Cloud/Cooperative Navigation

The ICON Concept Demonstrator

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Contents of the Presentation

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- Technical objectives of the Concept Demonstrator
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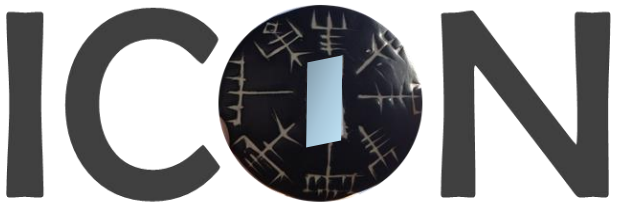
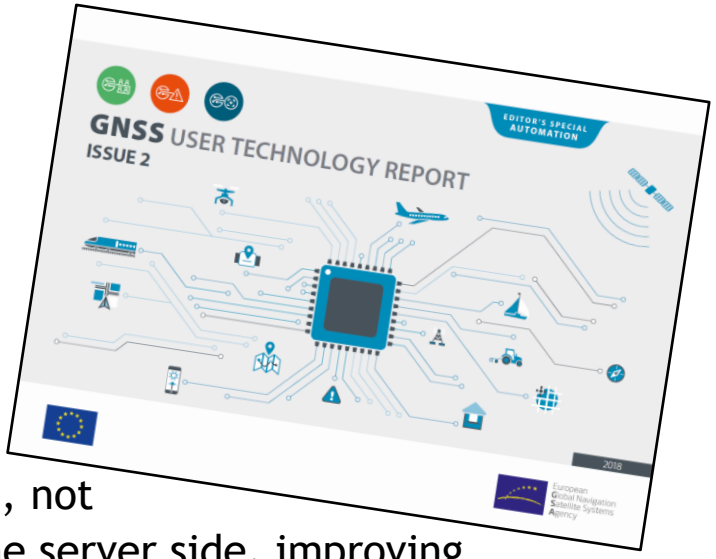
- Focus on some of the technologies and preliminary results
- Fusion approach
- Conclusions and next steps



The ICON Project: Innovative Cloud coOperative Navigation



- PNT is already pervading many aspects of our lives, plus there is a growing demand for ubiquitous positioning on low-cost/low-power mass-market devices (GSA User Tech. Report 2018)

- The proliferation of affordable cloud processing platforms opens new approaches where many different signals, raw data and information, not just GNSS-related, can be collected and processed at the server side, improving sensitivity, accuracy, availability, robustness and efficiency (energy per fix) of user's position

ICON

Funded by ESA through the NAVISP Element 1 Programme, NSL sole contractor

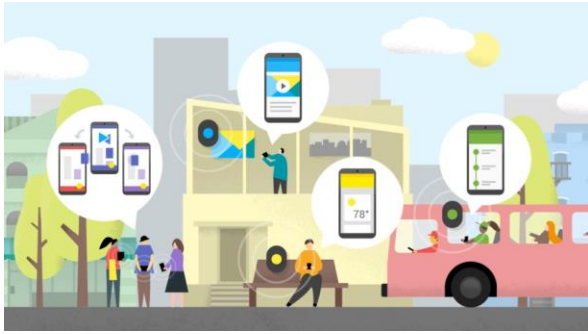
Project conclusion is expected within first half of 2019

The development is ongoing, this presentation does not contain final designs or results !

The ICON Project: Innovative Cloud coOperative Navigation

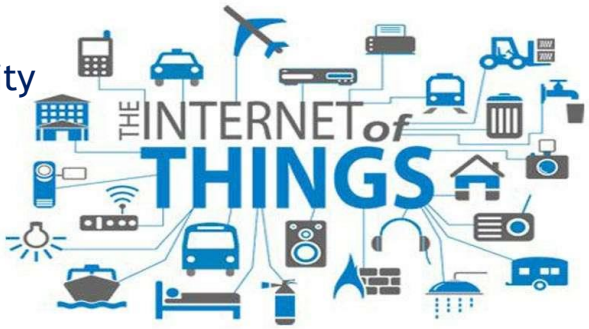
ICON aims to develop a Concept Demonstrator to:

- Study innovative navigation techniques exploiting different positioning technologies and sensors enabled by wireless communications and based on the cloud processing of the data/signals (including GNSS snapshots, signals of opportunity, wireless ranging and IMUs)
- Study cooperative processing and data crowd-sourcing approaches enabled by cloud-based processing of measurements from multiple users ("peers")



Design driving factors:

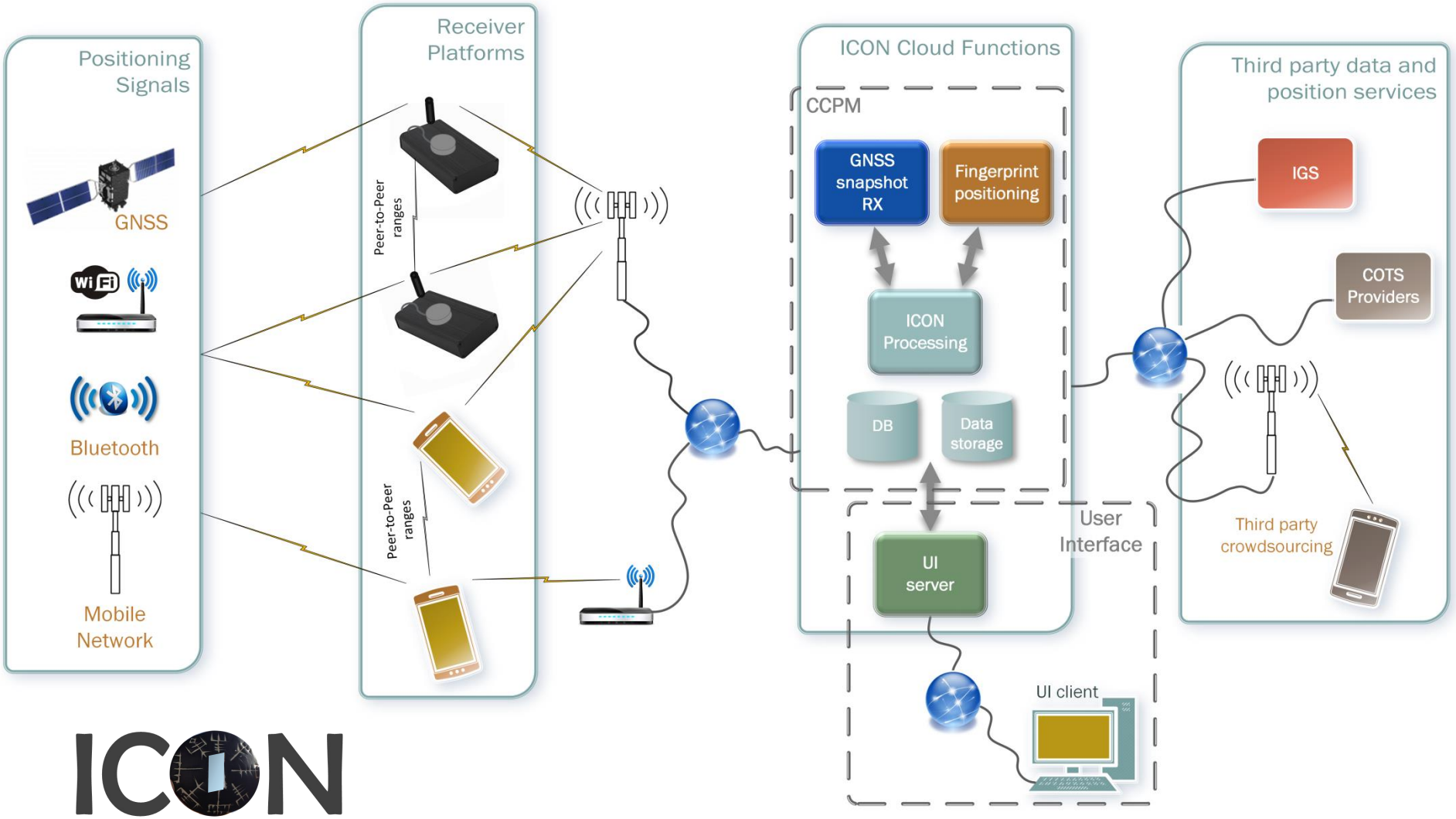
- ✓ Use of COTS products / wireless communications platforms / services
- ✓ Avoid use of bespoke infrastructure and location-specific information (e.g. map of buildings)
- ✓ Flexibility, for targeting different use cases (IoT, LBS, …)
- ✓ Potential scalability, e.g. by containing costs and processing complexity
- ✓ Efficiency, e.g. delivering an "energy per fix" figure that matches the use case
- ✓ Suitability for cloud processing integration
- ✓ Representativeness of state-of-art



Selection of Technologies for ICON

- Being integrated:
  - Cloud-based snapshot GNSS positioning
  - COTS GNSS chip (and Android raw meas.)
  - COTS fingerprinting signals of opportunity.
  - COTS Geolocation services with wireless signals of opportunity.
  - Peer-to-peer Wi-Fi ranging with Android P
  - Peer-to-peer UWB ranging
  - Cooperative positioning using peer-to-peer ranges and peer position estimate.
  - Crowd-sourced barometric measurements database for height measurements.
  - Cloud-based exploitation of IMU sensor data
- Discarded:
  - GNSS Shadow matching
  - Network-based techniques (e.g. OTDOA, UTDOA)
  - Installation of bespoke reference nodes
  - SLAM fingerprint development
  - Odometers, stand-alone INS units or tight GNSS/INS integration

Functional Architecture



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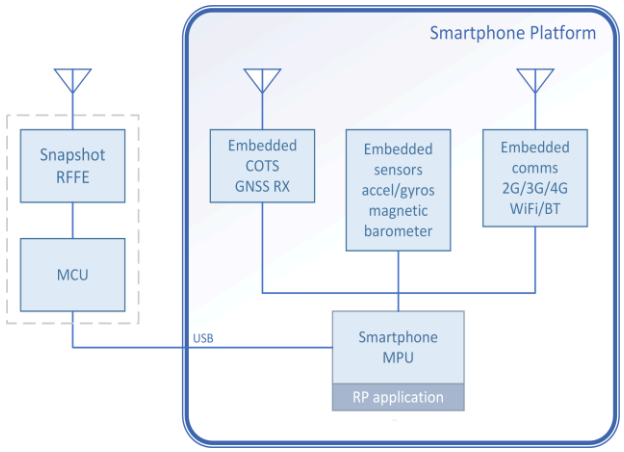
Cloud/Cooperative Processing Module (CCPM)

- Cloud hosting
  - TCP server- auto-scaling and load balancing
  - Input/output data storage
  - Processed data database – on-demand auto-scaling
  - Fix reprocessing – input data timestamp based
- Cloud processing modules
  - CCPM server
  - CCPM top level
  - Configuration reading
  - Data input
  - Data output
  - Results output
  - Crowdsourced barometric height
  - Snapshot positioning
  - SoO fingerprint positioning
  - SoO Geolocation services
  - IMU dead reckoning
  - COTS GNSS raw observations
  - Peer Ranging
  - Fused position computation
- System configuration
- Cost estimation: resource usage, parallel active devices, billing

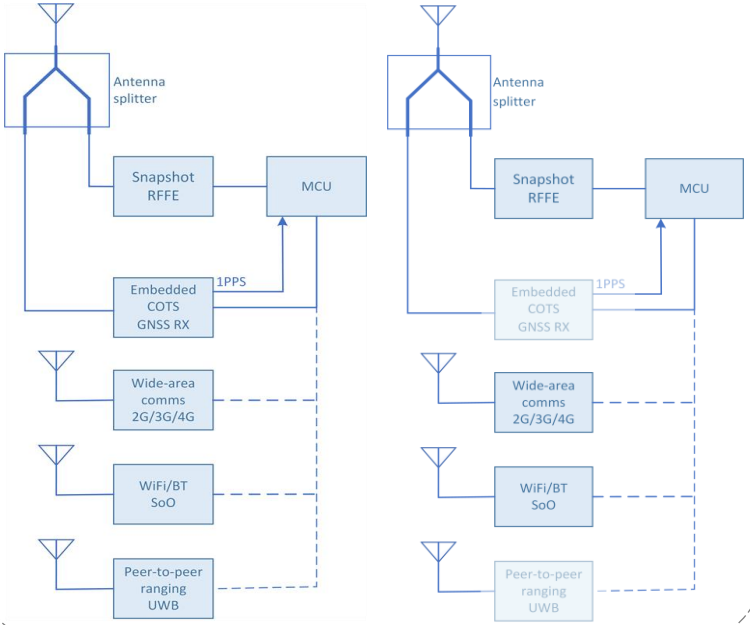
Two Receiver Platforms under development

Smartphone



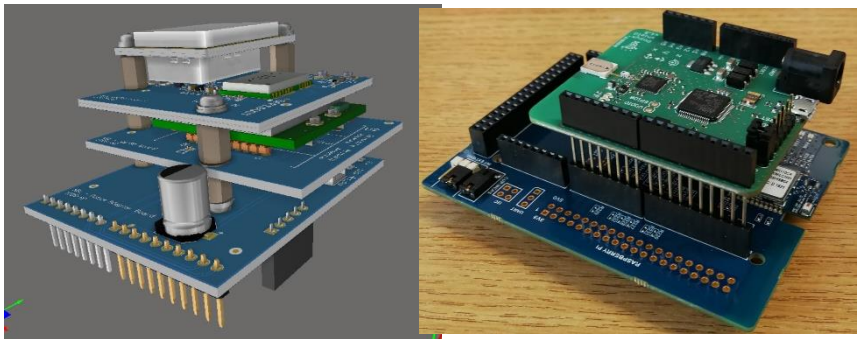
Phone-RP, “pRP”

Embedded Receivers



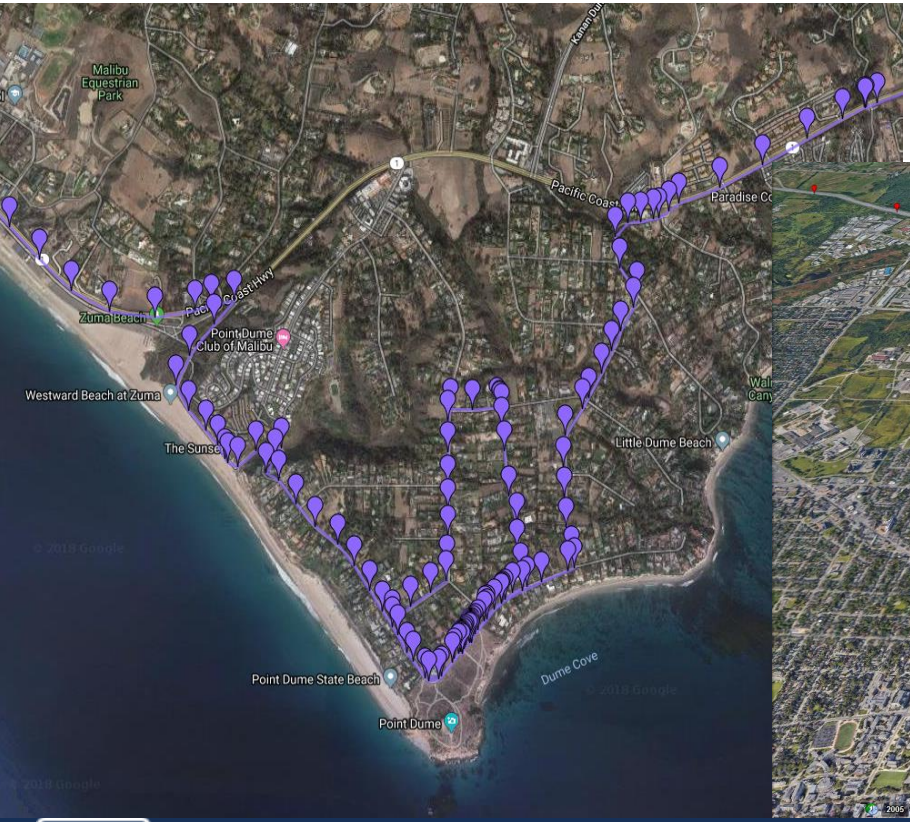
Embedded-RP, “eRP”

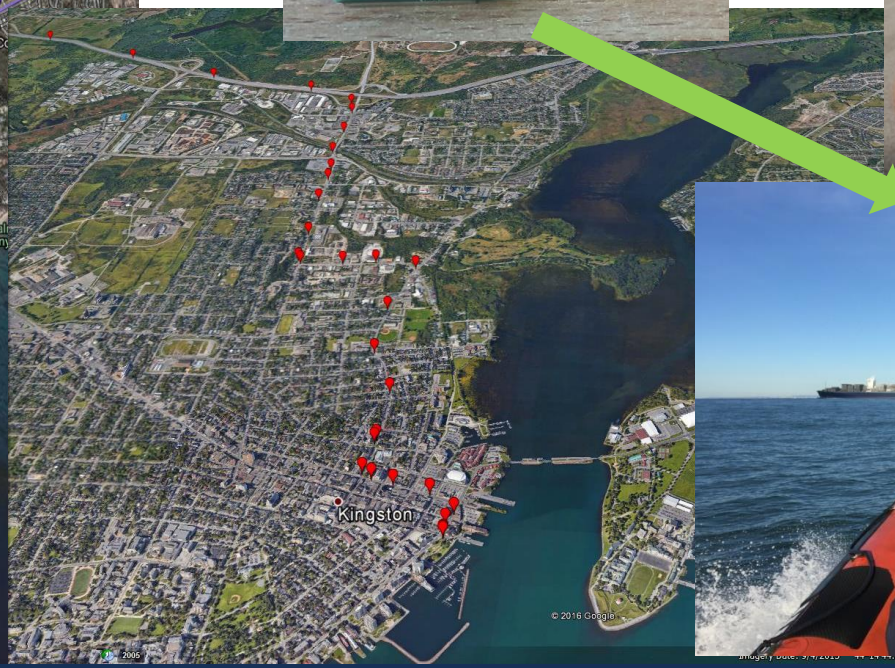
Configurable eRP functionality stack based around NSL RFFE core



Server-based Snapshot GNSS

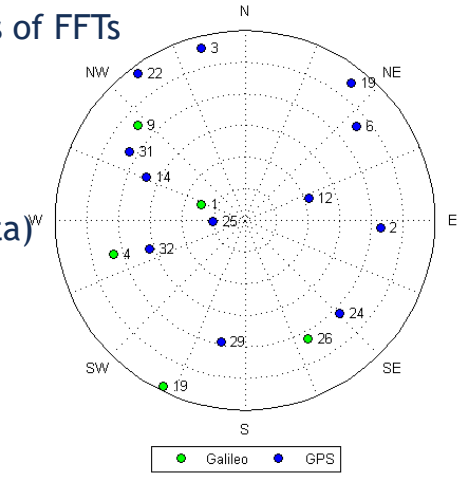
- NSL has been developing snapshot GNSS receivers over multiple projects
  - Open loop (“snapshot”) processing is the basis of NSL server-PRS approach
  - Cloud-based processing + IoT-type miniaturised receivers were baseline for ICON

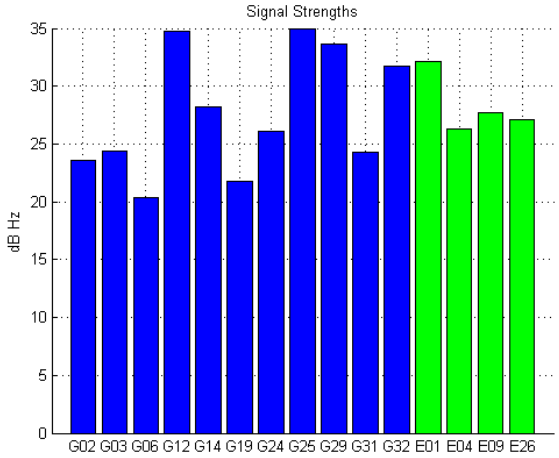


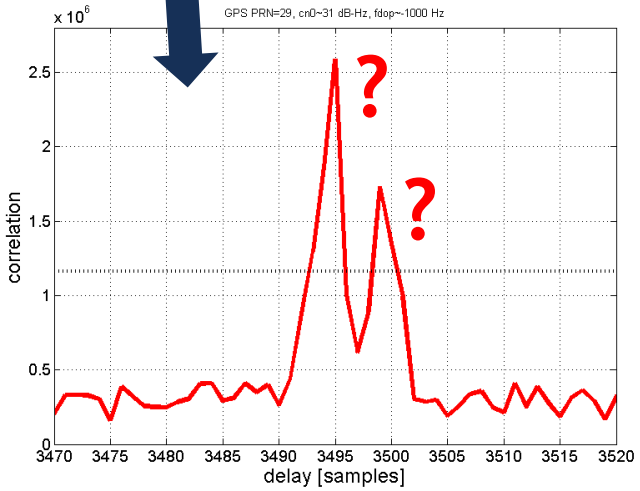


Server-based Snapshot GNSS (continued)

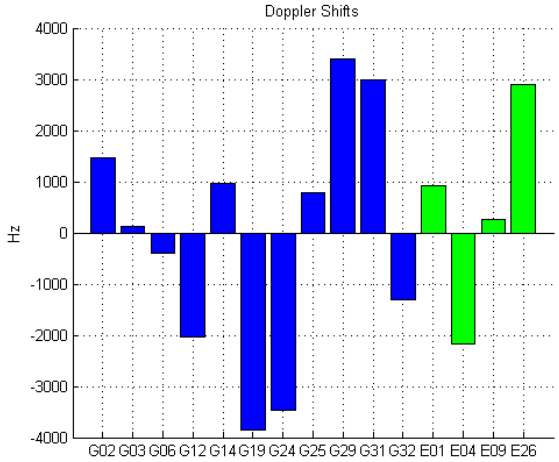
- High sensitivity snapshot processing
  - 20 dBHz target sensitivity → heavy in terms of FFTs
  - GPS/Galileo/GLONASS (L1)
  - Reduction of processing delay:
    - ✓ In the cloud and heavily parallelised
    - ✓ Assisted Acq. (including collaborative data)
  - Capture: 0.5~1.0 s and 1-bit samples, to limit amount of data to be uploaded
  - Multipath, near-far, interference: require checking and filtering observations







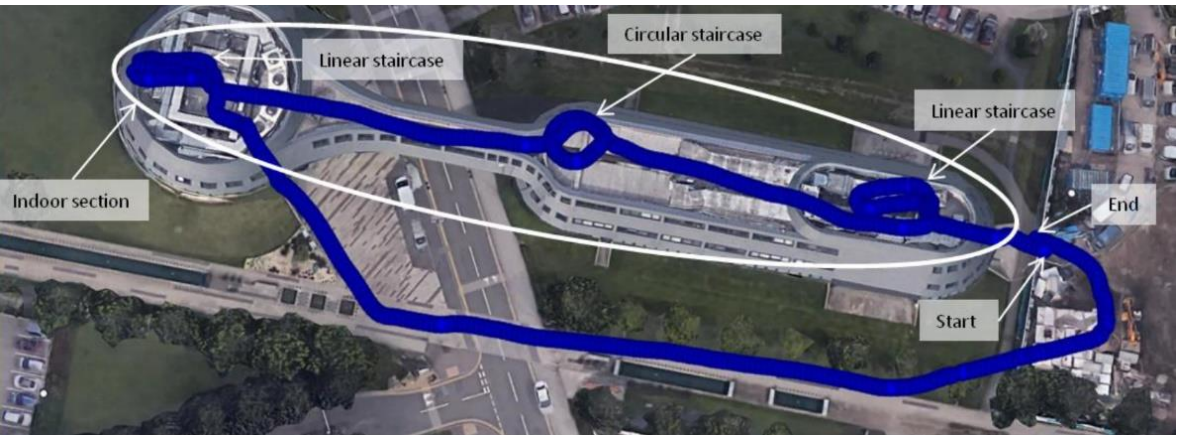
Clean, low-power signals

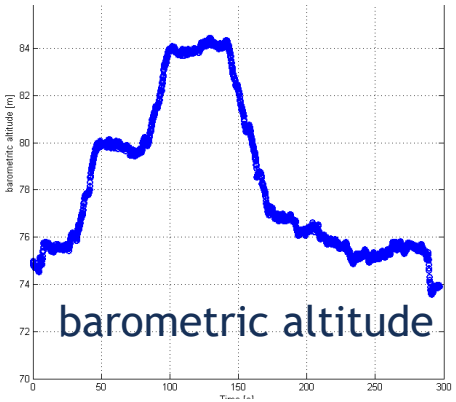


from an actual urban scenario:
GPS L1 C/A 31dBHz example

Use of Inertial Measurements Units

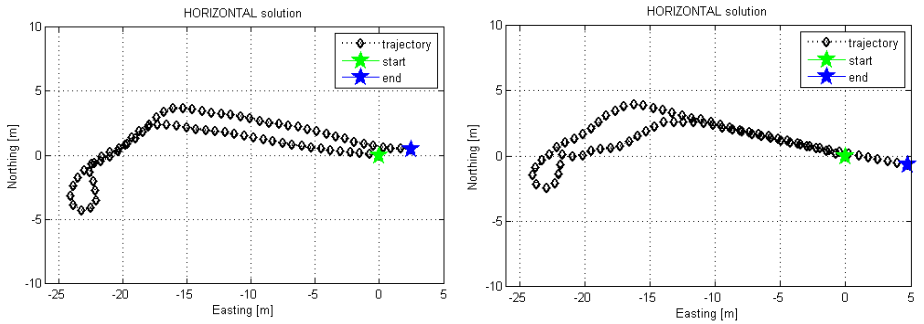
- Evaluating pedestrian dead reckoning for the LBS use case, i.e. smartphones
- Below: “semiconstrained” user looking at the phone while walking
- Evidence of good results even on walking trips of minutes:
  - Pixel 2 phone, 5 minutes loop, in/out NSL offices, <2 m error between start/end points
  - Stand-alone solution using phone IMU and barometer (no compass because of disturbances)





- On shorter trips (< 1 minute) results are more repeatable

Example: 2x the same
45 seconds indoor walk



Peer-2-Peer ranging: Wi-Fi RTT

- Wi-Fi RTT specification (802.11mc or Fine Timing Measurement) was released in 2016
- Android 9 “Pie” officially supports Wi-Fi RTT ranging to Access Points
- It is easy to use the RTT feature with an app against APs

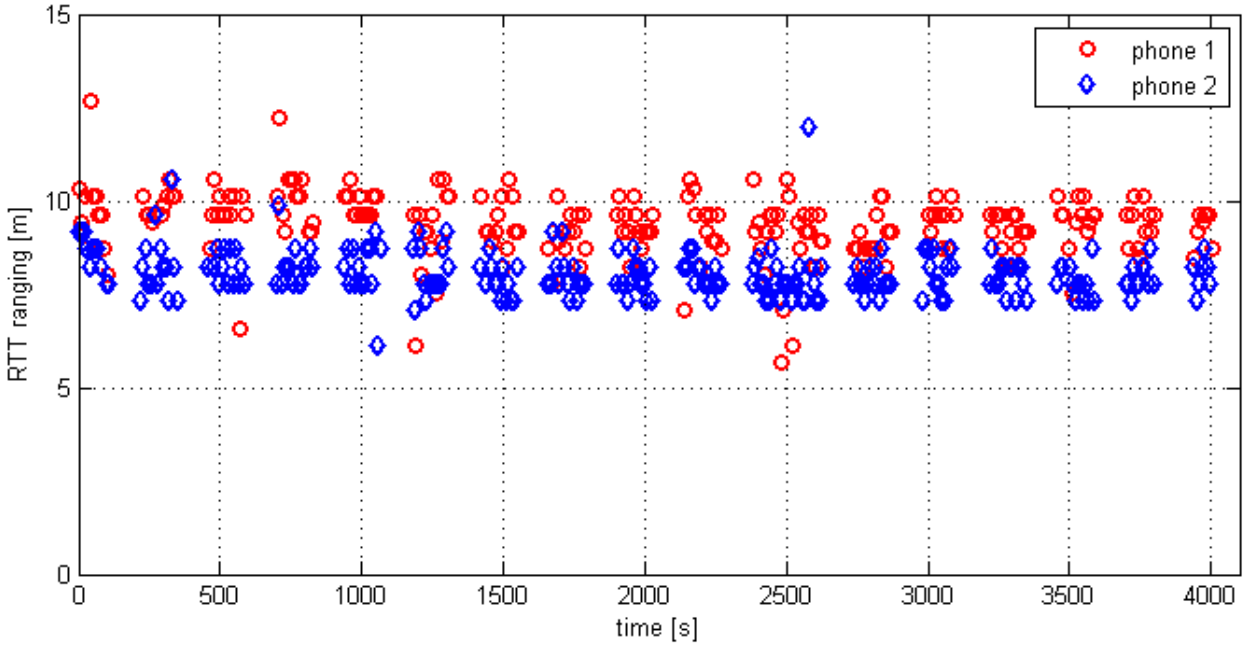
However…

- Within ICON we are looking for a solution that is mostly infrastructure-free (i.e. no knowledge and exploitation of APs positions)
- Android 9 has an additional interesting feature: direct peer-to-peer Wi-Fi RTT ranging between phones

- Unfortunately this comes with complications:
  - Before doing p2p ranging, devices need to belong to the local NAN cluster (Wi-Fi Aware, 2015)
  - Devices need to be publishers/subscribers of Aware services, several settings related to this
  - RTT operations between two devices are agreed during the Discovery Windows of the NAN cluster, but take place outside them (Google patent US9439089B2)
  - For privacy/security purposes the actual MAC addresses are obscured and regularly randomised
  - Documentation is a bit scarce as of today

Peer-2-Peer ranging: Wi-Fi RTT (continued)

- One-way p2p ranging works OK (some offsets in the measurements)
- Two-way p2p ranging still works ok
  - only occasional ranging failures
  - pretty stable when using a low rate, like every 10 seconds
  - the plot is an example using two Pixel 2 XL ranging each other, 10 metres apart and in LoS:
- Current issues:
  - A reliable configuration for continuous two-way p2p ranging across more than two devices
  - Calibration of hardware biases in RTT measurements



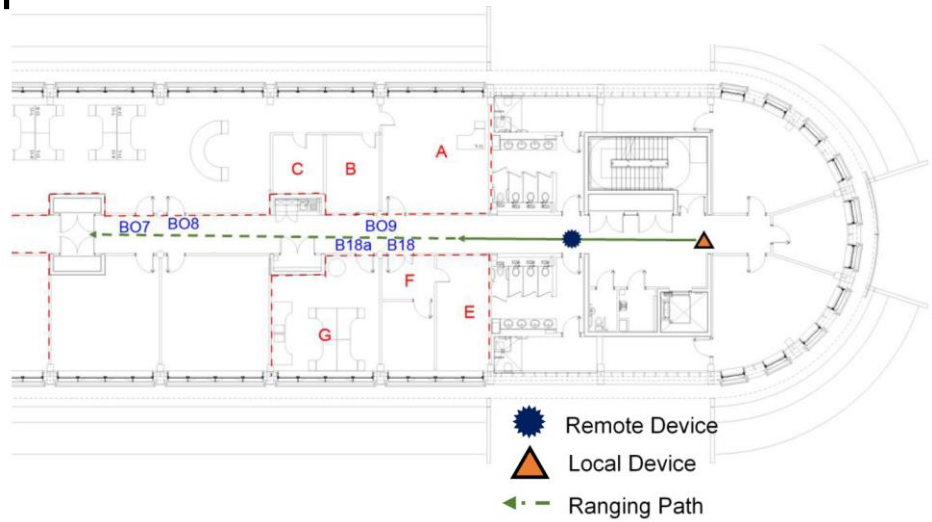
Other technologies being integrated

- COTS GNSS – integration of raw measurements
  - Observations can be used in fused position solution
  - Observations can be used to support snapshot positioning (complexity reduction)
  - COTS chip for the eRP, Android raw meas. for the pRP

- Wi-Fi / Bluetooth fingerprint positioning (FIND3)

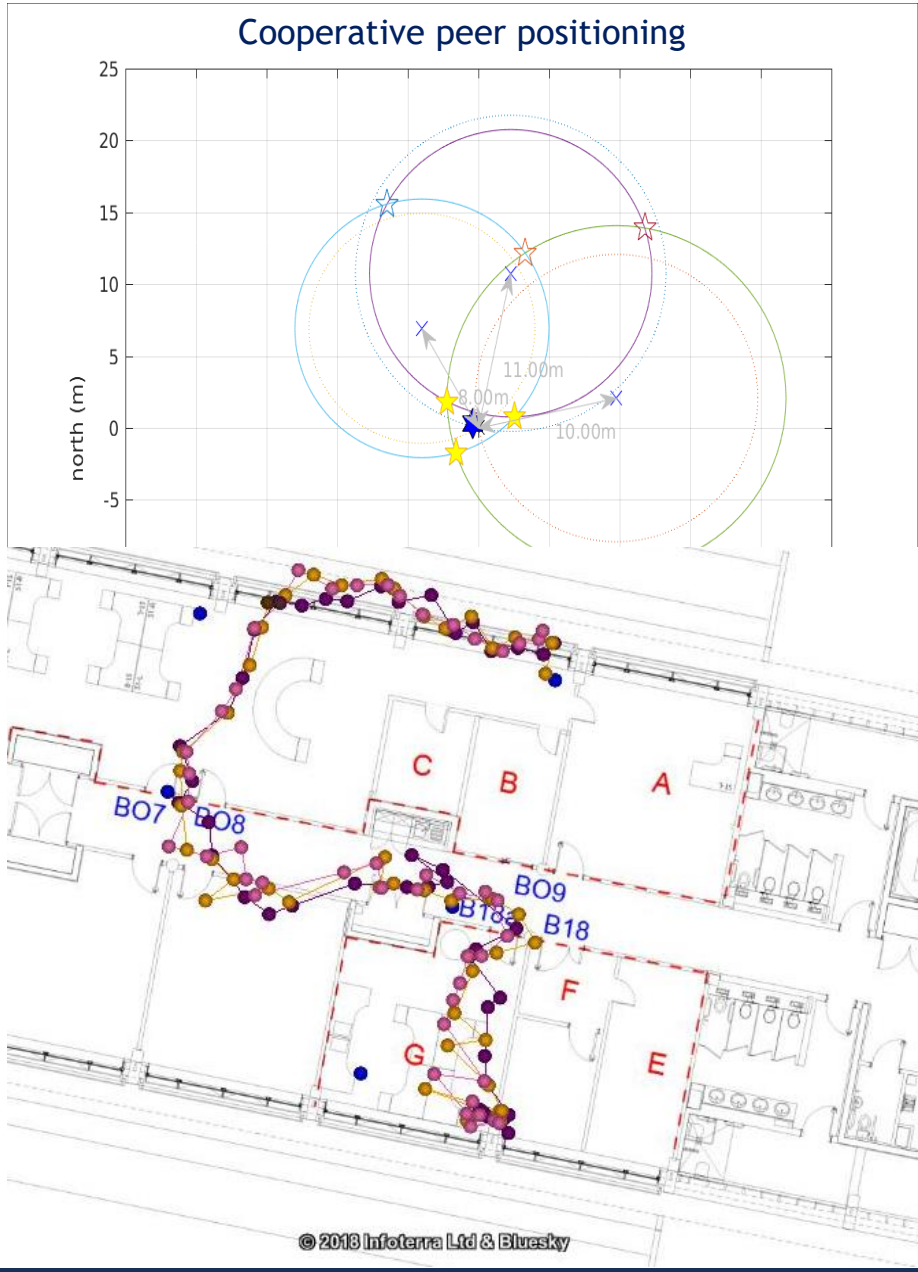
- UWB peer-to-peer ranging on eRP

- Geolocation APIs

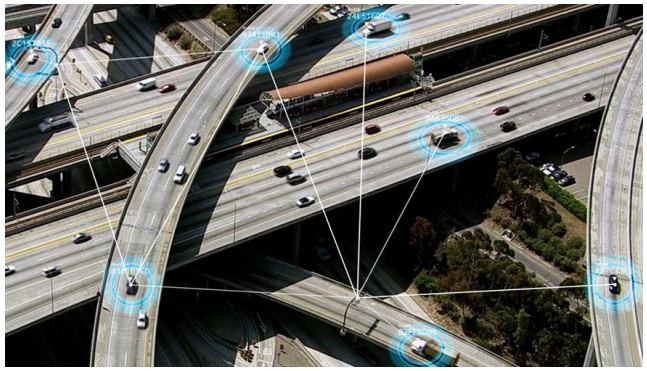


Fusion approach

- Combined COTS + snapshot GNSS,
  - loose synchronisation in phone (pRP), tight synchronisation in embedded receiver (eRP)
- Cooperative positioning using peer-to-peer ranges and peer position estimate
  - Iterated peer-solution computed on each fix
  - Peer position from up-to-date optimal fused solution for each peer
    - Quality: number of peers in view, quality of measurements, relative obs. geometry
- Crowd-sourced barometric measurements database for height measurements.
- Cloud-based pedestrian dead reckoning for smartphone platform.

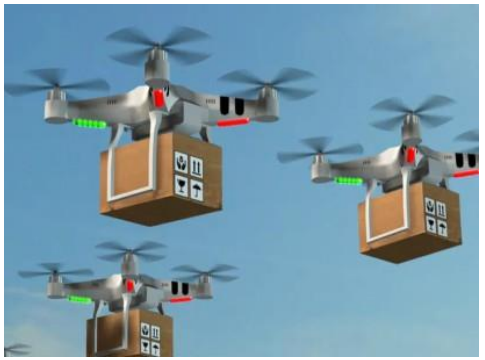


Conclusions and next steps



- The ICON demonstration platform will be a powerful tool to evaluate diverse cloud-based positioning techniques, including cooperative positioning and crowd-sourced aiding
- Different aspects of ICON will cover a wide variety of use cases for different combinations of the included techniques, e.g. Fire & Rescue Services
  - Operating in challenging environments, often disrupted by fire, structural collapse, ruins
  - Needing ubiquitous operation, particularly indoors, limited or no infrastructure, improved accuracy, low power

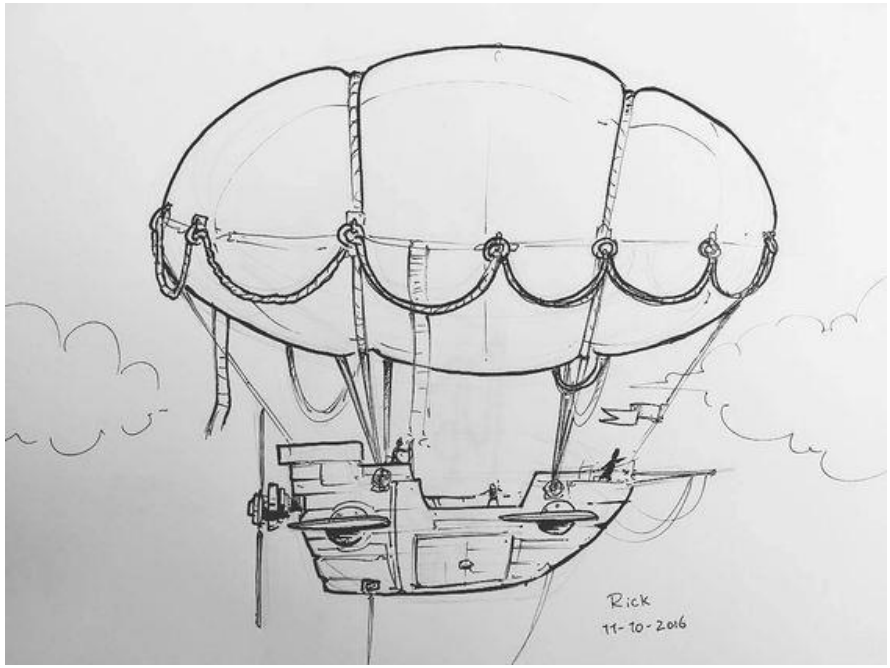
  ➔ Derivative product development, meet market/users demands



- ICON is being designed with scalability and costs in mind so that lessons learnt will progress to future products
- Design and development work is on-going. Despite a good starting point in many aspects of the project, the overall platform development is ambitious

Thank you for your attention

Any Questions?



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