Verifying telecom timing and synchronization

app note

EXFO

Verifying timing and synchronization in radio access networks (5G NR)

app note

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1. The importance of timing in a 5G network

In previous generations of mobile communications, such as 3G and LTE, network synchronization was important. However, in 5G, maintaining robust network synchronization is critical. While frequency synchronization was sufficient for LTE and earlier generations, 5G also requires phase synchronization to support advanced features like time division duplexing (TDD), coordinated multipoint (CoMP), carrier aggregation (CA), and beamforming. As a result, network operators are turning to network synchronization—relying on IEEE 1588 PTP (Precision Time Protocol) and Synchronous Ethernet (SyncE) as the preferred solution used to synchronize every network element (from the core to the radio) in frequency and in phase. But whether operators are qualifying new transport equipment in the lab or deploying 5G equipment in the field, simple and reliable test solutions are needed to confirm that 1588 PTP, SyncE protocols and time error across a network are delivered correctly. Operators must also validate that networks meet stringent 5G timing accuracy requirements—requirements that are now in the nanosecond range.

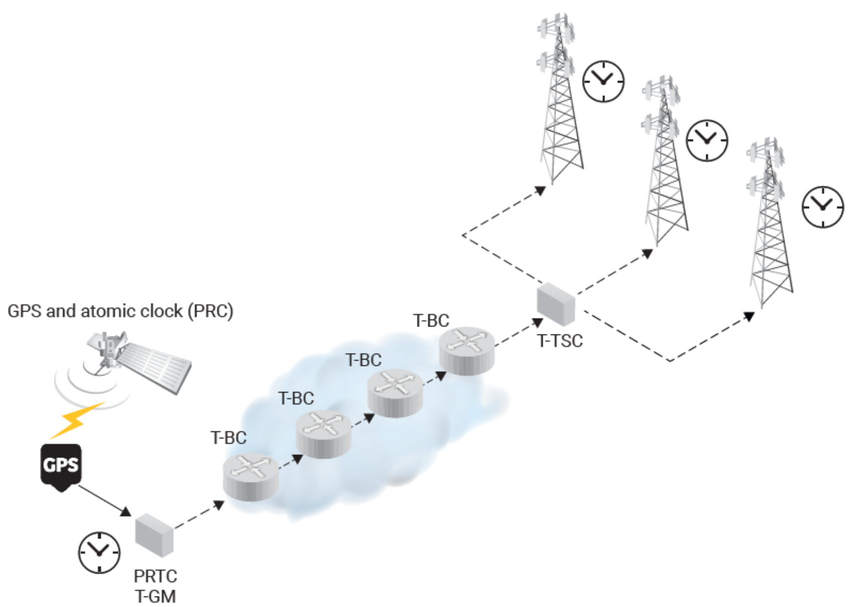

Figure 1. Network synchronization relying on 1588 PTP and SyncE.

Timing and synchronization must be validated at the deployment phase, otherwise numerous issues can occur that will seriously impact service quality and network performance.

2. Impact of a faulty synchronization network

Timing issues can dramatically impact both 5G and 4G/LTE networks. With 5G specifically, timing is vital because of the strict synchronization requirements for time, frequency, and phase. As a result, timing and synchronization must be validated at the deployment phase, otherwise numerous issues can occur that will seriously impact service quality and network performance.

Timing issues in a radio access network (RAN) can impact its performance in a variety of ways:

2.1 Inter-cell interference

With TDD, a single frequency channel is used for both transmit and receive. That channel is shared by assigning alternated time slots for transmission and reception tasks (uplink and downlink) respectively. In a 5G TDD network, if two overlapping cells are out of sync, there is a potential for the downlink from one tower to interfere with the uplink from an adjacent tower. This could be perceived as an increase in the received signal strength indicator (RSSI), resembling interference, and causing reduced coverage and a decrease in available throughput.

2.2 Handover issues

During handover between cell sites, there's a brief period when the user equipment (UE) cannot transmit or receive data. In LTE, this interruption typically lasted for tens of milliseconds. With 3GPP release 16/17, this downtime has been significantly reduced to support emerging use cases. However, any synchronization issue between cell sites could still prevent the network from meeting the new 5G requirements and might even cause the UE to lose connectivity with the network.

2.3 5G application issues

While synchronization requirements didn't change significantly for early 5G non-standalone (NSA)deployments, there are critical 5G applications in the new standalone (SA) architecture that require stricter synchronization standards. Applications that rely on time-sensitive networks, like device positioning and real-time communications in robotics, are especially dependent on precise synchronization. Any deficiencies in the network can negatively impact the performance of those applications.

3. Steps to validating timing in a 5G network

In current 5G networks, network synchronization primarily relies on the 1588 Precision Time Protocol (PTP), which uses high-precision clocks—typically cesium-based—to distribute synchronization signals throughout the network. For backup, GNSS-based synchronization is employed. Additionally, 1588 PTP networks can operate using various profiles, such as G.8275.1 or G.8275.2.

It is critical to validate that the 1588 PTP protocol propagates correctly across the network and that time error (TE) values are within acceptable ranges at various points. Multiple factors can impact the synchronization network, including misconfigured GNSS cable delay in the grandmaster, failures in network devices like boundary clocks, incorrect QoS settings, transmission-reception path asymmetries, and other configuration errors.

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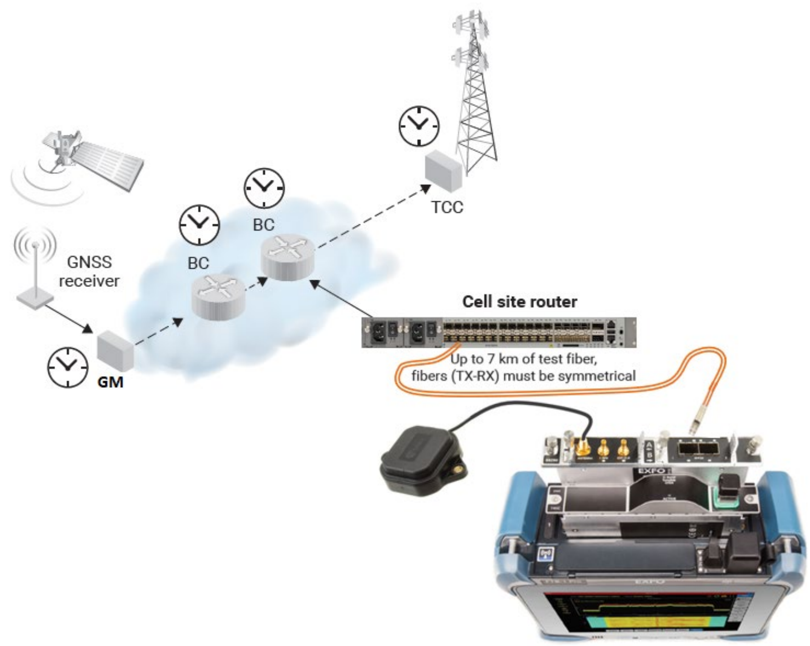

Figure 2. Setup for characterizing the synchronization performance of a wireless network.

3.1 Verification of 1588 PTP or SyncE protocols and synchronization health

When a synchronization issue occurs in the network, it may present itself as a different problem, like a rise in RSSI. To resolve this, an on-site investigation is crucial to uncover the underlying cause. The first priority is to test whether the 1588 PTP or SyncE protocols are being properly propagated and configured (e.g., address, domain settings). By connecting to the cell site router (CSR) and configuring EXFO's test solution as a 1588 client (see Figure 2), we can verify that the CSR successfully receives packets from the grandmaster (GM).

After confirming that the 1588 packets are being received at the test site, we need to evaluate the time error of these packets relative to the reference signal, typically provided by a GNSS signal. To achieve this, our test gear must be equipped with a high-precision clock and a GNSS receiver to compare the reference time with the timestamps of the 1588 packets (See Figure 3).

By using grandmaster emulation mode, we can simulate the grandmaster clock using the EXFO test device and observe the network's behavior.

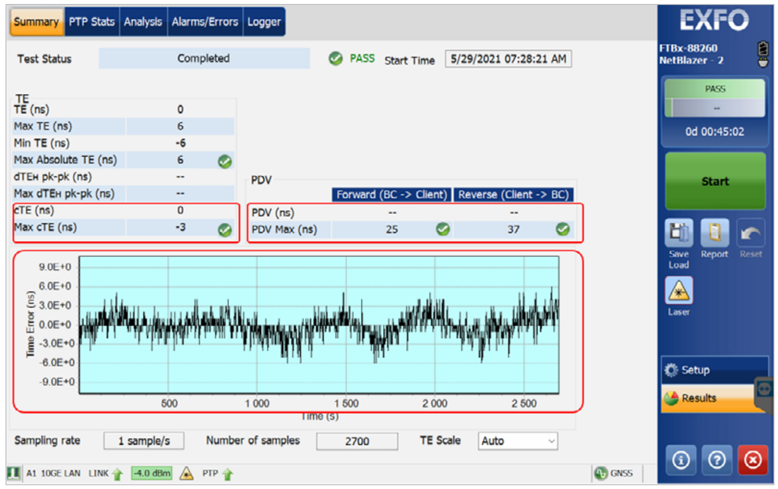

Figure 3. Summary screen for the time error related parameters measured in a cell site.

It is important to address the various inaccuracies introduced by ANY test setup when measuring time error, like GNSS delay compensation, or fiber compensation when connecting to the cell site router (e.g., this can offset up to 7 km with an EXFO solution, considering symmetrical fibers). EXFO's fiber compensation capability allows the technician to move the test setup to a position where GNSS reference is available, and avoid needing to go into holdover mode.

3.2 Troubleshooting the grandmaster clock

When dealing with synchronization issues in the network, we sometimes need to use the test device as a grandmaster to assess the performance of the actual grandmaster in the network and identify potential problems.

By using grandmaster emulation mode, we can simulate the grandmaster clock using the EXFO test device and observe the network's behavior (See Figure 4). If synchronization improves with the emulated grandmaster, this indicates an issue with the actual grandmaster. If synchronization remains problematic, we can isolate the problem by breaking network links and reintroducing the grandmaster emulator to test synchronization at different points. Repeating this process helps to identify and resolve points of failure, ultimately pinpointing the root cause of the synchronization issues.

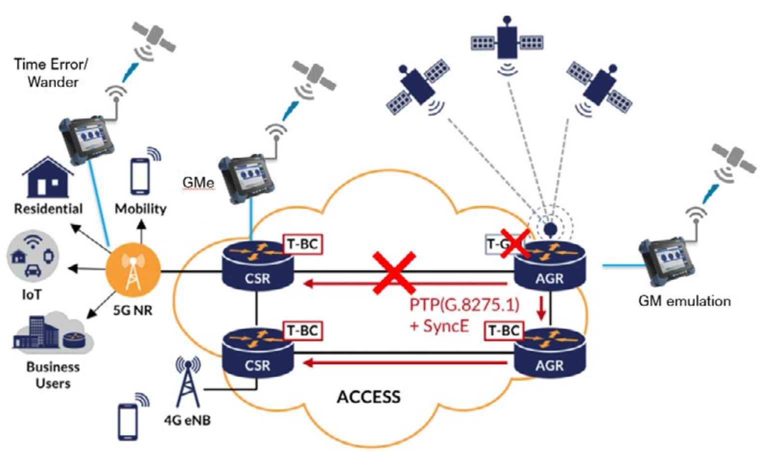

Figure 4. Grandmaster emulation.

With the high-accuracy reference clock inside EXFO's synchronization module, we can compare the time start of the 5G signal against this reference and measure the absolute time error

3.3 Over-the-air timing validation

The last step in timing validation for a mobile network involves testing over-the-air (OTA) time error. Although this process is similar to evaluating time error using the 1588 PTP protocol, the key difference lies in the methodology. Instead of inspecting timestamps in PTP packets, we measure the start of the 5G frame sent by the base station and compare it with the GNSS reference.

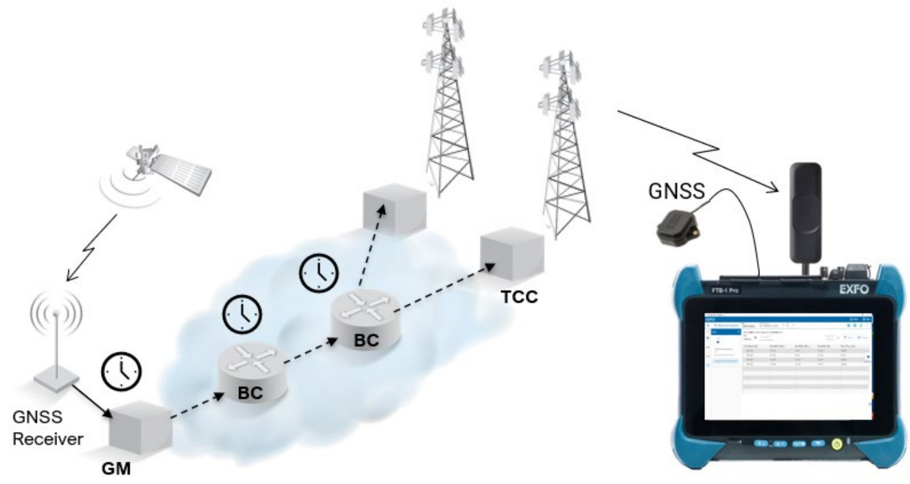

Figure 5. Over-the-air time error validation.

In this scenario, we use an RF signal analyzer to demodulate the synchronization signal block (SSB) within the 5G signal and extract the frame start information (See Figure 5). With the high-accuracy reference clock inside EXFO's synchronization module, we can compare the time start of the 5G signal against this reference and measure the absolute time error. Ideally, the frame start should align perfectly with the reference. By capturing the SSBs from multiple PCIs, we can obtain relative time error measurements, which can help identify potential issues in handover, CoMP, and other related processes.

4. EXFO's timing and synchronization solution

EXFO's timing solution allows technicians to verify network timing and synchronization by validating 1588 PTP, SyncE, measure time error/wander in the fronthaul and time error over-the-air, all in the same platform. This simple-to-use feature is available on the FTB 5GPro, a multipurpose and flexible platform designed to scale with your evolving testing requirements. Its unique Open Transceiver System (OTS) integrates synchronization, transport, and RF test capabilities into one comprehensive test platform.

4.1 1588 PTP and SyncE

EXFO's 1588 PTP and SyncE applications validate 1588 PTP packet network and SyncE synchronization services, ensuring that both protocols are delivered correctly at any critical location in the network. The 1588 PTP application supports the G.8265.1, G.8275.1 and G.8275.2 profiles which are critical for 5G.

Learn more

Products
FTB 5GPro - Complete, all-in-one 4G and 5G test solution

Timing and synchronization - 1588 PTP, SyncE and over-the-air time error test solution

Blog post
Timing and synchronization for 5G TDD networks

Webinar
The vital role of timing and synchronization for 5G NR TDD networks

4.2 Time error and Wander

EXFO's Wander application provides all the key test metrics to validate the accuracy of the network synchronization. And thanks to the built-in high precision GNSS OCXO-based receiver, the test is easy to setup and ready to measure in only a few minutes. The application performs multiple time error measurements such as maximum absolute time error (Max |TE|), dynamic time error (dTE), constant timer error (cTE), maximum time interval error (MTIE) and time deviation (TDEV). The time-error/Wander application automatically evaluates if the signal under test meets different standardized masks such as the MTIE mask as defined by ITU G.8271.1.

4.3 Time error over-the-air (TE OTA)

EXFO's TE OTA measurement provides the metrics to validate the timing characteristics of a base station. With a simple configuration and the same built-in high precision GNSS OCXO-based receiver, the test is very easy to setup and the technician will be ready to start taking measurements in only a few minutes.

5. Summary

Given the stringent requirements of 5G, validating timing accuracy is becoming increasingly critical for the successful delivery of 5G services. EXFO uses a simple-to-use, highly accurate GNSS receiver to deliver reliable timing and synchronization measurements. With a test set-up time of under 20 minutes, it measures latency, time error and Wander almost 90% faster than any other test solution. It offers a quick start process, simple-to-use test methodology and industry-leading accuracy. In addition, it offers a comprehensive list of test capabilities that can be performed in unison on the same platform, including RF over-the air (OTA); RF spectrum analysis over CPRI using EXFO's iORF application; CPRI and eCPRI link validation; Ethernet up to 100G and fiber link characterization with EXFO's iOLM/OTDR.