RETICLE v2.0 – Recent Developments of DLR’s Real-Time Clock Estimation (RETICLE) Engine
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Agenda

• Overview of RETICLE v2
• GNSS Clock Estimation Results
• Summary and Conclusion
• Recommendations
Brief History of RETICLE Development at GSOC

- Mid 2007: start of S/W development for v1.0
  - Single-threaded application, no parallelization, GPS only
  - Later addition of GIOVE and GLONASS

- Mid 2008: first operational real-time version

- End 2008: started participation in IGS Real-Time Pilot Project
  - One of the first real-time analysis centers to submit products

- Mid 2015: start of S/W development for v2.0
  - Multi-threading, designed for large network and multi-constellation
  - GPS, GLONASS, Galileo, BeiDou, QZSS
Overview of RETICLE

**Inputs**
- RT GNSS Data Stream (observations, broadcast ephemerides)
- GNSS Orbits (SP3) and EOPs* (frequently updated predictions)
- Station Meta-Data (SINEX) (Position, Antenna, Receiver, …)
- Satellite Meta-Data (SINEX, ANTEX) (Antenna type)

* Earth-Orientation Parameters

**Outputs**
- Real-Time GNSS Clock Offsets (every 5 sec)
- GNSS Broadcast Ephemerides (on change)
- Differential Code Biases (DCBs) (every 60 sec)
- Vertical Ionospheric Delay (every 60 sec)
Overview of RETICLE – Inputs

RT GNSS Data Stream (observations, broadcast eph.)

- RETICLE uses ~150 IGS RT network stations
  - Unification of stream to single access point
  - Conversion from raw (RTCM) to ASCII
- BKG’s BNC decoder for RTCMv3 decoding
  - Output of OBS and NAV feed streams

Internet

1 Hz RTCM Streams
(typical latency ~100ms ...~10sec)

Public IGS NTRIP Casters

Private DLR NTRIP Caster
Overview of RETICLE – Core Algorithm

- Core algorithm based on federated Kalman-filter
- “Local” Kalman-filters for each individual station
- “Global” Kalman-filter for fusion of “local”-filter estimates
  - Estimates clock offset and drift every 5 seconds, iono + DCBs every 60 seconds
- Capable of processing a large station network (tested with up to ~150 stations)
- Capable of processing all GNSS (G+R+E+C+J) (~85 SVs)
- Autonomous operation, minimize human interaction / maintenance
  - Automatic exclusion of unhealthy satellites
  - Handle changes in the real-time network (adding/removing stations)
  - Automated update of meta-data for stations and satellites
Overview of RETICLE – Core Algorithm

“Local” Filters (~100-150)
- Station Filter
- Un-combined processing @ 1Hz
- Iono, Clocks, Tropo, DCBs, Ambiguities
- G+R+E+C+J and all signals

“Global” Filters
- Clock Filter
- Iono Filter
- DCB Filter
Overview of RETICLE – Outputs

- Precise GNSS satellite clock offsets and clock drifts
  - Update rate 5 seconds, latency ~ 8 seconds
- GNSS Broadcast Ephemerides
  - File-based near real-time products updated every 5 minutes on FTP server
    - SP3 (sampling 10 min), Clock-RINEX (sampling 5sec), RINEX NAV
  - RTCMv3 SSR streams for real-time users streamed to NTRIP caster
    - Generated with BNC
Overview of RETICLE – Outputs

- Differential Code Biases (DCBs)
  - Stored in Bias-SINEX file updated every 60 seconds
- Vertical Ionospheric Delay
  - Stored in Iono-file updated every 60 seconds
- Not yet disseminated, but planned to
  - Stream DCBs in RTCMv3 SSR stream
  - Generate Real-Time GIM based on vertical delays
Overview of RETICLE – Results

• Orbit predictions
  • IGS ultra-rapid predictions for GPS and GLONASS
  • DLR ultra-rapid predictions for Galileo

• Clock accuracy assessment with SISRE (1)
  • Reference product DLR MGEX final orbit/clock

• Consistent clock reference signals
  • GPS C1C/C2W, GLO C1C/C2P, GAL C1X,C5X

• Typical SISRE rms
  • GPS: 7-8 cm
  • GAL: 9-11 cm
  • GLO: ~decimeters

• GLONASS clocks are biased (FDMA inter-channel biases), but stable

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Overview of RETICLE – Results

**GPS SISRE Mean**

Graph showing GPS SISRE mean with data points labeled.

**GPS SISRE StdDev**

Graph showing GPS SISRE standard deviation with data points labeled.
Overview of RETICLE – Results

GLONASS SISRE Mean

GLONASS SISRE StdDev

GLONASS SISRE rms: 85.17 cm
Overview of RETICLE – Results

Galileo SISRE Mean

Galileo SISRE StdDev
Summary and Conclusions

- New multi-GNSS version of RETICLE
  - Capable of processing GPS, GLONASS, Galileo, Beidou and QZSS
  - Un-combined observations, parallel processing
- Uses fixed predicted input orbits
  - GPS and GLONASS from IGV ultra-rapid product
  - Galileo from new DLR ultra-rapid product
  - Precise orbits for BeiDou and QZSS pending
- User access to products via
  - RTCMv3 SSR streams at DLR/GSOC caster
  - SP3, clock-RINEX and RINEV NAV files at DLR/GSOC FTP server
- Next steps: phase biases for PPP-AR and ionospheric corrections
RT-WG Needs and Recommendations (in order of urgency)

1. Need multi-GNSS ultra-rapid orbits
   - Is the IGV (GPS+GLONASS) already official or still “experimental”?
   - Include Galileo, BeiDou and QZSS in an official IGS ultra-rapid product

2. Need better quality control of GNSS broadcast ephemerides
   - Accumulated RINEX NAV files and SW/RCV generated RTCMv3 streams
   - Correct satellite health status is REALLY important!!

3. Need to get out of dead-end road with RTCM SSR messages
   - No progress in phase-bias and iono/tropo SSR message standard
   - Use a self-defined IGS format or other alternative for stream R/T corrections?

4. Need more multi-GNSS stations in North(1)-America, Russia and China
   - Mostly GPS-only stations of UNAVCO in USA