Interoperability through accurate prediction of [GNSS time – UTC]

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WG S-D Joint Workshop

Vienna 14 June 2019

Bureau International des Poids et Mesures

GNSS system times offsets / evaluation

The issue was already discussed at several gatherings under ICG (Workshop June 2018, ICG-13)

Interoperability: need to take care of the time offset between GNSS system times. Two approaches:

- Directly account for/determine GNSS to GNSS time offsets
- Each GNSS computes and broadcasts the offset of its system time with respect to **a reference adopted by convention** which can be
    1. A simple average of all GNSS times as realized by a calibrated multi-sytem receiver
    2. **A proxy of UTC e.g.**

This talk

    a. **the presently realized « prediction of UTC/UTC(k)» already computed and broadcast by each system .**
    b. A prediction of UTCr as can be accessed by each GNSS through a UTC(k) participating to UTCr

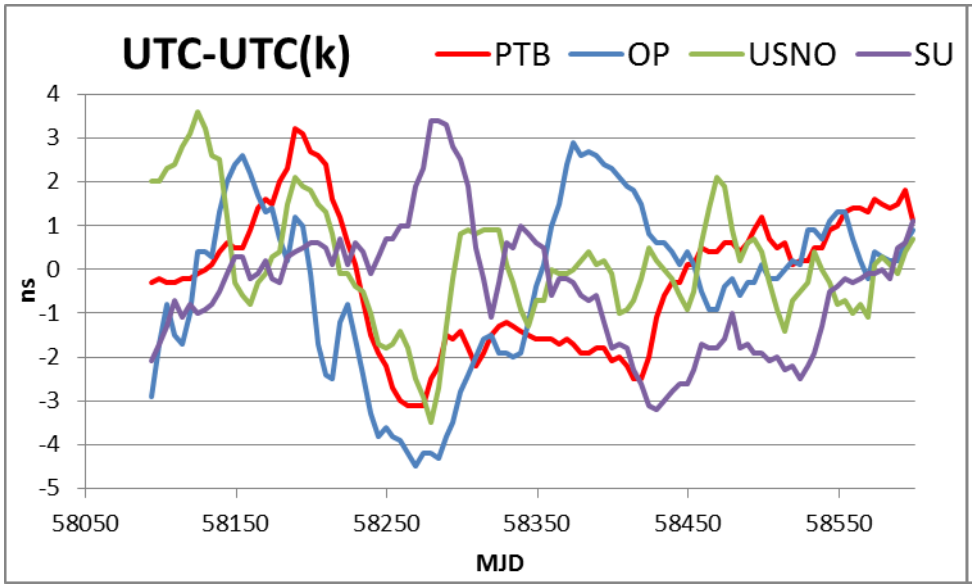
Prediction of [GNSS time – « UTC reference »]

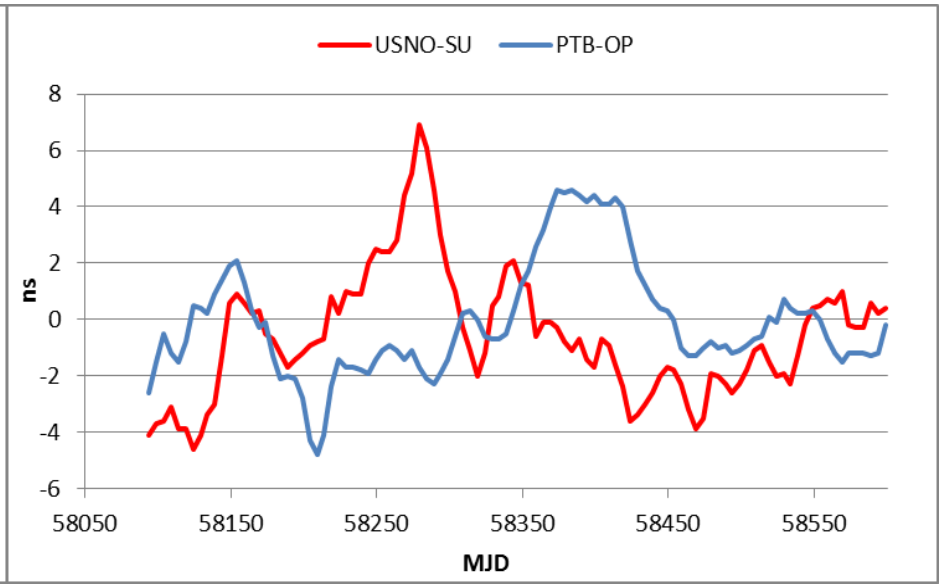
- Each GNSS already computes and broadcast the offset of its system time with respect to a reference that is a proxy of UTC (« UTC reference »).
- The « UTC reference », here noted UTC_ref(GNSS), is
  - UTC(USNO) for GPS
  - UTC(SU) for GLONASS
  - (A prediction of) UTC derived from 5 UTC(k) for Galileo
  - (A prediction of) UTC derived from UTC(NTSC) and UTC(NIM) for Beidou
- The broadcast offset is noted [GNSS time – UTC_GNSS-brdc] = $DUTC_{GNSS}$. It has to be predicted by GNSS providers.
- For two GNSS, assuming identity of the « UTC references », no error from calibration or prediction, we have $G2GTO = DUTC_{GNSS1} – DUTC_{GNSS2}$.

Which uncertainty can we expect from this approach?

Equivalence of all « UTC references »

- For many UTC participating labs, UTC(k) realizes UTC within a few ns RMS.
- E.g. OP, PTB, SU, USNO which are directly involved in referencing GNSS times have UTC(k) equivalent to UTC within 1.3 to 1.9 ns RMS (6.5 to 7.0 ns p-p) over the past 17 months.
- Several other UTC(k) achieve nearly similar performance e.g. UTC(NPL), UTC(ORB), UTC(BY), UTC(NTSC), UTC(ESTC), UTC(NIM)…
- Therefore, for the best laboratories that provide reference to GNSS, assimilating UTC(k) to UTC(l) causes errors of 2 to 2.5 ns RMS (9-11 ns p-p).





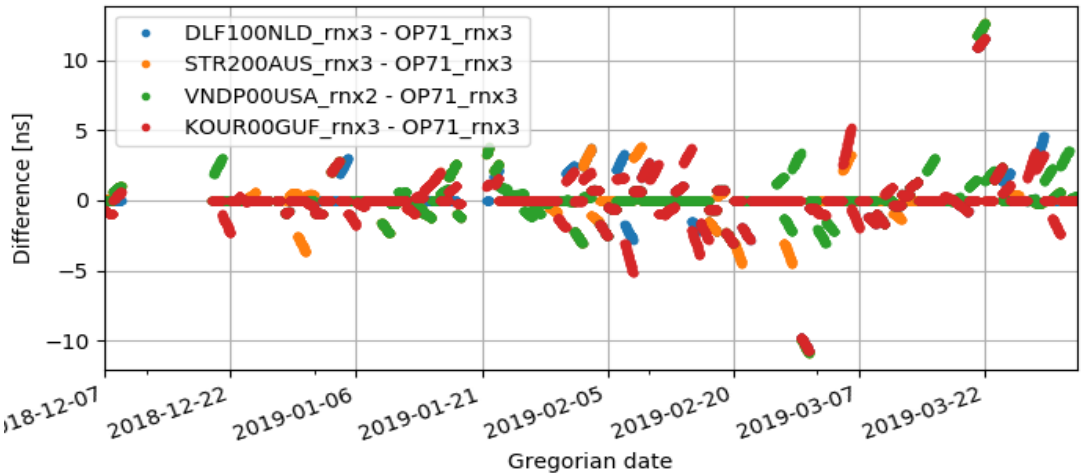
Equivalence of UTC_GNSS-brdc with the «UTC reference»

- Compare [UTC – UTC_ref(GNSS)] to [UTC – UTC_GNSS-brdc]
- The comparison is performed using a calibrated receiver installed in a UTC laboratory k
- [UTC – UTC_ref(GNSS)] is obtained from Circular T section 1 (directly for GPS and GLONASS)
- [UTC – UTC_GNSS-brdc] = [UTC – UTC(k)] Circular T
  + [UTC(k) – GNSS time] Measured
  + [GNSS time – UTC_GNSS-brdc] $DUTC_{GNSS}$

Work by R. Valceschini
guest scientist

Computation of $DUTC_{GNSS}$

- The computation of $DUTC_{GNSS}$ is decribed in GNSS ICD.
- Typically a linear model : $DUTC_{GNSS} = A0 + A1 \times (t - t0)$ where the parameters A0, A1, t0 are found in the navigation message.
- However there is no « Issue of data » to identify which model should be used
  - This is a problem for the real time user and also for us to study in deferred time
  - Use of different models (as received by different Rx and sources e.g. IGS) causes differences in $DUTC_{GPS}$ of order 1.5 ns RMS + some possible outliers. This provides an estimate of the present possible uncertainty on $DUTC_{GNSS}$.

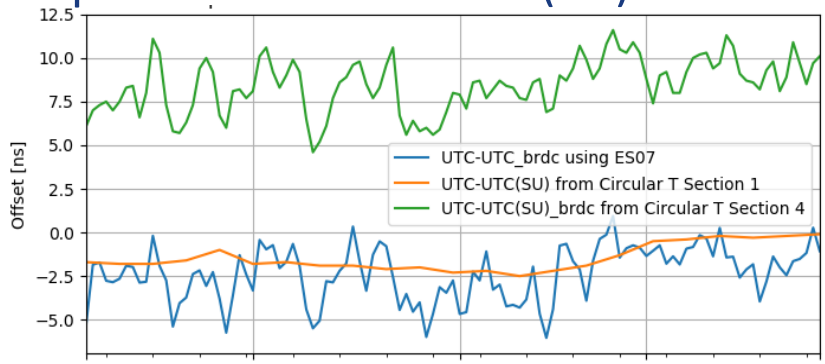


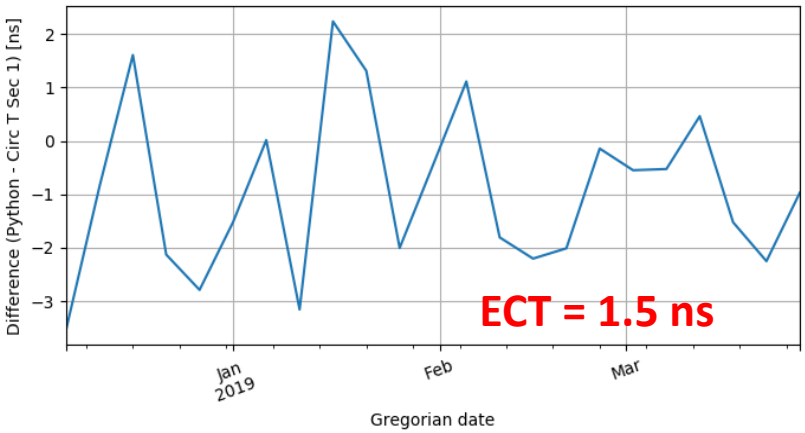
Comparisons for GPS and GLONASS

- UTC_GNSS-brdc and UTC_ref(GNSS) differ by calibration biases + random variations of order 1.5 ns RMS.

- GLONASS

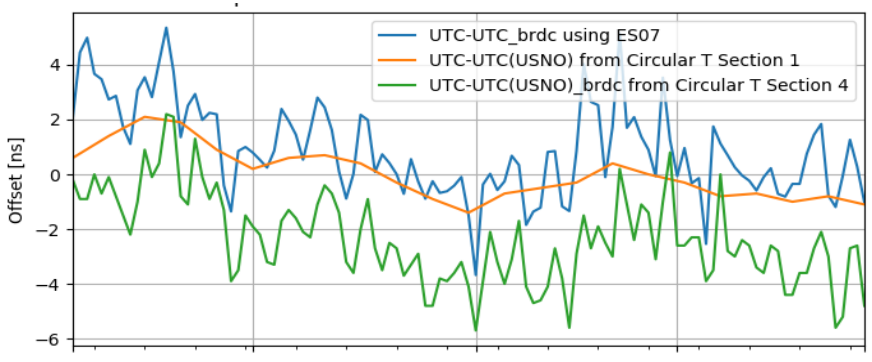
Comparison to UTC – UTC (SU)

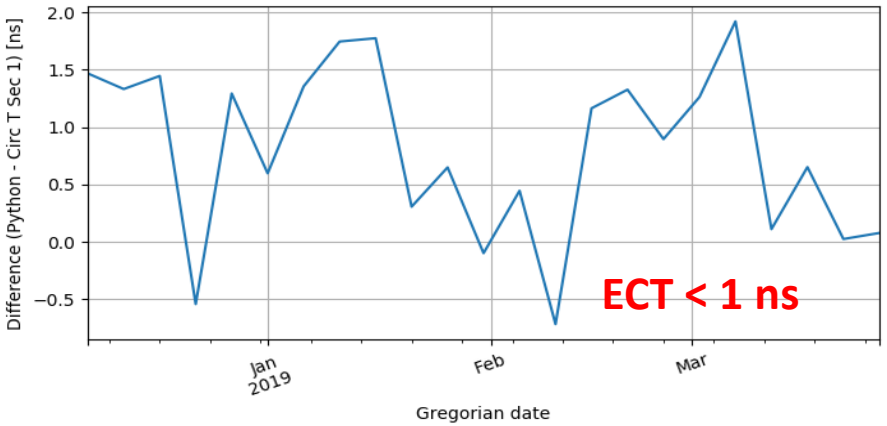




- GPS

Comparison to UTC – UTC (USNO)





Some conclusions

- Each GNSS already computes and broadcast the offset of its system time with respect to a reference that is a proxy of UTC (« UTC reference »).
- It is already possible to ensure that those « UTC references » are equivalent at the level of 2-2.5 ns RMS. Improvement is continuous

- Additional uncertainties in generating [GNSS time – UTC_GNSS-brdc] = $DUTC_{GNSS}$:

a) Calibration inconsistencies in linking GNSS times to « UTC references »

b) Extrapolation errors in generating DUTC

- Additional uncertainties at the user level:

c) Calibration inconsistencies between different GNSS

d) User mis-identification of DUTC model

- Items a and c depend on calibration, mostly at the GNSS provider level.
- Items b and d may have statistical uncertainty at the level of 2-2.5 ns.

- Total uncertainty on G2GTO may be of order 3.5 ns + calibration biases.

Some further conclusions

- Total uncertainty on G2GTO may be of order 3.5 ns + calibration biases.
- This is well in line with specs e.g. GST-GPS TIME OFFSET ACCURACY < 20ns (95%) from Galileo OS SDD 2019
- Other studies presented at last PTTI 2019 draw similar conclusions

- Uncertainties in generating [GNSS time – UTC_GNSS-brdc] = $DUTC_{GNSS}$ and additional uncertainties at the user level are already larger than / at least as large as uncertainties in assuming the equivalence of the « UTC references » of each GNSS.

- Therefore improvements should more be directed to calibrations and to the generation of [GNSS time – UTC_GNSS-brdc] = $DUTC_{GNSS}$ such as
  - Improving the prediction
  - Removing ambiguity in the broadcast info (identification / validity)