Precise Positioning with Smartphones running Android 7 or later

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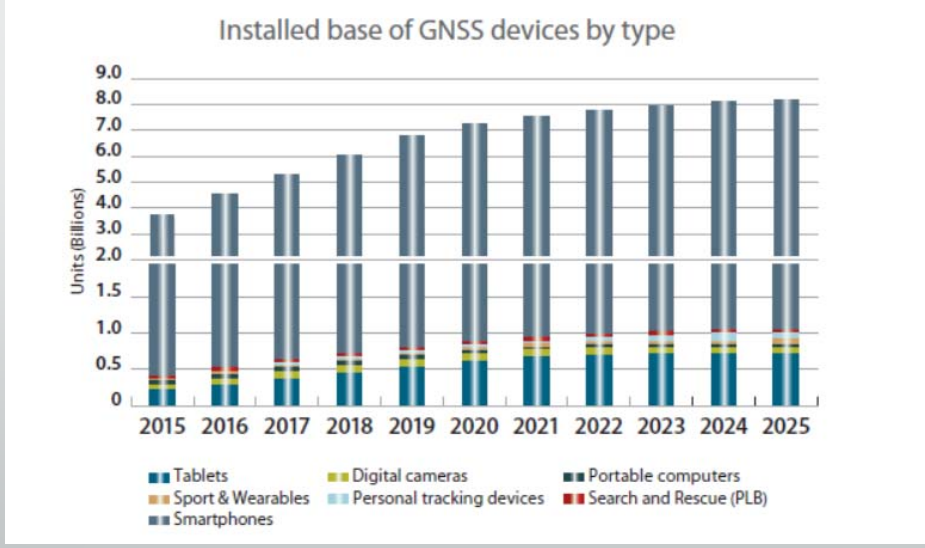
GNSS Market and Smartphones

- In 2017 : 5,8 billions GNSS devices
- GNSS market is dominated by smartphones (more than 80% of total market)
- Forecast for 2020 : 8 billions GNSS devices



From GSA market report 2017

Smartphones: which GNSS sensors ?

- Recent high-end smartphones are multi-constellation:
  - GPS (USA, operational)
  - GLONASS (Russia, operational)
  - Beidou (China, operational in 2020)
  - Galileo (Europe, operational in 2020)
  - QZSS (Japanese regional navigation system)
- Single frequency (L1/B1/E1) at the present time.

- **! In September 2017, Broadcom announced the availability of a dual frequency chipset (GPS L1/L5, Galileo E1/E5a) for smartphones !**

  ➔ Dual frequency smartphones should be available in 2018 !

Positioning under IOS or Android up to v6

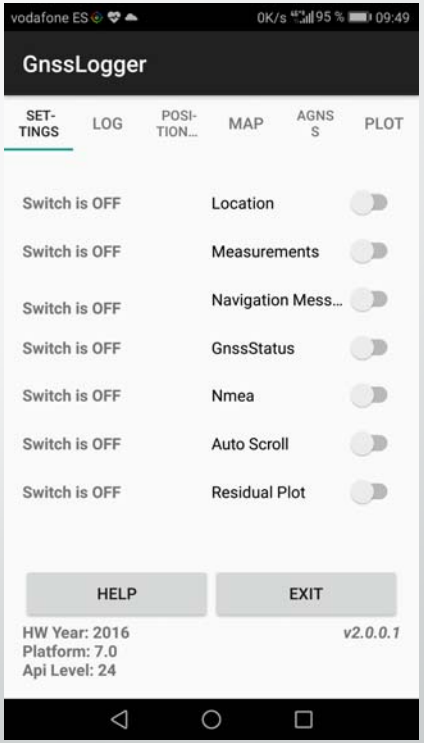
- The smartphone only provides the user with computed position and some ancillary information about satellites (azimuth, elevation, health, …).
- Users do not have access to raw GNSS measurements.
- The position is computed based on a "manufacturer receipt" which is not documented (Black Box !)
  - Depending on the model, the position can be obtained from sensor fusion, for example from GNSS, WIFI, inertial sensors, …
  - No information about integrity (does the computed position fit my requirements ?)

Positioning under Android 7 or later 1

- During it "I/O 2016" (June 2016), Google announced that the **raw GNSS measurements** collected by devices running Android 7 would be made available to users.
- This announcement opens new opportunities !
- Indeed, the development of **advanced processing strategies** might lead to decimeter-level positioning capabilities allowing the emergence of new applications.

Positioning under Android 7 or later 2

- Google also decided to provide support for developers who wish to write new applications based on raw GNSS data.
- For example, the Google "GNSSLogger" application allows to log raw GNSS data on compatible smartphones (for the moment, only a few devices).
- Free processing tools are also available.



Android v>7 : which raw data ?

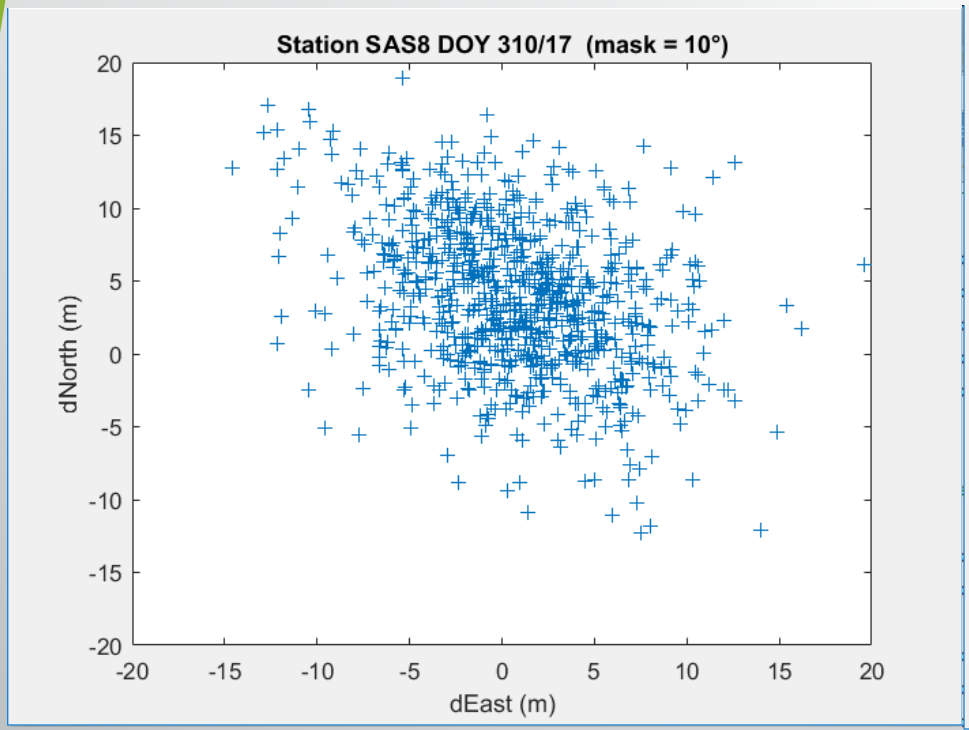
- Code pseudorange
  - The basic GNSS observable used in navigation.
- Doppler
  - Gives information on user velocity.
- Carrier phase pseudorange
  - **The necessary observable for precise positioning**
  - **! VERY UNEXPECTED to have this observable on smartphones !**

Android v>7 : which positioning technique 1 ?

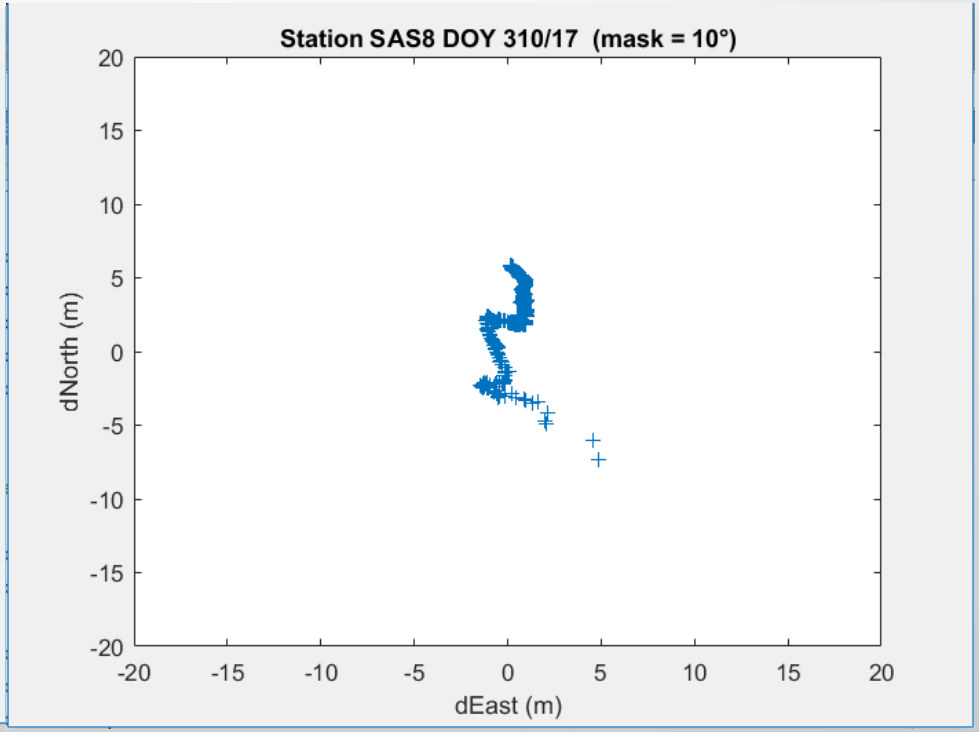
- Standard "standalone" positioning
  - Code-based only (no improvement expected).
  - Code + Doppler
    - To smooth noisy code
    - The user velocity obtained from Doppler gives a constraint on the "acceptable" position change from epoch to epoch.
  - Code smoothing with phase (not successful at the present time due to duty cycle)

Horizontal position repeatability (static case)

15 minutes of Samsung Galaxy S8 GPS code measurements (static smartphone)



Standard WLS with Code



Kalman filter using Code + Doppler

Android v>7 : which positioning technique 2 ?

- Differential Positioning
  - Code-based (+ Doppler)
  - Phase-based (Real Time Kinematics)

    ! Might lead to sub-decimetre positioning with dual frequency smartphones !
- Precise Point Positioning (PPP)
  - Requires precise clocks and orbits but no "external" raw data.
  - Slow convergence time.
- Fused sensors (GNSS + other Smartphone sensors, in particular, inertial sensors)
- Development of RAIMS ➔ Information on integrity !

Main weaknesses

- Smartphone antenna
  - Low-quality linearly polarized antenna optimized for voice communication but not for navigation signals which are circularly polarized (right-handed).
  - **Very susceptible to multipath (in particular in urban environment).**
  - No information about antenna phase centre (mandatory for precise positioning).
- Duty cycle
  - Smartphone components are regularly switched off and on to save battery life (including navigation filter)
  - **This results in discontinuous carrier phase measurements**
  - From Android 8, Google considers to insert an option (under developers options) allowing to switch the duty cycle off.
- Battery Life

Applications

- Any application which requires cheap and quick precise positioning
- Location-based services
- Virtual (augmented) reality
- Autonomous car
- Earth Sciences/Earth Observation
  - Precise positioning
  - Atmosphere Monitoring (Ionosphere and Water vapour)
  - ? Reflectometry ? (soil moisture, …)
  - **Millions of smartphones** might send atmospheric information through the internet to a central computing facility allowing to feed models

Conclusion

- The availability of dual frequency multi-constellation GNSS raw code, phase and Doppler data on smartphones running android v>7 might lead to sub-decimetre real-time positioning within the next few years.
- Important benefits for “every-day-life” applications and also in Earth Sciences.