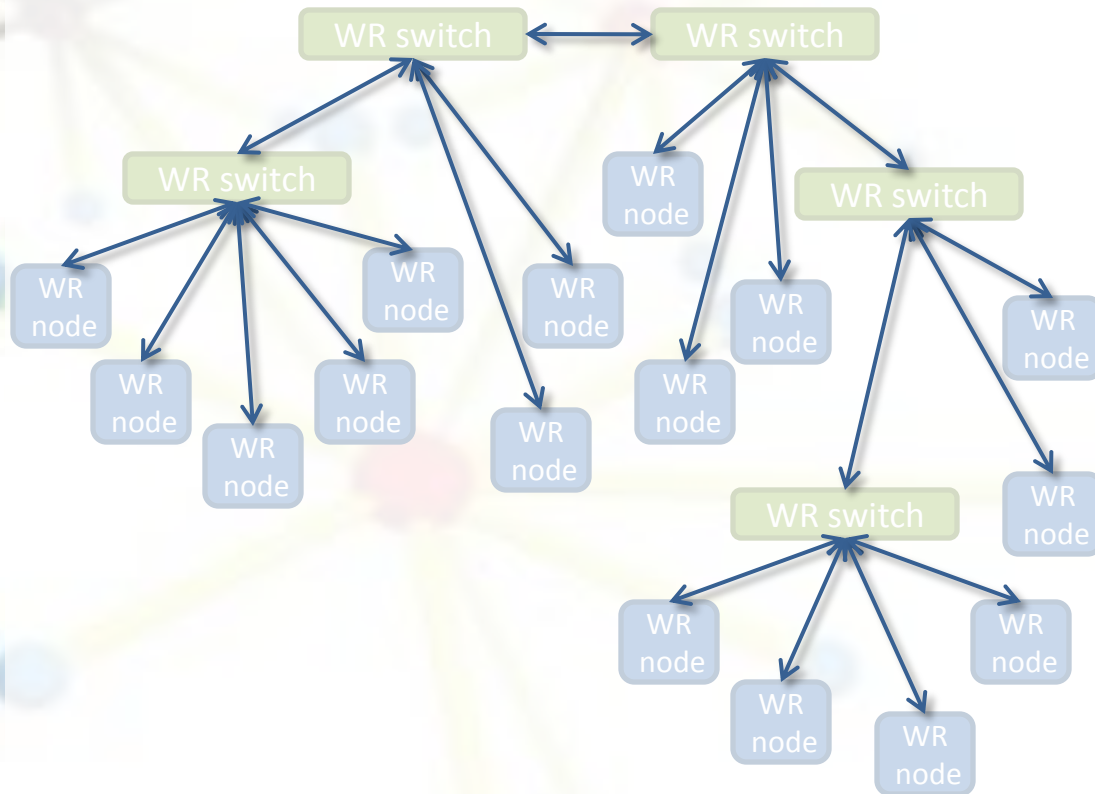
Ethernet

Ethernet

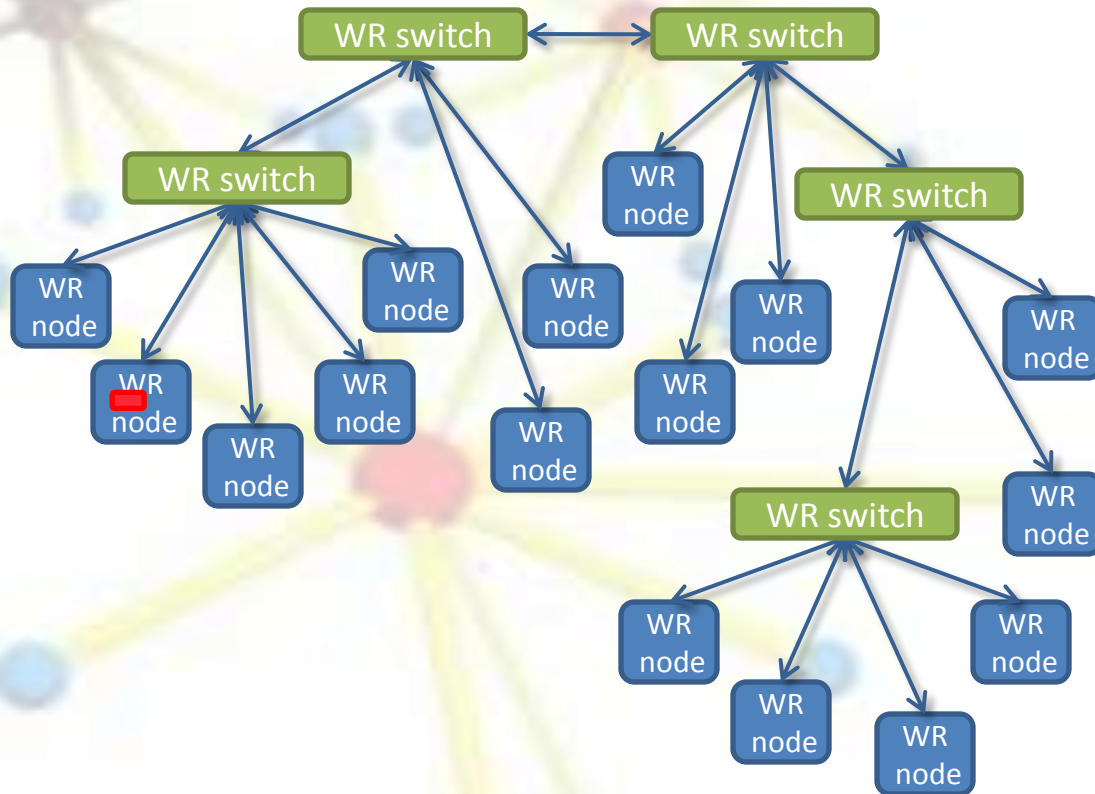o Up to 2000 nodes

Ethernet

- o Up to 2000 nodes

- o Copper or fiber medium

- o Up to 10 Km fiber links
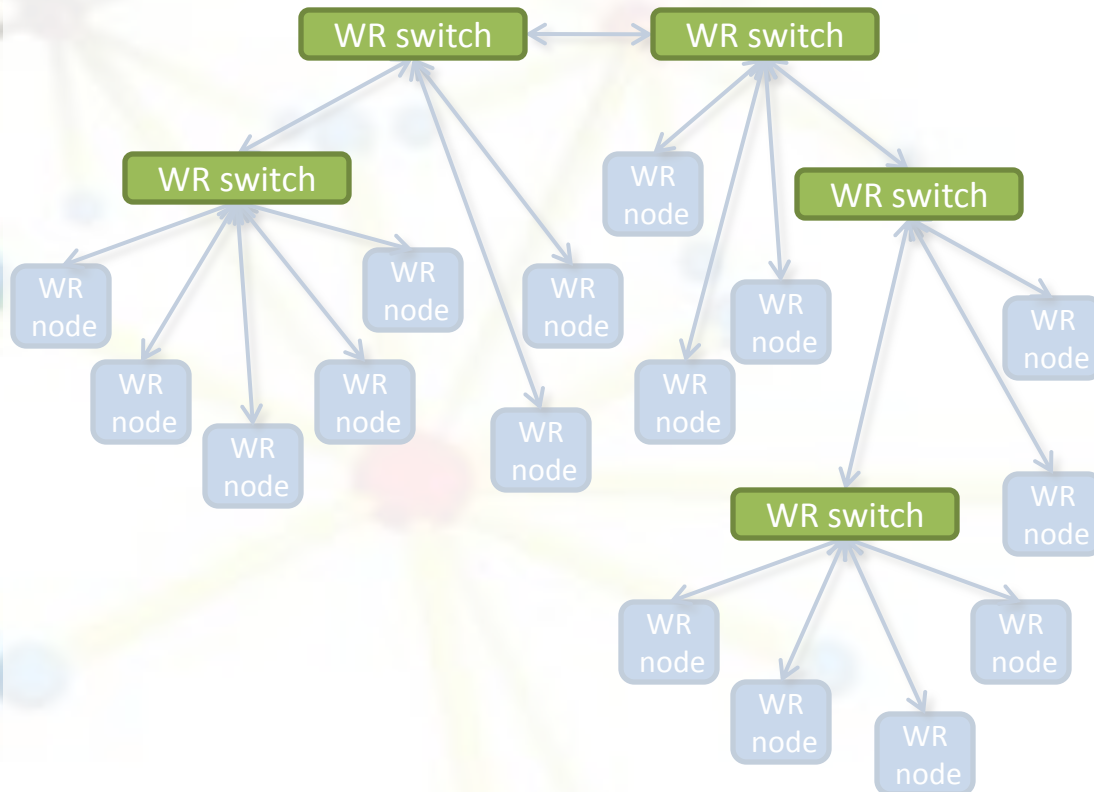
Ethernet

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- Bandwidth: 1 Gbps

Ethernet

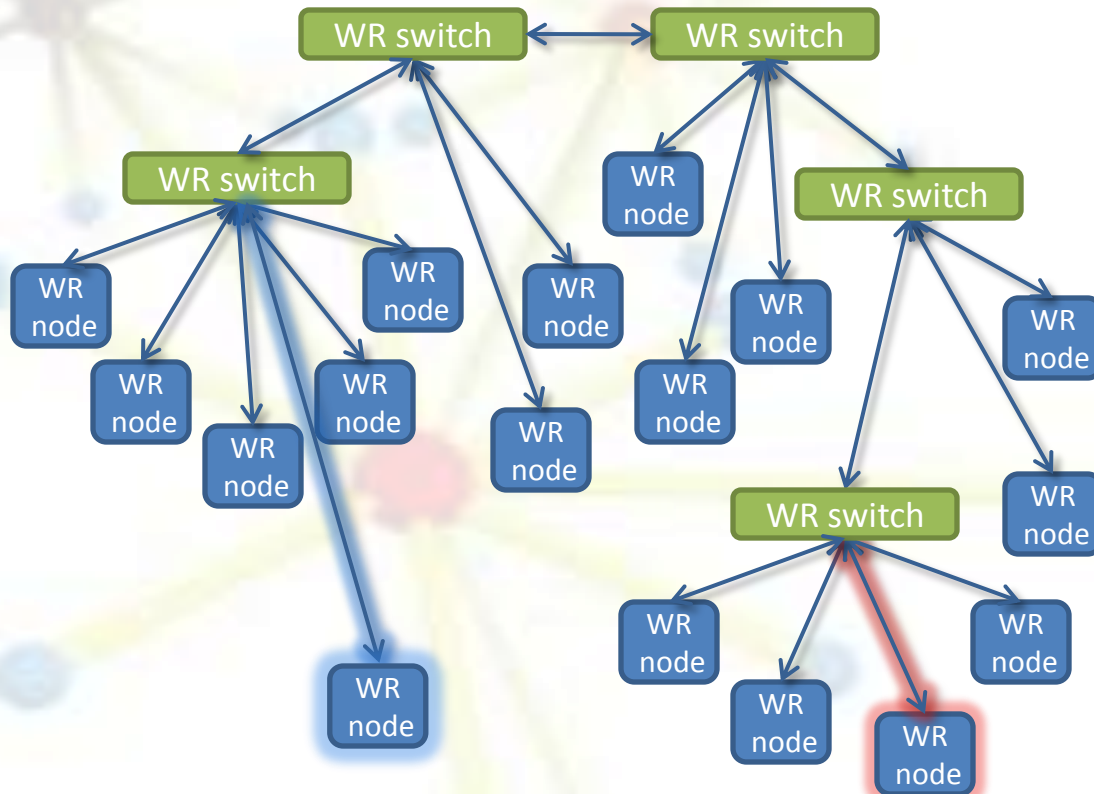- Up to 2000 nodes
- Copper or fiber medium
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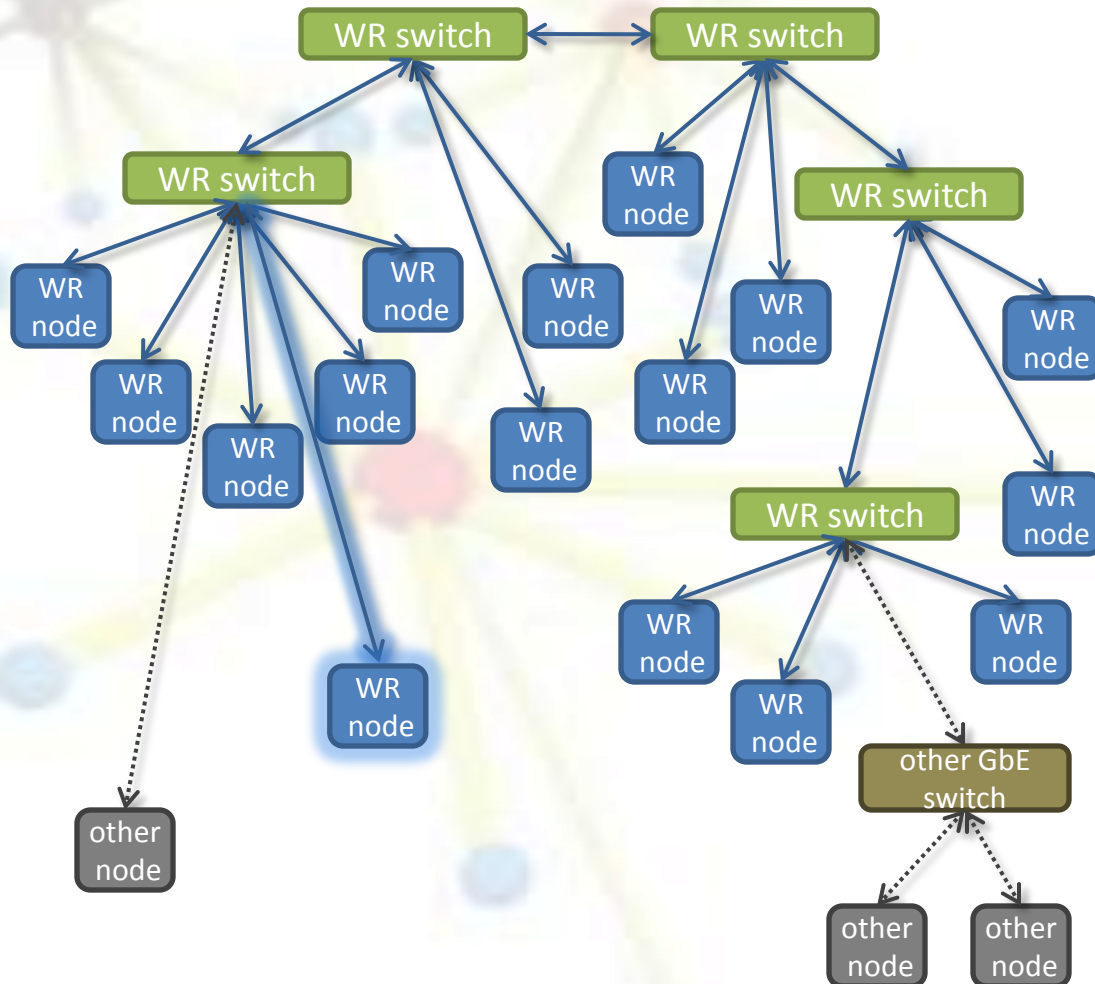- Bandwidth: 1 Gbps
- WR switch: 18 ports

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Ethernet

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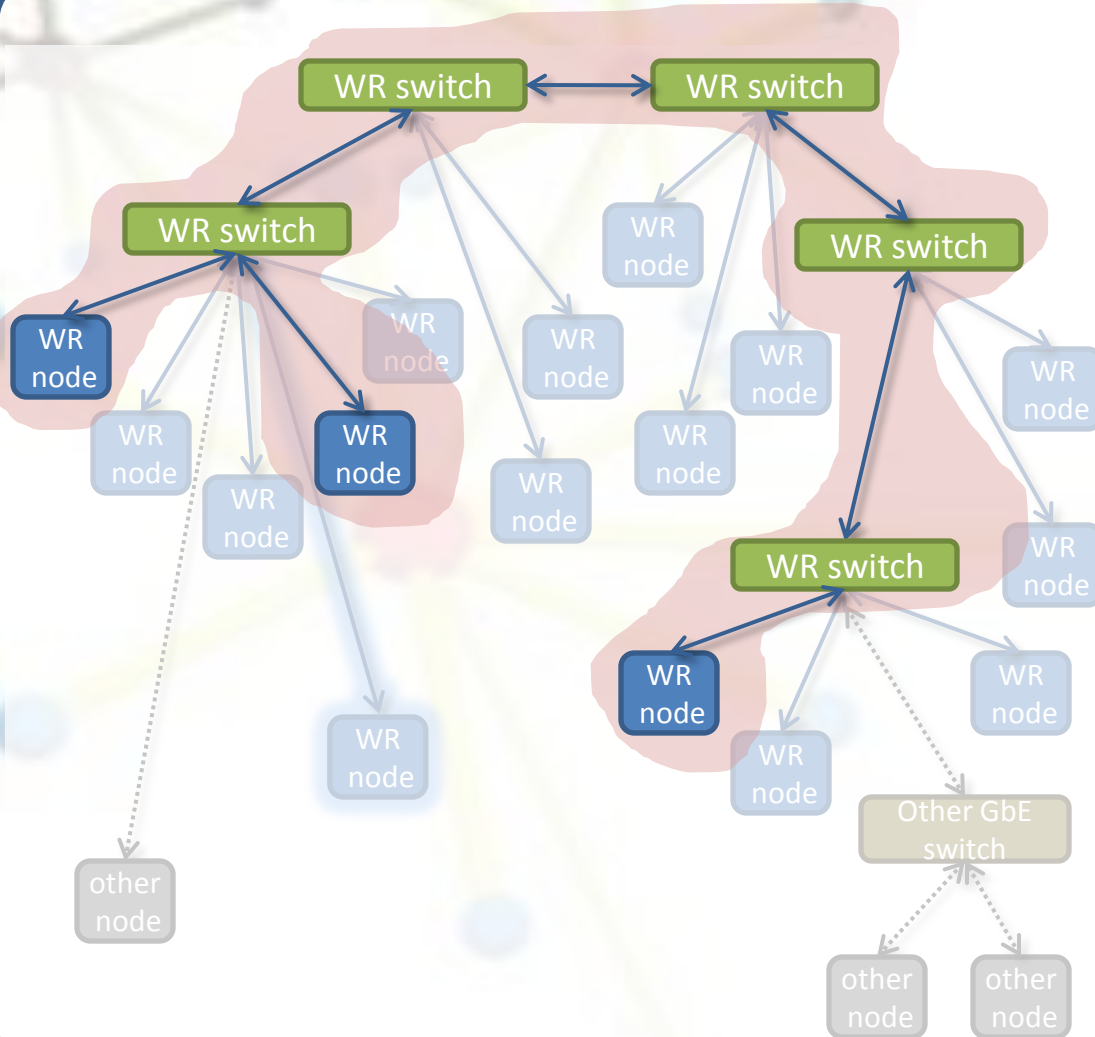- Up to 10 Km fiber links
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Ethernet

- o Up to 2000 nodes
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- o Up to 10 Km fiber links
- o Bandwidth: 1 Gbps
- o WR switch: 18 ports
- o Add/ Remove nodes dynamically
- o Non WR devices
- o Ethernet Features (VLAN) & Protocols (SNMP)

What is White Rabbit
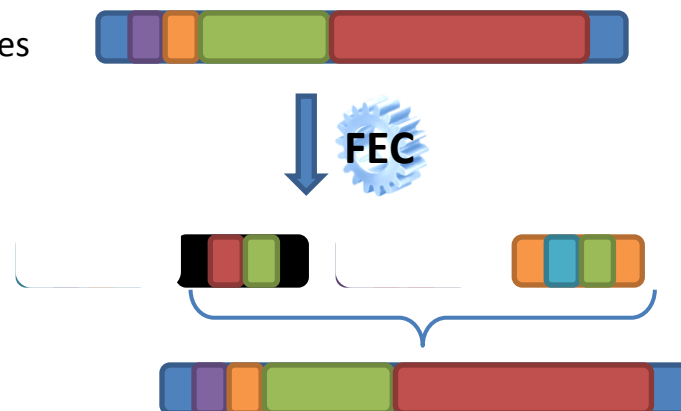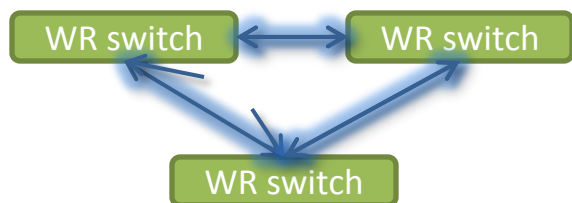
White Rabbit is:

Ethernet

+ Determinism & Reliability

+ Synchronization

Deterministic & Reliable

o **Determinism** is the guarantee that packet transmission delay between two stations will never exceed a certain **boundary.**

o The upper bound delay latency can be **verified** by analyzing the **publicly available** source code.

o **Reliability** is the ability of a system to provide its services to clients under both **routine** and **abnormal** conditions. White Rabbit ensures reliable services by supporting:

   o **Topology Redundancy**

   o **Data Resilience** with Forward Error Correction schemes

What is White Rabbit

White Rabbit combines:

Ethernet

+ Determinism & Reliability
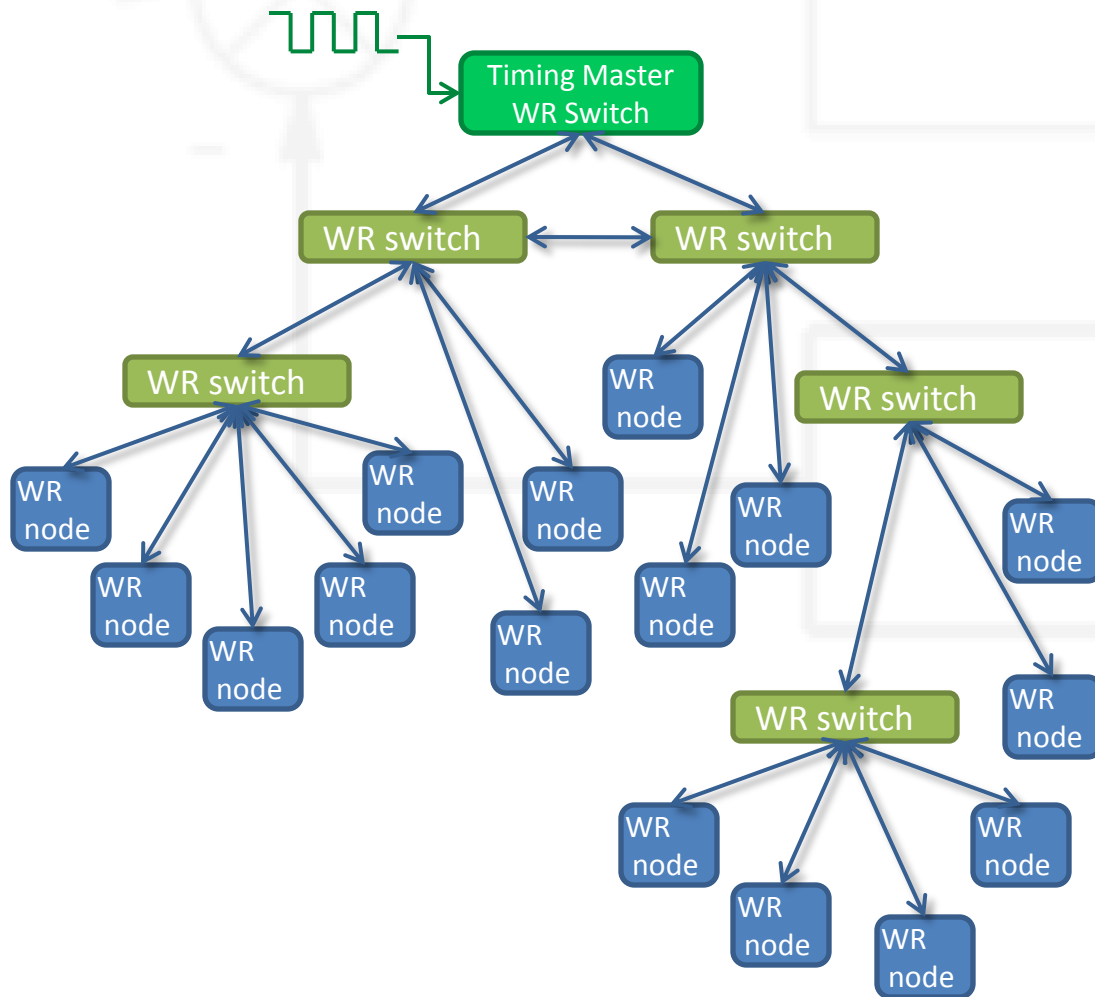
+ Synchronization

Synchronization

- Synchronization: common notion of time in the entire network

- In White Rabbit sub-nanosecond synchronization is achieved in parallel and transparently to the data exchange

- Two main technologies are used together:

  - **Synchronous Ethernet** (SyncE)

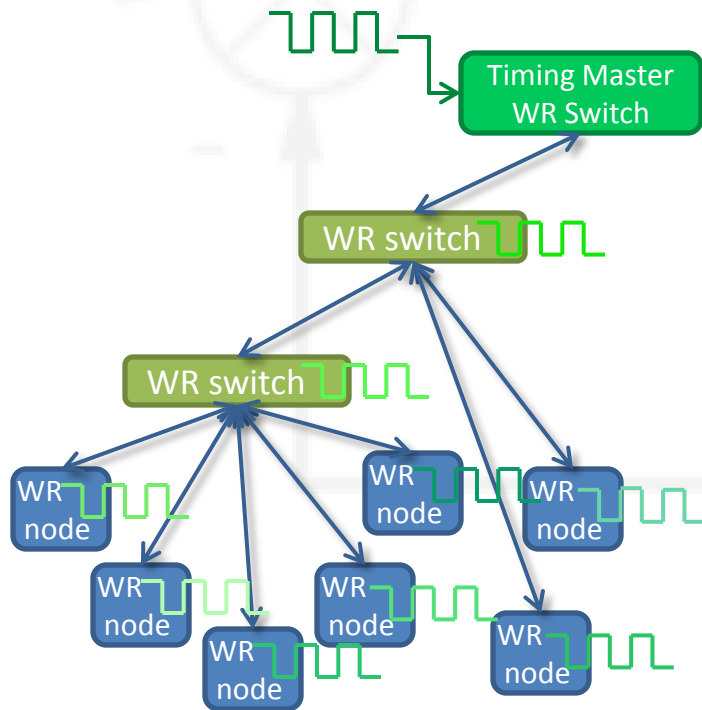 - **White Rabbit Precision Time Protocol** (enhanced PTP)
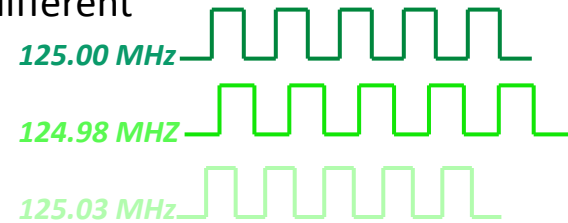
Syntonization with SynchE

Timing Master WR Switch

WR switch

WR switch

WR node

WR node

WR node

WR node

WR node

WR node

WR node

WR node

o The individual clocks of the nodes/ switches can be slightly different
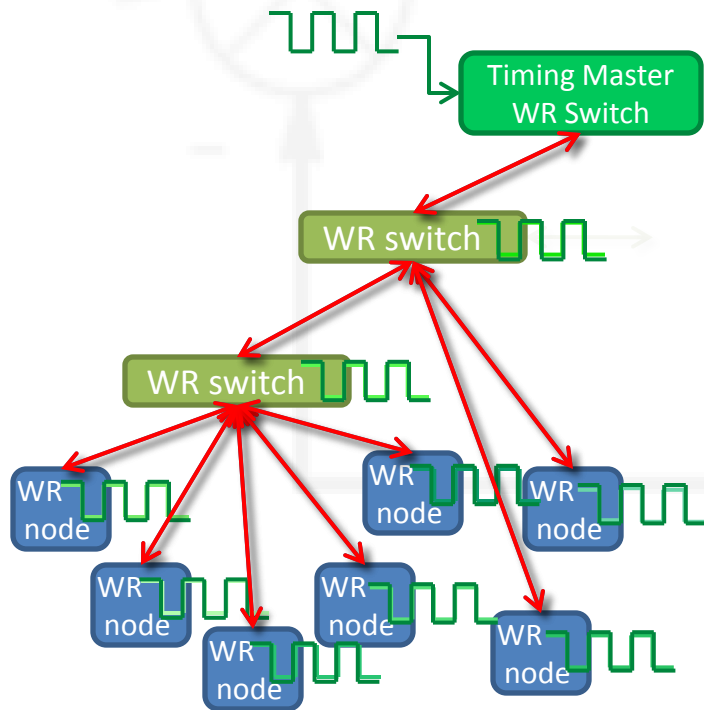
125.00 MHz

124.98 MHZ

125.03 MHz

Synchronization

Syntonization with SynchE

o All the network devices have the same frequency!

125.00 MHz
125.00 MHz
125.00 MHz

o With SyncE all network devices manage to have the same clock, generated by the System Timing Master

o The clock is encoded in the Ethernet carrier and recovered by the PLL of the PHY; no extra traffic cost!

o Common notion of **frequency**

Synchronization
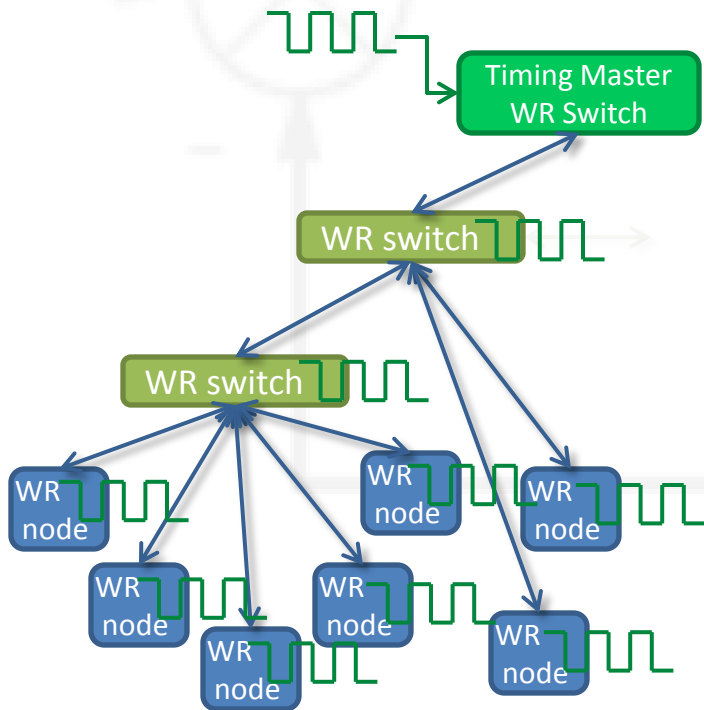
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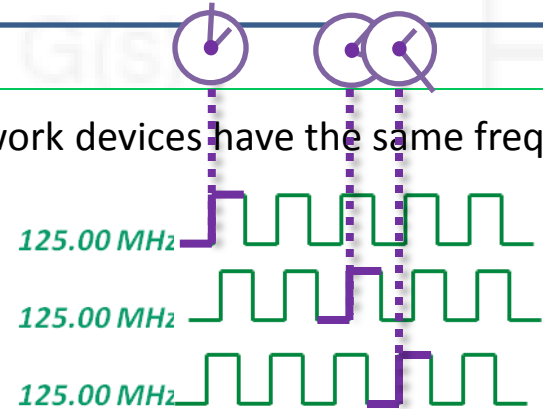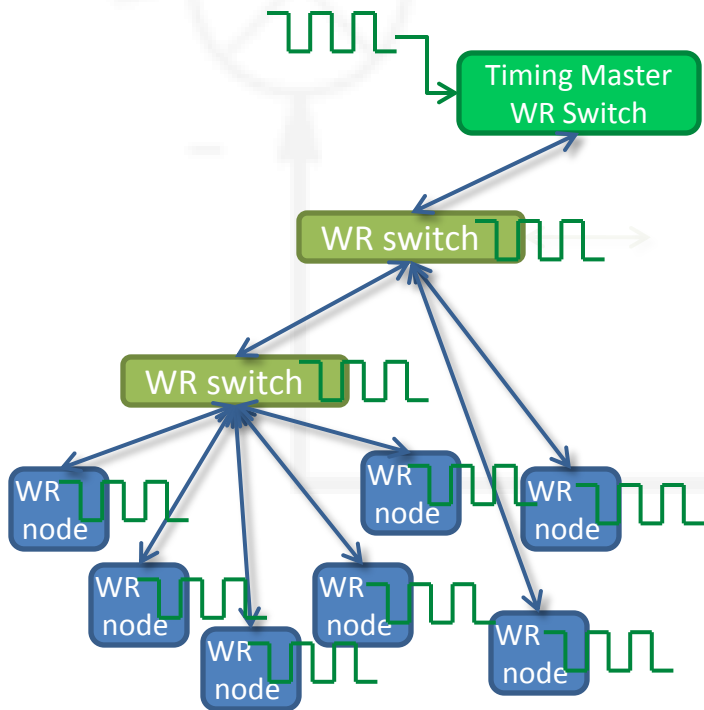
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- However, there are offsets between the clocks!

Synchronization

Syntonization with SynchE

Timing Master
WR Switch

WR switch

WR switch

WR node

WR node

WR node

WR node

WR node

WR node

WR node

o All the network devices have the same frequency!
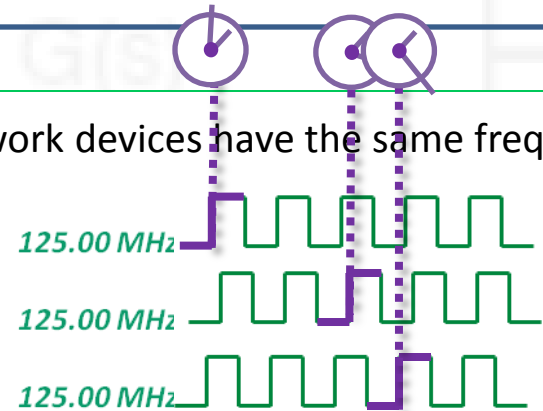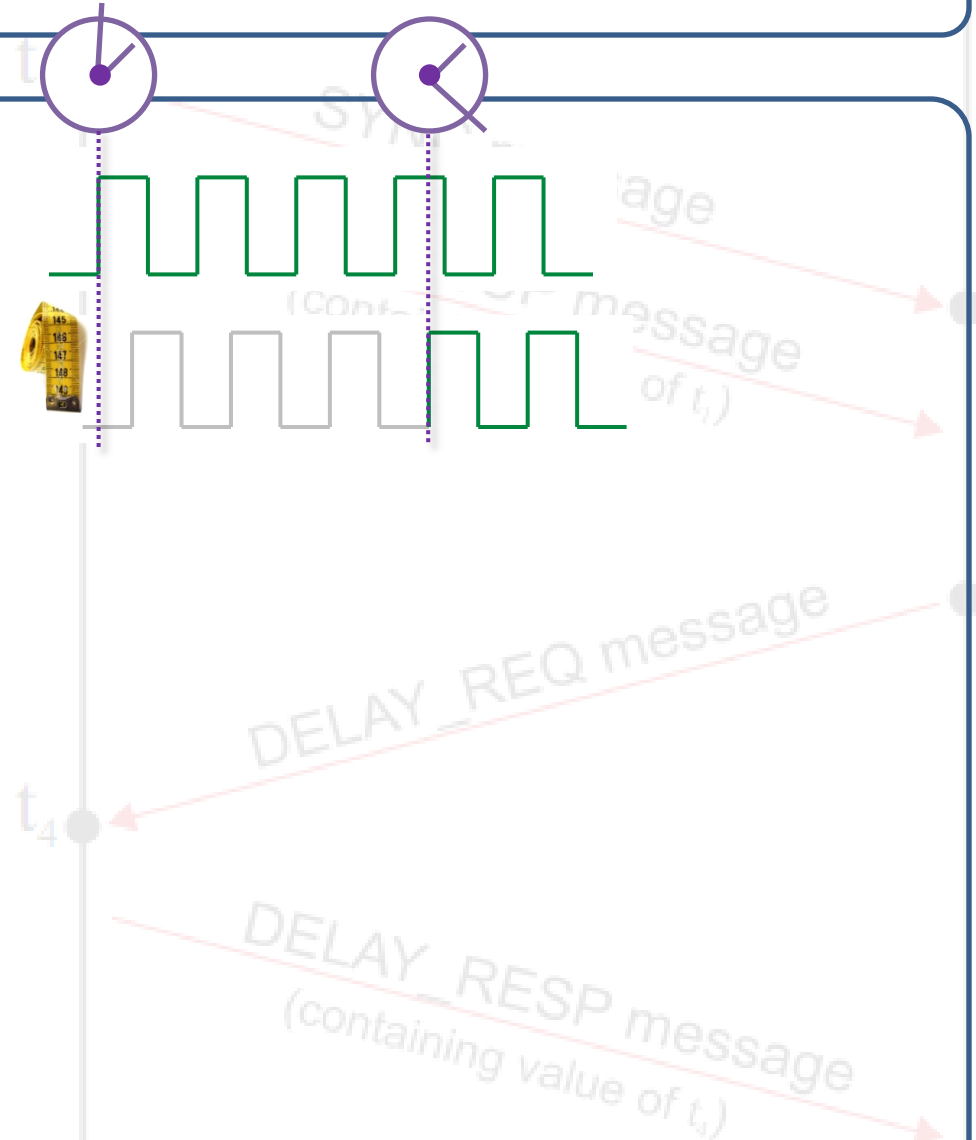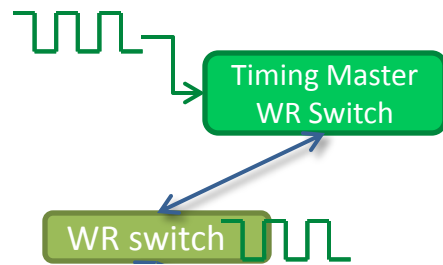
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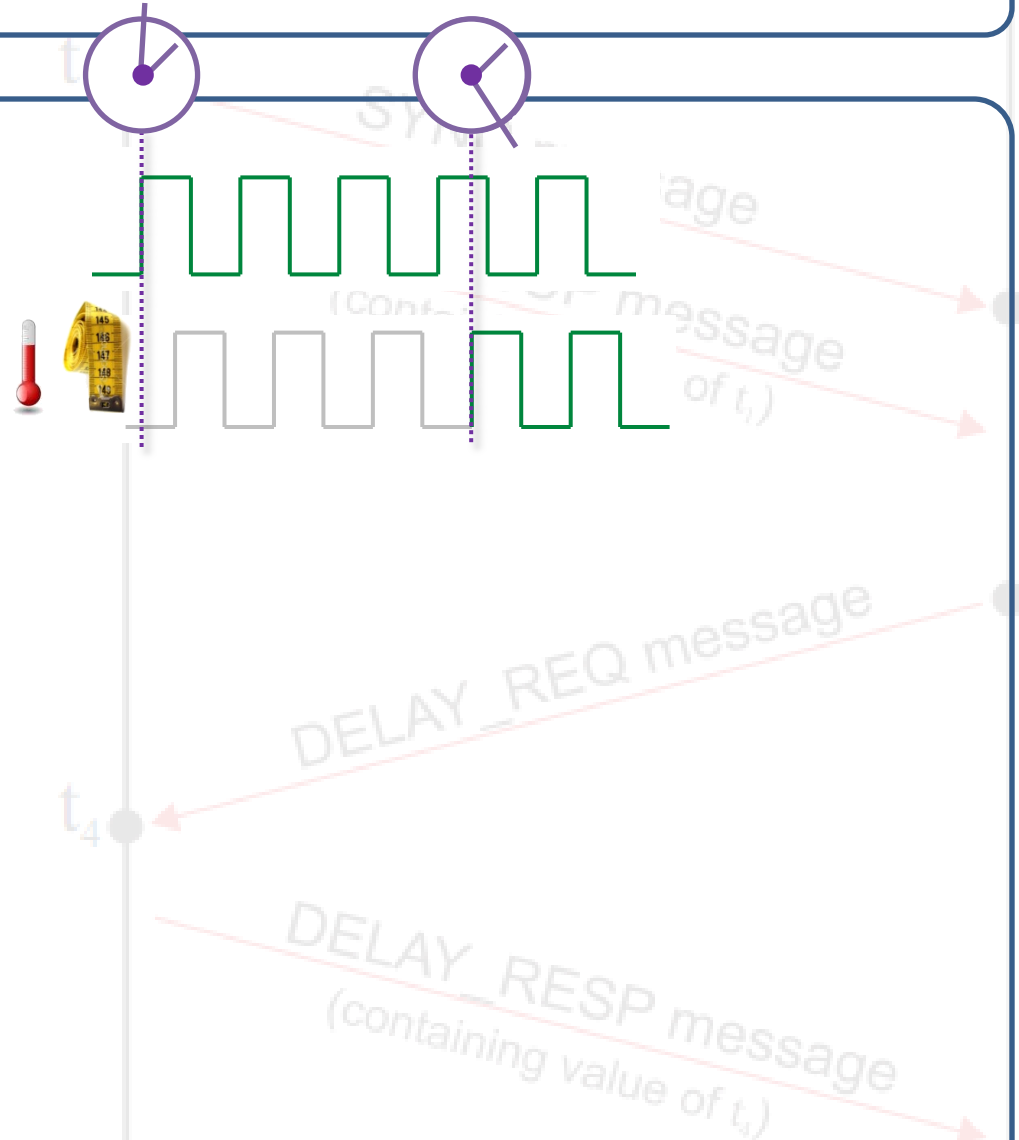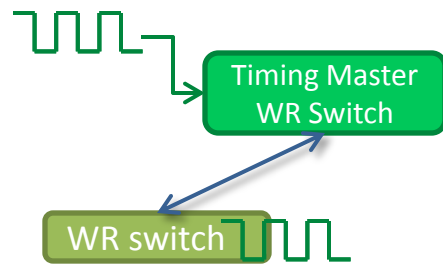# Offset Adjustment with Enhanced Precision Time Protocol

Timing Master
WR Switch

WR switch

t_4

DELAY_REQ message

DELAY_RESP message
(containing value of t_3)

Offset Adjustment with Enhanced Precision Time Protocol

Timing Master WR Switch

WR switch

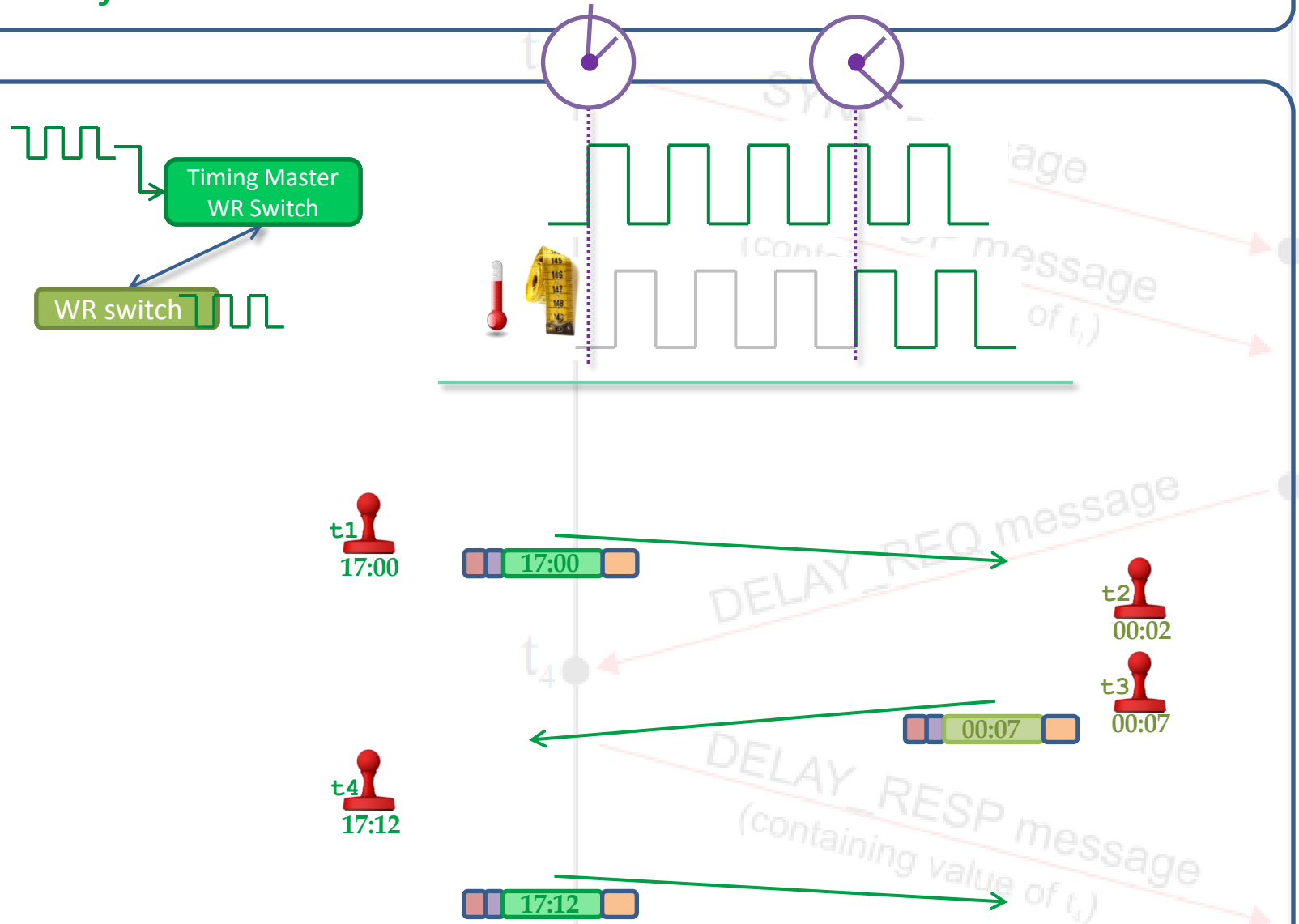DELAY_REQ message

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Offset Adjustment with Enhanced Precision Time Protocol

Synchronization

Offset Adjustment with Enhanced Precision Time Protocol

Timing Master WR Switch

WR switch

Timing Master WR Switch

WR switch

t1
17:00

17:00

t2
00:02

t3
00:07

t4
17:12

17:12

Timing Master
WR Switch

WR switch

WR switch

$$offset = t_2 - t_1 + \delta_{ms}$$

$$\delta_{ms} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2}$$

17:00

t2
00:02

t3
00:07

17:12

Timing Master
WR Switch

WR switch

SYNC message

(containing value of t_1)

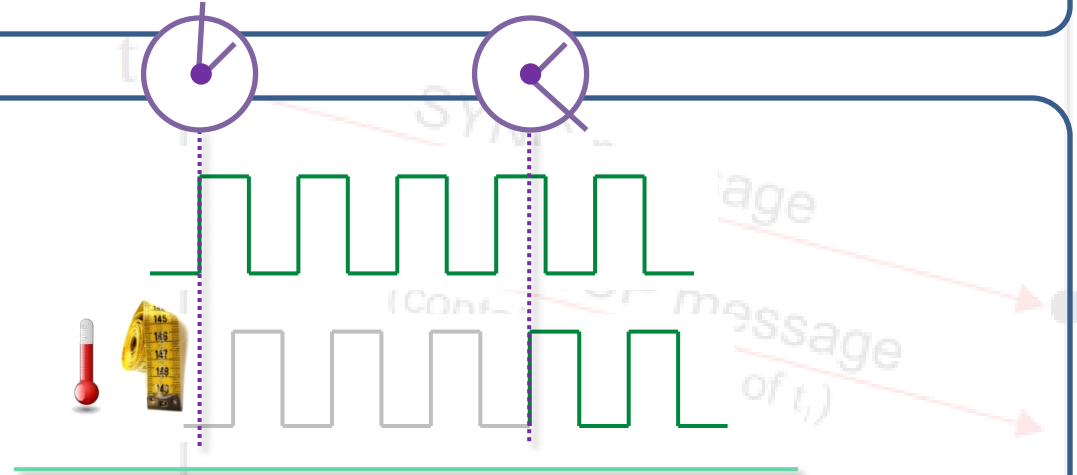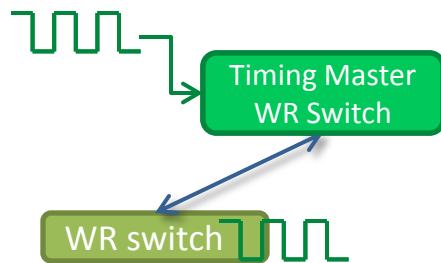DELAY_REQ message

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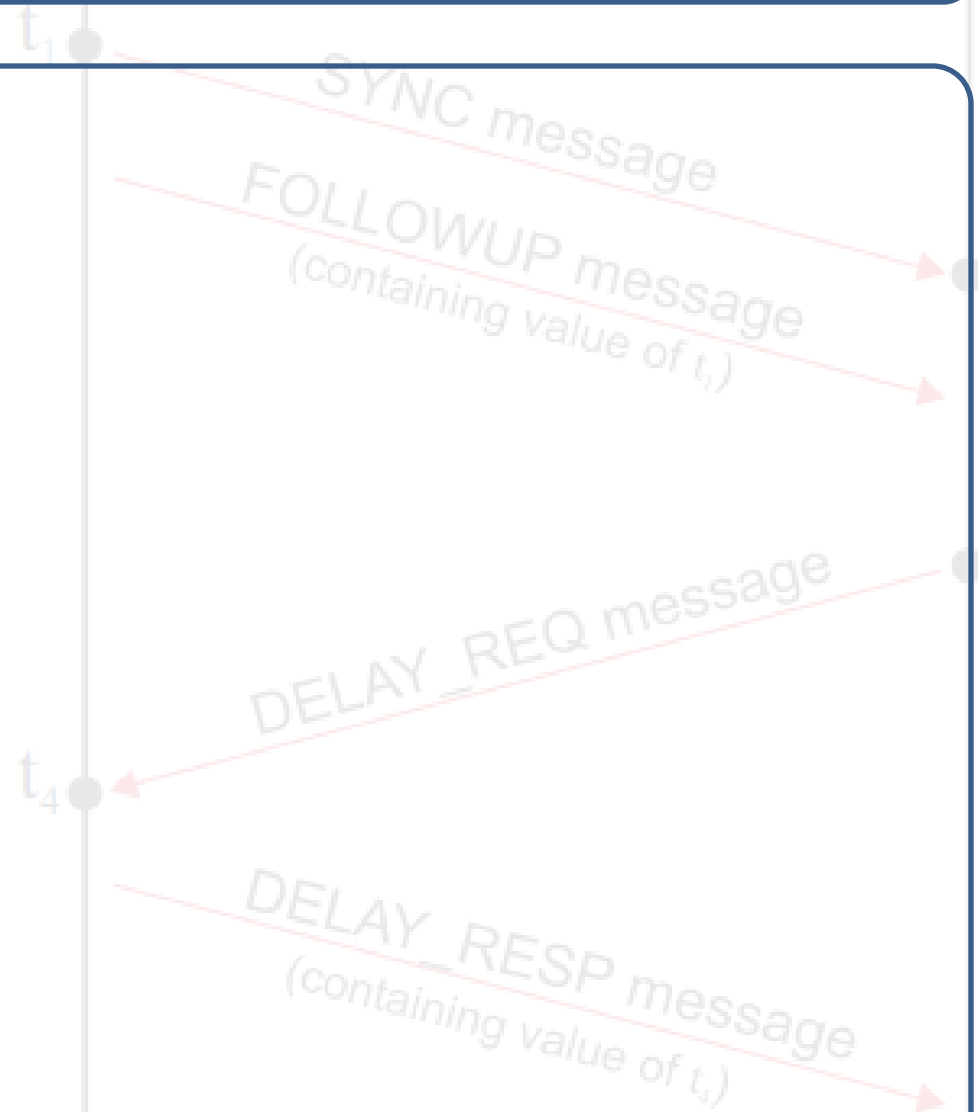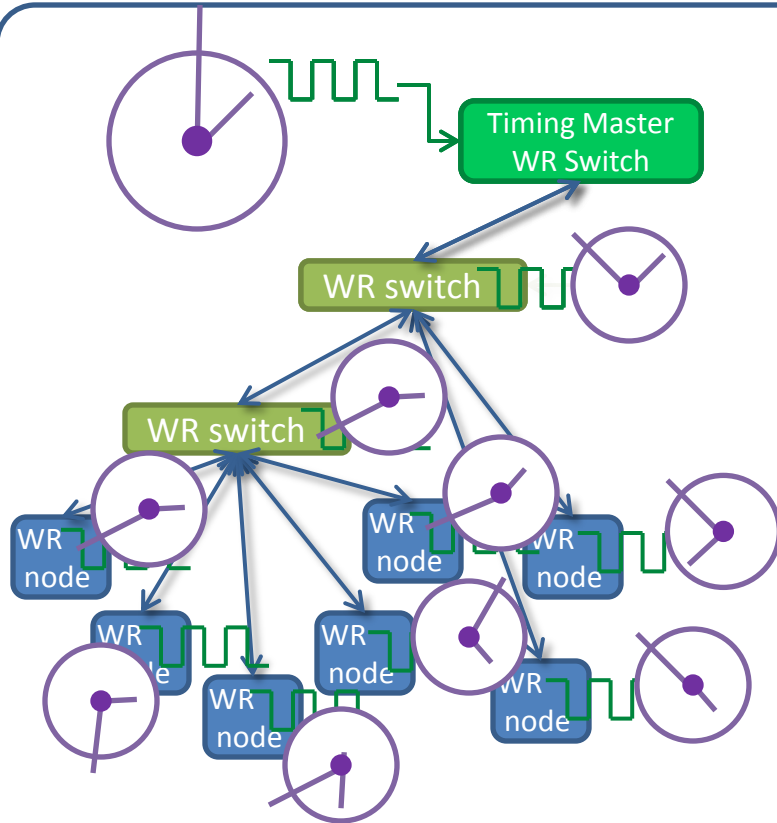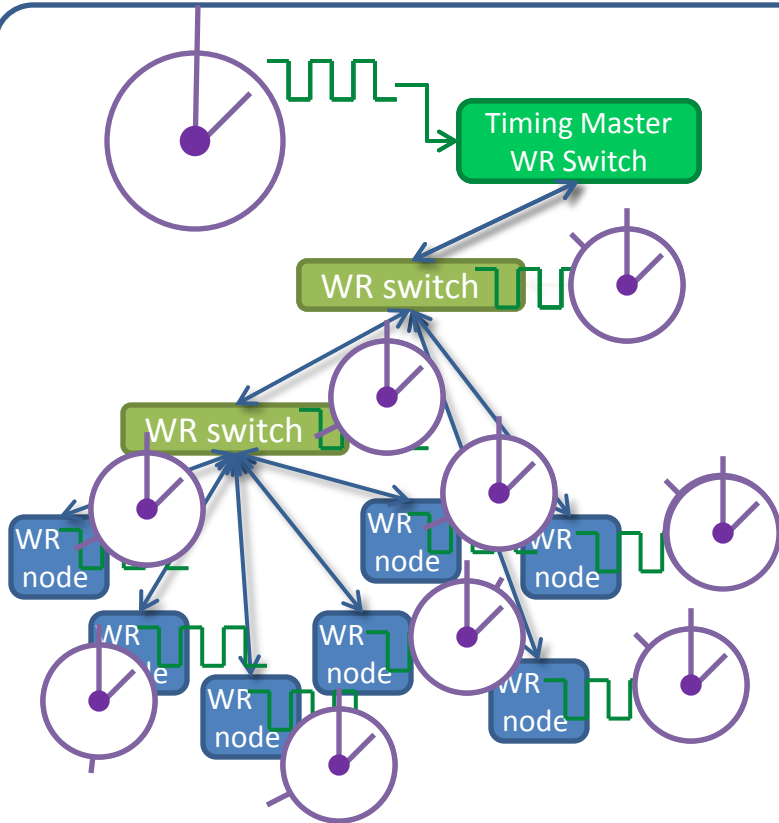- o PTP synchronizes the local clocks with the master clock by measuring and compensating the delays introduced by the link.
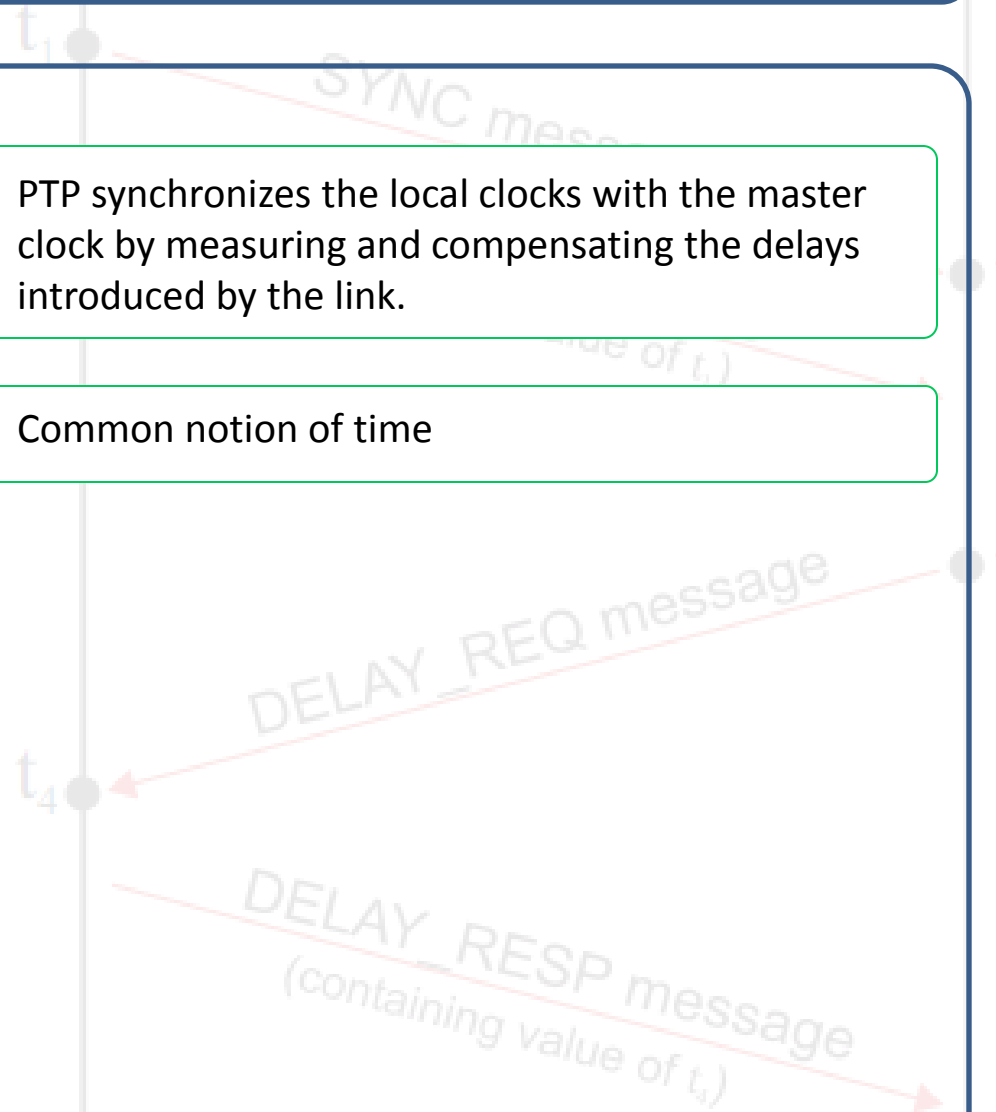
- o Common notion of time

What is White Rabbit

White Rabbit provides:

- o a large scale **monitoring and control network** with all nodes **synchronized** (sub-ns)

- o a scalable and modular platform that **reconfigures automatically**

- o **deterministic** & **robust delivery** messages

sensor

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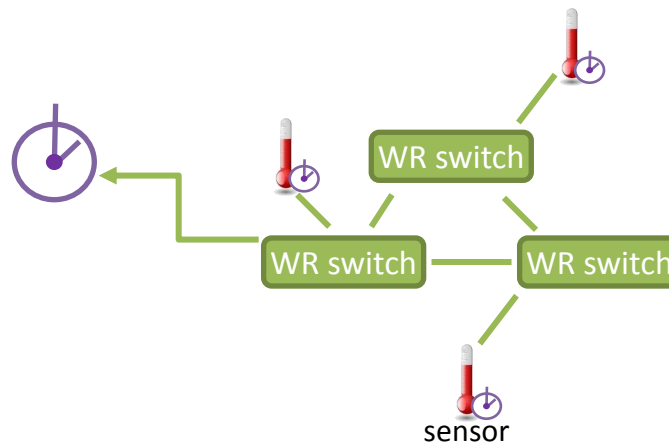WR switch

PXI crate

actuator

sensor

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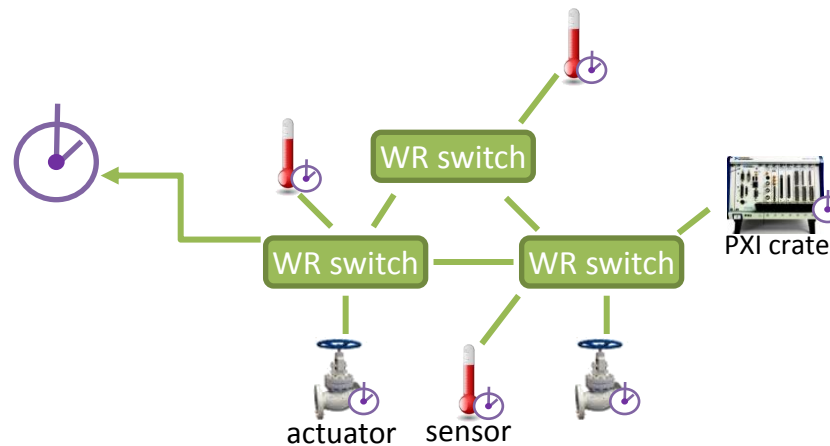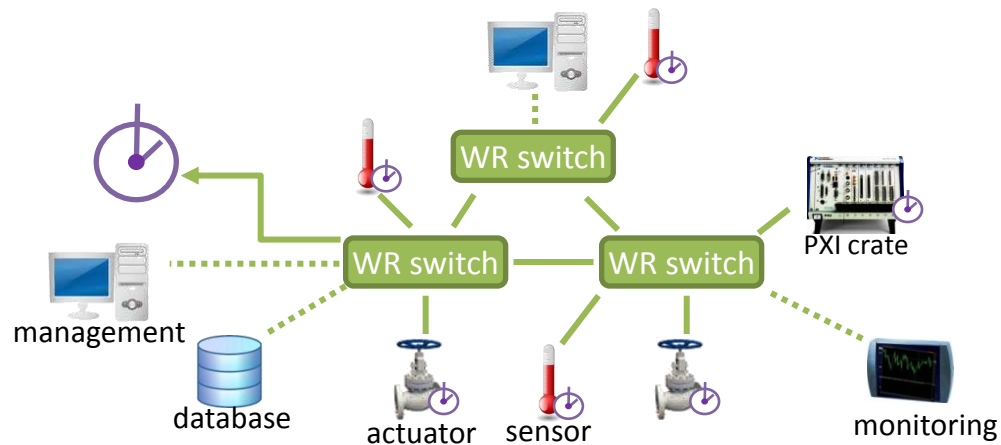- **deterministic** & **robust delivery** messages

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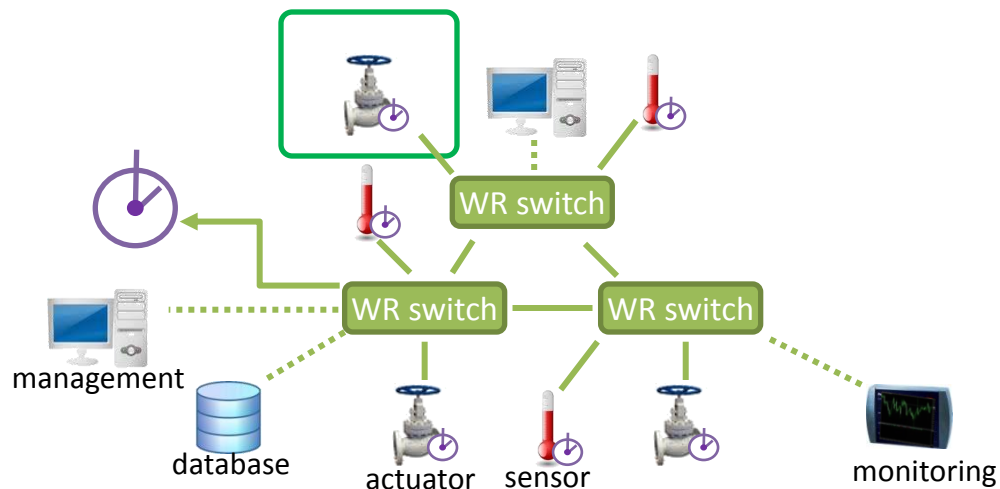- **deterministic** & **robust delivery** messages

WR switch

WR switch WR switch

management

database

actuator sensor monitoring

Outline

o Introduction to WR & Technology Overview

o Implementation & Support

o Cost Analysis

o Conclusions

Implementation & Support

○ White Rabbit technology will be made of commercially available **off-the-shelf network gear;** the **components** of a WR network will be offered through the catalogues of companies

○ CO will provide a **local knowledge hub** for CERN users with reference designs, documentation, linux SW; technical support will **also** be provided by the **companies**

A White Rabbit network is composed of

WR Switches	WR switch	
WR Nodes	WR node	IP core
WR Timing Master	Timing Master WR Switch	
Copper/ Fiber links		

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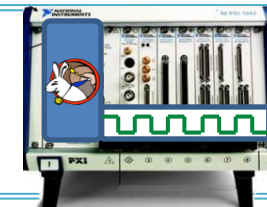
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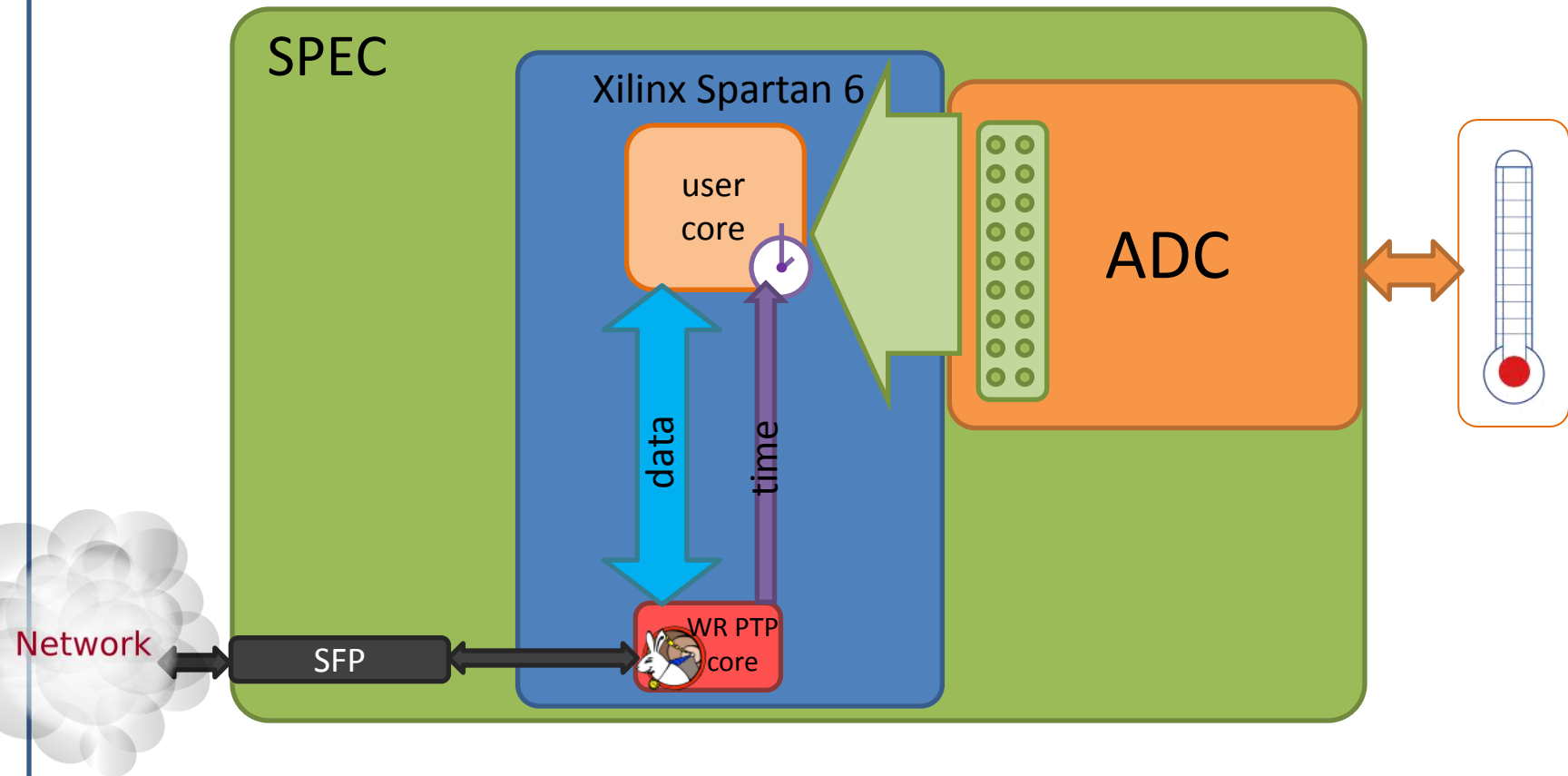|	
WR Switches	WR switch
WR Nodes	WR node · IP core · SPEC ADC · DAC ⋯ TDC
WR Timing Master	Timing Master WR Switch · WR switch · WR node
Copper/ Fiber links	same optical link used for transmission/ reception

An example application

SPEC

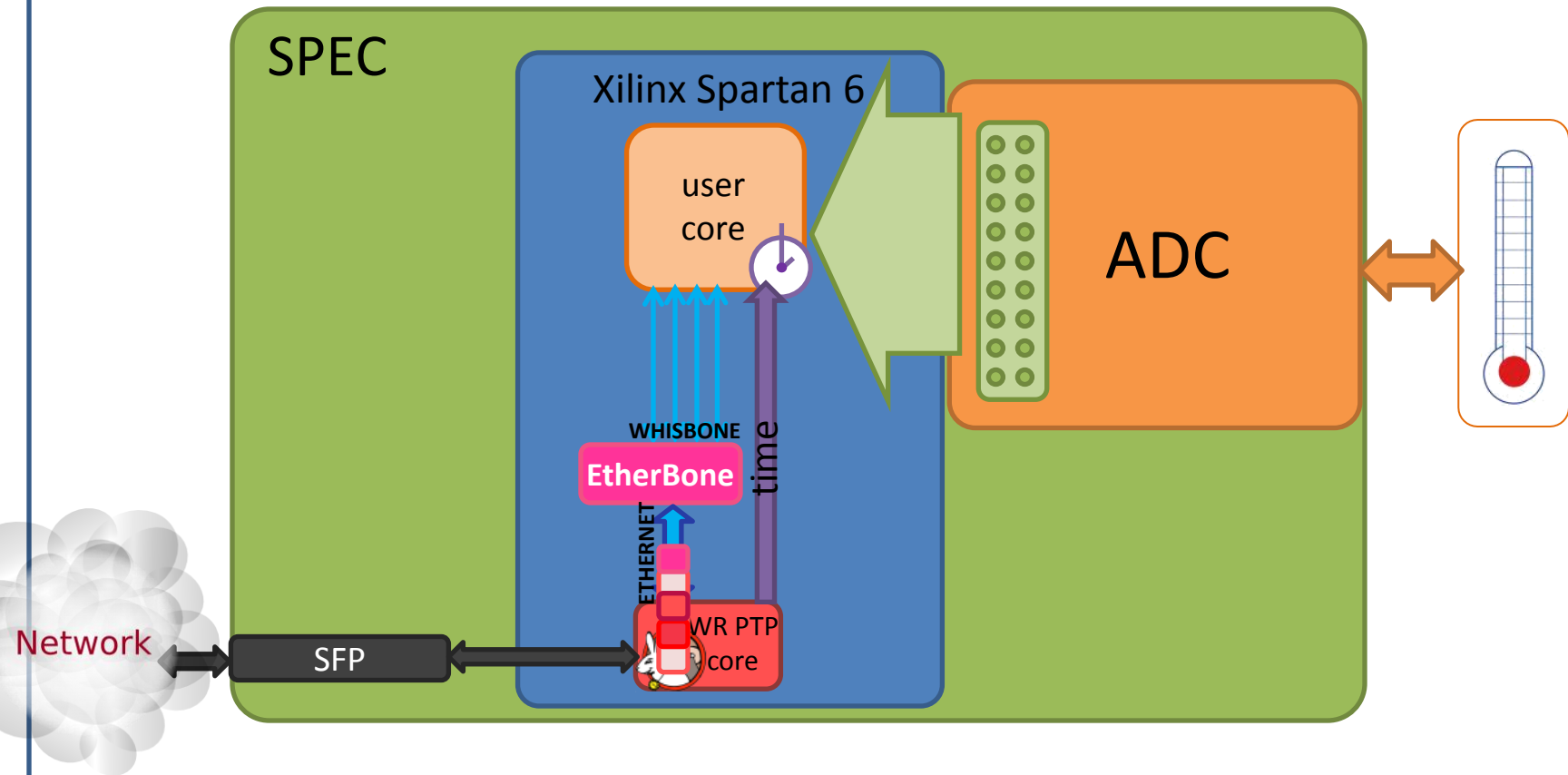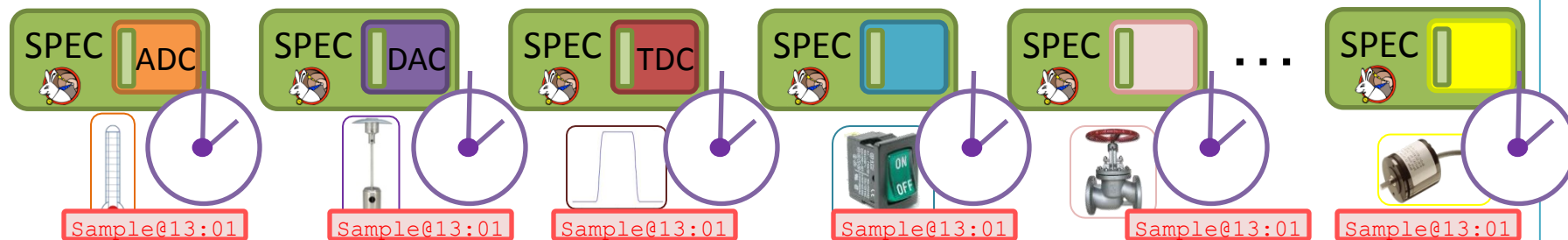# An example application
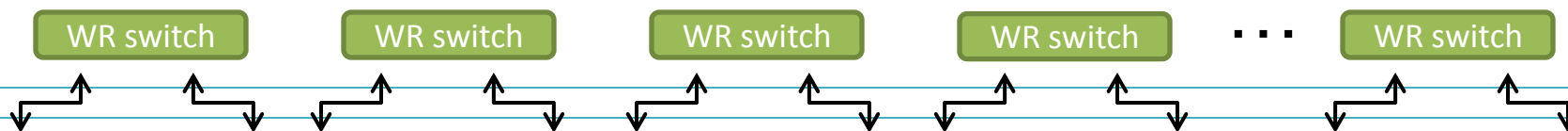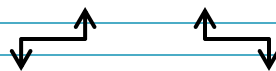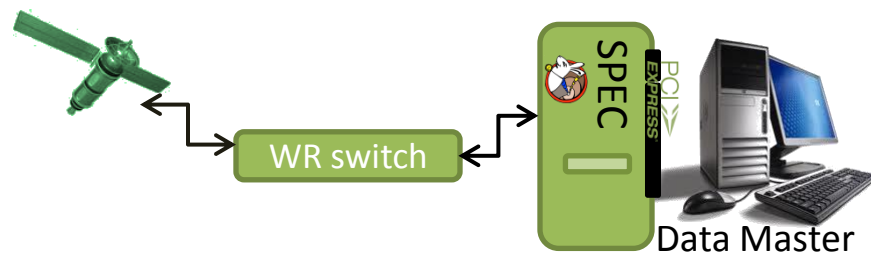
An example application

An example application

Outline

Components Costs

White Rabbit network components costs

- WR Switch — `WR switch` — 3K CHF

- WR Node — `WR node` — 0 CHF
  - SPEC board — `SPEC` — 1K CHF
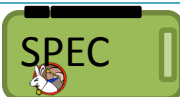
- Fiber links — < 1 CHF/ m

White Rabbit VS standard PTP

	# 1Gb SFP Ports	Technologies Used			Accuracy	Price (CHF)
		SyncE	PTP	HW timestamps		
○ CISCO Nexus 5548	32	NO	YES	NO	sub ms	19K
○ Hirschmann MACH1000	16	NO	YES	YES	30 ns	5K7
○ Ruggedcom RSG2288	9	NO	YES	YES	1 us	17K
○ White Rabbit	18	YES	YES	YES	sub ns	3K

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o Media Markt	18	NO	NO	NO	?	0.2K

Maintenance Costs

- Network **Configuration** & **Management** through standard Ethernet protocols (SNMP, MIB)

- Use of **well-established tools** (Wireshark with WR pluggin)

- Any unexpected behavior can be **diagnosed** by verifying the source code or simulating the use case; if necessary **modifications** can be implemented

Outline

"Oh dear! Oh dear! I shall not be too late!"

- **Deterministic** and **Reliable** Ethernet

- Offering transparently sub-ns **synchronization**

- **Easy** to use; well established standards

- **Support** by companies and internally at CERN
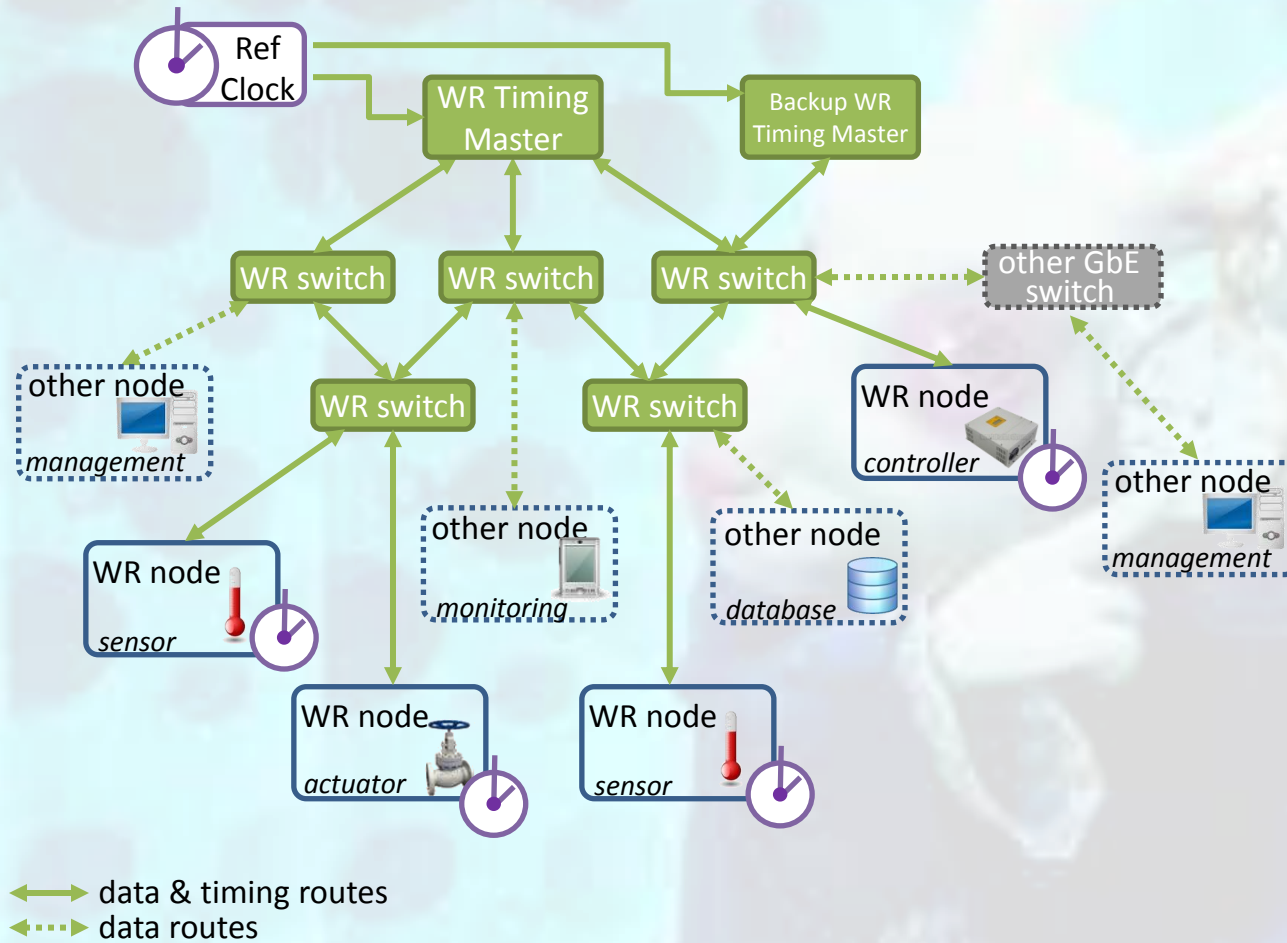
- **Guaranteed** and **risk free** solution with publicly available source code

Extras

White Rabbit network

White Rabbit network

Ref. Clock → WR timing master → Backup WR timing master

WR switch, WR switch, WR switch

WR switch, WR switch, WR node

WR node, WR node

↔ data and timing routes