SEVEN Solutions
When every nanosecond counts

GNSS Backup using White Rabbit & IEEE-1588-2019

Defense and Critical Infrastructures

Precise time distribution is usually performed using GNSS technology due to the wide availability and easy access to well synchronized and stable satellite clocks. This enables distributed measurement systems to be tightly synchronized over large areas and allows accurate time stamps with respect to a global time reference. However, there are diverse factors or actions (accidental or malevolent) that can lead to a GNSS outage.




User Challenges

- Provide countermeasures against interference, jamming, and spoofing.
- Maximize the availability of the system and synchronization signals.
- Ensure system scalability.
- Distribute time and frequency with the best possible accuracy and precision.
- Provide failover mechanisms, cybersecurity, and timing error detection features.
- Provide interoperability with COTS devices based on Ethernet interfaces.
- Allow the utilization of networking configuration and monitoring tools.

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Context

A **distributed system** can be seen as a set of devices (computers, instruments, etc), connected through a network that can be coordinated (tightly synchronized) to perform a set of tasks in an open and scalable way. Nowadays, there are many **infrastructures classified as time-critical** by governments, that are, in fact, distributed facilities depending so much on timing that a failure on the time reference may have catastrophic impact. Examples include nuclear reactors, power stations, financial networks, and telecom facilities, among others. **GNSS** is the dominant enabling technology for applications and services requiring **positioning, navigation, and timing (PNT)**.

Precise time distribution is usually performed using GNSS technology due to the wide availability and easy access to well synchronized and stable satellite clocks. This enables measurement systems to be tightly synchronized over large areas and allows accurate time stamps with respect to a global time reference. However, there are diverse factors or actions (accidental or malevolent) that can lead to a **GNSS outage**. For instance, space weather influence, failures on satellites, interferences and **jamming** or spoofing. The main concern arises precisely from the use of GNSS jammers. These devices can be easily bought on the internet and can invalidate the weak GNSS signal in a local area (as caused for instance by truck drivers with GPS jammers) or even in wider areas if high power or directional jammers are used (as detected in some actions driven by North Korea). This concern appears to be widespread, since the disruptions can have different nature and **duration** varying from microseconds, days to permanent damage depending on the failure and the resiliency of the system.

Since GNSS technology is used for critical infrastructures, a failure can **compromise business** and safety. For this reason, it is crucial to complement the timing services that GNSS provides. Thus**, backup systems** should step in when GNSS signals become compromised, unreliable, or corrupted.

The Solution

Recently, the new **IEEE-1588-2019 HA** standard protocol has been launched. This new version includes an extension for wide area network (WAN) utilization, cybersecurity mechanisms and the High Accuracy (HA) profile to distribute time and frequency with a performance better than 1 ns and a very low jitter. As indicated in the standard, this profile is strongly based on **White Rabbit**. This protocol was conceptually designed at CERN and translated into an industrial solution by Seven Solutions, which is now the leading company in the field of sub nanosecond timing with thousands of devices distributed worldwide for different industry segments. Seven Solutions has demonstrated its scalability to distances of thousands of kilometers, and how its accuracy is kept across multiple hops, as well as the capability to integrate the technology using existing optical telecommunication networks. Moreover, Seven Solutions' IEEE-1588-2019-HA implementation provides network-based failover, inter-links monitoring and interoperability with multiple time protocols. GNSS-dependent industries can benefit from accurate time distribution with negligible degradation and bandwidth consumption.

The solution, based on this new profile, uses an infrastructure of **redundant GNSS time receivers** whose references are scattered across hundreds of kilometres and connected through fibre optics links from existing telecommunications networks. In this way, the system can get and distribute the time references available from safe locations to those ones that are under attack (**Figure 1**). Due to the distributed nature of critical infrastructures, this scheme perfectly suits their requirements.

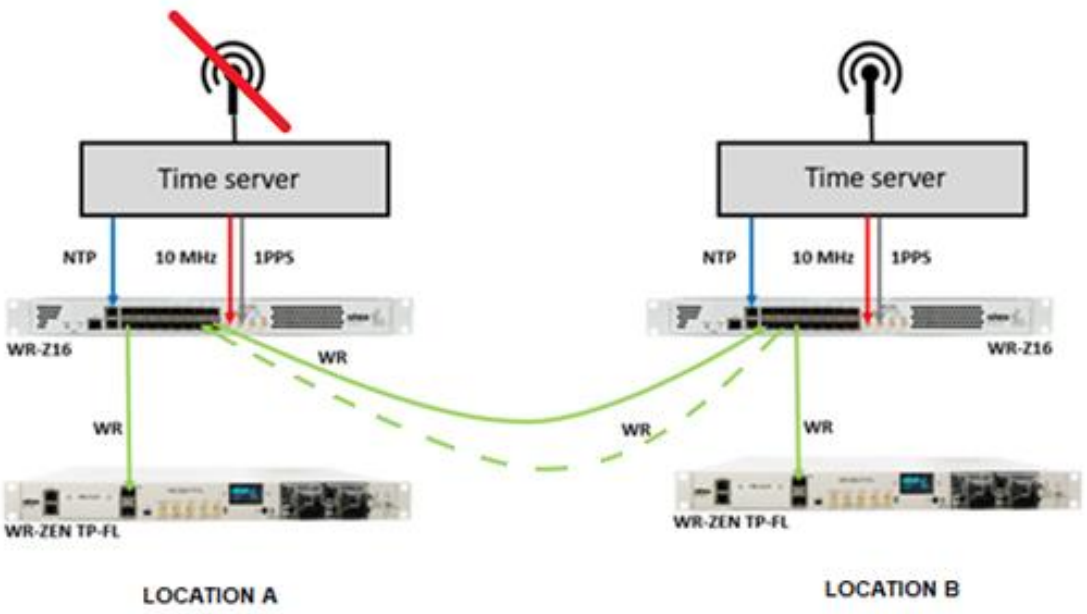

Figure 1: Example of the proposed PNT solution: Scenario with 2 locations.

In this solution, the nodes of the system are implemented using WR-Z16 devices. This device includes failover mechanisms with the capability of managing multiple time sources (**Failover Clock Algorithm**), including holdover. This means that, for instance, if a certain node is using a GNSS system as primary time source, the WR-Z16 system can detect when this primary time source fails (via jamming/spoofing attack or any malfunctioning) and **switch to the next valid time source available** in the network, preserving the synchronization of the full system. In this way, the redundant time references provided to each node will work as a **GNSS backup**, providing a full resilient synchronization solution to the network. Note that additional nodes can be added to the network so that voting schemes can be used to automatically reject false tickers for more complex and demanding scenarios.

In **Figure1**, a link between two different sites located in the wide area is shown. On each location, a local time server is used taking the GNSS time reference, which acts as the **main time source** for each node. A **second time reference** for each WR-Z16 is provided through the link via PTP IEEE 1588-2019 HA or White Rabbit. In this way, the GNSS time reference of one site can be transferred to the other site through an optical fibre link. So, at location A (left side), the main time reference is provided by the primary GNSS time server, and the secondary reference (GNSS backup) is provided through the PTP IEEE 1588-2019 HA link which transfers the GNSS reference of location B (right site) as a backup. This time transfer through the link is done with **sub-ns accuracy**. The same redundancy exists at location B. This represents network-based resiliency.

It is important to remark that if **both references are lost**, the WR-Z16 can jump to its internal **holdover** clock which ensures a **time drift** lower than 1.5 µs after 24 hours.

The other devices, the WR ZEN TP FL ones are included only as an example of different **intermediate or end nodes** which can be obtaining timing from the system through different **widely used protocols** (IEEE-1588-2008, NTP, PPS, 10 MHz, IRIG-B, etc.).

In the configuration presented, two links are being used to interconnect two locations. Seven Solutions recommends improving the resilience (with redundant time sources), reducing the asymmetry on the links and improving the monitoring of the system.

Finally, Seven Solutions has developed specific templates which facilitate the integration of the devices via SNMP with the most used external tools for **monitoring and management** of networks, such as **Zabbix** (**Figure 2**), InfluxDB, Grafana, Cronograf, etc. This integration, which requires configuration and customization of the monitoring tools, is complex, but once carried out by Seven Solutions, the client will be able to monitor its system in a **very visual and easy-to-use way**. Furthermore, Seven Solutions' devices include multiple **security features** against cyberattacks, allowing the deployment of different security policies according to the security level required for the infrastructure.

Figure 2: Zabbix alarms generation and monitoring tool.

Conclusions

This solution is based on the most advanced time transfer technology available in the market, which is the implementation of the PTP IEEE-1588-2019-HA protocol offered by Seven Solutions. It allows complete GNSS resilience on the most demanding scenarios. In this example, we illustrate how the redundancy can be obtained using two GNSS receivers to detect time reference drifts. Note that additional redundancy can be added by including extra receivers and locations on the network. This allows not only the detection of inter-clocks drifts but also the identification of the false ticker by using voting algorithms to automatically reject wrong references.

The system can provide synchronization performance over hundreds of kilometers with time errors below one nanosecond strengthening system PNT resilience, robustness and network and RF security. Moreover, the system can cascade more than twenty devices connected in a daisy chain ring topology with minimal performance degradation. This allows a scalability to thousands of synchronized COTS devices, making possible the deployment of a complete and secure resilience core on critical infrastructures with an expected outstanding average monthly system availability (based on similar deployments) better than 99.9%.

About Seven Solutions

Seven Solutions S.L. is a telecommunications company leader in accurate sub-nanosecond time transfer for reliable industrial and scientific applications. We have more than 15 years of expertise in embedded systems design and control (electronics, firmware, and embedded software), with a remarkable track-record in cutting-edge projects at different sectors such as fintech, avionics, telecommunications, Smart-Grid, space, defence and scientific facilities as particle accelerators and distributed radio-telescopes.

We are leaders in ultra-accurate time transfer and synchronization in the Fintech and Science segments. We were born in the framework of Large Scientific Infrastructures (Industry for Science). In this segment we are continuously growing and consolidating creating break-through solutions for timing and for advanced control systems and diagnosis in particle accelerators.

We are leaders in time and frequency distribution solutions based on White-Rabbit technology and derived standards (IEEE-1588-2019-HA). www.sevensols.com.

About Open PNT Industry Alliance

Seven Solutions is member of the **Open PNT Industry Alliance** which is an alliance of time devices manufacturers and service providers that help customers to use back up GPS/GNSS by delivering alternative forms of positioning, navigation, and timing (PNT). https://openpnt.org/