Progress on Multi-GNSS Timing Offsets: XGTO, MGET
ICG-13

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Background

- The 2nd Timing Workshop (Vienna, June 2018) concluded that the proposals of ESA on the methods based on broadcasting corrections relative to **xGTO** and **MGET** are of considerable interest and require further work on:
  - Assessment of implementation
  - Assess the impact for the different user cases.

- The WG-S Intersessional Meeting (July 2018) invited ESA to consolidate their xGTO and MGET concepts into one proposal for consideration by System Providers with a view to propose a plan for experimentation for the testing of Multi-GNSS time interoperability.

- This presentation presents further results on both concepts and a first assessment of suitability to the different use cases.

- Note, today **Galileo** broadcasts a GPS-Galileo Time Offset on all operational satellites to users !!!

Recall of xGTO approach:

- The aim of xGTO is:
  - to bridge the gap between different GNSS systems that do not have arranged techniques or strategies to provide an inter-system time offset parameter
  - to improve navigation solution in case of limited satellite visibility
  - to establish an independent method to derive inter-system offsets
  - reduce strict dependency on one GNSS provider

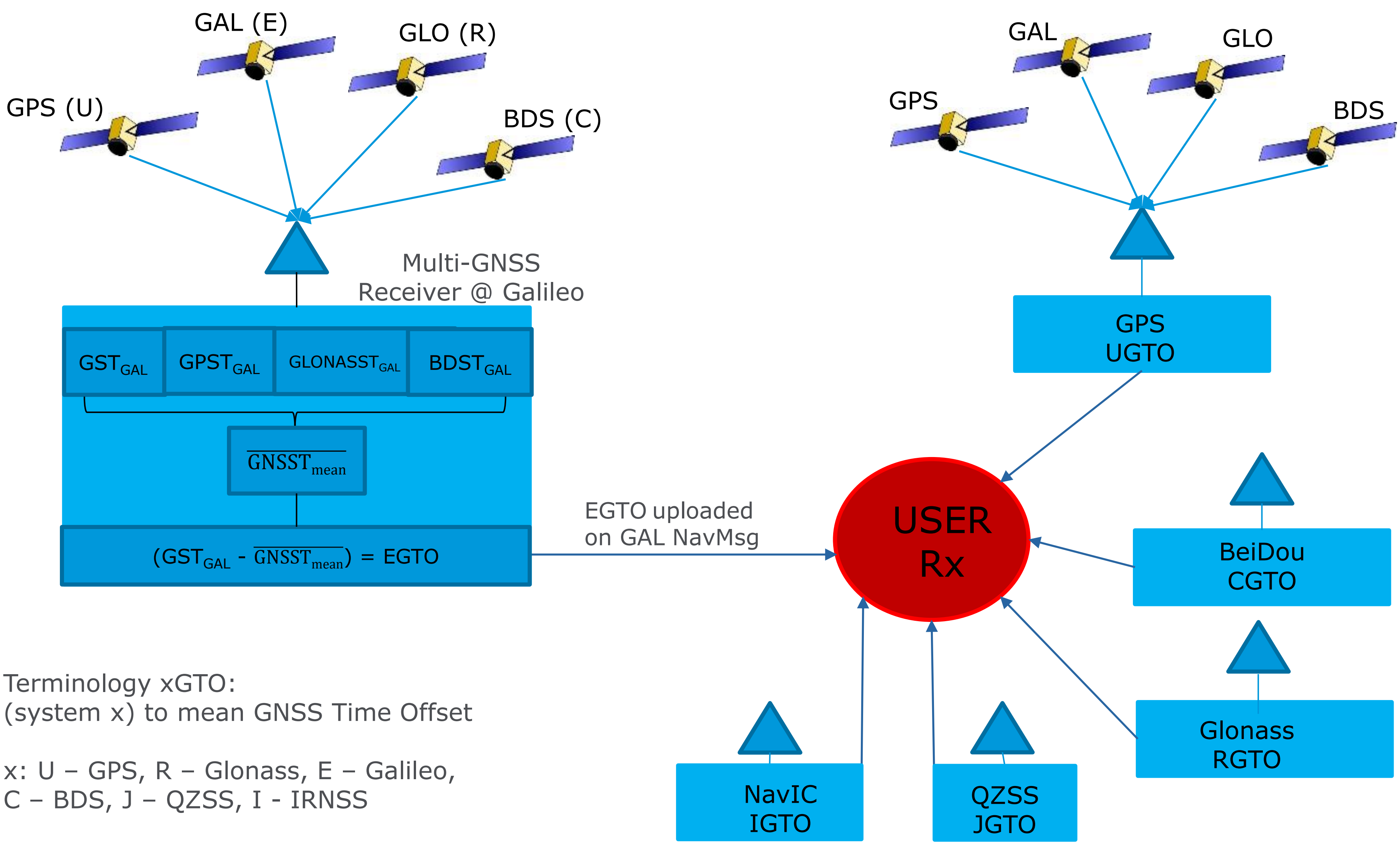
- The implementation and computation of xGTO aims to be common for all GNSS providers.

- Each GNSS system provider X can use a harmonised PVT/PPP technique to obtain a local realization of each GNSS time scale ($GNSST_x$) by means of a calibrated combined receiver.

- Each GNSS system provider estimates the offset of the local realisation of its own time scale and the mean of all GNSS system time scales, obtained by the simple average of all $GNSST_x$. The offset is defined as Multi-GNSS Time Offset (xGTO)

- xGTO would be broadcasted to users as part of the respective navigation messages

Scheme of xGTO concept



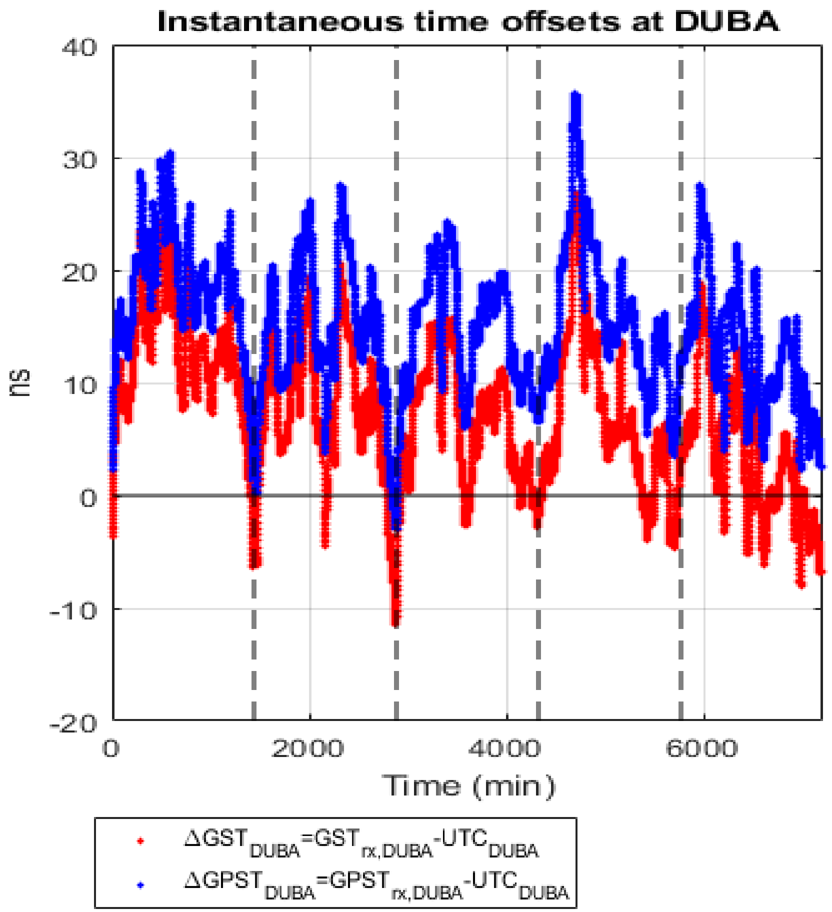
Terminology xGTO:
(system x) to mean GNSS Time Offset

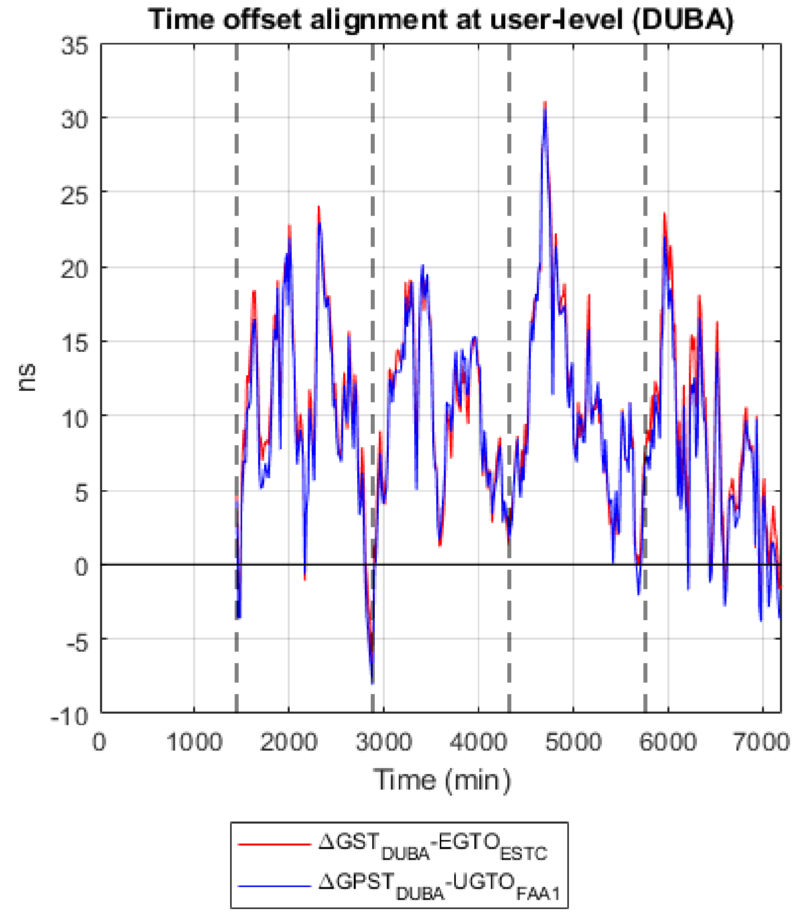
x: U – GPS, R – Glonass, E – Galileo,
C – BDS, J – QZSS, I - IRNSS

Results from xGTO analysis

CGGTTS files (GPS+Galileo) from ESTC (ESTEC), FAA1 (Tahiti), DUBA (Dubai)

- **ESTC** = rx1 **generates** EGTO for GAL
- **FAA1** = rx2 **generates** UGTO for GPS
- **DUBA = user receiver** uses EGTO and UGTO to align System Times





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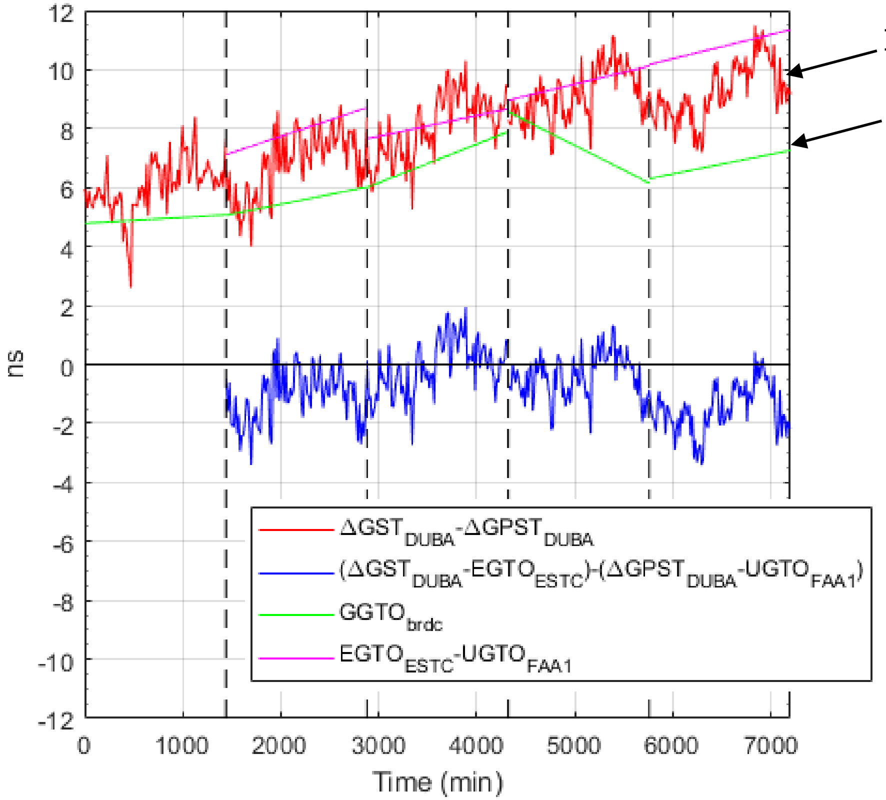
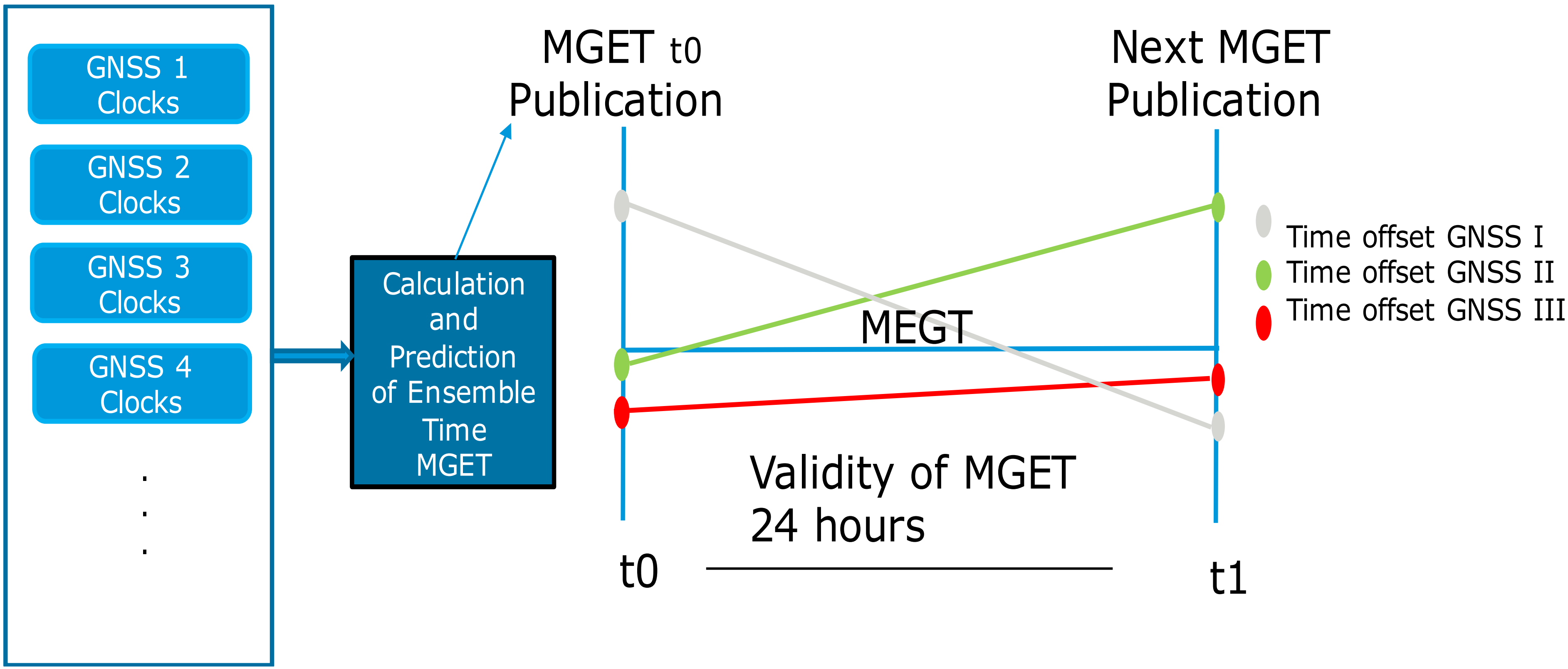


- **Red line** is the difference between GST and GPST raw data, namely the instantaneous GGTO derived from measurements.
- **Blue line** is an indication of the residual error for the time offset estimation at different locations.
- **By using xGTO a similar or better performance can be expected wrt to the current GGTO.**
- Note, this case was limited to GPS and Galileo times

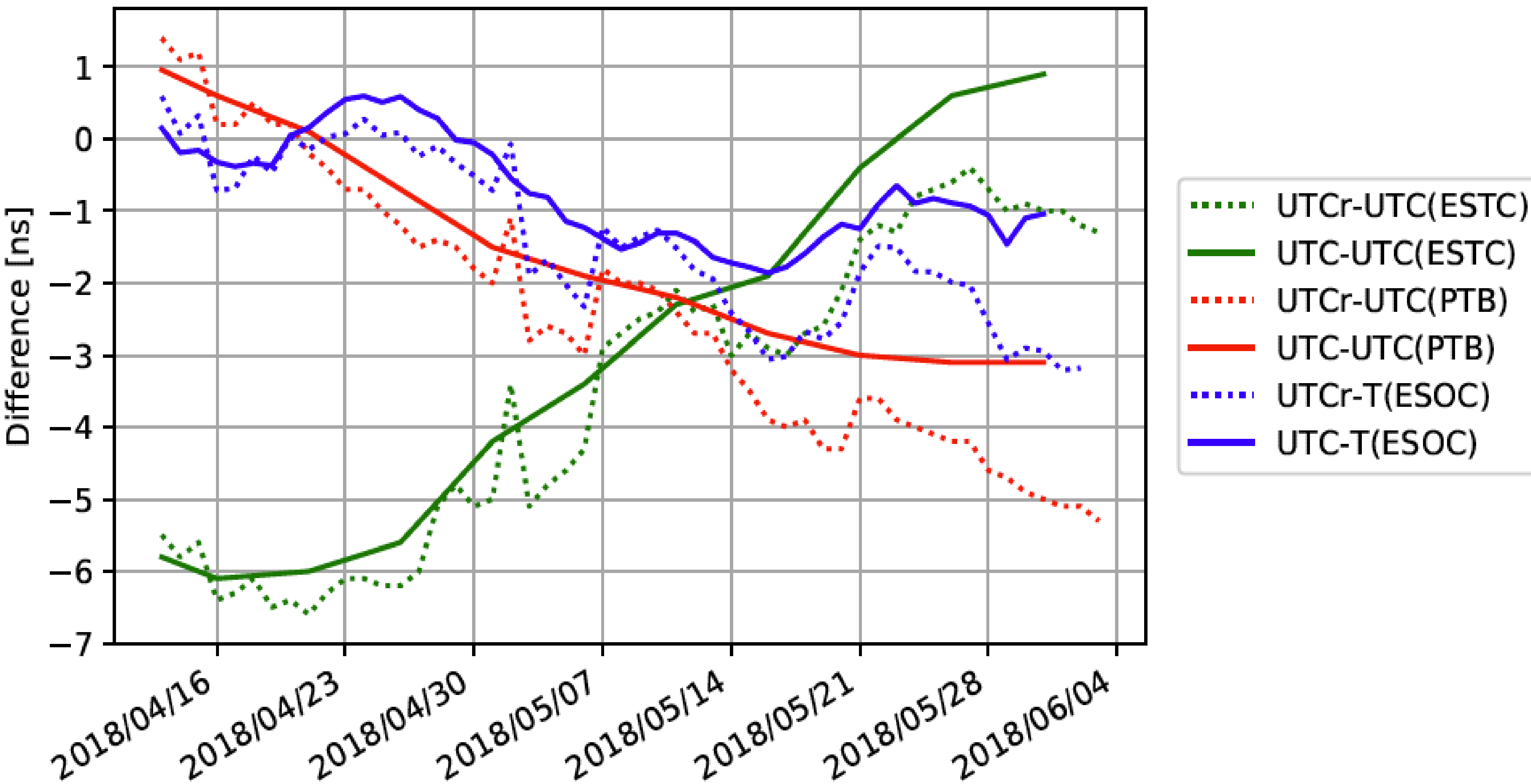
Recall of MGET Approach

- All GNSS providers have committed to steer their system time towards UTC
- MGET is proposed to be common, but system independent time reference
- MGET is proposed to be an ensemble paper time, generated based on contributions from the different GNSS, predicted and valid for a specified time period, e.g. 24 hours
- MGET has to be generated, provided and maintained by an entity
- GNSS Systems Time offsets against MGET is considered to be known in advance with a certain accuracy
- Each GNSS Service Provider would provide the respective time off-set between MGET and their GNSS System Time in the navigation message
- Each GNSS Service Provider would be solely responsible for computing their offset to the common time scale - MGET

Recall of MGET Basic Concept



Recall of MGET Results – ESOC Tests



User cases

1. **Space applications** (e.g. Precise Orbit Determination)
   - Use of raw GNSSS measurements to estimate the satellite kinematic position
   - High accuracy and precision requirements: orbit accuracy < 5 cm, clock below 0.1 ns.

2. **Timing user** (carrier phase measurements)
   - General purpose timing receivers
   - High accuracy (ns)
   - Examples: system time synchronization applications (telecommunications, financial services), frequency/phase synchronization applications (electricity grids).

3. **High-accuracy user** (e.g. PPP, RTK)
   - At the moment no PPP user is using broadcasted GGTO, even in urban environment, too inaccurate
   - Minimum requirements for PPP user: high number of visible satellites, receiver calibration provided by a reliable source
   - Examples: Surveying, Precision Farming and Agriculture Technology, Augmented GNSS with integrated sensors, etc.

4. **Mass-market user** (code phase measurements)
   - Accuracy at meter-level
   - In urban canyon: due to the critical nature of this environment, system interoperability is a necessary requirement.
   - In open sky: good visibility, which means sufficient amount of measurements; the user could be able to estimate the inter-system time offsets on its own .

Test activities

- **Identify suitable calibrated multi-GNSS receivers at different locations** around the world, in order to take into account varying satellite visibility conditions.
- **Exchange of data** with other GNSS system provider or GNSS research institutes.
- **Compute in parallel xGTO at the different locations** as well as **emulate MGET** calculation in a centralized way.
- Work on the **User PVT engine** to implement GNSS Time Offset !

- Suggested experimentation setup:
  - Assuming GPS+GAL+GLO+BDS, deployment of 4 receivers: 1 rx in USA, 1 rx in Europe, 1 rx in Russia, 1 rx in China.
  - Example of suitable receivers: SEPT POLARX4TR / SEPT POLARX5TR
  - File format: CGGTTS Version 2E files or RINEX
  - Long data sets, at least 6 months of data, common time interval to be agreed
  - Exchange of information regarding the test setup. Parameters required:
    - type of receiver (serial number, number of channels, name of laboratory)
    - precise coordinates of antenna phase centre
    - Information about receiver calibration:
      - Receiver + antenna internal delay
      - Antenna cable delay
      - Delay to receiver reference

Critical issues to be evaluated

The results obtained from the test activities shall clarify the following points:

- Impact of receiver calibration for different GNSS systems.
- Assess the quality of the results obtained with receivers deployed at different locations.
- Evaluate the impact of shorter/longer observation periods for the algorithm prediction of xGTO.
- Consolidate the need for harmonization of the concept at system level:
  - Agreed measurements, algorithm, computation need to be identical for all systems
  - Calibration techniques as well
  - Handling of outliers
- Consequences on other systems interoperability in case of failure of one GNSS time dissemination.

Conclusions (1)

- The xGTO concept presents a simpler implementation wrt to the computation of individual inter-system time offsets by each GNSS provider, which requires significant effort at system-level in order to be able to compute and broadcast several.

- Whereas, each GNSS providers would need to broadcast only one xGTO time correction parameter. Also, xGTO aims at reducing dependency between GNSS systems.

- The implementation of xGTO is independent on predictions of UTC/UTC(k), the accuracy of such predictions and from the latency of dissemination of UTC rapid.

- From preliminary tests (only GPS and Galileo) and results, the concept of xGTO has shown good feasibility and potential to solve the problem.

- Results are in agreement at ns level with the current GGTO at user level, however the differences in the averaging and prediction algorithm among GNSS and the use of different receivers need to be considered.

Conclusions (2)

- xGTO and MGET concept, both concepts appears to be feasible.

- xGTO performance could be appropriate for mass-market users.
- MGET could be appropriate for demanding users (e.g. POD, Timing).

- WG-S is encouraged to promote among the Service Providers a campaign of tests with live signals on the different approaches to compute inter-system time offsets. This will allow to expose the merits and drawbacks of each approach:

    - A Task Force on this matter could be established.

- ESA is ready to support the above, i.e. with the experience gained on GGTO and the precise calibration of multi-GNSS timing receivers as well as the computation of intersystem time offsets with global networks of receivers.