GLONASS Time and GNSS Interoperability

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Synchronization in GLONASS

Time Scales

- SV1 Time
- SV2 Time
- SV24 Time

Facilities

- Onboard Frequency Standards
- Central Synchronizer (CS) Main/Reserve
- State Time and Frequency Reference (STFR)

GLONASS Time

Reference Time UTC(SU)

corrections to SV time

correction to GLONASS Time
GLONASS Time Computation

\[ \Delta T_{GL}(t) = \Delta T_{CSM}(t) + \Delta T_{CSM}^{ph}(t_i) + \Delta T_{CSM}^{fr}(t_j) - \Delta T^c(t) = \]
\[ = \Delta T_{CSR}(t) + \Delta T_{CSR}^{ph}(t_k) + \Delta T_{CSR}^{fr}(t_l) - \Delta T^c(t) - \Delta T_{M-R}(t) \]

- \( \Delta T_{GL}(t) \) – GLONASS Time – UTC(SU) offset
- \( \Delta T_{CS}(t) \) – Main/Reserve CS – UTC(SU) offset
- \( \Delta T_{CS}^{ph}(t) \) – corrections for Main/Reserve CS phase steering
- \( \Delta T_{CS}^{fr}(t) \) – corrections for Main/Reserve CS frequency steering
- \( \Delta T^c(t) \) – correction for controlling GLONASS Time – UTC(SU) offset
- \( \Delta T_{M-R}(t) \) – Main–Reserve CS Time offset
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CS-STFR Time Transfer

\[ \Delta T_{STFR-CS} = \Delta T_{GL/GPS-CS} - \Delta T_{GL/GPS-STFR} \]

STFR Time Transfer Facilities
(GTR-51, Dicom, since 27.04.2019)

CS Time Transfer Facilities
(TTU-1, RIRT)
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GLONASS Time by GLONASS, UTC(SU) by GLONASS and $\tau_c$ correction

Systematic error ~20 ns
Improvement of GLONASS Time

The main approaches to increase the accuracy of GLONASS Time calculation and synchronization to UTC(SU):

- to increase the accuracy parameters of CS;
- to increase the accuracy parameters of CS-STFR Time Transfer Facilities;
- to improve the algorithms of CS operation and GLONASS Time calculation;
- to increase the rate of calculating the initial data for producing GLONASS Time, corrections to GLONASS Time and Frequency/Time Corrections to SV Time.
Interoperability of GLONASS with other GNSS

GLONASS Time Interoperability with other GNSS can be provided based on the following currently broadcast information:

- broadcast UTC(k)-GNSS Time offset parameters;
- direct GNSS-GNSS Time offset parameters:
  - broadcast GGTO correction - $\tau_{GPS}$
Analysis of GNSS Time Interoperability Methods suggested by ESA experts

Suggested methods:
- based on broadcast XGTO corrections;
- based on Multi-GNSS Ensemble Time (MGET).

The key advantage of the methods:
- the need to broadcast only one correction for GNSS Time interoperability
XGTO Disadvantages:

• GNSS Time disturbances influence interoperability of all GNSS;

• Changes in navigation message structure are required to provide backward compatibility;

• Estimated accuracy is lower than the accuracy of the methods based on currently broadcast corrections
Analysis of GNSS Time Interoperability Methods suggested by ESA experts

MGET Disadvantages:

• MGET is supposed to be produced by some international service => influences the independence of GNSS;
• providers are to broadcast data that they can’t be responsible for;
• MGET disturbances influence interoperability of all GNSS;
• GNSS Time disturbances influence MGET quality;
• In order to provide backward compatibility changes in the navigation message structure are required;
• Estimated accuracy is lower than the accuracy of the methods based on currently broadcast corrections
The Key Problems Connected with XGTO/MGET Implementation

- Producing and maintaining the new time scale (MGET).
- Measurements (agreed measurement and calibration techniques /facilities).
- Processing, calculating, uploading, broadcasting.
- Changes in navigation message structure - to provide backward compatibility at the receiver level XGTO/MGET corrections are to be broadcast in addition to currently broadcast corrections.
Suggested approaches to GNSS Time Interoperability

(I) Based on Broadcast GNSS-UTC(k) Time Offset Parameters

- doesn’t require changes in GNSS at the system level
- the accuracy depends on:
  - the accuracy of broadcast UTC(k)-GNSS Time offset parameters;
  - the value of UTC-UTC(k) Time offset.

*The values of UTC-UTC(k) offset are being minimized from year to year. Now the offsets of UTC(USNO), UTC(SU), UTC(NTSC) and the UTC which is the Reference for Galileo Time relative to UTC are within ±4 ns.*
Suggested approaches to GNSS Time Interoperability

(II) Based on broadcast GGTO Corrections

• provides the highest accuracy of GNSS-GNSS Time offset
• is being implemented step-by-step in different GNSS
  – GLONASS-GPS Time offset corrections are broadcast by GLONASS;
  – Galileo-GPS Time Offset corrections are broadcast by Galileo;
  – BDS-GPS/GLONASS/Galileo Time offset corrections are specified to be broadcast in BeiDou;
  – GPS-GNSS corrections are specified to be broadcast by GPS.
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Conclusion

• GLONASS Time parameters meet specified requirements;
• GLONASS Time interoperability with other GNSS is currently provided by broadcasting GLONASS Time – UTC(SU) offset corrections and GLONASS-GPS Time offset corrections;
• Suggested approaches to GNSS Time Interoperability are:
  – Based on Broadcast GNSS-UTC(k) Time Offset Parameters;
  – Based on Broadcast GGTO Corrections;
• Implementation of MGET/XGTO methods now doesn’t seem to be feasible.
Thank you for your attention!
Proposed Time Interoperability Actions

2. ESA is invited to consolidate their MGET and xGTO concepts into one proposal for consideration by System Providers

3. System Providers are invited to consider the ESA MGET and xGTO proposal
   - Seek further information from ESA as necessary regarding the technical details of the concepts
   - Assess implementation feasibility, taking into account the necessary accuracy of providing GNSS-to-GNSS Time offsets to multi-GNSS users and backward compatibility with the existing user equipment

4. Based on the outcome of the first three actions, the WG-S Interoperability Subgroup will prepare a proposal for the testing of Multi-GNSS time interoperability
   - Incorporating Multi-GNSS time monitoring into the ICG-IGS IGMA Trial Project is an option to consider

5. WG-S [will ask WG-D] to endorse a recommendation for interested members of the BIPM Consulting Committee for Time and Frequency to prepare a recommendation for national time laboratories to improve the accuracy of synchronization of UTC-UTC (k) and to reduce the publication delay of UTC-UTC (k) data