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BUILDING A NATIONAL TIMING GRID FOR IRELAND

AGENDA

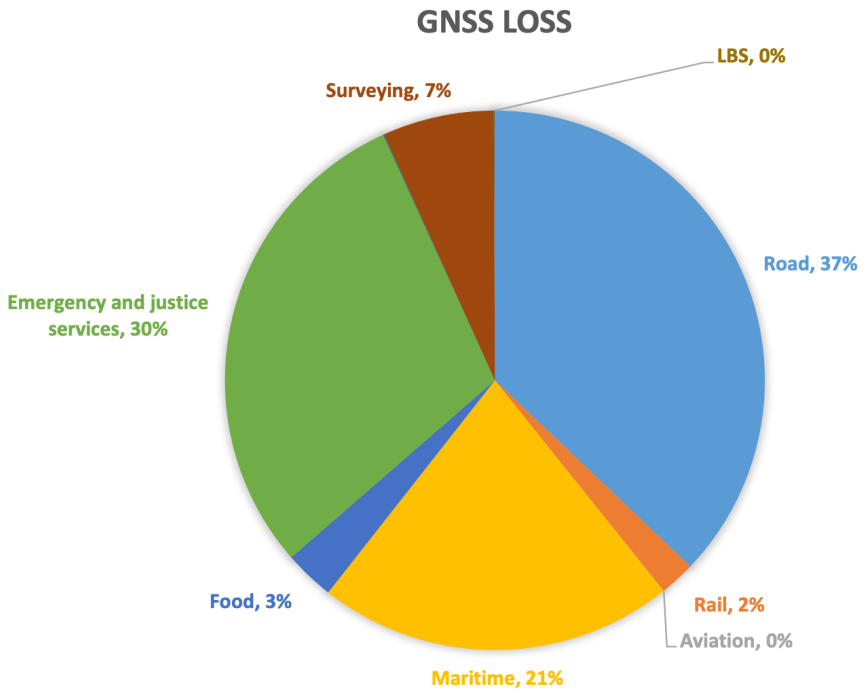
- Introduction
- Motivation for building a National Timing Grid
- Architecture
- Practical case study for an NTG node

TIMING SOLUTIONS – WHO WE ARE

- Timing Solutions Ltd is a start-up company hoping to introduce innovative ideas to the telecom market.
- One man show, but more than 12 years of experience in telecom timing:
  - u-blox (GNSS chip vendor) – Head of Timing Product team.
    - Common View Time Transfer feature design and implementation.
    - Timing reference infrastructure design using Passive Hydrogen Maser clock (algorithms & HW).
    - ITU-T Q13/15 Network synchronization and time distribution performance group delegate.
  - ESA – Research Fellow
    - Next generation requirements for Galileo Services.
    - Delegate for ITU-T Q13/15 Network synchronization and time distribution performance group delegate.
    - 3GPP RAN and SA contributions.
  - Etisalat/BT research center – Senior Researcher
    - Timing and synchronization algorithms for 4G.
  - Contributing member of IEEE P1952 Resilient Positioning, Navigation, and Timing User Equipment Working Group. WG is led by US DHS.

CRITICAL INFRASTRUCTURE & GNSS

- Time and timing distribution has become increasingly important for Critical Infrastructure sectors such as communications, energy, transportation, emergency and financial services, and cloud data centers.
- The most common time distribution methods are: packet-based (PTP, NTP) over wire/fiber media, or GNSS using RF signals over the air. These two methods are usually used in combination as, for example, PTP/NTP is most often traced to a GNSS receiver.
- Due to this over-reliance on GNSS any GNSS failure could have a potential to adversely impact national economy. A study done in UK showed a price tag of £1 billion per day for a five day disruption*. The report assumes telecom networks have long holdover capabilities (> 5 days).



* HTTPS://LONDONECONOMICS.CO.UK/WP-CONTENT/UPLOADS/2017/10/LE-IUK-ECONOMIC-IMPACT-TO-UK-OF-A-DISRUPTION-TO-GNSS-FULLREDACTED-PUBLISH-S2C190517.PDF

GNSS THREATS

- GPS UTC Offset Anomaly – January 2016 – lasted 12-24 hours, introduced 13µs timing error, caused by a software bug. The reason why it took so long to find and recover:
  - **Slow monitoring feedback loop.**
- Galileo Broadcast data error – July 2019 – lasted 7 days, caused by several unlikely factors happening at the same time. The reason why it took so long to find and recover:
  - No operational backup available.
  - **Slow monitoring feedback loop!**
- Space weather and solar storm.

Event Summary Table

	Network Type	Region	Qty GPS Elements	Notes
Customer A	Fixed Line	UK	Large	Generated nearly 2000 alarms and standing condition events throughout duration
Customer B	Transport Comms	UK	Small	Customer in panic mode as systems in holdover
Customer C	Fixed Line	Global	Large	Nearly 2500 alarms generated during event. Roughly 40 elements entered holdover due to lack of backup inputs.
Customer D	Fixed Line	UK	Small	Element in holdover
Customer E	Transport Comms	UK	Small	TimeSource only systems. Caused local switches to go into free run.
Customer F	Mobile	UK	Medium	No adverse impact. All systems have backup network feeds and Rb clocks
Customer G	Private Network	UK	Small	System backed up by Caesium
Customer H	Mobile	UK	Medium	Difficult to determine number of affected elements but majority of elements have backup sync feeds taken from another Telecom operator.
Customer I	Fixed Line	Sweden	Medium	Affected all SSU 2000 units
Customer J	Mobile	UK	Medium	Some TimeSource inputs reporting high MTIE and MTIE alarms on SSU2000
Customer K	Mobile	UK	Medium	All SSU2000 disqualified GPS inputs. Systems reverted to line timing traceable to another carrier

Table: Chronos Technology, on-line https://www.gpsworld.com/world-dodges-gps-bullet/

WHAT CAN WE DO?

- There is a high number of independent Cesium atomic clocks in Ireland.
- In case of GNSS failure those atomic clocks provide a very long-term stability and would guarantee that over a 14-day period those clock would drift as little as 200 ns apart (if properly steered and conditioned).
- However, over a longer period of times those atomic clocks would inevitably drift apart, as there would be no common time scale available (currently provided by a GNSS, most likely GPS, to be specific).
- In case the GNSS provides inaccurate information (e.g. the incident from January 2016, where UTC derived from GPS was biased by -13 μs), atomic clocks could be affected too.
- Each individual atomic clock provides great value to its owner, but having them combined, or interlinked, would enable creation of a much more resilient timing infrastructure – National Timing Grid of Ireland.

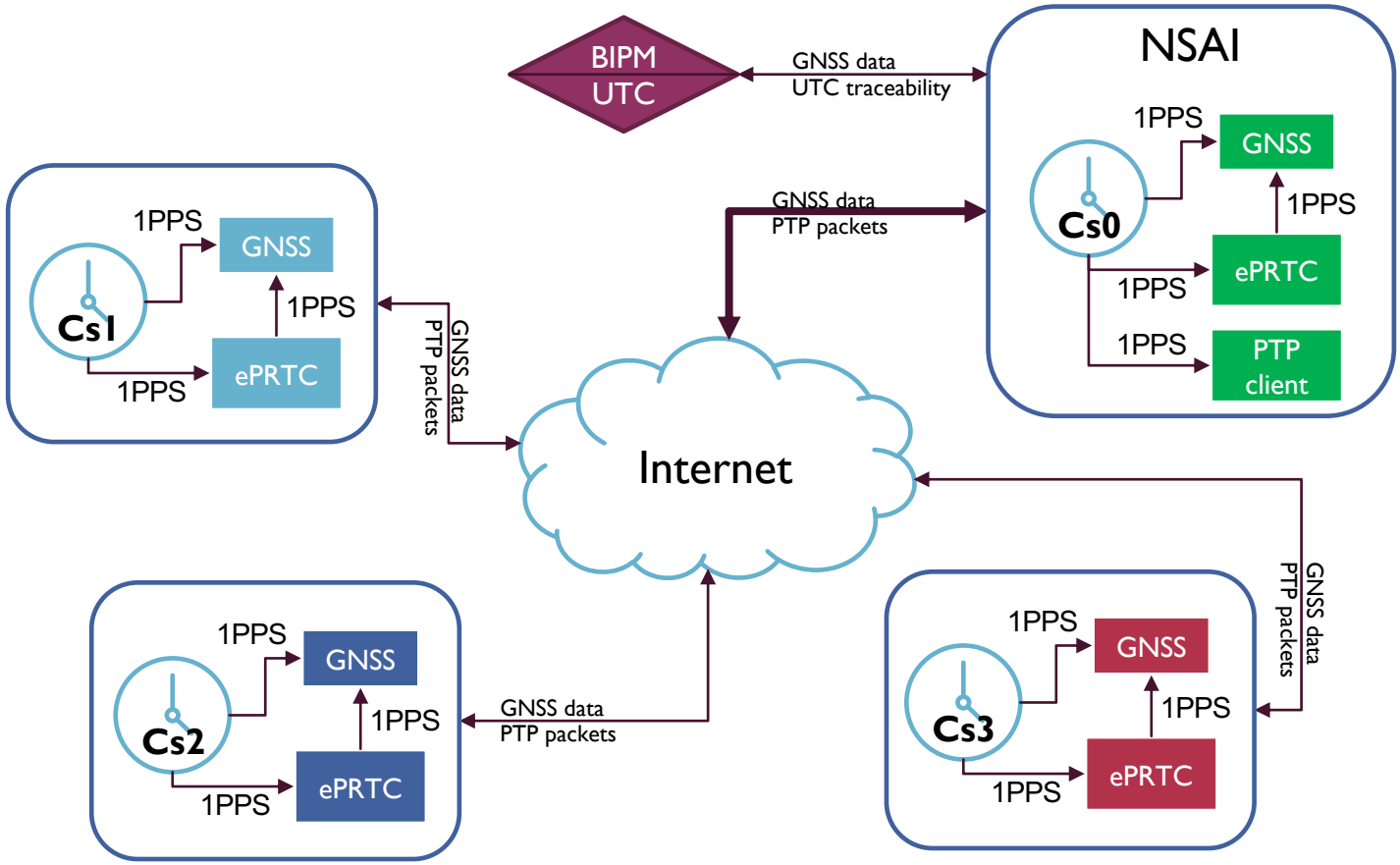
NATIONAL TIMING GRID – PHASES & BENEFITS

- In the "zeroth phase", we are **looking for participants and contributors**. Please spread the word: the more clocks, the better.
- In the first phase we assume the following services will be available for immediate benefits of the participants:
  - **Near real time tracking of stability** against other atomic clocks providing **early warnings** in case of performance degradation.
  - **Direct traceability to UTC through UTC(NSAI)** instead of UTC through GNSS (e.g., UTC(NIST) through GPS time).
  - PTP link **stability evaluation.**
- The next phase will focus on the following services:
  - Options for sub-nanoseconds time transfer: 1588 PTP WR links.
  - Improved holdover in case of GNSS degradation through a common timescale observation and steering.
  - GNSS time stability observation (GPS, Galileo, BeiDou, GLONASS) and failure detection.
  - Improved robustness to GNSS failures and glitches.

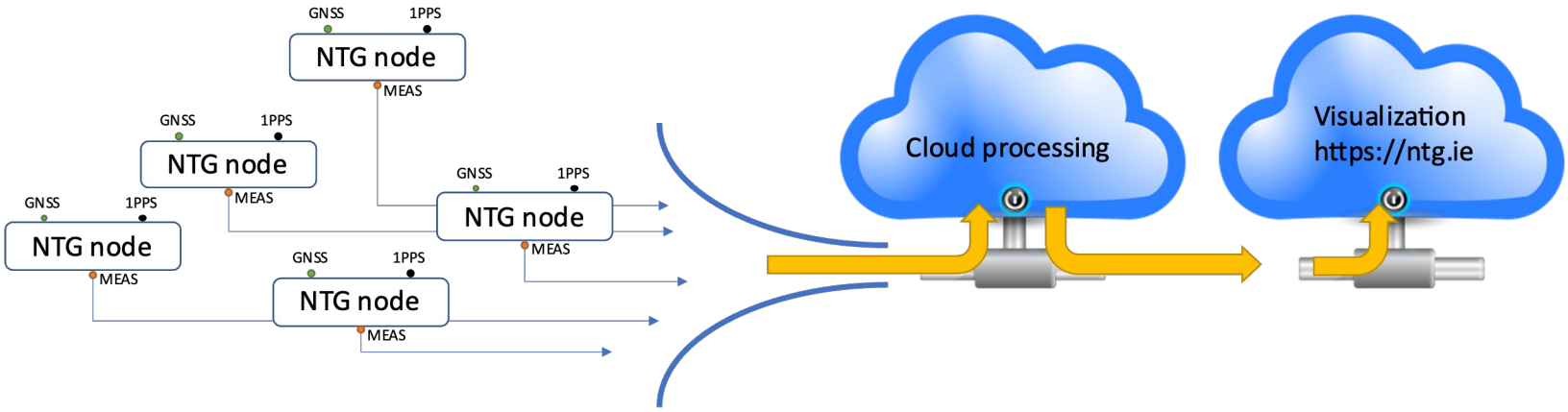
NATIONAL TIMING GRID – REQUIREMENTS

- What is required for the initial testing phase?
- Atomic clock (Caesium, or better). We could consider including Rb atomic clocks too, but their stability is too short to really benefit NTG.
- A high quality GNSS receiver with Common View Time Transfer capability.
- A good antenna (L1/L2/L5 capable) with an unobstructed sky view.
- 1PPS signal with 3V or 10/5/2.5/1MHz with 1V RMS.
- Means to provision the data to outside world, i.e., internet connection.

NATIONAL TIMING GRID – ARCHITECTURE I



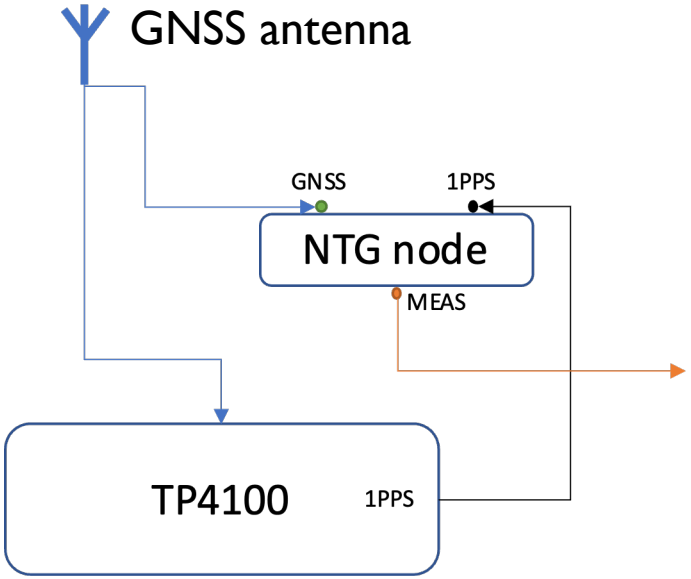
NATIONAL TIMING GRID – ARCHITECTURE II



- Clock data visible at https://ntg.ie.
- GNSS status (signal quality, spectrum plot, jamming and spoofing indicators, satellite measurements, etc.) available on demand.
- New data available every 5 minutes.

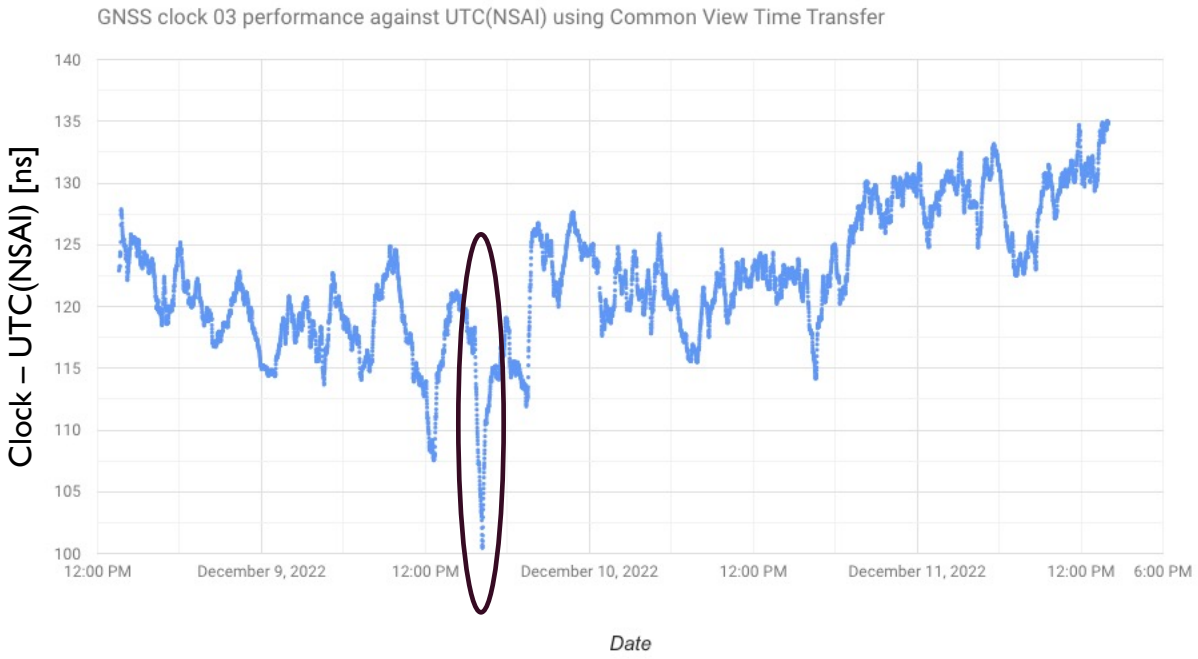
NATIONAL TIMING GRID – PRACTICAL CASE STUDY FOR HEANET

- NTG node installed in Dublin Citywest (thanks to Eoin Kenny, Dónal Cunnigham, Paul McDonnell for making this possible).
- Microchip's TP4100 (PTP & NTP server) 1PPS measured against UTC(NSAI) using NTG node.
- Real time data of TP4100 1PPS against UTC(NSAI) available at https://ntg.ie.



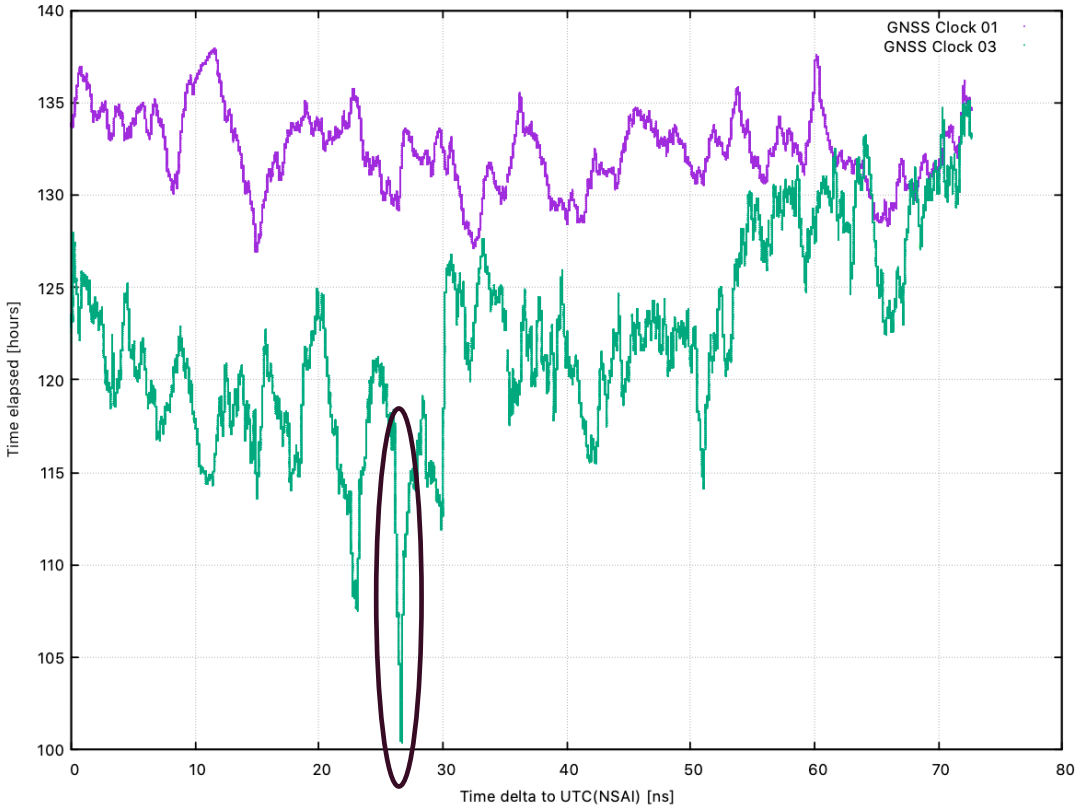
NATIONAL TIMING GRID – PRACTICAL CASE STUDY

- Performance peak-to-peak ~35 ns.
- A suspicious dip in time delta series.



NATIONAL TIMING GRID – PRACTICAL CASE STUDY

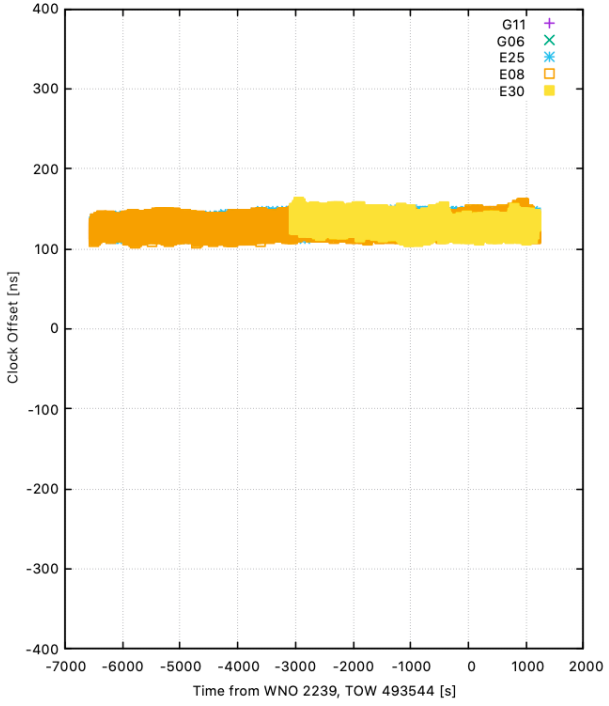
- Comparison of evaluation for GNSS clock 01 & 03.
- This points to local errors, as anything common (algorithm, data, processes, etc.) would be visible also on GNSS clock 01.
- The digging started!



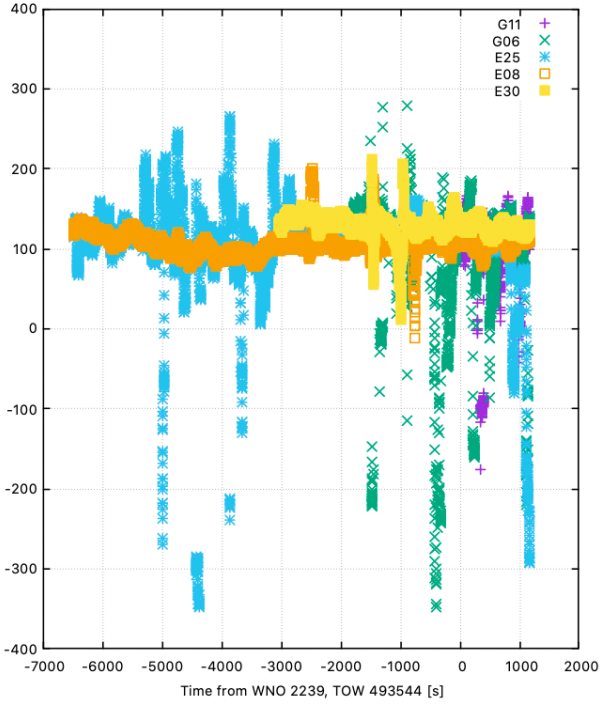
NATIONAL TIMING GRID – PRACTICAL CASE STUDY

- First realization: the antenna on site is L1 only (single frequency measurement).
- Measurement residuals are very high, this points to signal quality.
- Let's do sky plots.

GNSS Clock 01

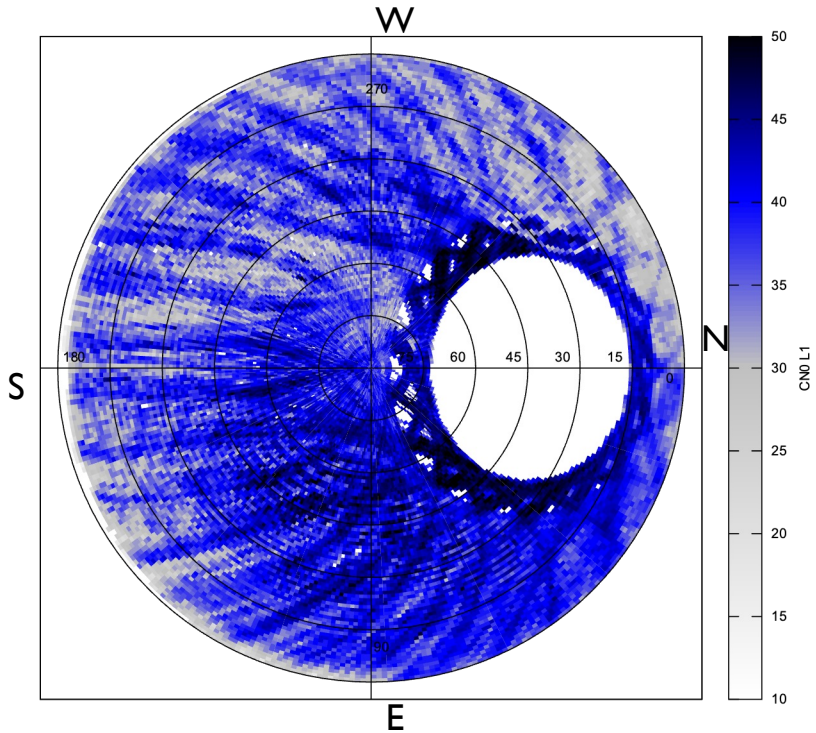


GNSS Clock 03

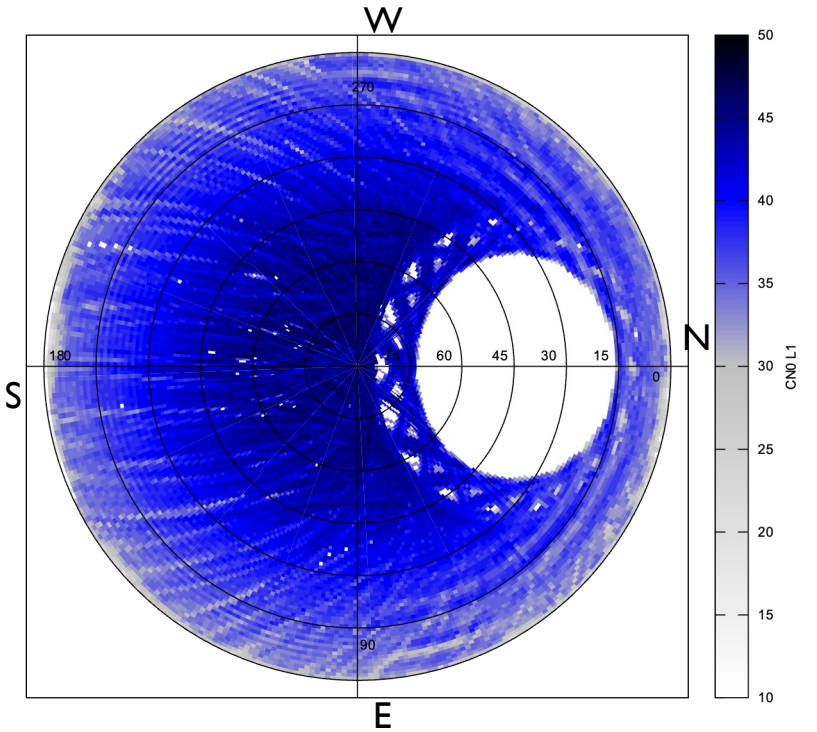


NATIONAL TIMING GRID – PRACTICAL CASE STUDY

- Skymap plot – shows signal power levels (dB-Hz) for all satellites in view over the course of a day.
- Plot on the left has significantly more white spaces and strong signals from weird direction (North).



GNSS Clock 03



GNSS Clock 01

NATIONAL TIMING GRID – SUMMARY

- Then NTG will provide a resiliency measure for timing and synchronization infrastructure.
- The NTG will bring the following services for immediate benefits of the contributors:
  - Near real time tracking of stability against other atomic clocks providing early warnings in case of performance degradation.
  - Direct traceability to UTC through UTC(NSAI).
  - PTP link stability evaluation.
- We are looking for contributors so spread the word, please.
- NTG node is a very useful device that can help evaluate PTP/NTP server sync stability and provide an independent GNSS receiver monitoring.

Thank you for your attention!