The Role of GNSS in 5G Wireless Networks

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Evolution of PNT landscape: applications and technologies

The Position-Navigation-Time (PNT) landscape is rapidly evolving

More demanding use cases (incl. safety-critical) in challenging environments

Growing interests for PNT resilience

5G landscape expands the scope of PNT (e.g. high-accuracy, indoor)

Ongoing GNSS evolutions, and new space-based PNTs emerge

Opportunity for hybridization of PNT technologies, in particular multi-GNSS and 5G

- Support the growing commercial PNT applications, including safety-critical ones
- Continue to use and foster further adoption of GNSS in these emerging applications
5G context: Overview

Enhanced mobile broadband
- Multi-Gbps data rates
- Extreme capacity
- Uniformity
- Deep awareness

Mission-critical services
- Ultra-low latency
- High reliability
- High availability
- Strong security

Massive Internet of Things
- Low cost
- Ultra-low energy
- Deep coverage
- High density

Mobile devices
Networking
Automotive
Robotics
Health
Wearables
Smart cities
Smart homes
5G context: Overview

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- Ultra-low energy
- Deep coverage
- High density

Device:
- Smartphones and tablets
- Internet of Things
- Autonomous vehicles
- Wearables
- Smart cities
- Smart homes

Worldwide smartphone market share 2014

Mobile devices
Networking

Autonomous
Robotics
Health

Weaves, smart cities, smart homes
5G context: examples of new elements (New Radio)

4G LTE technologies plus

Large antenna arrays
Directional transmission

Large bandwidths
Higher carrier frequencies

Device-to-device communication

Network densification

Credits: G. Seco-Granadios
5G Positioning: a context shaped by very diverse verticals

**Transportation**
(typ. <0.3m–3m, high reliability)
Autonomous vehicles, UAV, Rail, Road-tolling, etc.

**Factories of the future**
(< 0.3m–10m, very high availability, low energy)
Machine control, Industry automation, Asset tracking, etc.

**High-accuracy LBS, Augmented Reality, eHealth**
(wide area coverage, 1m-10m)

+ **Network synchronization**
  - Energy, PSTN, 4G/5G Cellular Networks
  - Financial Transaction
Galileo and multi-GNSS high-accuracy capabilities

Interoperability with other GNSS: Combined use of 4 GNSS yields high availability and good accuracy, even in urban environments

Galileo is a reality, also in mass-market devices
Check for Galileo-enabled devices www.usegalileo.eu

Dual frequency GPS/Galileo chipsets are reaching mass-market devices (sub-meter accuracy)

Galileo HAS (High-Accuracy Service)

Dual frequency GPS/Galileo chipsets are reaching mass-market devices (sub-meter accuracy)

Figure of Merit: MM RX
Horiz. Perc-68 [m] 1.6
Horiz. Perc-95 [m] 6.4
3D Perc-68 [m] 3.2
3D Perc-95 [m] 10.9
Availability [%] 100

Galileo Signals-in-Space + Real-time corrections

High-Accuracy: Ability of the system to provide a positioning accuracy in the order of a few centimeters.

Global coverage

GAL Ground Segment
User Equipment

Mass-market multi-GNSS receiver

Error [meters]

Horizontal Position error [m]
Motivation for 3GPP standardization landscape

Capture 5G trends and use cases (e.g. critical applications, IoT) and take them into account for evolutions of satellite-based PNT

Understand emerging 5G PNT technologies and their capabilities to complement GNSS

Promote GNSS state-of-the-art and interoperability with 5G (e.g. high accuracy)
Areas of focus in 3GPP standardization

**HIGH-ACCURACY GNSS**
Augmented GNSS with cm-level accuracy

**USE CASES**
Positioning Requirements
- 0.3m Hacc
- 1-3m Hacc
- >10m Hacc

**HIGH-ACCURACY HYBRID POSITIONING**
Augmented GNSS + 5G-based techniques + sensors

**NETWORK SYNCHRONISATION**
Prerequisite for High-accuracy positioning in 5G

Network synchronisation is a prerequisite for high-accuracy positioning in 5G.
5G Positioning: standardised Positioning Service Levels in 3GPP

- **Service Level 7:** relative positioning with 0.2m accuracy
  - V2V, industry automation (machine control)

Useful 3GPP documents related to positioning (www.3gpp.org):
- Reports: TR 22.872, TR 22.804, TR 22.889
- Specifications: TS 22.261
PNT Hybridization: mix of complementary technologies to support environment-independent and resilient PNT in 5G context

4G positioning technology mix

3GPP positioning methods, Ericsson [https://ieeexplore.ieee.org/document/8377447/]

- Multi GNSS (and their evolutions)
- Dead-reckoning (INS, barometer, vision, radar, etc.)
- APNT & local PNT infrastructures (TBS, BLE beacons, LEO, etc.)

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## Coverage of 5G positioning requirements with current technologies

<table>
<thead>
<tr>
<th>Positioning service level</th>
<th>Absolute(A) or Relative(R) positioning</th>
<th>Accuracy (95% confidence level)</th>
<th>Availability</th>
<th>Latency</th>
<th>Coverage, environment of use and UE velocity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Vertical Accuracy</td>
<td>Horizontal Accuracy</td>
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<td>5G positioning service area</td>
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<td>(note 1)</td>
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<td>5G enhanced positioning service area (note 2)</td>
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<td>Outdoor and tunnels</td>
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<td>Indoor - up to 30 km/h</td>
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<td>1</td>
<td>A</td>
<td>10 m</td>
<td>3 m</td>
<td>95%</td>
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<td>1 s</td>
<td>(rural and urban) up to 250 km/h</td>
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<td>(rural and urban) up to 500 km/h for trains and up to 250 km/h for other vehicles</td>
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<td>2</td>
<td>A</td>
<td>3 m</td>
<td>3 m</td>
<td>99%</td>
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<td>(rural and urban) up to 500 km/h for trains and up to 250 km/h for other vehicles</td>
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<td>4</td>
<td>A</td>
<td>1 m</td>
<td>2 m</td>
<td>99.9%</td>
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<td>5</td>
<td>A</td>
<td>0.3 m</td>
<td>2 m</td>
<td>99%</td>
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<td>(rural) up to 250 km/h</td>
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<td>6</td>
<td>A</td>
<td>0.3 m</td>
<td>2 m</td>
<td>99.9%</td>
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<td>(dense urban) up to 60 km/h</td>
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<td>(dense urban) up to 60 km/h</td>
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<tr>
<td>7</td>
<td>R</td>
<td>0.2 m</td>
<td>0.2 m</td>
<td>99%</td>
<td>Relative positioning is between two UEs within 10 m of each other or between one UE and 5G positioning nodes within 10 m of each others (note 3)</td>
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<td></td>
<td>1 s</td>
<td>Indoor and outdoor (rural, urban, dense urban) up to 30 km/h</td>
</tr>
</tbody>
</table>

**NOTE 1:** The objective for the vertical positioning requirement is to determine the floor for indoor use cases and to distinguish between superposed tracks for road and rail use cases (e.g. bridges).

**NOTE 2:** Indoor includes location inside buildings such as offices, hospital, industrial buildings.

**NOTE 3:** 5G positioning nodes are infrastructure equipment deployed in the service area to enhance positioning capabilities (e.g. beacons deployed on the perimeter of a rendezvous area or on the side of a warehouse).
# The opportunity of hybrid GNSS/5G for 5G positioning services

## Positioning service levels

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Areas of focus in 3GPP standardization

**HIGH-ACCURACY GNSS**
Augmented GNSS with cm-level accuracy

**USE CASES**
Positioning Requirements
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**HIGH-ACCURACY HYBRID POSITIONING**
Augmented GNSS + 5G-based techniques + sensors

**NETWORK SYNCHRONISATION**
Prerequisite for High-accuracy positioning in 5G

0.3m Hacc  1 -3m Hacc  >10m Hacc
Positioning enhancements in LTE/4G Technologies - before and after the WI

Releases 14

A-GNSS & DGNSS (Code-based)

3GPP: OTDoA, UTDoA, ECID

Non-3GPP: TBS with MBS signals

W-LAN

Bluetooth

Barometric pressure sensor

Releases 15

Release 14 positioning methods

RTK and N-RTK (VRS, FKP, MAC)

PPP

IMU (displacement reporting, not raw output)
Positioning in LTE/4G
Architecture (U-plane & C-plane)

User plane = DATA LINK (IP)
Control plane = CELLULAR SIGNAL

!The focus in 3GPP is on the LPP (C-plane)
Broadcast solution for High-Accuracy GNSS (HA-GNSS) over LTE (Release 15)

<table>
<thead>
<tr>
<th>GNSS technology (Mass-market UE)</th>
<th>Rural</th>
<th>Sub-urban</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-GNSS (AGNSS)</td>
<td>&lt; 1m</td>
<td>&lt; 3m</td>
<td>&lt; 10m</td>
</tr>
<tr>
<td>Multi GNSS augmented with PPP or RTK</td>
<td>&lt; 10 cm</td>
<td>&lt; 1m</td>
<td>&lt; 3m</td>
</tr>
</tbody>
</table>

Typical performances of mass-market GNSS technologies

<table>
<thead>
<tr>
<th>OSR</th>
<th>SSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-GNSS</td>
<td>SSR</td>
</tr>
<tr>
<td>Single-base RTK</td>
<td>PPP</td>
</tr>
<tr>
<td>N-RTK 1: MAC</td>
<td>PPP-RTK</td>
</tr>
<tr>
<td>N-RTK 2: FKP</td>
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<tr>
<td>N-RTK 3: VRS</td>
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<tr>
<td>PPP</td>
<td></td>
</tr>
<tr>
<td>PPP-RTK</td>
<td></td>
</tr>
</tbody>
</table>

Perspective for Release-16 / 17: extend protocol to PPP/RTK solutions for mass-market
GNSS and 5G: A mutually-beneficial partnership

Augment GNSS
(e.g. convergence time, integrity, reliability)

Broadcast HA-GNSS corrections
(perfect dissemination channel for commercial applications)

Extend coverage of high-accuracy positioning
(outside NR hotspots)

5G Network synchronization
(for precise network-based positioning)

Ubiquitous high-accuracy PNT
(seamless positioning service, indoor to rural)

Drive PNT innovation
(GNSS and 5G are key building blocks for new PNT architectures)
RAN: Items to be considered for NR Positioning standardization (Release 16 and beyond)

SA1 Use cases & service level requirements versus NR performance targets

- Carry forward LTE hybridisation capabilities (LPP) to NR (NPP), including RTK/PPP corrections

Assess performance of hybrid between RAT-dependent and GNSS

Provide ubiquitous high-accuracy outside 5G NR coverage (limited to densely populated area)

Broadcasting capabilities for dissemination of HA-GNSS

- e.g. same data for thousands of vehicles in a cell

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Network time synchronisation

5G PPP.eu

© GSA
### Supporting project: GNSS integration into 5G wireless networks (GINTO5G)

<table>
<thead>
<tr>
<th>WP1 – Field experiments</th>
<th>WP2 – Simulation platform</th>
<th>WP3 – Support to Standardization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-Accuracy:</strong> for ADAS and UAV. Data collection in Munich expected to start in late February 2019.</td>
<td>Analysis of data from field test cases results and derivation of error models.</td>
<td>Support to <strong>3GPP standardisation</strong> (SA and RAN)</td>
</tr>
<tr>
<td><strong>IoT low power:</strong> platform under discussion. Measurements in 2019.</td>
<td><strong>Positioning Performance Coverage and Trajectory</strong> (PoPeCoT) simulator - - for performance derivation by different technologies and hybridisation, for different environmental conditions during trajectories or coverage areas.</td>
<td></td>
</tr>
</tbody>
</table>

- Different technologies (High Accuracy GNSS, LTE / NR, inertials)

Funded under ESA’s European GNSS Evolutions Programme
Conclusions / Key messages

The **PNT landscape** is rapidly evolving
- Emergence of more demanding, safety-critical use cases (accuracy, ubiquity, security, etc.)
- 5G landscape expands the scope of PNT to address new use cases / verticals

**Multi-GNSS** is expected to continue being a cornerstone of modern, ubiquitous, reliable, accurate PNT, also in the context of 5G
- **Hybridization** with other technologies may complement GNSS towards environment-independent (e.g. *indoor*), reliable PNT

More stringent PNT use cases and associated positioning requirements are identified in 5G:
- larger number of consumers of **high accuracy positioning**, exploiting the availability of high-accuracy augmentation data dissemination
- for **Internet of Things IoT positioning**, low power consumption is a key driver. 3GPP technologies, such as NB-IoT, are suitable for communications but cannot provide reasonable accuracies (<50m). Hybridisation of optimised GNSS for low-power together with 3GPP technologies for comms may provide the right balance.
- the importance of **timing** by GNSS is likely to increase for 5G (e.g. GNSS as primary source of V2X sidelink synchronisation).
Thank you