# Precise Positioning with Dual Frequency Smartphones

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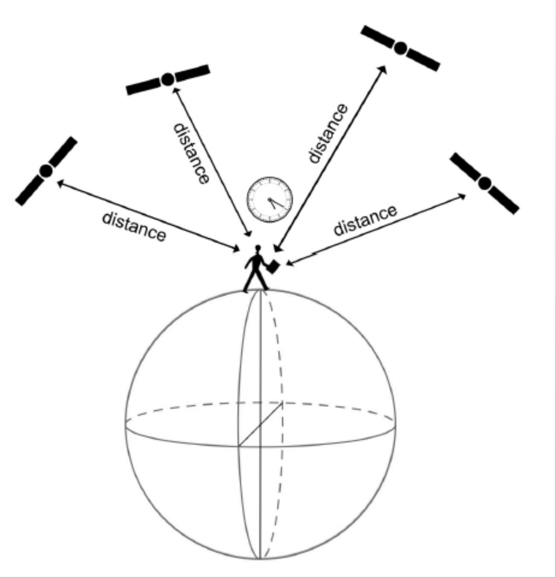
# Smartphones and GNSS

- GNSS = Global Navigation Satellite Systems
  - GPS (USA), GLONASS (Russia), Galileo (Europe), Beidou (China)
- For many years, smartphones are equipped with a GNSS (at least GPS) chip
- GNSS market is dominated by smartphones (more than 80% of total market)
- Major progress ongoing in smartphone-based positioning

# Positioning with GNSS: Raw measurements

- In GNSS, the base observable is the satellite-to-receiver range.
- The simultaneous measurement of ranges to (at least) 4 different satellites allows to compute the user position.
- Two possible ways to measure the satellite-to-receiver range:
  - Ranging code.
  - Phase difference.



# Positioning with GNSS: Raw measurements

- Ranging Code
  - Simplest observable available on ALL GNSS devices.
  - Provides users with 5-10 m positioning accuracy (GPS).
  - Used by smartphones to compute positions.
- Phase difference
  - Most precise observable.
  - Provides cm-level positioning accuracy.
  - Until recently, was only available on high end devices (geodetic receivers).
- Code and Phase measurements can be performed on several frequencies
  - Further improves accuracy and reliability.
  - Until recently, was only available on high end device.

# 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 positioning accuracy depends on the environment (rural, urban, ...): 5-10 m in optimal conditions using GPS only.
- 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

- 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 on compatible smartphones.
- 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.

# Android v>=7 : which raw data ?

- Raw GNSS data are not necessarily available on all Android v>=7 smartphones
- Most “sophisticated” compatible devices :
  - Xiaomi Mi 8 (June 2018).
  - Huawei Mate 20 (November 2018).
  - Xiaomi Mi 9 (March 2019).

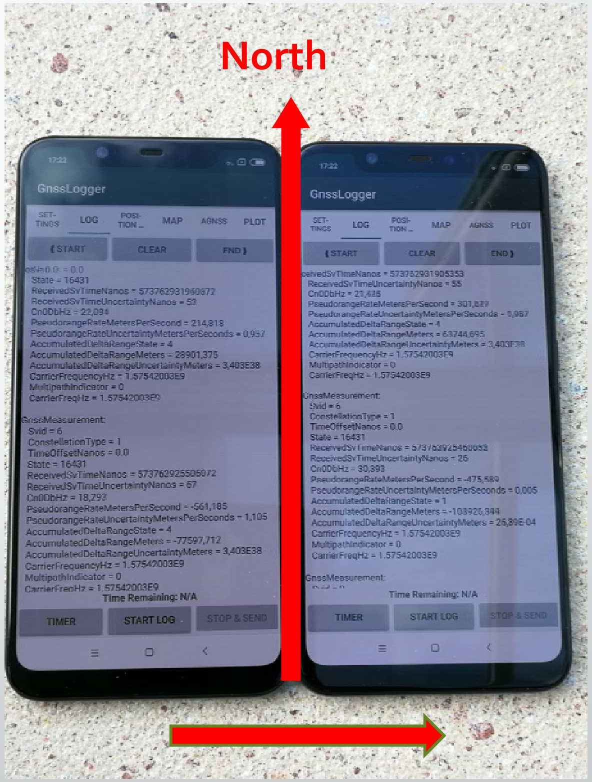

- Available observables:
  - Code (expected).
  - Phase (unexpected).
  - Two frequencies for GPS and Galileo (VERY unexpected)

# Android v>=7 : which raw data ?

- In addition, these smartphones are multi-constellation
  - GPS (USA)
  - GLONASS (Russia)
  - Beidou (China)
  - Galileo (Europe)
  - QZSS (Japanese regional navigation system)

# Short Baseline experiment

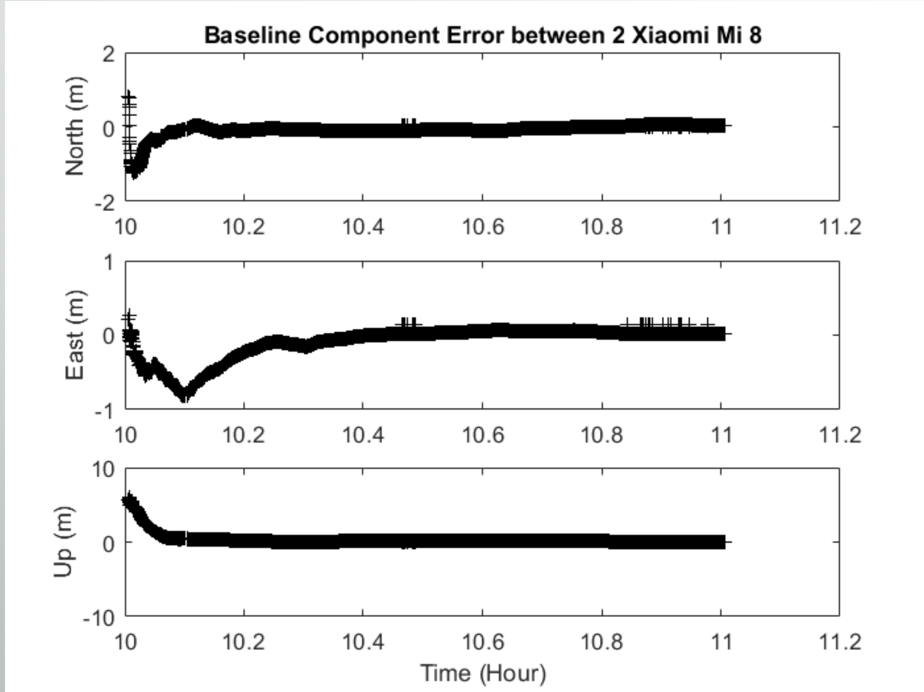
- Experiment on the roof of our building (open sky)
- Carrier phase-based static relative positioning using GPS and Galileo (L1/E1+L5/E5a)
- Short Baseline between 2 Xiaomi Mi 8.
  - dNorth=0,000 m
  - dEast=-0,075 m
  - dUp=0,000m
- 2 Sessions of 1 hour on DOY 246 (03 Sept. 2018).

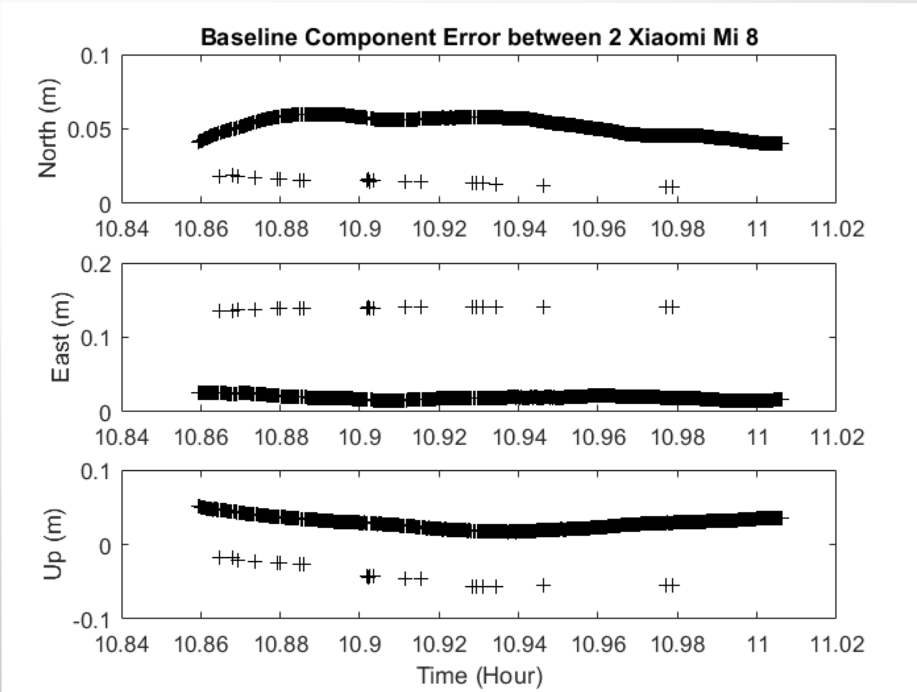



dEast = 0,075 m

# Positioning results – Session 1

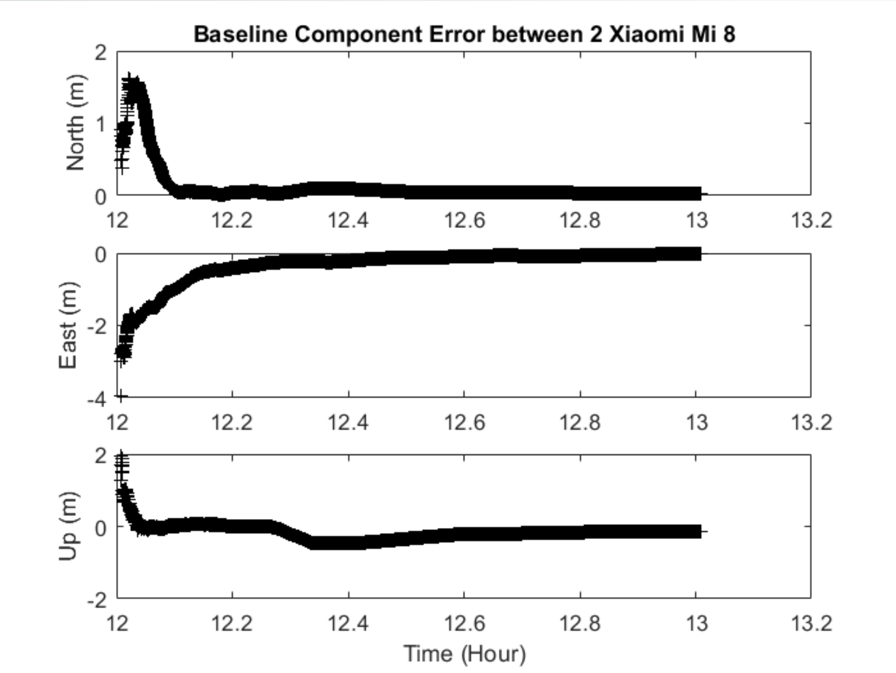
- Session 1: DOY246, 10h00-11h00.
- cm-level accuracy in all components except for a few outliers (dm).

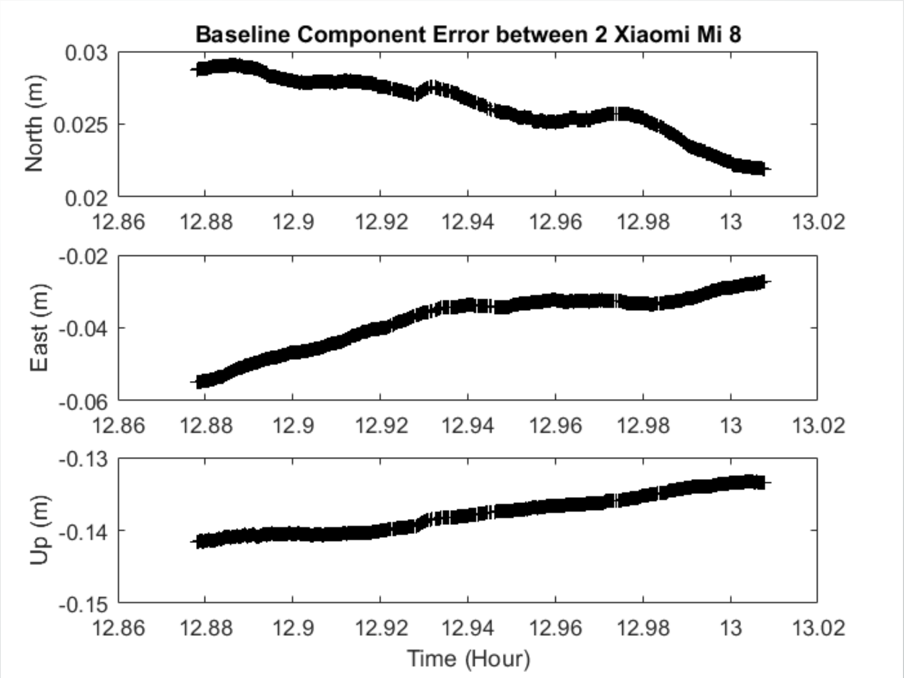


# RTK results – Session 2

- Session 2: DOY246, 12h00-13h00.
- cm-level accuracy in horizontal component and dm-level in vertical component.



# Applications

- Everyday 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 (collaborative networks)

# Conclusions and outlook

- The availability of dual frequency multi-constellation GNSS code and phase data on smartphones running android v=>7 allows real-time positioning at sub-decimetre level in "ideal" conditions.
- Further experiments have to be conducted in more difficult environments.
- Main weakness: 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).
- Patch antennas for smartphones are being developed.