Integrating Terrestrial 5G PNT into Network Synchronization Architectures

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Abstract

- In this joint talk, NextNav and Oscilloquartz will demonstrate results from lab and field work showing how 5G based terrestrial Positioning, Navigation, and Timing (PNT) signals can be used as a time source for network synchronization and other timing applications. This 5G terrestrial solution operates at 900 MHz to broadcast a 5G standard Positioning Reference Signal (PRS) which provides an accurate timing signal to provide resilient PNT services when GPS is unavailable.

- The session will show how PPS/TOD outputs from a 5G NR PRS based timing receiver connect into a timing grandmaster and show system performance using standard timing metrics. We will present results with timing accuracy in the tens of nanoseconds range, traceable to UTC, and stable operation in both indoor and outdoor GNSS-denied cases. The talk will highlight what worked well, what calibration was required, and the key challenges. The focus will be on practical lessons and why adding terrestrial PNT as another source makes sense for building more resilient sync networks

GNSS is the Foundation of Modern Timing

- Primary source of UTC traceable time globally
- Widely used in telecom, data centers, utilities, finance, Defense
- High accuracy at relatively low deployment cost

GNSS underpins most timing infrastructure today

Alternative Sources is crucial for Resilient Timing

- Satellite alternatives (LEO-based PNT)
- Network-based timing (PTP/WR)
- Extended holdover (using atomic clocks)
- Terrestrial RF (e.g., 5G PRS, eLoran)

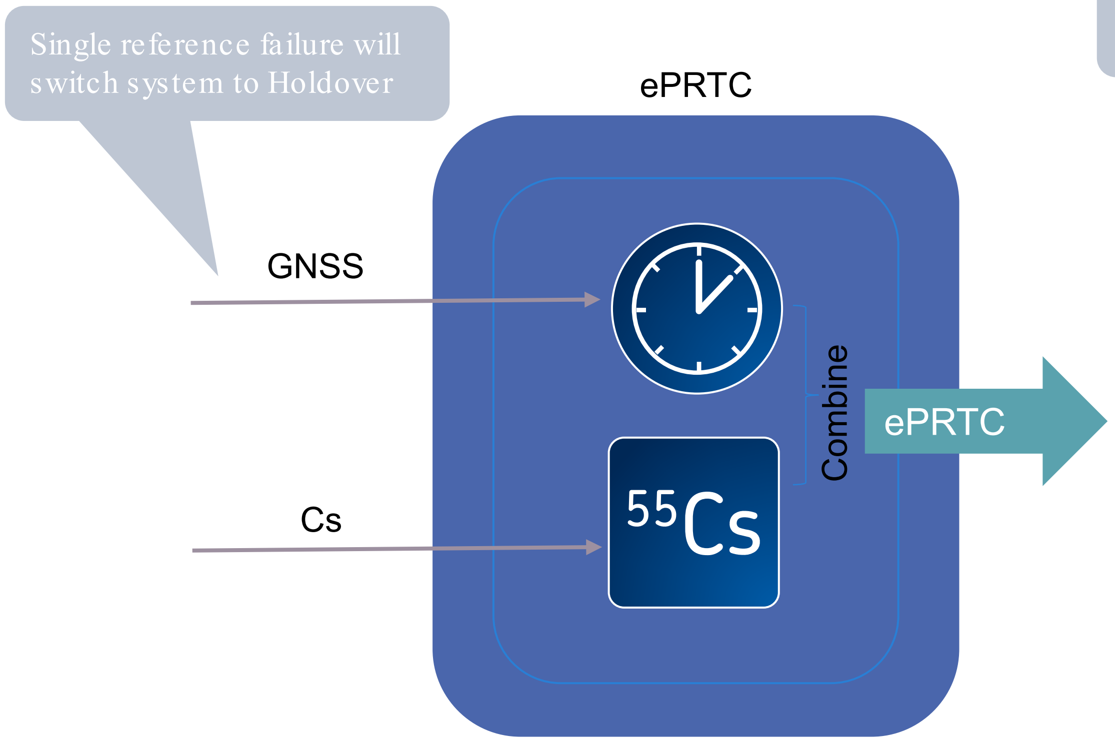
Alternative sources are key for resilient timing

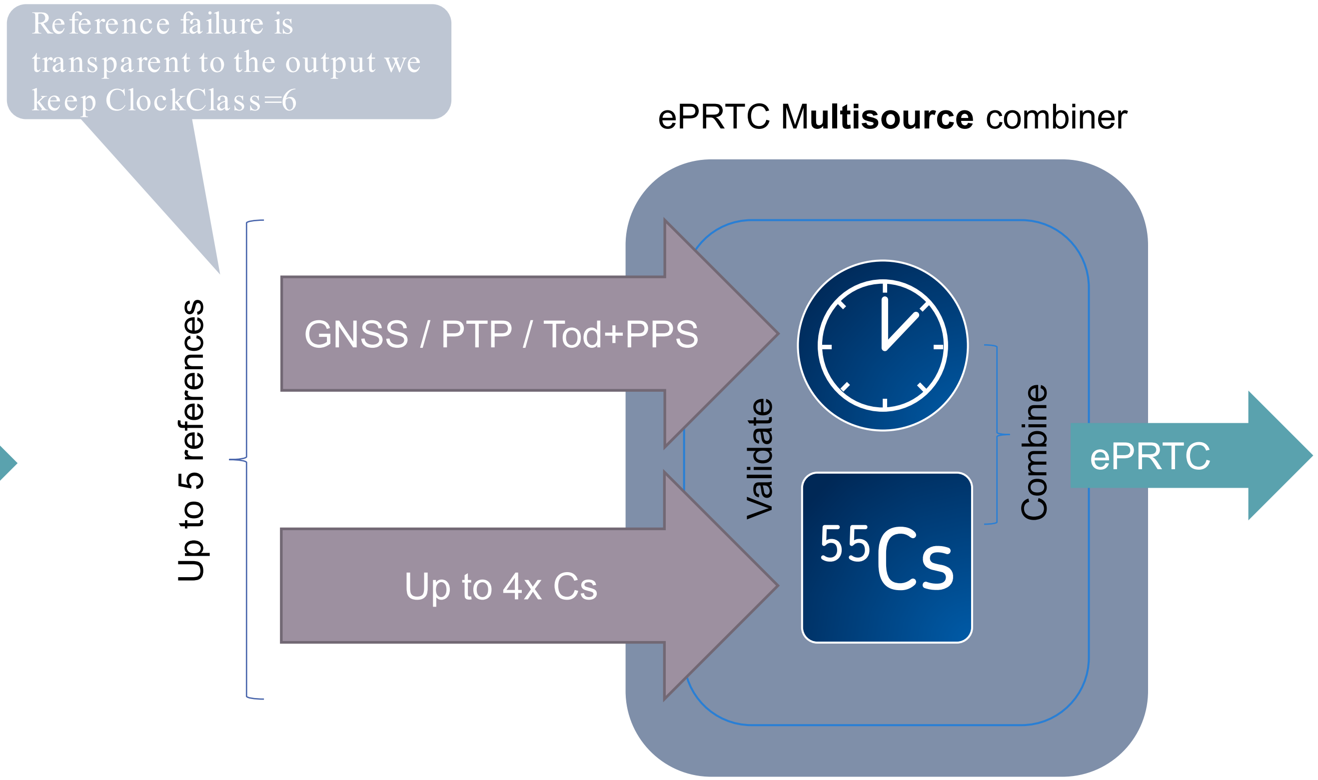
The Gap: Limited Ability to Combine Multiple Sources

- Switching between sources is not seamless
- Limited weighting / cross-validation between inputs
- Integration complexity across heterogeneous sources

True resilience requires effective multi-source fusion

Multisource redundancy for ePRTC





Two refences:
- 1x Phase references
  GNSS, PTP, ToD+PPS
- 1x Frequency reference
  ePRC

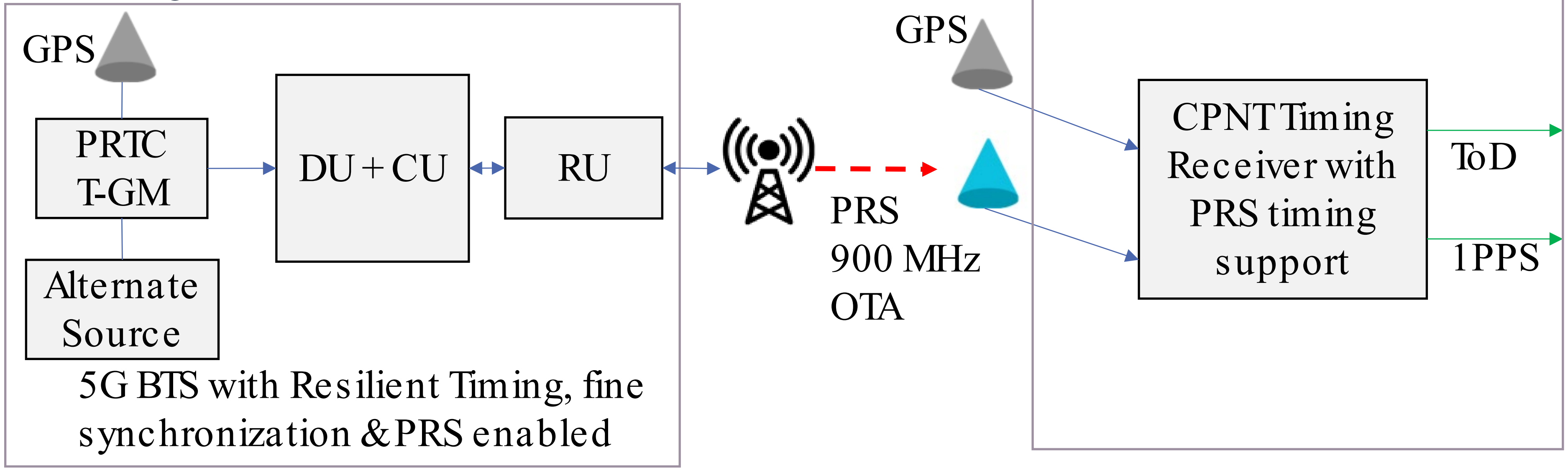
- 5 references in total
- Mandatory:
  1x Phase
  1x Frequency reference (ePRC)
  Up to three extra references (phase or frequency)

Using 5G Signals for Time Distribution

- 5G NR Release 16 supports Position Reference Signal (PRS), a broadcast downlink signal, that can be used by devices to derive timing.
  - Timing service can be provided using a minimum of one Transmitter
  - Time of Day (ToD) transferred over SIB messages
  - When multiple transmitters are available, positioning can be derived by trilateration
- NextNav and Oscilloquartz will show integration results from lab and field work which show how the PRS signals can be used to distribute timing in GPS denied environments for critical infrastructure such as utilities, telecom networks and data centers.
- The 5G terrestrial solution presented here operates in the 900 MHz to transmit PRS signals.

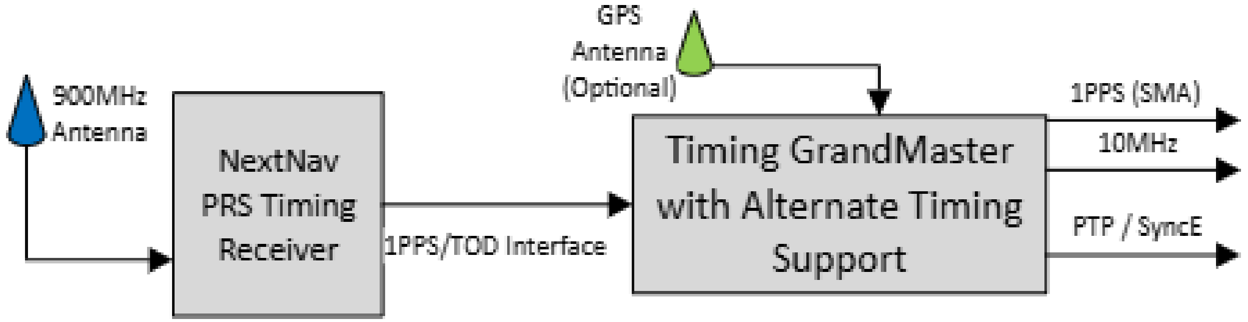
PRS timing distribution from 5G Network

- 5G base station with
  - Release 16 complaint PRS enabled
  - Fine timing accuracy within BTS
    - Delays in the RU well calibrated to the antenna
    - BTS antenna coordinates accurately surveyed
  - Timing Grand Master resilient to GPS outage
    - Uses OCXO, provides traceability to UTC, and has alternate source option
    - Distributes PTP to all base station components
  - D/L PRS signal uses full 10 MHz BW



Timing Receiver Interface to T-GM

- The PRS timing receiver outputs ToD/1PPS over an RJ-45 timing port (ITU-T G.8271 and V.11 standards)
- PRS based timing receiver provides an Alternate time source to the Timing Grandmaster (T-GM), in addition to GPS (if present).

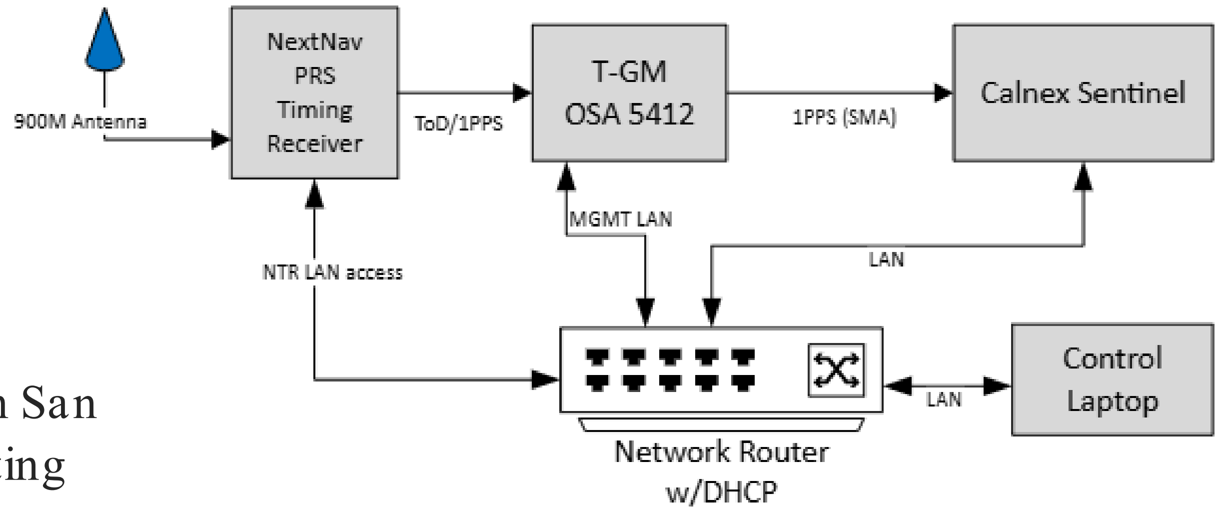


- When GPS is jammed/spoofed, the T-GM can continue to provide timing service by switching its timing source to the PRS time receiver.
- In GPS denied environments, the PRS time receiver can provide timing input to the T/GM for disciplining and distribution.
- The T-GM disciplines its clock to the selected timing input and provides timing over PTP (ITU-T G.8275.1), or other standard interfaces to the gNB and the RUs/TRPs at the base station or standalone systems that need UTC traceable timing.

Field Setup & Test Locations

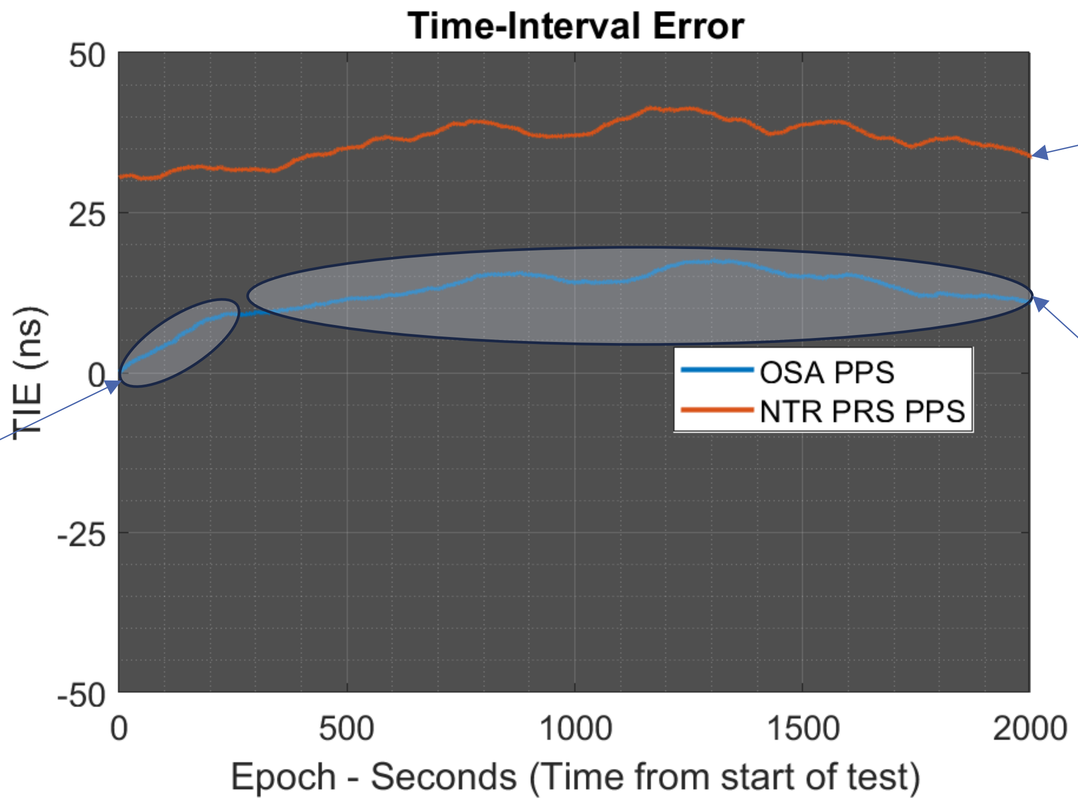
- Outdoor Location
    - Open top floor of four-level parking garage in San Jose, CA.

      Range = 466m
    - Store Open Parking lot
        - Range = 442m
- Indoor location
    - Basement in a four-level parking garage in San Jose, CA. There is no LOS to the Transmitting station. No GPS reception available.
        - Range = 471m
- TX and RX antenna Coordinates surveyed to sub-meter level



Outdoor Timing Performance (Parking Structure Roof)

- Test time: ~30 minutes
- At time t=0, the time source is switched from GPS to alternate PRS time source on T-GM simulating a GPS outage



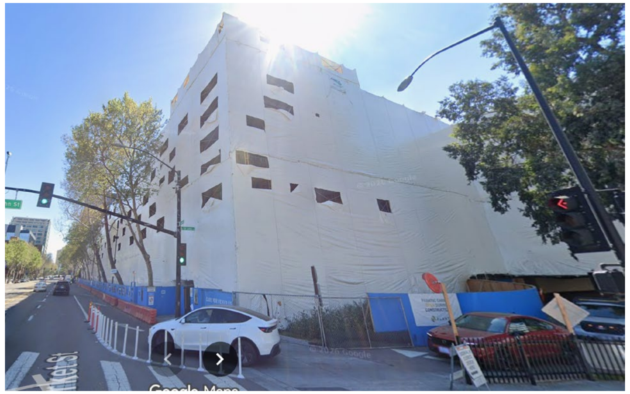
Input PPS to T-GM is intentionally shifted in the plot

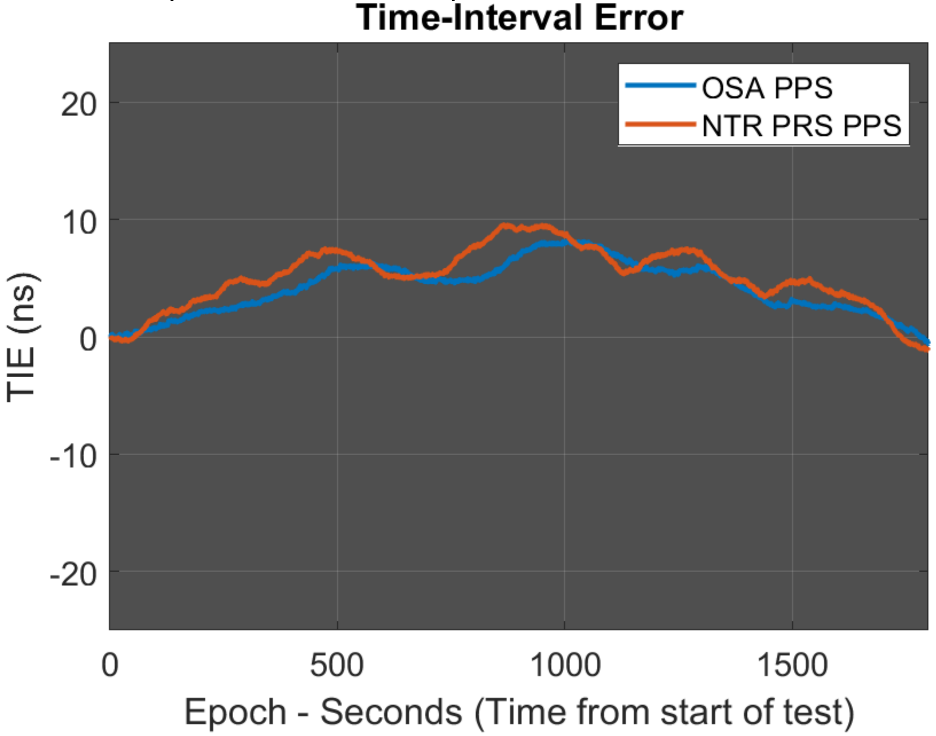
Beyond that T-GM smooths the alternate source in its servo loop to deliver timing

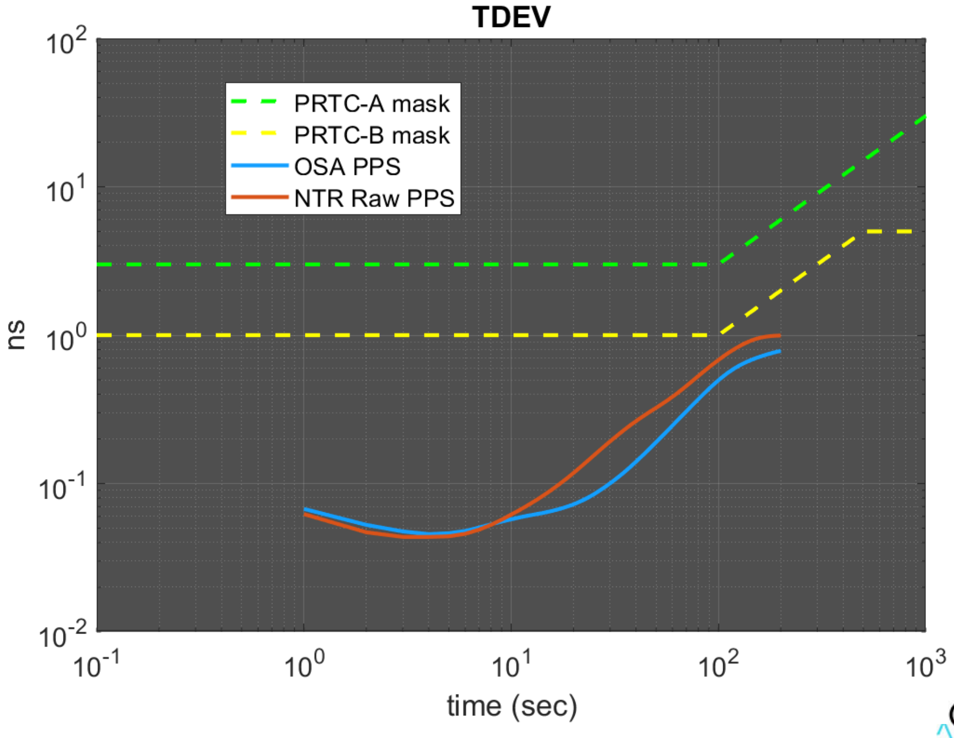
Solution shows a smooth transition from GPS to PRS and settles

Outdoor Timing Performance (Parking Structure Roof)

- Test time: ~30 minutes
- Performance results when using alternate time source from 5G PRS
- TIE plot shows that
  - MTIE is within 10ns
  - Performance is well within MTIE limits of 100ns (G8272-PTRC-MaskA) and 40ns (G8272-PRTC-MaskB)
- TDEV plot shows that
  - The platform (OCXO based) meets both the PRTC masks







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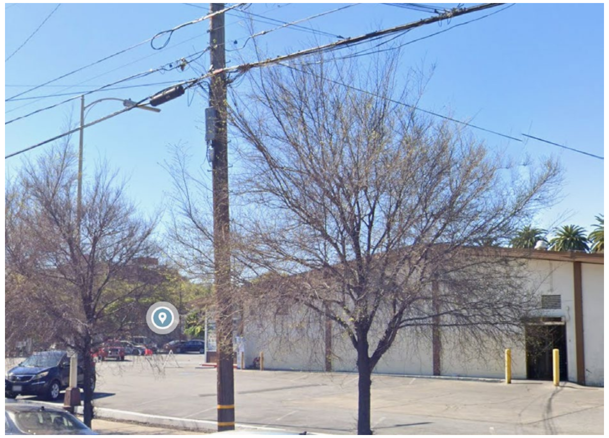
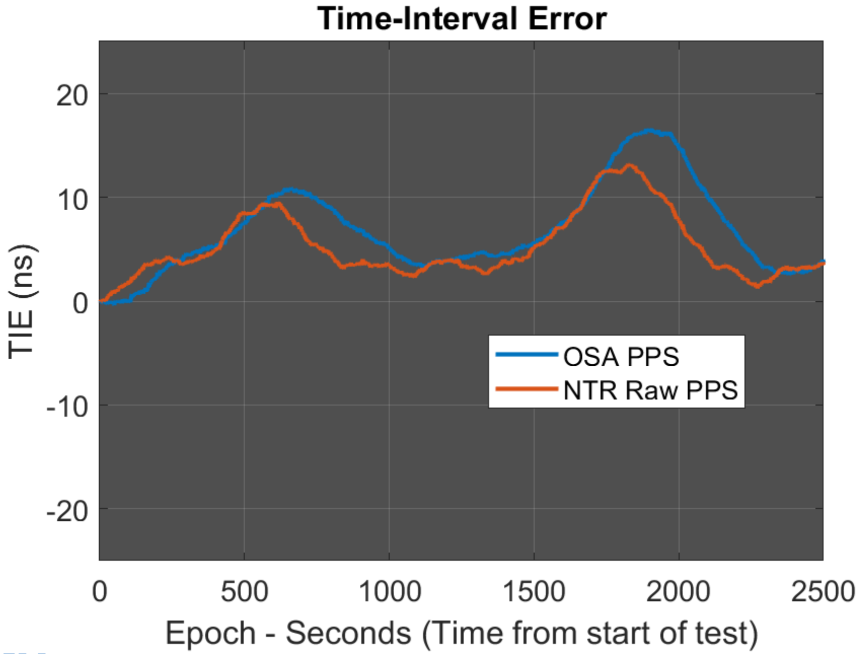
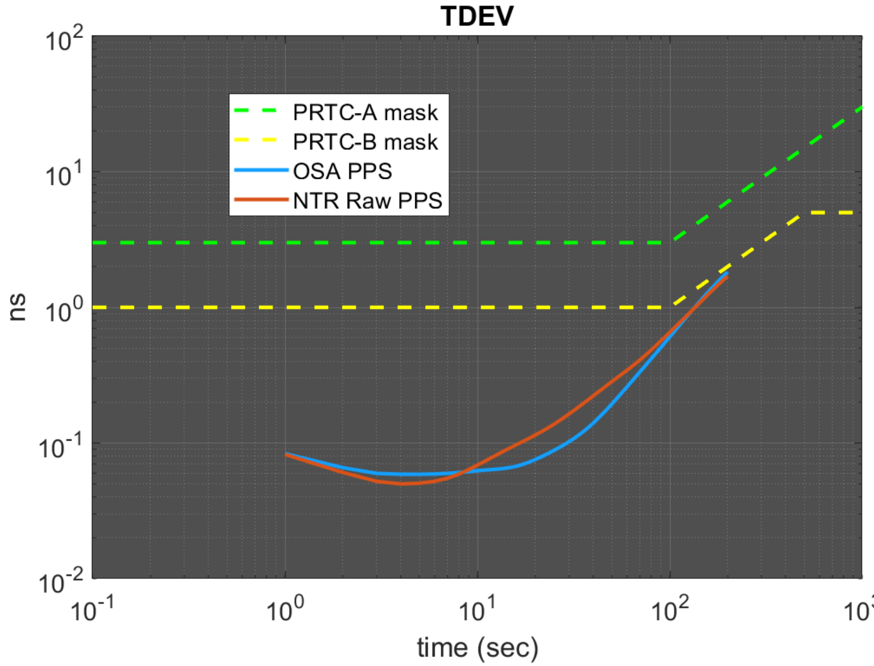
Outdoor Timing Performance (Store Parking Lot)

- Test time: ~40 minutes
- Performance results when using alternate time source from 5G PRS
- TIE plot shows that
  - MTIE is within ~15ns
  - Performance is well within MTIE limits of 100ns (G8272-PTRC-MaskA) and 40ns (G8272-PRTC-MaskB)
- TDEV plot shows that
  - The platform (OCXO based) meets both the PRTC masks

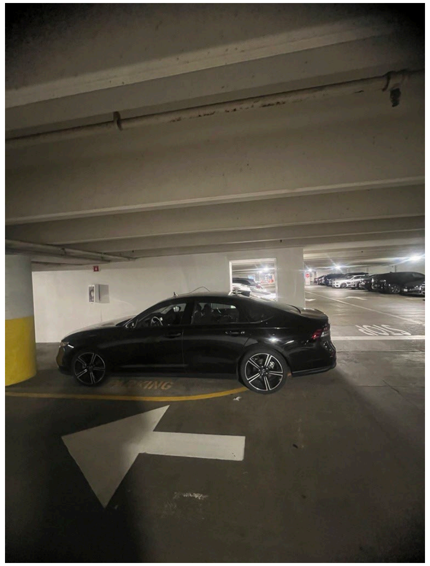


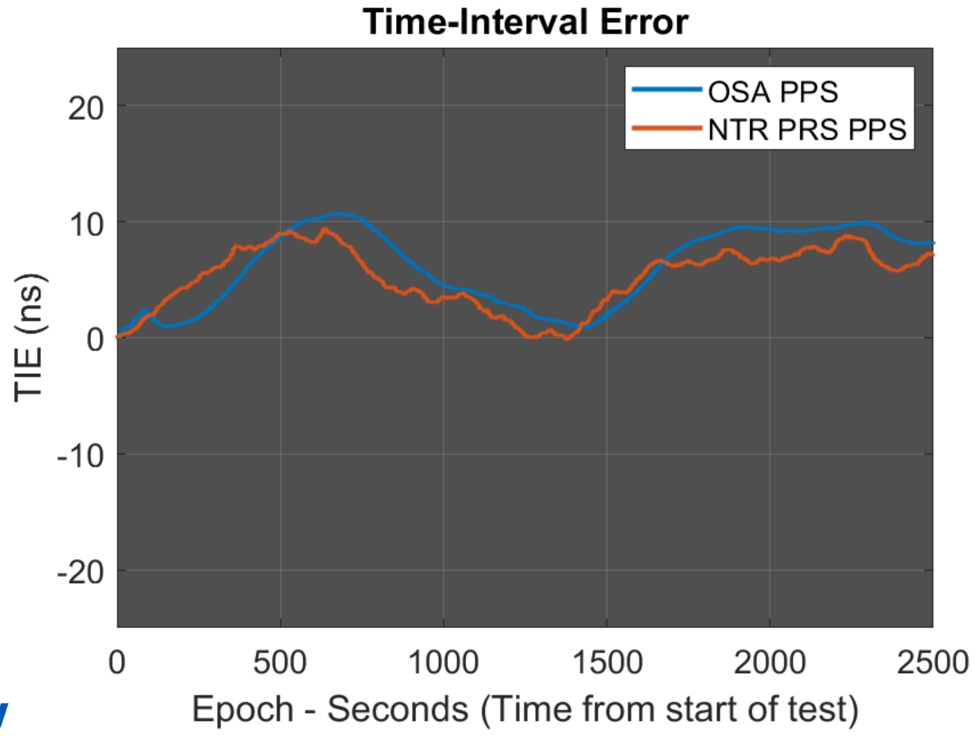


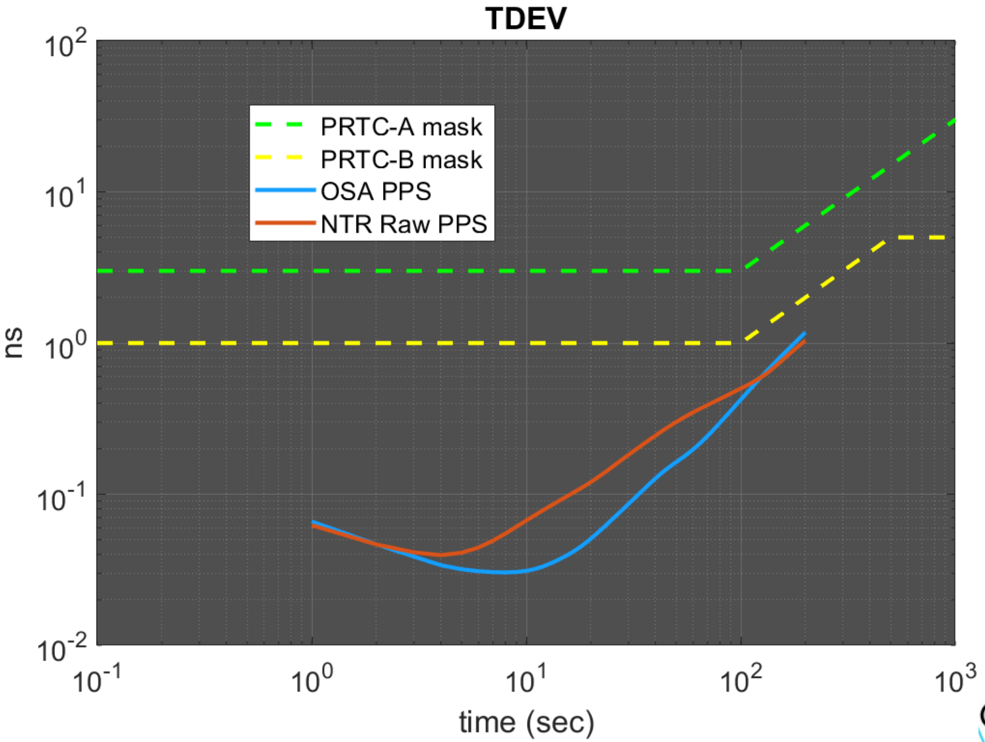


Indoor Timing Performance (Basement)

- Test time: ~40 minutes [No GPS signal available]
- Performance results when using alternate time source from 5G PRS
- TIE plot shows that
  - MTIE is within 10ns
  - Performance is well within MTIE limits of 100ns (G8272-PTRC-MaskA) and 40ns (G8272-PRTC-MaskB)
- TDEV plot shows that
  - The platform (OCXO based) meets both the PRTC masks







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Observations

- During our initial testing, MTIE was within 20ns and meets PRTC Mask B across all tested Indoor and Outdoor Locations.
- TDEV stability met the more stringent PRTC Mask B

Conclusions

- Terrestrial 5G PRS based timing distribution can feasibly meet the accuracy and stability requirements for resilient timing in critical infrastructure applications such as utilities, telecom and data centers
- PRS based timing can be easily integrated into existing T-GM platforms that support an alternate source
- Such timing solutions can provide a backup to GPS outdoors (absence of GPS) as well as a complement to GPS indoors (where GPS is unavailable)