What's a White Rabbit?

It's Time for Better GPS Backup

By Anne Marie M. Munoz and Trinidad Garcia

A distributed system can be defined as a collection of computer, instruments or tools, connected through a network and whose activities can be coordinated to perform a single or small set of related tasks in an open and scalable way. On those systems, the timing information is a key magnitude for the control and operation but also for monitoring the state of the different elements. At least 17 of 21 types of infrastructures classified as critical by government authorities (USA Presidential Policy Directive, Critical Infrastructure Security and Resilience, PPD 2013.) require timing information. They depend on timing, which in case of failure could have catastrophic impact (like Nuclear Reactors, Power stations, critical Telecom facilities, etc.), and represent a direct worldwide market of more than 250M€(nearly 300M$). These facilities are, in fact, distributed facilities that require the timing source to be available at multiple points in a dependable way.

Usually, precise time distribution is performed using GPS technology (due to the wide availability and easy access to well-synchronized and stable satellite clocks). This enables measurement systems to synchronize their activities 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 GPS breakdown. GPS failures can be due to both environmental factors (as the space weather influence, and failures on satellites) and human actions as interferences with radio emissions in specific frequencies or malevolent jamming or spoofing.

The biggest concern/alarm arises precisely from the use of GPS jammers. These devices can be easily bought on the Internet, and can invalidate a GPS signal in a local area (as caused, for instance, by track drivers with GPS jammers) or even on wider areas if high power or directional jammers are used (as proven in some actions driven by North Korea). Therefore, there is serious concern about the facility vulnerability due to the use of GPS that can easily fail. This concern appears to be widespread, since the disruptions can be of different nature and duration varying from microseconds, days to permanent damage depending on the failure mechanism and the resiliency of the system.

A famous incident, well known in the GPS community, occurred in San Diego Harbor in 2007 when the GPS services were disrupted throughout the city. Different industries and institutions were seriously affected: the Naval Medical Center emergency pagers stopped working; the sea traffic control shipping system failed, and the Automated Teller Machines (ATMs) failed, etc. The serious impact on the bay was immediate, and during the time the system stopped working the chaos gripped the city.

More recently (2015), according to the US Air Force (USAF), a satellite named SVN 23 was decommissioned causing 13 microsecond loss of the GPS signals. This 13 microsecond error resulted in thousands of system warnings being activated worldwide.

Since 2010, North Korea has also activated high power jammers that have seriously affected many civil distributed facilities in South Korea as the Incheon International airport located at Seoul. Aircraft had to rely on alternative navigation aids, and even cars in the city's northern suburbs found their GPS equipment affected.

Since GPS 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 GPS provides. Thus, backup systems should step in when GPS signals become abnormal, unreliable or corrupted.

How Navigation Systems Work

Global Navigation Satellite Systems (GNSS) stands for the generic term of satellite navigation systems. This term includes the GPS, GLONASS, Galileo, Beidou, and other systems. GNSS consists on a system of satellites that provides accurate autonomous geo-spatial positioning with global coverage using time signals transmitted from satellites through radio.

The positioning is calculated from the measured time delay between the emission time of the satellite and the reception time at the receiver using at least 4 radio signals coming from different satellites. The radio waves travel at the speed of the light in the vacuum of the space (and a bit slower in the atmosphere), which implies that in a nanosecond light travels around 30 cm in the vacuum. In other words, small errors in time can cause large errors in position. Thus, the precision of GNSS depends on knowing the exact time the signal left the satellite and the instant the signal arrived to the receiver.

Thus, each satellite carries several atomic clocks (clocks whose precision depends on the operation of a voltage-controlled oscillator regulated with the natural vibration modes of a crystal atomic network). Receivers decode these signals effectively, and estimate position based on the difference of travelling time and the reference satellite position.

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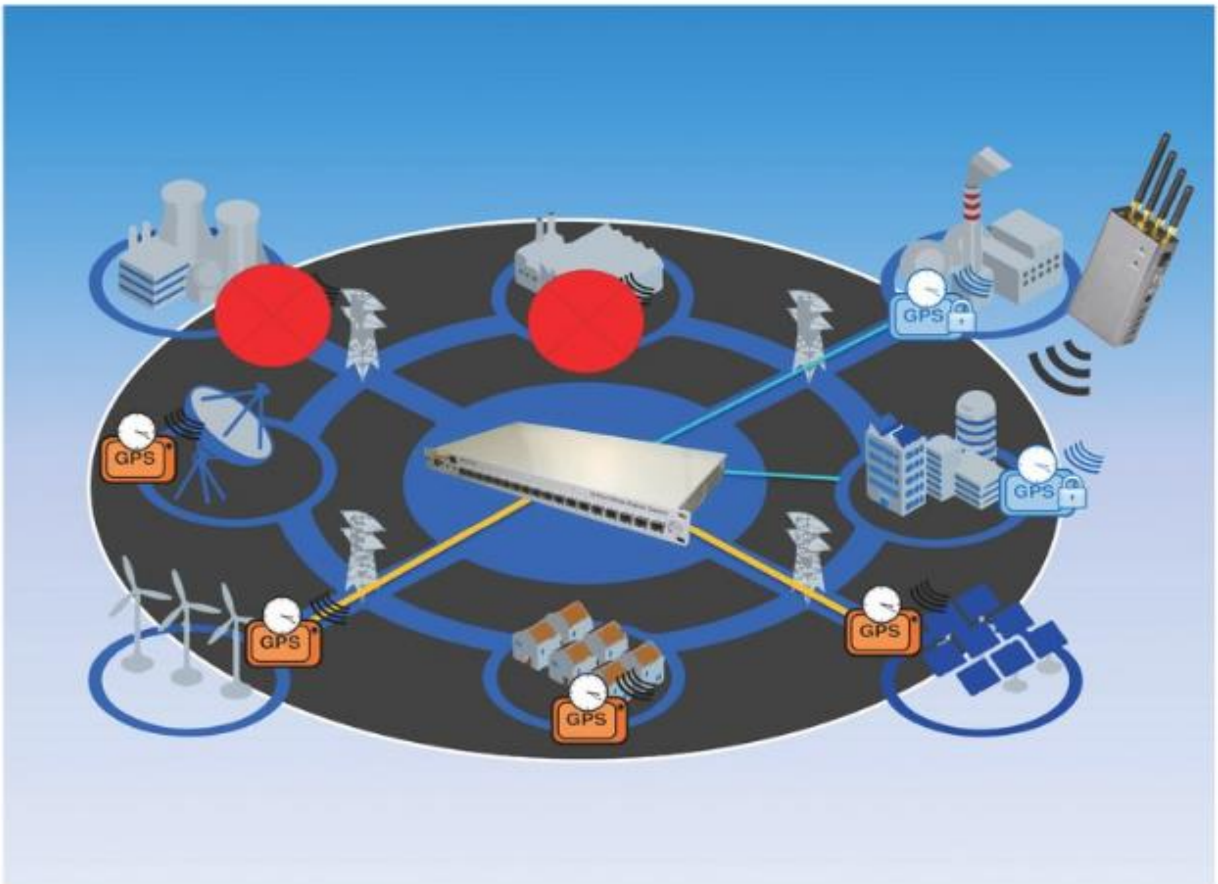
A Prevention Plan

As stated before, accidental or deliberate interference in GPS signals is already an alarming issue. Thus, when used for time distribution it is recommended that critical infrastructures use GPS alternatives as complementary redundant mechanisms.

Some facilities make use of complementary atomic clocks but although rather stable as hold-over mechanisms, during their use traceable synchronization to a global reference is lost (it is also a rather expensive choice).

Another worldwide alternative for time sources is to use the Internet to distribute clocks, but in this case the accuracy achievable is not good enough for many applications (e.g., using Network Time Protocol (NTP) over long distance does not provide anything better than tens of milliseconds, and it suffers from dependencies on the network traffic load). On the other hand, solutions based on IEEE 1588 Precision Time Protocol (PTP) use free-running oscillators in each node, which leads to drifts caused by asymmetries and miscalibration (due to temperature changes and other factors) between master and slave nodes. Thus, the synchronization accuracy achievable depends very much on the specific characteristics of the links, and usually degrades with distance, traffic, and number of hops.

Other proposals for a GPS backup solution have been made recently. For example, frequency synchronization experiments were carried out by the United States Naval Observatory (USNO) to test a GPS backup solution over the Washington urban area. The solution based in the TimeLoc methodology, yields some nanoseconds of time accuracy. However, this technology is not exempted of problems derived from the additional vulnerability of wireless networks. Recently, according to the Department of Home Security of the United States, the National Institute of Standards and Technology proposed the use of



WR Switch backup for Jammed GPS signals.

fiber networks as the safest alternative to GPS disruptions.

Under these circumstances, GPS-dependent industries could benefit from accurate time distribution with negligible degradation and bandwidth consumption. The solution, based on a new profile of IEEE-1588 standard (PTP) usually known as the White Rabbit PTP (WR-PTP), is scalable and accurate. This protocol works as an enhanced wired but backward compatible version of PTPv2. 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.


White Rabbit secures GPS failures all over the world.

To carry out this solution, Seven Solutions company, with expertise in WR technology, has been recently awarded with a prestigious contract sponsored by the European Commission. It is the time for a dependable timing reference.

White Rabbit Precision Time Protocol (WR-PTP)

The White Rabbit (WR) project was born with the purpose of improving the IEEE 1588 PTP for adapting it to the requirements of the particle accelerators industry. 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 include the 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 (SyncE) and Precision Time Protocol (PTP), and fully compatible with these standards. The enhancements introduced by WR can be summarized as follows:

- Synchronization and time-stamping with sub-nanosecond accuracy.
- Distribution through thousands of nodes and tens of kilometers over standard optical fiber networks. Specific network configuration is required for larger distances. (The WR networks consist on WR Switches and nodes interconnected typically by fiber links).
- 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 more than 2,000 nodes with subnanosecond 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 more than 14 countries. In addition, WR-PTP is on its way to become part of the next PTP standard in 2018, as an enhancement of PTP for high-accuracy applications.

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, WR has well-defined tolerance levels that ensure the system reliability even in the presence of complex interactions between the different nodes.

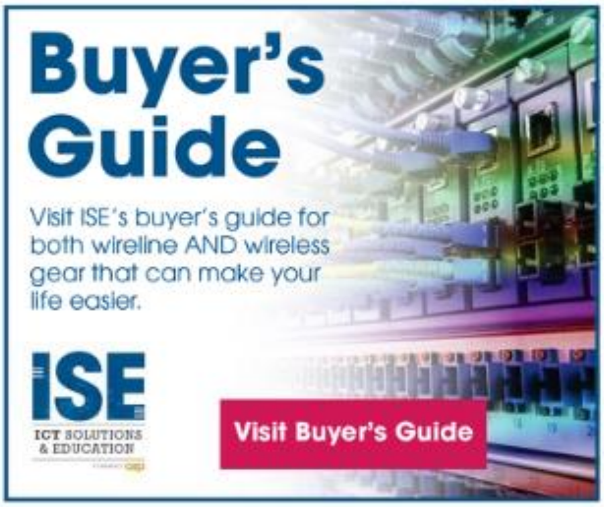
A wide range of specific products has been recently produced to bring WR synchronization to different applications according to the new industrial requirements. Among them, the White Rabbit Switch (WRS) is considered the central element for providing sub-nanosecond accuracy to distributed systems over tens of kilometers. It presents a multiport design that facilitates the exchange of data traffic between any pair of devices connected to the switch. Moreover, there is evidence of mechanism to provide timing over optical fiber over distances longer than 100Km.

Conclusion

Currently, there are numerous and diverse GPS-dependent infrastructures requiring highly accurate time distribution. These infrastructures, and our society's reliance on GNSS navigation, keep growing every day.

The dependence of these critical industries and services on vulnerable GNSS signals represents a real risk that must be managed.

With WR, synchronization and time-stamping is achieved with sub-nanosecond accuracy, through thousands of nodes and more than hundreds of kilometers. In the light of the WR-PTP synchronization and reliability features, this technology is a strong candidate to implement the next generation of GNSS timing backup systems using just available telecommunication operators' networks. ■



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Anne Marie M. Munoz is Engineering Developer, Seven Solutions, with more than 1 year of experience in Software Engineering and Quality development in telecommunication institutes and companies. For more information, please email anne@sevensols.com.

Trinidad Garcia is Postdoctoral Researcher, Torres Quevedo Grand Holder, Seven Solutions. She has more than 5 years of experience in Research and Innovation activity. For more information, please email trinidadgcia@sevensols.com.

Seven Solutions provides solutions in accurate sub-nanosecond time transfer and frequency distribution for reliable industrial and scientific applications. Their solutions are based on the IEEE 1588 Precision Time Protocol (PTP), solving the most demanding synchronization issues. For more information, please visit www.sevensols.com.

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