Establishing “Truth” in Network Synchronization

NETWORK TIMING & SYNCHRONIZATION IN AN UNTRUSTWORTHY WORLD

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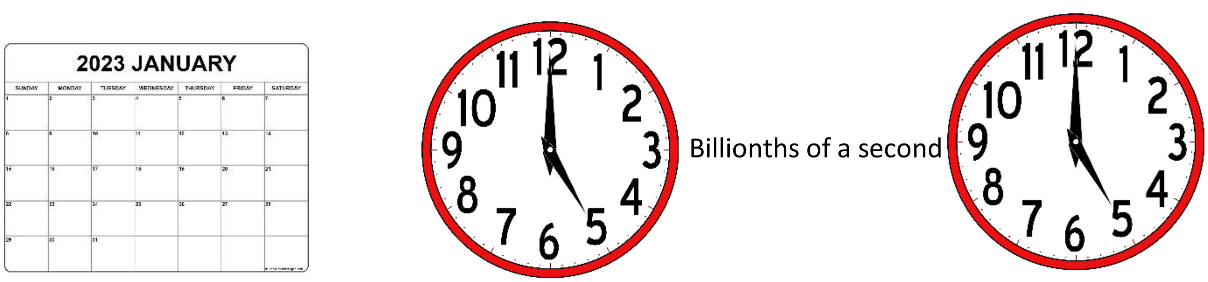
Version II- Rise of Satellite Time & Location (STL) Service using Low Earth Satellites (LEO)

<u>What time is it, really?</u>

It is humorous to contemplate exactly what time it is at any moment, as we really don’t know what time it is; we only know what we have *designated* as the current time. In earlier eras we felt good if everyone in the world could coordinate with each other by a day on the calendar. Moving forward, we came closer to coordinating our clocks to within minutes of each other. Today, we synchronize world clocks to within billionths of a second.

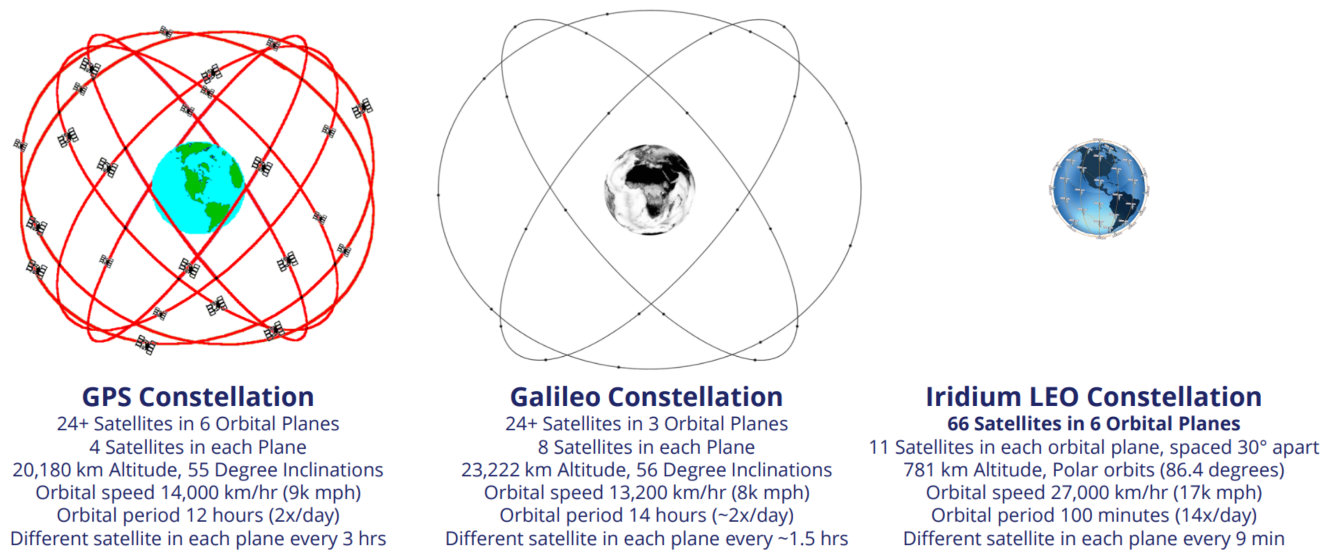


THEN **NOW**

The ability to synchronize a clock anywhere in the world with high accuracy is made possible by a concept called *Coordinated Universal Time* (UTC). If you are a PhD in physics, you will argue multiple timekeeper scales exist, but the explanation for the rest of us dealing with local network synchronization principles, UTC is basically an approved group of world clocks with exceptional accuracy that contribute their time measurements to a central authority that averages the readings to arrive at what is generally accepted as “Truth” relating to exactly what time it is at any moment. That “Truth” is then transmitted globally by various means which include a method to account for transit time for each transmission medium.

In most cases, Truth is disseminated globally by several *Global Navigation Satellite Systems* (GNSS) such as:

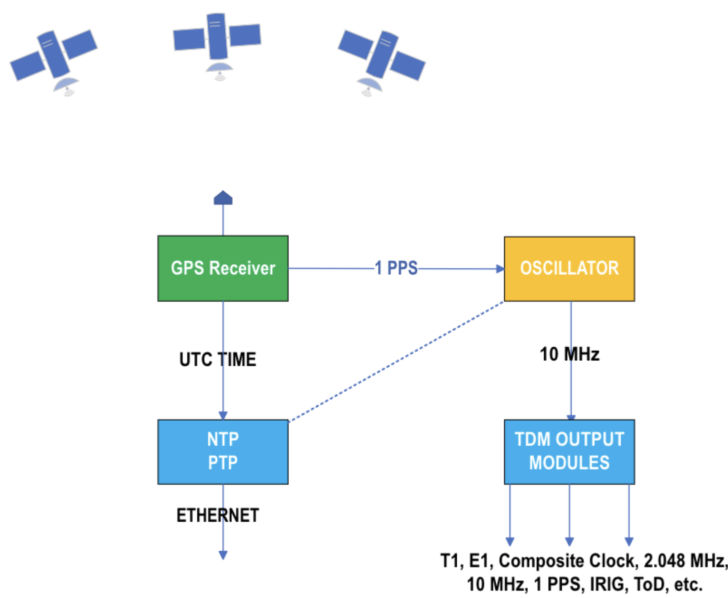
USA: GPS – and new for 2023- Iridium/Satelles Low Earth Orbit (LEO) Satellite Time & Location (STL)
Europe: Galileo
China: Beidou
Russia: Glonass



GPS, Galileo & Iridium/Satelles Satellite Constellations

It is notable these satellite constellations do not generate Truth; they merely transmit Truth to all corners of the earth. As a reminder, Truth is what is generally accepted as Coordinated Universal Time (UTC) or what the world experts agree is the exact time at any moment, delivered by GNSS within +/- 30ns 90% of the time.

Once Truth is transmitted over satellite constellations it can be recovered at nearly any point on earth using a satellite receiver. The receiver then decodes the satellite messages to provide data elements to resolve Latitude, Longitude, Altitude and Time. This method is utilized to discipline, or tune local oscillators that can transfer UTC frequency and phase (Time) to a local "clock".



The official designation for the metrics shown above are ***P**osition, **N**avigation, and **T**iming* (**PNT**). These three entities: *Position* (where you are), *Navigation* (where you are going) and *Timing* (exact time of day) are used together and separately depending on your needs. For example, when you use GPS for travel routing you rely on **P**&**N**- where am I and where am I going? Likewise ships and airliners use **P**&**N** to determine exactly where they are and the proper route forward to their intended destinations.

However, power, telephone, finance, cellular and cable TV/broadband providers use the *Timing* aspect to synchronize their vast networks. Since most of their equipment is installed in buildings that don't move, they care less about *Position* & *Navigation* (with exception of California and Florida where buildings may move during earthquakes and hurricanes).

Time is of the essence

Regardless of GNSS use case, without accurate *Time* there would be no *Position* & *Navigation*. The accuracy of *Time* is of utmost importance in making Truth available globally.

Humans are now overly dependent on GNSS in nearly every aspect of life from driving a car, making financial transactions, receiving emergency services (fire, police, ambulance), enjoying reliable electrical power, traveling commercially, and much more.

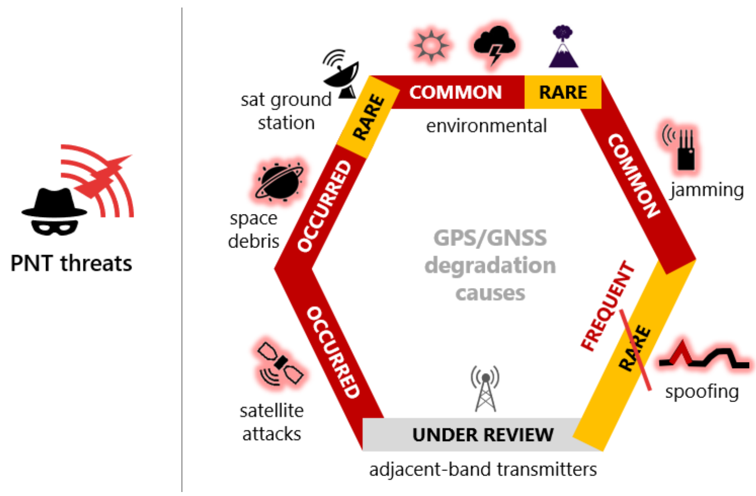
Since GNSS impacts nearly everything we do daily, it has also become a tempting target for signal jamming and spoofing, leading to disruption of societies and neutralizing critical military advantages.

Imagine a world without GNSS

It is difficult for the average person to consider loss of GNSS availability. However, GNSS jamming occurs around the globe on a daily basis. In some cases, GNSS jamming is unintentional as myriads of new, potentially interfering Radio Frequency technologies are deployed. However, the majority of GNSS jamming is intentional by individuals and governments.

There are growing numbers of people who do not want their location trackable, so they purchase low-cost GNSS jamming devices to obscure the location of their automobiles. This is highly illegal and leads to disruption of critical GNSS reception as they drive by power utilities, telephone and cable company buildings and especially at airports.

Likewise, GNSS reception is often erased on a broader scale during armed conflicts, provocations between countries, while ships at sea are lured off-course by GNSS spoofing.



GNSS (GPS) Disruptors

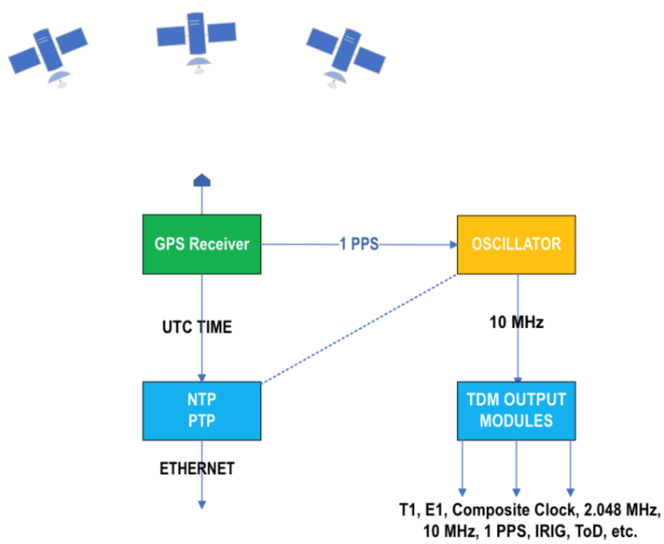
Are you resilient?

Since jamming & spoofing have become everyday occurrences, governments around the globe have warned critical service providers they may no longer rely on GNSS alone for PNT accuracy. The concept of safeguarding critical infrastructure from GNSS jamming & spoofing is called “Resiliency”.

Therefore, all critical service providers (Communications, Financial Institutions, Power Utilities, Emergency Services/E911, Transportation, Broadcast, Military) *MUST* design Resilience into their timing and synchronization schemes.

Historically, GNSS has been the prime distribution method for Truth. Since we are all now informed that GNSS vulnerabilities can make GNSS untrustworthy, how do we then arrive at dependable Truth for timing & synchronization?

The good news is that Truth is transferable from one media to another. In some cases, it can also be made portable. Therefore, Truth is available from more than one source, so long as that source can trace back to UTC. To understand this, let’s see how local network synchronization systems make use of the Truth they receive from GNSS.



Once GNSS signals are decoded the local clock can process the information to derive two distinct types of timing & synchronization outputs: analog & digital time-domain (electrical) signals, and Ethernet/packet messages. However, both types must be traceable back to a UTC reference or stand-alone Cesium reference clock.

<u>Resilience thru additional timing sources</u>

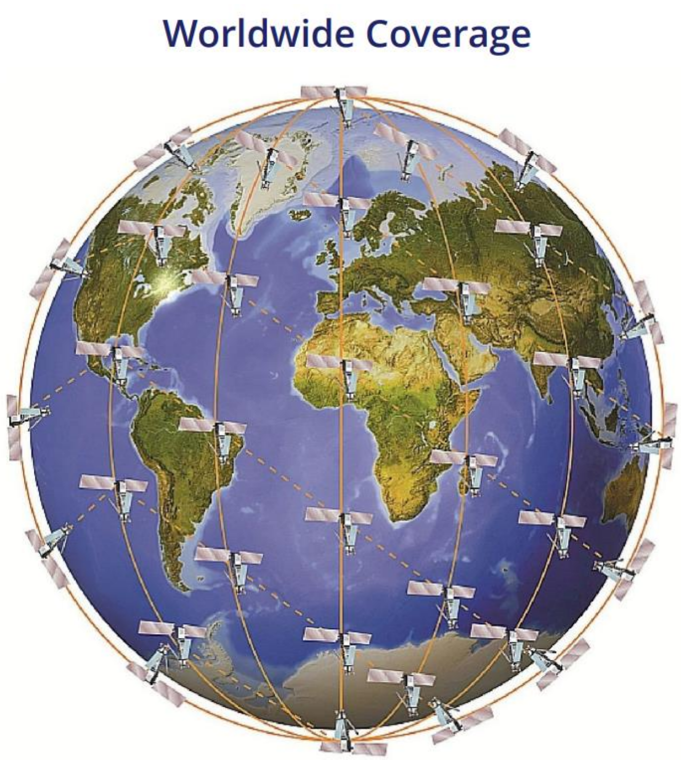
For many years GNSS was the only practical source of PNT for network timing and synchronization. However, additional PNT services are now available from Satelles using the Iridium constellation of Low Earth Orbit (LEO) satellites. As shown previously, these satellites are very near the earth, providing up to 1,000 times more radio frequency power than GNSS satellite signals at the surface of the earth. The Satelles service is called Satellite Time & Location (STL).

The LEO satellite signals can penetrate buildings and also fill in gap areas not currently served via GNSS such as canyons and deep forests. Since these signals penetrate buildings, it eliminates the requirement for an outdoor antenna which counts for a significant portion of cost for GNSS clock installations. Therefore, a small antenna may be installed at the top of the equipment rack housing the STL receiver.

STL signals are encrypted, so spoofing is not ans issue, and the signal levels are up to 1,000 times stronger than GNSS/GPS power levels, so in live tests, GPS jammers do not impair the STL signals.

Adtran has partnered with Satelles to include STL receivers in many Oscilloquartz synchronization systems (clocks).

STL indoor antenna (approx. 3 inches)



Polar orbits of the Iridium/Satelles Constellation

STL service from Satelles has been tested & analyzed by the European Commission, US National Institute of Science & Technology (NIST) and the US Department of Transportation with each reporting the service exceeded all expectations in rigorous testing scenarios.

STL service is available today and Oscilloquartz is an enabler for utilizing STL as a reliable timing & synchronization source for your network. Our embedded STP receivers allow dual operation of GNSS and STL in the same clock system, or use of either GNSS or STL separately.

<u>Not your father's network</u>

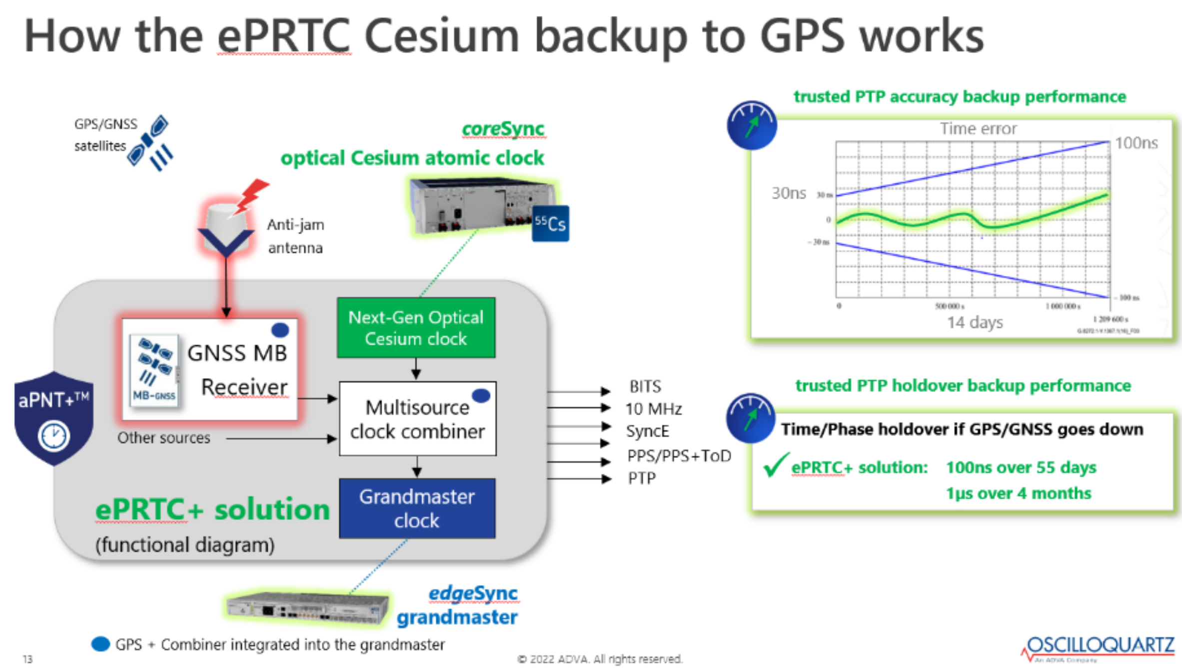
Legacy communications systems and networks have much simpler requirements for timing & synchronization. A GNSS-referenced local clock with a rubidium holdover oscillator could maintain the required accuracy for nearly a month. However, that same setup could not meet the new packet network timing requirements for more than several hours. Therefore, new timing & synchronization strategies and components are required.

One aspect of legacy sync designs is the concept of multiple inputs for a local clock. For example, a local clock may utilize GNSS for primary reference, but also have a T1 digital signal from a distant GNSS (or STL)-referenced clock or local cesium-beam reference to use as a backup to local GNSS. These are in addition to whatever quality internal oscillator is installed. Therefore, when GNSS is lost, the clock automatically switches to whichever additional external reference is available and has been qualified as reliable, such as STL. This illustrates the concept of "local Truth."

The concept of "local Truth" means the local clock is smart enough that, once warmed and normal timing signals are applied the internal brains (processors, programs, algorithms, etc.) can monitor and evaluate every potential timing source, from GNSS to other signals for local or distant references. Once the clock evaluates all potential timing references, the internal oscillator is disciplined to a state where it becomes the "local Truth" against which all references are evaluated. The local clock can then either manually (by user selection) or automatically determine a priority list for selecting timing references. If one or more of the references is unstable as compared with the "local Truth", the clock will remove that source from the priority list.

Now that we have established a "local Truth", if GNSS is jammed or spoofed in a manner that impacts timing, the local clock will remove GNSS as a viable reference until such a time as it returns to stable performance. It is notable the simple GNSS jamming devices have little or no impact on STL signals. This scheme worked well for older networks over decades of dependable service. However, it falls short of the needs for modern networks.

The timing & synchronization needs for modern networks require accuracies down to the billionths of a second. In order to reliably meet those needs in the absence of GNSS for up to 4-5 months, a new solution called the *enhanced Primary Reference Time Clock* (**ePRTC**) is required. The ePRTC is almost like plucking a GNSS satellite from the sky and installing it at your site.

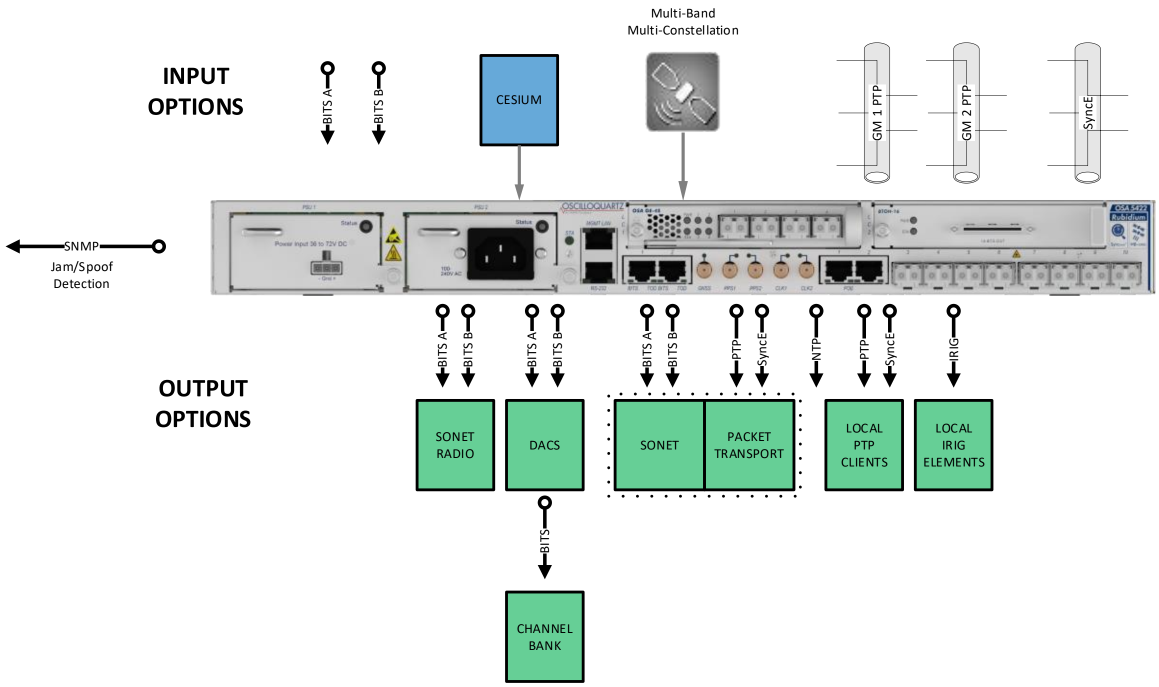


As the ePRTC warms and becomes stable, it uses GNSS for Phase reference, and "learns" the characteristics of the local cesium clock. Once fully warmed, the ePRTC is capable of maintaining frequency and phase requirements for the modern network of up to 4 months with no GNSS input.

The requirement to maintain accuracy for months with no GNSS input is relatively new but driven by the realities of the modern era. Rogue countries have already demonstrated the ability to easily cripple GNSS satellites, rendering them unusable for months if not destroyed completely. Major US airports are reporting loss of GPS for guiding planes for takeoffs and landings for up to a whole day per occurrence. Communications facilities near major highways experience daily GNSS disruptions as cars and trucks with jammers travel past their buildings. Surviving GNSS disruptions is no longer a luxury, it is a firm requirement for critical communications needs. GNSS is no longer the trusted entity we have enjoyed for decades of care-free service. And STL is now available as a GNSS back-up or complete replacement timing source.

Trust no one

The new design criteria for planning timing & synchronization networks demands a "zero-trust" concept whereby every potential timing source can be monitored and qualified by as many additional references as possible. Implementing this philosophy will ensure 100% uptime for timing & synchronization signals and messages even in absence of GNSS. No longer optional, it has become table stakes for modern network event survival.



When designing resilient, survivable network timing & synchronization strategies, a single ePRTC can harden an entire network. Once this "local Truth" is established, it can be transported across your network utilizing Precision Time Protocol (PTP), Synchronous Ethernet (SyncE) or both at the same time. If the network is highly diverse geographically, a second or third ePRTC will provide adequate protection. These needs are determined during the design phase, with support and guidance from Oscilloquartz Network Planners.

As you enter the era of modern networks, Oscilloquartz has a wide range of products to meet these needs for any budget or risk requirements. Our solutions available today are already implemented in communications, power utility, finance, broadband, E911/public safety, transportation and enterprise networks worldwide.

Let Oscilloquartz help you establish Truth for your own networks.