The Role of GPS/ NavIC (IRNSS) Satellite Synchronization in the 5G Network

With the rollout of 5G, synchronization in carrier networks is becoming even more critical. Mobile cellular networks need to be synchronized to avoid base stations with shared coverage interfering and disrupting each other, leading to declining network quality for customers. Throughout the Third Generation (3G) cellular communications, the NodeBs relied on GPS satellite communications for synchronization, which is also the same case with the Baseband Units (BBUs) in 4G cellular communications. Until now, most mobile network operators (MNOs) have relied on the Global Positioning System (GPS) satellite constellation for synchronization, as satellite antennas have high speed and accurately timed pulses.

Background Inputs

1. Normally drift rate of Local Oscillator in any of the system is vulnerable. As the time progress, drifting rate will be high and different in each system. This will affect communication between systems. To maintain common time & frequency in all systems, reference time source is required.

2. Best economical reference time source is satellite-based system (i.e GPS/ IRNSS/ GLONASS receiver) and this receiver provides common time to all client systems through IEEE 1588 (PTP) and NTP protocol with an accuracy of Nano seconds /Milli seconds. GNSS satellites will have atomic clocks which are high stable and there will be continuous monitoring and updates from Ground control station.

3. All GNSS constellations will have dedicated Time scale in the respective country to maintain high stable and accurate time on satellites, however difference is number of visible satellites in any of given location. In GPS, at any point of time, maximum visible will be 10 to 12, where as in IRNSS, total available satellites are only 7 and all are visible to Indian continent and surrounding countries. ISRO is having plan to increase this 11 in upcoming days.

   Because of this number, there will be difference in Position accuracy on each constellation, but there will be not much impact on IEEE 1588 and NTP accuracy. By using dual frequency GNSS receiver, position and time accuracy can be improved. Today we are getting 1 PPS accuracy with 20 ns and IEEE 1588 with few nano second accuracy.

Updated Synchronization Requirements for the 5G Network

With the 5G network coming into the picture, the speed requirements will increase substantially, so radios will need to be placed closer to the users. More antennas will need to be installed so that signals can overlap, and more interference can be detected. The latency in exchanging data and messages across the network decreases, which would pave the way for newer technologies such as autonomous vehicles. This is called the Ultra-Reliable Low Latency Communications (URLLC).

Lastly, the network needs to support an exponential number of devices, especially for the Internet of Things (IoT) to occur. Massive Machine Type Communications (mMTC) must be supported by the 5G network. The direct implication of this is that more sub-frequencies will need to be used, as many devices will communicate systematically and continuously. However, more sub-frequencies will increase the risk of signal interference, which is why the timing and synchronization techniques used in the cellular network will need to evolve to adapt to the new requirements of the 5G network.

The predecessors of the 5G network, the 3G and 4G networks, embedded satellite receivers in NodeBs and BBUs. These controllers take the time-of-day messages and propagate them over the air to UEs. To keep all cell towers' frequency synchronized, they also take the accurately timed pulse received every second (1PPS). Both the 3G and 4G networks need a line of sight to only one satellite to frequency synchronize.

With the 5G network, the satellites are used slightly differently. The time-of-day messages will still be received and sent over the air to UEs and the Distributed Units (DUs), the controllers used in 5G networks. To stay frequency synchronized, the DUs will also use the 1PPS received from the satellite. However, there is a second use to the time-of-day messages: to keep overlapping cells phase synchronized to avoid interference. A line of sight to multiple satellites will therefore be required to achieve this type of synchronization.

Why Does GPS/NavIC (IRNSS) Satellite based Time Synchronization in 5G Matter?

Timing and synchronization is everything in 5G

For a mobile network operator, timing is everything. Not just determining when to upgrade the network to bring new services to market, but in the literal sense as well. If the radio clock loses synchronization accuracy in a radio access network (RAN), or the radios are out of synchronization, interference between cells is likely. The less accurate the clock source, the higher the probability for time shifts. Ultimately there will be performance challenges. This issue wasn't a significant concern in legacy networks, but as we transition to 5G it becomes a really big deal.

To use available spectrum as efficiently as possible, 5G technology introduces a time division duplex (TDD) environment. Here both uplink (UL) and downlink (DL) use the same radio channel. Consider this: operators need large amounts of spectrum to deliver on the enhanced mobile broadband (eMBB) use case of 5G, amounts much greater than the 5 to 20MHz that is generally available for LTE networks. Further, most of the available wideband 5G spectrum is either in the C-Band or mmWave, which only supports TDD. This means that TDD is a key factor in enabling eMBB services.

Complexities in terms of synchronization

Because a lack of synchronization in UL/DL frames further exacerbates interference problems, industry standards introduce stringent restrictions on LTE and 5G new radio (NR) TDD transmission. While the absolute time synchronization margin in a frequency division duplex (FDD) LTE environment is in the magnitude of 10µs, in the TDD radio environment it is restricted to just 1.5µs. In addition to the absolute time error margin, another consideration is management of over-the-air synchronization requirements for advanced radio features. These include MIMO, eCIC, COMP, and location-based services. In 5G, we are moving away from a synchronized fronthaul CPRI to a packet-based fronthaul. While this approach offers several advantages, packet-based fronthaul introduces complexities for synchronization. Providers need different approaches depending on the topology and configuration of their networks. In most cases, we expect to see precision timing protocol (PTP) for distributing time of day (ToD), and Synchronized Ethernet (SyncE) for distributing frequency. This means that radio units (RU) will be synchronized over Ethernet.

A test of time, synchronization requirements

Providers can implement various methods to meet these stringent phase and time synchronization requirements. The intent is to ensure synchronization of all nodes to the primary reference time clock (PRTC) source However, the location of the source may vary depending on the network topology, cost, and application. **By using a grand master clock synced to a satellite source (GPS/NavIC satellite based Grand master clock). and a combination of boundary clock and slave clocks, network nodes can be aligned to a common time and phase**. For networks that cannot adhere to full timing support, such as networks that are not PTP aware, there are other options. For example, network operators can implement assisted partial timing support with appropriate consideration for the network topology and cost.

Lastly, it's important to consider the use cases for frame and slot synchronization. 5G 3GPP standards defined 56 slot formats, each of which is a predefined pattern of downlink/flexible/uplink symbols during one slot. These formats allow flexibility in terms of the application supported on a 5G node B (gNB). Yet, this also creates a challenge if two networks offering different types of service are located next to each other. Interference can result even if they are synchronized in time, but their slot formats are not synchronized. Essentially, when operating a 5G or 4G LTE network in a TDD environment, we not only need frequency and phase synchronization, but also frame and slot synchronization. This avoids inter-network interference

Conclusion

Synchronization is fundamental to the performance of a cellular network and the services it offers. Both 3G and 4G cellular technology required frequency synchronization, primarily to prevent interference when cells overlap. But with the **introduction of 5G technology, we've reached a new level in terms of TDD phase and frame synchronization. Validation testing is essential to meet stricter synchronization requirements and to ensure quality of service.**

Any Indian company who are developed dual frequency GNSS receiver including NavIC is an IPR and using this if they develop reference time source, then complete system will be under Make in India category. This should be criteria to select Indigenous system for Time & Frequency synchronization.