POMELO

Precise pOSitioning for Mass-market – optimaL data dissemination demOnstrator
POMELO Objectives
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- Implement a **demonstrator** for the broadcast of RTK and PPP corrections aligned with the 3GPP protocols and architecture for positioning services in 4G and 5G.

- Exploit **terrestrial broadcast technologies** as means to provide mass-market users with high-accuracy multi-GNSS data and products hence to allow performing positioning strategies such as RTK and PPP.

- Prove the feasibility of the concept and demonstrate an **end-to-end** terrestrial broadcast service in **real** operational scenarios and environments.

- To assess the data rate, size of coverage area, end-to-end latency and positioning accuracy.
KPI and Target Requirements

- High Level: e.g. Drones applications
- Medium Level: ADAS, Mapping and GIS, Augmented Reality applications
- Low Level: the applications e.g. eHealth

TRR Test – Performance metrics

- TD03: PPP computation on the device
  - Target 5m
- TD04: RTK computation on the device
  - Target 5m

Target Performances for POMELO

<table>
<thead>
<tr>
<th>Use case requirement</th>
<th>High Level</th>
<th>Medium Level</th>
<th>Low Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal accuracy (95%)</td>
<td>10cm – 50cm</td>
<td>50cm – 100cm</td>
<td>&gt; 1m</td>
</tr>
<tr>
<td>Vertical accuracy (95%)</td>
<td>10cm – 50cm</td>
<td>5m</td>
<td>5m</td>
</tr>
<tr>
<td>Measurement rate</td>
<td>1 Hz</td>
<td>1 Hz</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Availability</td>
<td>&gt; 99.9%</td>
<td>&gt; 98%</td>
<td>Better than 95%</td>
</tr>
<tr>
<td>TTFF</td>
<td>15 s</td>
<td>30s</td>
<td>1 minute</td>
</tr>
<tr>
<td>Integrity</td>
<td>Yes</td>
<td>Some</td>
<td>N/A</td>
</tr>
<tr>
<td>Authentication</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Format</td>
<td>WGS84</td>
<td>WGS84</td>
<td>WGS84</td>
</tr>
<tr>
<td>PVT Latency</td>
<td>100 ms</td>
<td>100 ms</td>
<td>100 ms</td>
</tr>
</tbody>
</table>
GNSS Data Dissemination

Broadcast via GNSS satellites

SouthPAN – Australia and New Zealand

Galileo HAS - Europe

www.euspa.europa.eu

QZSS CLAS and MADOCA - Japan

https://home.csis.u-tokyo.ac.jp

www.gmv.com
Private companies sell PPP correction broadcast via dedicated geostationary satellites

- The service is at a cost
- The format is proprietary

https://veripos.com/
GNSS Data Dissemination

Broadcast via Internet

RTCM (Radio Technical Commission for Maritime Services) is a standard for transmitting differential corrections in GPS and GNSS systems.

NTRIP protocol used to stream RTCM (and consequently PPP corrections) via Internet

- Not scalable
GNSS Data Dissemination

Broadcast via Cellular Networks

3GPP TS 38.331 V17.3.0 (2022-12)

3rd Generation Partnership Project;
NR;
Radio Resource Control (RRC) protocol specification
(Release 17)

Assistance Data

Reference Time
Reference Location
Ionospheric Models
Earth Orientation Parameters
GNSS-GNSS Time Offsets
Differential GNSS Corrections
Ephemeris and Clock Models
Real-Time Integrity
Data Bit Assistance
Acquisition Assistance
Almanac
UTC Models
RTK Reference Station Information
RTK Auxiliary Station Data
RTK Observations
RTK Common Observation Information
GLONASS RTK Bias Information
RTK MAC Correction Differences
RTK Residuals
RTK FKP Gradients
SSR Orbit Corrections
SSR Clock Corrections
SSR Code Bias
POMELO testbed
POMELO Testbed – How?
3GPP Standard (3GPP15 –LTE Advanced Pro)

- 3GPP (Third Generation Partnership Project) is a consortium of major Telecom Vendors and Operators formed to develop the future of mobiles communication systems.

<table>
<thead>
<tr>
<th>USER EQUIPMENT</th>
<th>ACCESS NETWORK</th>
<th>CORE NETWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE User Equipment</td>
<td>eNB E-UTRAN NodeB</td>
<td>E-SMLC LCS-AP MME</td>
</tr>
<tr>
<td>RRC (OTA)</td>
<td>LPP/LPPa</td>
<td>Evolved Packet Core</td>
</tr>
</tbody>
</table>

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Positioning System Information Blocks

Positioning assistance data can be included in positioning System Information Blocks (posSIBs).

**posSIB types:**

- $posSIB\_type\ 1 - 5 \rightarrow$ Reference Station Info
- $posSIB\_type\ 1 - 6 \rightarrow$ Common Observation Info
- $posSIB\_type\ 2 - 12 \rightarrow$ Observations (GPS or GAL)
- $posSIB\_type\ 2 - 3 \rightarrow$ Navigation Model

\[
\begin{align*}
\text{RTK} & \\
posSIB\_type\ 2 - 3 & \rightarrow \text{Navigation Model} \\
posSIB\_type\ 2 - 17 & \rightarrow \text{SSR Orbit Corrections (GPS or GAL)} \\
posSIB\_type\ 2 - 18 & \rightarrow \text{SSR Clock Corrections (GPS or GAL)} \\
posSIB\_type\ 2 - 19 & \rightarrow \text{SSR Code Bias (GPS or GAL)} \\
posSIB\_type\ 3 - 1 & \rightarrow \text{SSR Phase Bias (GPS or GAL)}
\end{align*}
\]

\[
\begin{align*}
\text{PPP} & \\
posSIB\_type\ 2 - 3 & \rightarrow \text{Navigation Model} \\
posSIB\_type\ 2 - 17 & \rightarrow \text{SSR Orbit Corrections (GPS or GAL)} \\
posSIB\_type\ 2 - 18 & \rightarrow \text{SSR Clock Corrections (GPS or GAL)} \\
posSIB\_type\ 2 - 19 & \rightarrow \text{SSR Code Bias (GPS or GAL)} \\
posSIB\_type\ 3 - 1 & \rightarrow \text{SSR Phase Bias (GPS or GAL)}
\end{align*}
\]
Communications protocols

- **RTCM** → Radio Telemetry Command and Monitoring
- **PosSIB** → Positioning Service Information Block
- **LPPa** → LTE Positioning Protocol A
- **LPP** → LTE Positioning Protocol
- **RTCM** → Radio Telemetry Command and Monitoring
- **LCS-AP** → Location Services Application Protocol
- **S1-AP** → S1 Application Protocol
- **S1-MME** → S1-MME (S1-Mobility Management Entity)
- **UE** → User Equipment
- **eNode B** → Evolved Node B
- **MME** → Mobility Management Entity
- **E-SMILC** → Enhanced Services Model for Interworking with Location Intelligence

**Raw GNSS Meas.**

- **IP** → Internet Protocol
- **SCTP** → Stream Control Transmission Protocol

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POMELO Testbed – How?

RTCM

LCS-AP

NTRIP

LS Laptop

Location Server

EPC/eNB Laptop

u-blox's GNSS antenna

LRRP

TD Laptop

Target Device

u-blox

RTCM

UCS-LRPa

UE Laptop

USRP1

USRP2

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POMELO challenges
POMELO challenges – Size of packages

The main issue laid in the RRC protocol within the srsLTE software.

We can look at the LPPa message as a set of information blocks (posSIBs), each one divided into one or more segments. Such a structured data package can easily reach a size of ~6000 bytes.

We discovered that only packages of max 125 bytes were able to be converted to RRC and correctly sent over the air.
POMELO challenges – Size of packages (solution)

FIRST CHUNK
AB CD EF 05 00 C3 48 00 02 00 83 4F 00 00 04 00
13 00 02 80 01 00 03 00 09 00 02 4A AA 40 54 38
...
70 4D 89 63 50 CF D7 9D C1 BC C2 1F 36 FA 13
E6 29 4A CD 8E 48 82 DD C0 13 76 6F E9 00 76 6F
E9 00
[... ] Size 125 bytes

- AB CD EF: Unique pattern
- 05: Total number of chunks
- 00/01: Sequence number
- C3: Chunk size without header and footer (195 bytes – grey message)
- 48: remainder of the division between the original size of the package and the maximum chunk dimension allowed (195 bytes).
  In this case 852/195 = 4 with reminder 72.
- 07 42 EB 00: CRC-24 computed on the header + data content (used for integrity check).
- 76 6F E9 00: CRC-24 of the FIRST chunk of the sequence (used as unique ID of the original message)

SECOND CHUNK
AB CD EF 05 01 C3 48 0B 19 C1 8D 6D D7 4F 97 23
58 26 D6 30 6D 1B DD 18 9F 2D 86 DE 8C EC 9F 4A
...
EE FF 06 6A 9F 25 87 8B 6D 9F DB B2 00 A4 9D 3E
4D 8F FC 99 BF 83 74 01 A2 A2 07 42 EB 00 76 6F
E9 00
[... ] Size 125 bytes
POMELO challenges – Collateral damage

The use of short messaged introduced the need to adjust and tune the synchronization between the submodules across the testbed.

A configuration of 1 second delay between the chunks is required, increasing the system latencies.
POMELO Experiments
Experiments and demo equipment

Static tests

- POMELO testbed
- Test 1. RTK Zero baseline configuration:
  - U-blox F9P, configured as Rover, connected to the same antenna as the GNSS Reference Station used to stream the corrections.
- Test 2. PPP, with corrections supplied by GEOFLEX

Dynamic tests

- POMELO testbed located on the Wombat robot (pedestrian mode)
- 2 u-blox F9P connected to a GNSS NavXP antenna via a splitter, one used as device under test and one as reference solution.
- Test 1. RTK correction stream from a nearby Reference Station
- Test 2. PPP corrections from GEOFLEX
**POMELO Testbed Results – RTK Static**

**Zero baseline – ublox F9P (rover)/FLM (base)**

**RTK Static**

11:15:09 → 11:44:57 ~ half an hour

**SOLUTION AVAILABILITY:**

- Available epochs: 1063 / 1798 --> **59.12 %**
- Max time between solutions: **55 seconds**

**POSITIONING PERFORMANCE:**

- Knowing exact position of roof antenna:
  Lat +52.9511392700,
  Lon -1.1835868500,
  H +90.2622000000

The 2D Distance from Roof Antenna:
(Considering the median of all 2D distances from the known roof antenna coordinates)

+0.075 m
POMELO Testbed Results – RTK Static

Zero baseline – ublox F9P (rover)/FLM (base)

RTK Static

11:15:09 → 11:44:57 ~ half an hour

- Max latency: 0.786505 s
  (from when the chunk is dispatched from the LS to when it is received at TD; please note this may include clock biases between machines)

- Received correctly: 308 / 308
- Received corrupted: 0
- Sent but not received: 0
- Availability: 100.00 %
POMELO Testbed Results – PPP Static

Ublox F9P

13:40:04 → 14:09:57 ~ half an hour

SOLUTION AVAILABILITY:
- Available epochs: 834 / 1799 --> 46.36 %
- Max time between solutions: 35 seconds

POSITIONING PERFORMANCE:
- Knowing exact position of roof antenna:
  Lat +52.9511392700,
  Lon -1.1835868500,
  H +90.2622000000

2D Distance from Roof Antenna:

+1.118 m

(Considering the median of all 2D distances from the known roof antenna)
13:40:04 → 14:09:57 ~ half an hour

- Max latency: 0.582807 s
(from when the chunk is dispatched from the LS to when it is received at TD; please note this may include clock biases between machines)

- Received correctly: 291 / 291
- Received corrupted: 0
- Sent but not received: 0
- Availability: 100.00 %
POMELO Testbed Results – PPP Dynamic

- 2D distance from reference solution (Rtknavi): ~1.70 m
- Availability: 63.95%

- Latency: 76.41s
- Received correctly: 162/249
- Received corrupted: 0
- Sent but not received: 87
- Availability: 65.06%
POMELO Testbed Results – RTK Dynamic

- 2D distance from reference solution (Rtknavi): ~0.44 m
- Availability: 60.20%

- Latency: 86.27s
- Received correctly: 190/496
- Received corrupted: 0
- Sent but not received: 306
- Availability: 38.31 %
## Statistics

<table>
<thead>
<tr>
<th>TEST</th>
<th>2D Distance from REF Solution [m]</th>
<th>RMSE [m]</th>
<th>AVAILABILITY [%]</th>
<th>MAX LATENCY [s]</th>
<th>Duration [mins]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZERO BASELINE RTK + U-BLOX</td>
<td>0.08</td>
<td>0.15</td>
<td>59.12</td>
<td>55</td>
<td>15</td>
</tr>
<tr>
<td>ZERO BASELINE PPP + U-BLOX</td>
<td>1.12</td>
<td>1.14</td>
<td>46.36</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>DYNAMIC RTK + U-BLOX</td>
<td>0.44</td>
<td>0.59</td>
<td>60.2</td>
<td>57</td>
<td>40</td>
</tr>
<tr>
<td>DYNAMIC PPP + U-BLOX</td>
<td>1.70</td>
<td>2.08</td>
<td>63.95</td>
<td>59</td>
<td>40</td>
</tr>
</tbody>
</table>
POMELO Demonstration at FR
POMELO Demonstration at FR
POMELO Testbed Results – RTK Dynamic Demo

- **2D distance from reference solution (RTKnavi):** \(~0.60\) m
- **Availability:** 26.16%
Recommendations & Future Steps
Recommendations and future steps

• srsLTE library allows the transmission of data up to 125 bytes at a time, which is significantly less compared to the total size of GNSS assistance data required in RTK and PPP. This affected the end-to-end latency, positioning accuracy and availability.

  • **Rec #1:** The testbed is based on the open library srsLTE version 20.10.1. As the library is continuously updated with new features, it is worth engaging with the srsLTE community, now called srsRAN, and discuss mitigation of the limitations encountered.

• The POMELO demonstrator are currently based on SDR hardware (ettus USRP 2901) and the OTA tests made use of the 2.4 GHz band due to lean regulations constraints; however, because the 2.4 GHz band is a Wi-Fi frequency, this is very noisy, and we experienced many interruptions (which impacted the availability) and reduced the transmission range to no more than 5m distance.

  • **Rec #2:** Use high end USRP models and attempt OTA transmission in other frequency bands, preferably not Wi-Fi.
  • **Rec #2:** Partner with mobile network operators and user equipment manufacturers to carry out high fidelity tests.
Recommendations and future steps

• The testbed has been tested with just one user at TD hence the potential of the testbed and the technology that it represents has not been explored in full considering multiple users

  • **Rec #4: Repeat tests with one Transmitting Point and multiple users to demonstrate the scalability of this solution.**

• The concept supports the GNSS Assistance Data up to 3GPP Release 15 and it has been tested using standard SSR provided by Geoflex (partner of POMELO) and occasionally, with IGS

  • **Rec #5: Tests can be done using different corrections providers (ESA,...) and additional data, such as complete SSR (corresponding to 3GPP Release 16).**
Thank you

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