# Department of Transportation

# Agency/Docket Number:

# DOT-OST-2019-0051

**SUMMARY:**

**The U.S. Department of Transportation (DOT) is planning to conduct a field demonstration of technologies with a Technology Readiness Level (TRL) of six or higher, as described in the Federal Highway Administration *Technology Readiness Level Guidebook,*[1] that are capable of providing backup positioning, navigation, and/or timing services to critical infrastructure (CI) in the event of a temporary disruption to GPS. This demonstration effort also is expected to encompass technologies capable of providing complementary PNT functions to GPS by either expanding PNT capabilities, including cross checks, or extending them to GPS or Global Navigation Satellite System (GNSS)-denied or degraded user environments. DOT is issuing this Request for Information (RFI) to seek levels of interest and additional information from PNT technology vendors on participation in the demonstration. The information requested can be found in the supplemental information section of this RFI.**

**Submitted by**

**Seven Solutions S. L.**

**Calle Periodista Rafael Gómez Montero, nº 2.**
**CETIC-UGR 13 - 18014**

**Granada - SPAIN**

**Contact:**

**Francisco Girela Lopez**

**Francisco Girela <francisco.girela@sevensols.com>**

**408-981-2381**

**1. A description of the technology(ies) and CI application(s), including cybersecurity and other security measures inherent in the system, and if the technology(ies) is/are for timing only, location only, or both timing and location.**

The enclosed Seven Solutions offering is a timing only solution. This unique technology uses a standard based, new IEEE 1588-2008 v2, for distribution of time and frequency with sub-Nano-second accuracy. Seven Solutions has a 10-year history of producing high performance time transfer products and installing them in the Scientific and Metrology laboratory community.

Nowadays, there are many infrastructures classified as Critical Infrastructure, that are, in fact, depend on timing which in case of failure could have a catastrophic impact. Examples include nuclear reactors, power stations, financial networks (trusted timestamping), and critical telecom facilities.

It is Seven Solutions objective to demonstrate the capability to transfer an inference of time across many tens of kilometers allowing the interconnection of disparately located GNSS receiver sites so an algorithm could compare several instances of time, in mathematical terms a comparative ensemble, with such high precision any location can decide it its time is off enough to warrant a switching to a provided high precision alternative. This technique would render local jamming and spoofing activities moot.

The physical infrastructure of this time transport mechanism is hack proof since the actual transfer mechanism is a physical clock signal embedded within a chosen lambda. By using an infrastructure of redundant GNSS time receivers distributed and connected through redundant WR-PTP links with references scattered across hundreds of Km, the infrastructure can get the time references available from safe locations. In addition, the scheme fits the critical infrastructures most specific needs.

The solution offered here is explained in the following paragraphs. It is based upon a technology named White Rabbit.

**White Rabbit Precision Time Protocol (WR-PTP)**

The White Rabbit Protocol has the purpose of improving the IEEE 1588 PTP (Precision Time Protocol) for adapting it to the requirements of the particle accelerator industry. This technology has been in use by CERN for several years. It is a multi-collaborative project led by the European Organization for Nuclear Research (CERN) with participation of GSI Helmholtz Centre for Heavy Ion Research and other partners from universities and industry. The WR initial goal was to develop a new timing and control system at CERN, and later at the Facility for Antiproton and Ion Research (FAIR) in GSI for reliable data transfer and ultra-accurate time synchronization. Other participants as University of Granada are porting WR-

PTP to Astrophysics applications in the framework of array of Telescopes. To achieve this, WR is based on Synchronous Ethernet (Standard ITU-T SG15Q13 G.8262) and IEEE 1588-2008, Precision Time Protocol (PTP), and fully compatible with these ratified standards. The enhancements introduced by WR can be summarized as follows:



• Synchronization and timestamping with sub-nanosecond accuracy.

• Clock frequency distribution with a precision better than 50 picoseconds.

• Distribution through thousands of nodes and tens of kilometers over standard optical fiber networks. Specific network configuration is required for larger distances.

• Dependable and deterministic global time reference. Timing is not significantly affected by network traffic, weather conditions or number of hops.

Using WR, the facilities above mentioned obtained reliable data transfer and improved the synchronization of thousands of nodes with sub nanosecond accuracy. Currently, numerous and important scientific and industrial facilities have already started to incorporate the WR components to distribute ultra-accurately timing and data in tens of countries.

The increasing requirements of time synchronization on different markets as finance and telecom has led to the development of a new High Accuracy profile, which is intensively based on White Rabbit technology, that will be included on the standard IEEE 1588 (PTP) v2.1 revision.

The default version of White Rabbit allows plug-and-play links up to 10 kilometers with sub-nanosecond accuracy. Due to that, this technology has been adopted by many datacenter-centric applications as finance, where clock synchronization accuracy is used for traceability reasons and for enhanced trading strategies. For example, this technology has been adopted by Deutshe Börse stock exchange in Frankfurt to synchronize all their network capture and timestamping devices and offers this data to their customers as well as a clock reference aligned to the stock exchange reference. In this sector, several companies already trust in this technology as their main network synchronization mechanism, distributing a time reference between the multiple locations where their trading systems are placed that allows to correlate timestamps, legally trace the events and to enable a back-up reference in case of GPS malfunctioning.

Datacenter companies are also pursuing better synchronization performance in their networks as a result of the increasing demand of on-the-cloud services which are distributed in servers placed in several locations inside one datacenter or in different datacenters.

In the framework of telecommunication or broadcasting networks, packet-based synchronization is used for timing dissemination to reduce the GNSS dependency, the associated costs and to improve timing performance.  In example, Fifth Generation (5G) technologies demand more strict synchronization requirements between 110 and 12.5

nanoseconds and, at the same time, require advanced capabilities related to reliability and redundancy.

Another critical sector which requires accurate time information is electrical power grids. New smart grids include synchronophasor where data is time sensitive and requires very accurate synchronization mechanism for event timestamping. Additionally, timing information must be provided to the Power Management Unit (PMU) in a reliable way. These new conditions show that timing synchronization requirements are becoming more demanding for this kind of applications.

White Rabbit has been proved to be a resilient time backup to GNSS based sources and it is being used to distribute timing information through optical fibers using already deployed DWDM based networks. In this context, different European funded projects focus on pan-European White Rabbit based clock distribution for scientific and industrial applications as CLOck NETwork Services (CLONETS) or White Rabbit for Industrial Timing Enhancement (WRITE).

Another advantage of this innovative protocol is its capability to improve the reliability of the network. Reliability is defined as the probability of a device performing its intended function under given operating conditions and environments for a specified length of time, including abnormal circumstances. Then, a reliable distributed system should be able to make its functions even if the system is damaged. To do this, White Rabbit has well defined tolerance level that ensures the system reliability even in presence of complex interactions between the different nodes.

## White Rabbit RFI demo proposal

In order to show the White Rabbit technology synchronization capabilities in the Demonstration of Backup and Complementary Positioning, Navigation, and Timing (PNT) Capabilities of Global Positioning System (GPS) for the Department of Transport, Seven Solutions would be open to loan material (hardware and user equipment when applicable), provide technical support (technology deployment, configuration, and data collection support), and logistical support during the preparation and execution phases of the demonstration.

The demo deployment will include the following items:

- 1x DOWR
- 2x WR-ZEN TP family devices

The DOWR device will be used as the time server for the White Rabbit chain. This device includes a GPS receiver in order to retrieve time information and can be used as the timing reference in the design.

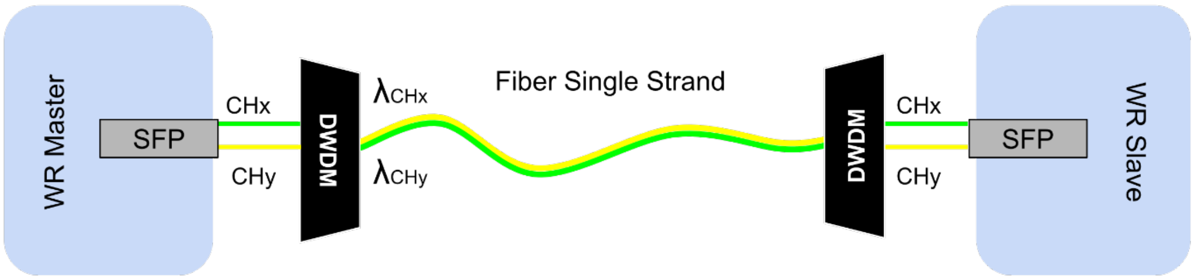
The DOWR device will be connected to a WR-ZEN TP family device using different alternatives:

- Short distance White Rabbit connection.

- Short distance 1PPS, 10 MHz and NTP connection.

The goal of these configurations is to show the synchronization capabilities of the DOWR device to distribute timing using its internal GPS receiver, but also to show that any of the WR devices is capable to synchronize with very high accuracy to an external source which provides 1PPS and 10 MHz analog signals and an optional NTP link for Time of Day information. This last capability allows to use different time sources as atomic clocks, masers or GNSS receivers to provide information to the WR time distribution chain.

After this first synchronization level from the time source, a long-distance link based on DWDM technology can be deployed. Due to the amount of different possible scenarios, we propose a specific configuration based on bidirectional DWDM links without amplification as shown in the following image:




This deployment allows to deploy a plug-and-play long-distance White Rabbit link using pre-calibrated values up to 100 km without amplification.

**2. Identify the TRL for the proposed technology(ies).**

The TRL Level for the Seven Solutions technology is 9. This is fully productized and deployed in Europe and the US.

**3. Identify whether the vendor is willing to participate in the demonstration by providing material (hardware and user equipment when applicable), engineering (technology deployment, configuration, and data collection support), and logistical support during the preparation and execution phases of the demonstration.**

Seven Solutions is willing and prepared to participate in the DOT demonstration as requested and needed to insure a successful demonstration of this GNSS resilience technology.

**4. Identify whether this support is contingent on the government providing some funding**.

Seven Solutions does not anticipate or require funding support from the DOT or US Government in this demonstration activity.

**5. Provide information about the needed infrastructure (*e.g.,* power, network, etc.) that would be necessary to deploy the vendor technology(ies) at a DOT-furnished demonstration site.**

The Seven Solutions demonstration equipment infrastructure needs are fairly simple, Seven Solutions would request the capability to visit the demonstration site prior to actual demonstration to ensure success when the actual testing occurs. The needs for infrastructure are basically AC power.

**6. Identify any constraints on participation, *e.g.,* lead-time, demonstration timelines, funding, infrastructure (HVAC, power, shelter, and equipment space, etc.).**

Seven Solutions would appreciate a 60 day lead time prior to being the demonstration. This would facilitate a pre-site visit plus the capability to schedule manpower, organize equipment and arrange for shipment and receiving at the DOT location selected.

**7. Identify radiofrequency bands and transmit power levels in terms of peak Effective Isotropic Radiated Power (EIRP). This is needed during the planning phase depending on the selected demonstration site(s).**

The Seven Solutions demonstration will not generate any EIRP nor does it us any radio equipment.

**8. Identify where the technology(ies) is/are currently deployed and in use, if applicable. Provide location, date of deployment, and if the deployment is available for examination.**

The Seven Solutions white rabbit installations are typically in sensitive locations requiring special access permits and are covered under NDA regarding the customer name. However, US public institutions as NIST Boulder, Fermilab and the University of California which have worked and deployed experiments using White Rabbit technology.

While it could be arranged for a site visit, we have taken the initiative and included use case scenarios to exemplify the industrial implications.

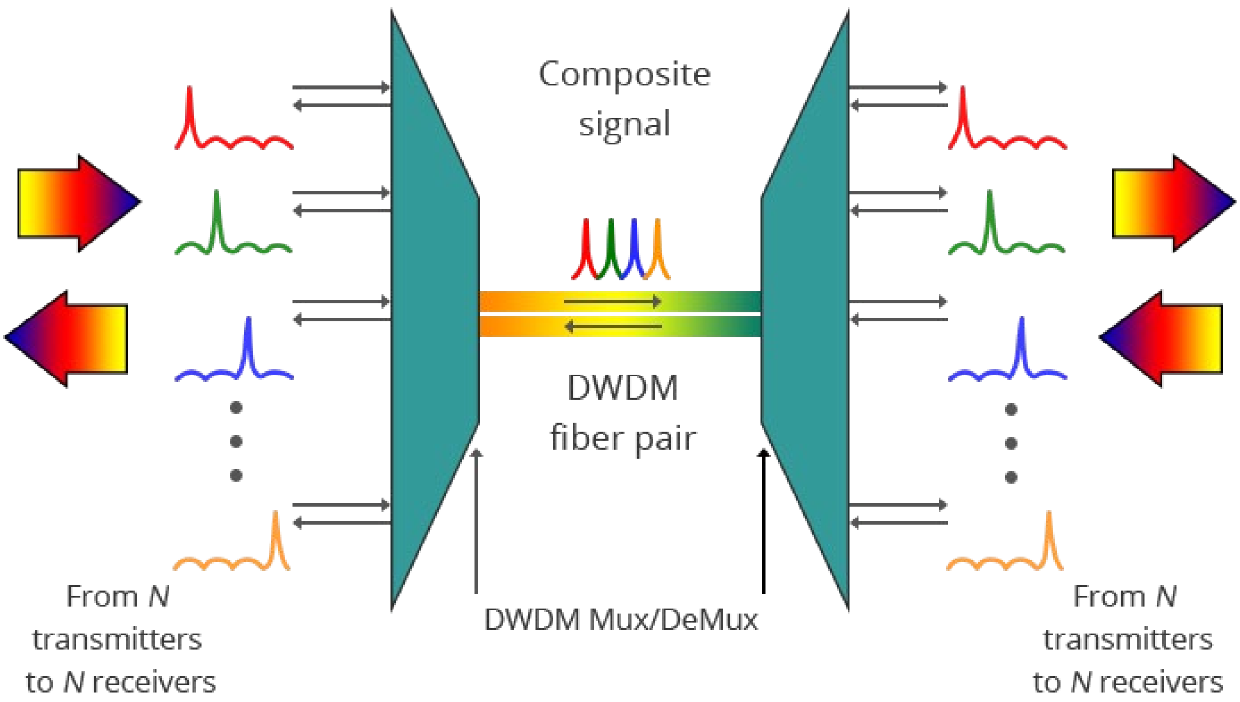
## White Rabbit PTP use cases

The default version of White Rabbit allows plug-and-play links up to 10 kilometers with sub-nanosecond accuracy. Due to that, this technology has been adopted by many datacenter-centric applications:

In **finance**, where clock synchronization accuracy is used for traceability reasons and for enhanced trading strategies. For example, this technology has been adopted by Deutshe Börse stock exchange [1] in Frankfurt to synchronize all their network capture and timestamping devices and offers this data to their customers as well as a clock reference aligned to the stock exchange reference. In this sector, several companies already trust in this technology as their main network synchronization mechanism, distributing a time reference between the multiple locations where their trading systems are placed that allows to correlate timestamps, legally trace the events and to enable a back-up reference in case of GPS malfunctioning.

[1] https://www.eurexchange.com/exchange-en/resources/initiatives/technical-changes/high-precision-time-white-rabbit-pilot

For metro area synchronization, many Tier 1 traders, High Frequency Traders and investment banks have deployed WR-PTP networks. The typical implementation uses bi-fiber links where WR-PTP devices are connected to an optical multiplexer/demultiplexer that receives multiple signals and sends a multiplexed signal. This device allows to multiplex and demultiplex different signals in just one link.

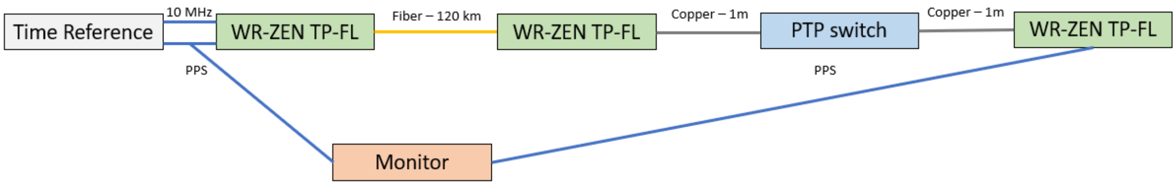



This topology leads to an asymmetry issue because of different latencies in the fiber paths. This asymmetry can be removed combining pre-calibration of the used optical components and specific link calibration.

**Datacenter** companies are also pursuing better synchronization performance in their networks as a result of the increasing demand of on-the-cloud services which are distributed in servers placed in several locations inside one datacenter or in different datacenters.

A Tier 1 datacenter company has deployed a WR-PTP link that reach up to 120 kilometers without amplification using bidirectional links. In order to complete this deployment, internal timing distribution after a long-distance link has been set up using IEEE 1588 (PTP) connections on the last hop and comparing the time difference with the time reference.

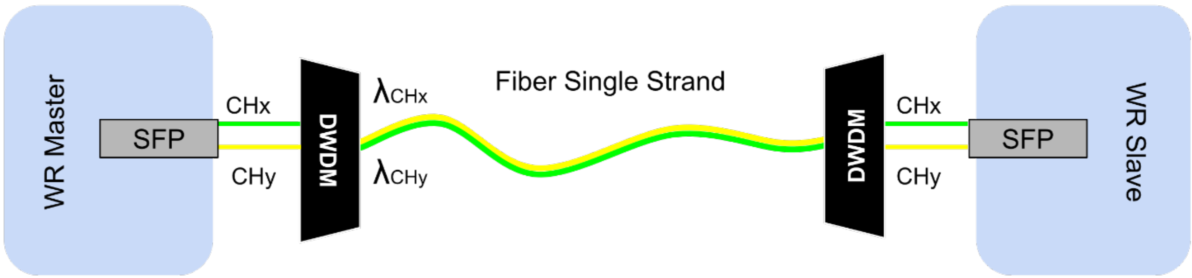





In the framework of **telecommunication** networks, packet-based synchronization is used for timing dissemination to reduce the GNSS dependency, the associated costs and to improve timing performance. In example, Fifth Generation (5G) technologies demand more strict synchronization requirements between 110 and 12.5 nanoseconds and, at the same time, require advanced capabilities related to reliability and redundancy.

This set up hosted by a Tier 1 telecommunication company has a pilot with 4 White Rabbit ZEN TP-FL units connected in a chain. The first ZEN is fed with 1PPS and 10 Mhz signals as reference. The 4 White Rabbit ZEN-TP-FL devices are connected between them using several DWDM fiber optic links with 60, 80 and 80 Km respectively.

In this case, a single fiber strand is used where two different wavelengths are used for communication between the different devices. This deployment allows to reach distances longer than 100 km without regenerating or amplifying the signal as a plug-and-play system which is pre-calibrated by Seven Solutions.




**Electrical power grids** also require accurate time information. New smart grids include synchrophasor where data is time sensitive and requires very accurate synchronization mechanism for event timestamping. Additionally, timing information must be provided to the Power Management Unit (PMU) in a reliable way. These new conditions show that timing synchronization requirements are becoming more demanding for this kind of applications. Several WR-PTP pilots have been driven by this sector.

WR-PTP has been proved to be a resilient time **backup to GNSS** based sources and it is being used to distribute timing information through optical fibers using already deployed DWDM based networks. In this context, different European funded projects focus on pan-European White Rabbit based clock distribution for scientific and industrial applications as CLOck NETwork Services (CLONETS) [2] or White Rabbit for Industrial Timing Enhancement (WRITE) [3].

Another advantage of this innovative protocol is its capability to improve the reliability of the network. Reliability is defined as the probability of a device performing its intended function under given operating conditions and environments for a specified length of time, including abnormal circumstances. Then, a reliable distributed system should be able to make its functions even if the system is damaged. To do this, White Rabbit has well defined tolerance level that ensures the system reliability even in presence of complex interactions between the different nodes.

[2] https://www.clonets.eu/

[3] http://empir.npl.co.uk/write/

**Metrology** institutes all around the world have validated and deployed WR-PTP networks to distribute highly precise clocks for their experiments and applications. As well, some of the most exigent scientific facilities as particle accelerators or radio telescopes also deploy this technology [4].

[4] https://www.ohwr.org/projects/white-rabbit/wiki/WRUsers

# Appendixes

The following appendixes are provided as information only content to exemplify the product suite available from Seven Solutions. The products used in the DOT RFI demonstration will come from this product suite.



Seven Solutions products

A wide range of commercial products with very high TRL level have been produced to bring White Rabbit synchronization to different applications according to the new industrial requirements:

WR-Switch is the main element of the White Rabbit Technology. It has 18 SFP 1GbE ports in a 1U form factor that can be configured to work as master or slave to deploy an operational White Rabbit network. This device can obtain its time reference from an external source using both 10MHz and 1PPS signals, from another White Rabbit device through its optical ports or can work as a free-running device. The WR-Switch can provide 1PPS and 10 MHz outputs on its SMC connectors, as well as a limited layer 2 standard PTP on its optical ports. It has two different management ports, a RJ45 and a miniUSB. It supports SNMP v2.c, rsyslogd 8.9.0 and it has an integrated web GUI. Its internal statistics can be exported using SNMP.

WR-ZEN TP family is the interoperability element of the White Rabbit Technology. It has 2 SFP 1GbE ports that can be configured to work as master or slave to deploy daisy-chain configurations or to provide a redundant White Rabbit connection. The WR-ZEN TP devices have a redundant dual power supply. This device can obtain its time reference from an external source using both 10MHz and 1PPS signals, from another White Rabbit device through its optical ports or can work as a free-running device. The WR-ZEN TP family has multiple interoperability options depending on the specific devices that include 1PPS/10 MHz signals, standard PTP and NTP. It has three different management ports, two RJ45s and a miniUSB. It supports SNMP v3, rsyslogd 8.22.0 and it has an integrated web GUI. Its internal statistics can be exported using JSON, SNMP, rsyslog, the web GUI or the command line.

• WR-ZEN TP-FL: It is a fan-less, cost-effective 1U form factor version of the WR-ZEN TP. It has a front dual power supply. It includes 1PPS/10 MHz SMA outputs and standard PTP interoperability on its management interfaces. It also includes a limited layer 2 standard PTP on its optical ports. It can include a 4 1PPS expansion under demand.

• WR-ZEN TP: The standard 1U form factor version of the time provider. It accepts multiple fans and it has a rear dual power supply. It includes multiple 1PPS/10 MHz on the SMA or DB9 outputs, standard PTP interoperability on its management interfaces, IRIG-B, NMEA and ToD. It also includes a limited layer 2 standard PTP on its optical ports.

• WR-ZEN TP-32BNC: The expanded 2U form factor version of the WR-ZEN TP. It has a front dual power supply. It includes 1PPS/10 MHz SMA outputs and standard PTP interoperability on its management interfaces. The main characteristic is that it includes 32

BNC ports configured to work as 16 1PPS and 16 10 MHz outputs. A 32 1PPS outputs configuration can be used with an PPS expansion license. It also includes a limited layer 2 standard PTP on its optical ports.

WR-LEN



It is the competitive WR alternative capable of supporting daisy chain configurations. It allows a cost-effective solution to distribute PPS/10MHz signals or IRIG-B protocol to your equipment. The WR-LEN is also available in its OEM version in order to integrate accurate timing synchronization into your product.

DOWR

High performance GPS grandmaster clock and network time server capable of distributing GPS Time or UTC using White Rabbit networks with sub-nanosecond accuracy over long-distance fiber links (typically hundreds of km). The DOWR is built as a white box solution, including timing integrity monitoring of the GPS navigation data. It provides raw GPS data for the calculation of a precise antenna position and for legal traceability to UTC(k) laboratories.

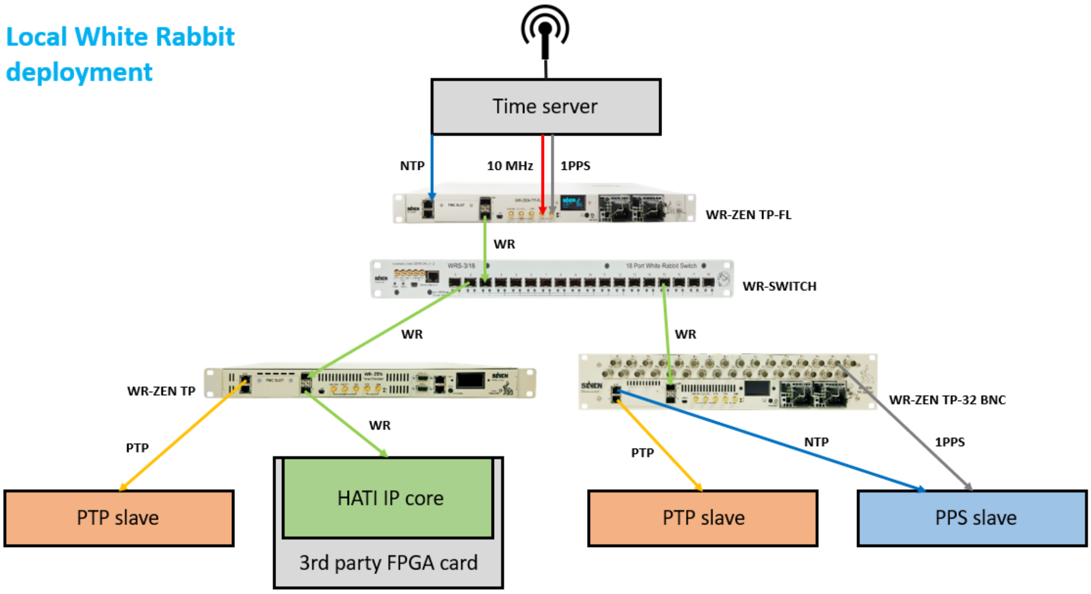
Local Area White Rabbit network

This section covers all the deployments that use the recommended pre-calibrated bidirectional links with distances below 10 kilometers.

- **First White Rabbit device:** As it was explained in previous sections, this device gets the timing information from an external time source (GNSS receiver, Time Server, clock) providing both 1PPS and 10 MHz signals.
  We recommend using a WR-ZEN TP family device for this step because it integrates easy calibration tools that allow to remove any offset between the time source and the first WR device caused by cables or unexpected electronic delays. Additionally, the WR-ZEN TP devices allow better monitoring from the incoming signals.
  Time of Day information must be provided to this first device if an absolute notion of time is required in the timing system.
  This device would be able to get its time reference from a PTP master too, with an appropriate configuration that avoids clock jumps. In any case, PTP is not recommended as time reference, because its synchronization performance is worse than receiving 1PPS and 10 MHz signals.

- **Intermediate White Rabbit device:** This device would receive the timing information from the previous White Rabbit device. WR-ZEN TP devices can be used in a daisy-chain configuration if the number of needed nodes is low. If multiple White Rabbit nodes are needed, using a WR-Switch is recommended to set a tree topology.
  **Last White Rabbit device:** This device supports different synchronization mechanisms to provide the time information to a non-White Rabbit compliant device. Using a WR-ZEN TP family device is recommended because they support highly

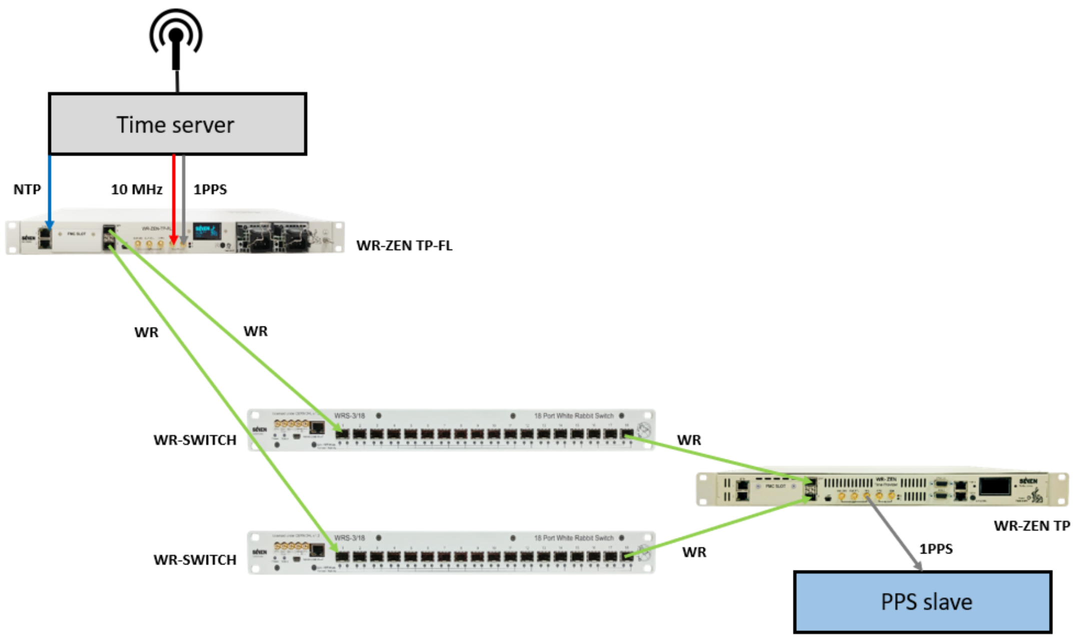
configurable IEEE 1588 PTP v2, multiple PPS ports depending on the device, 10 MHz clock output, NTP and others synchronization mechanisms.



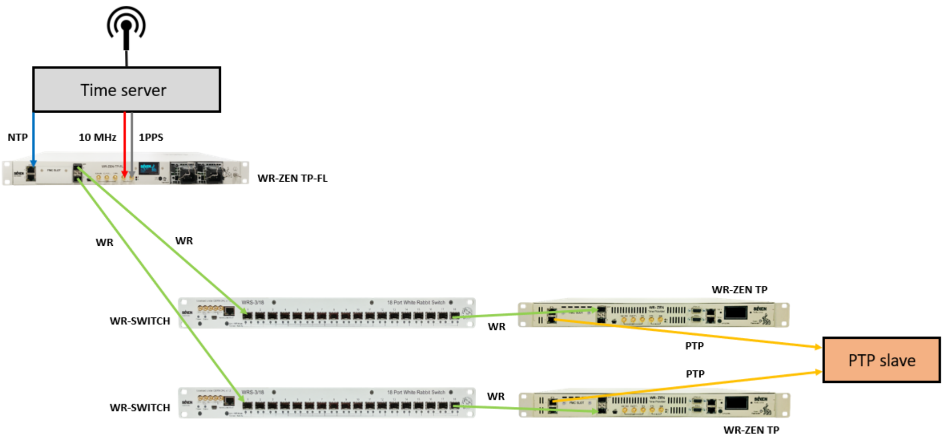



Redundancy on WR network

This deployment avoids single points of failure in the White Rabbit network, except in the last White Rabbit device.

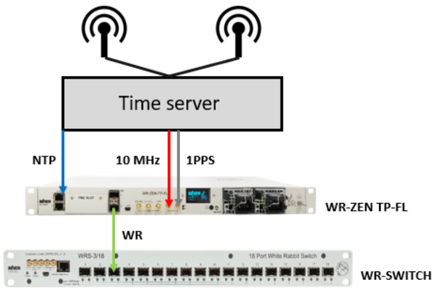



Additionally, a second WR-ZEN TP can be deployed as last White Rabbit device to feed a PTP switch or slave that implements Best Master Clock Algorithm

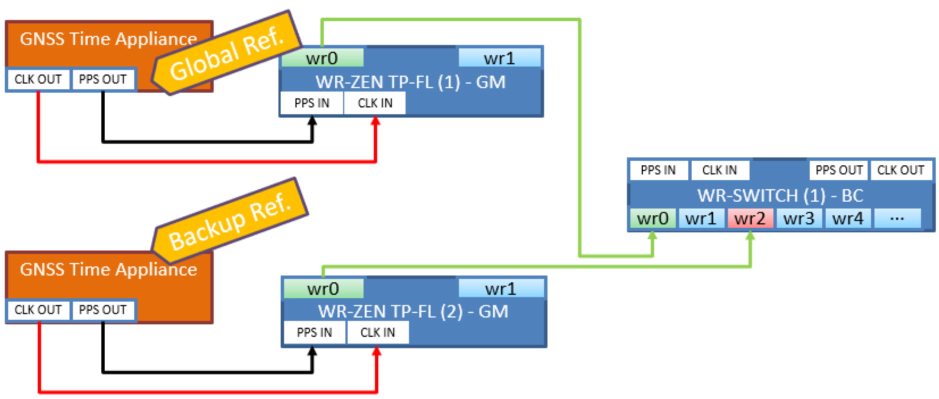



Redundancy on time reference

This deployment allows to have multiple time references in one place, avoiding the main point of failure in timing networks which are GNSS receivers. The first option is to use a time server which has holdover capabilities and can support multiple time inputs (GNSS receivers, clocks).




If the time server does not support these capabilities, two WR-ZEN TP devices can be used to get the time references and a WR-switch that can be manually configured to switch from a primary to a backup time reference.




It can be combined with White Rabbit network redundancy if needed.

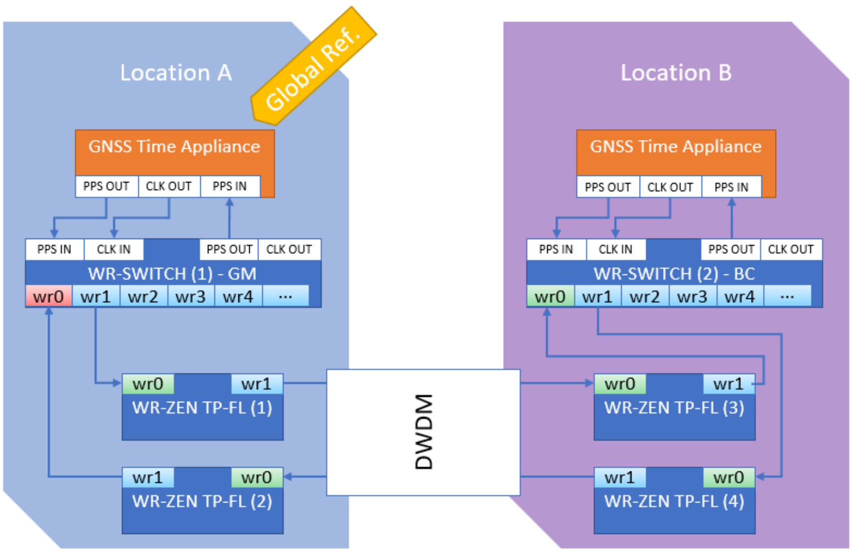
Wide Area White Rabbit network

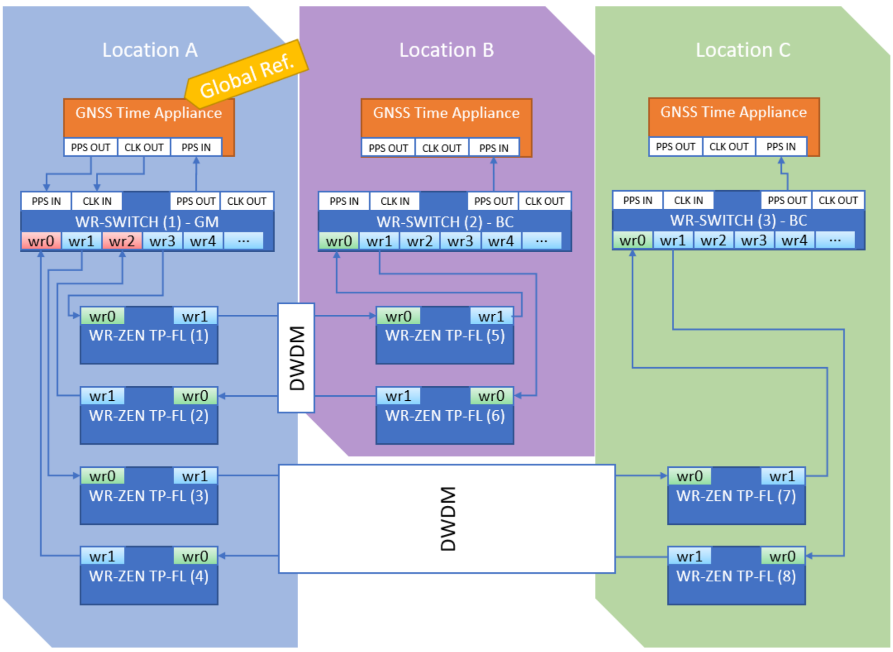
This section covers all the links that use DWDM equipment or non-pre-calibrated bidirectional links over dark fiber for long distance.

In both cases, a specific calibration must be implemented to remove any synchronization offset caused by unknown asymmetries.

Remote time signal backup based on White Rabbit redundancy

This deployment uses the WR-switch configuration to manually jump from a primary time reference to a backup time reference. It allows the whole system to work with the same clock and time information.

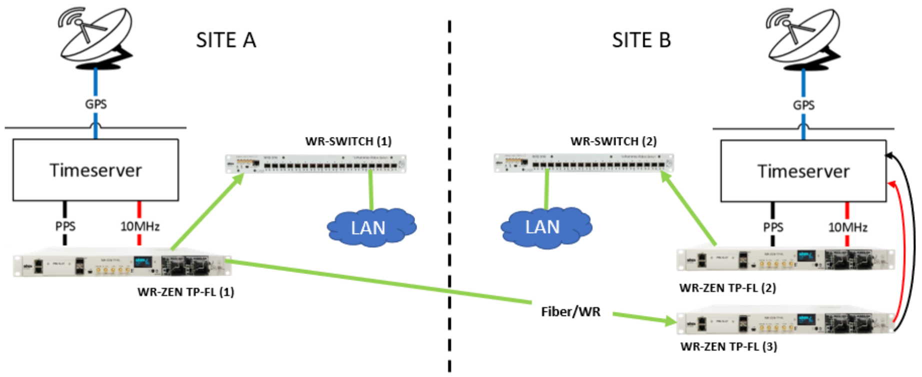



Remote time signal backup based on a time server

This deployment needs a time server capable to switch between different time references. One location receives the time signal from a remote place through a White Rabbit link. It can be used as GNSS receiver backup in the remote location.






Remote bidirectional time signal backup based on a time server

This deployment needs a time server capable to switch between different time references. It allows the whole system to work with the same clock and time information.