

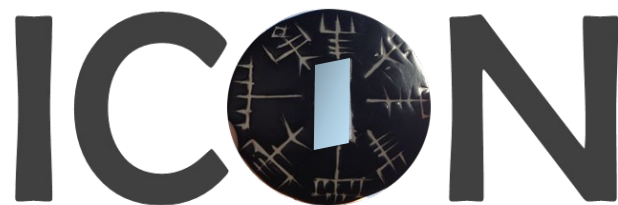
NAVISP-EL1-007

ICON

Innovative Cloud coOperative Navigation

Final Presentation

17th July 2024, 14:00 – 15:30 CET



Presentation Contents

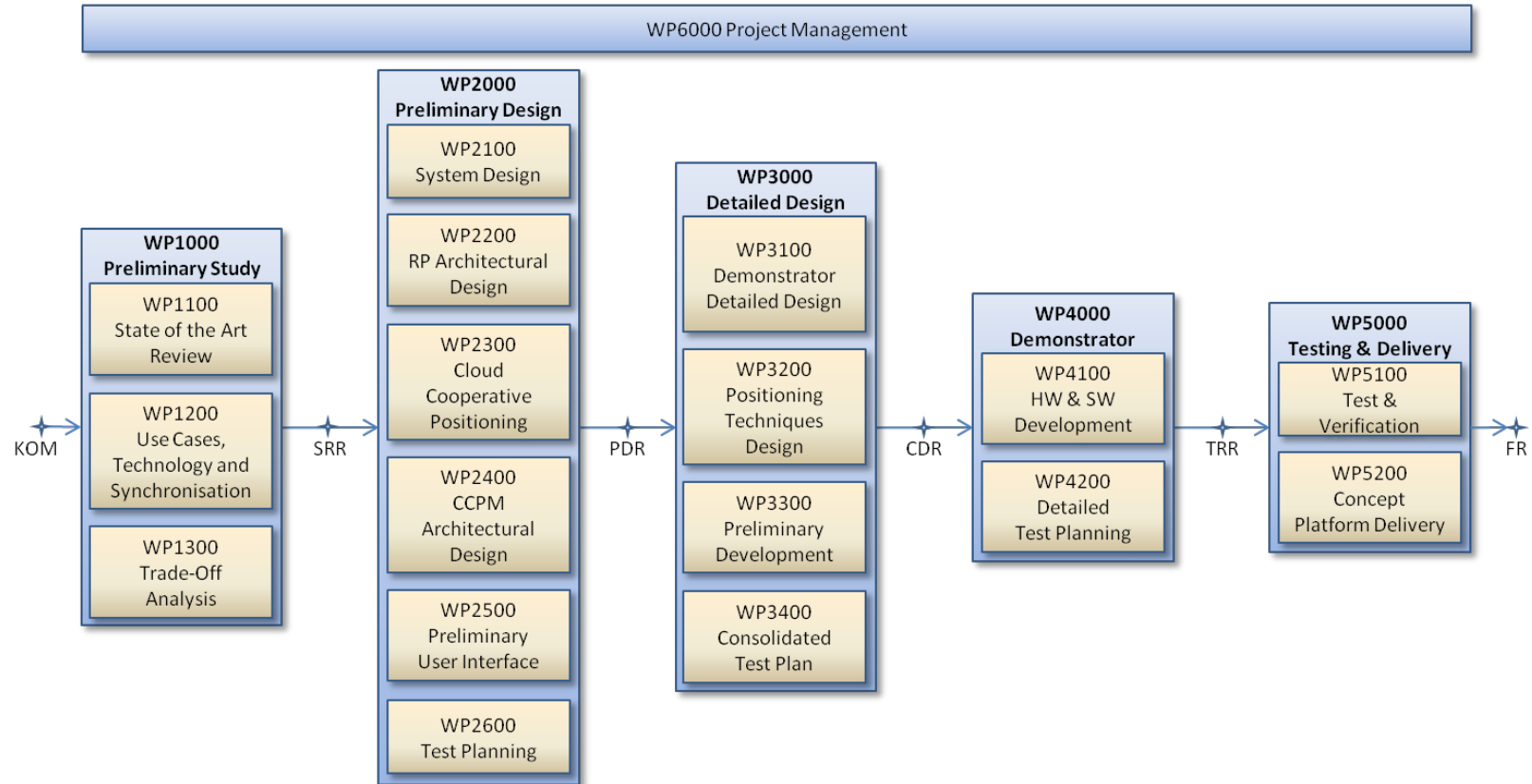
Introduction to ICON

Description of concept demonstrator

Validation testing

Conclusions

The Programme of Work



Technologies for ICON

Evaluated / Integrated:

- Cloud-based snapshot GNSS positioning
- COTS GNSS module (IoT) / Android raw meas. (LBS)
- COTS fingerprint of signals of opportunity.
- COTS Geolocation services for signals of opportunity.
- Peer-to-peer Wi-Fi ranging in Android
- Peer-to-peer UWB ranging
- Cooperative positioning using peer-to-peer ranges
- Crowd-sourced barometric measurements calibration
- Client-Cloud Pedestrian Dead Reckoning

Discarded:

- GNSS Shadow matching
- Network-based techniques (e.g. OTDOA, UTDOA)
- Bespoke reference nodes
- SLAM fingerprint development
- Odometers, stand-alone INS units or tight GNSS/INS integration

Presentation Contents

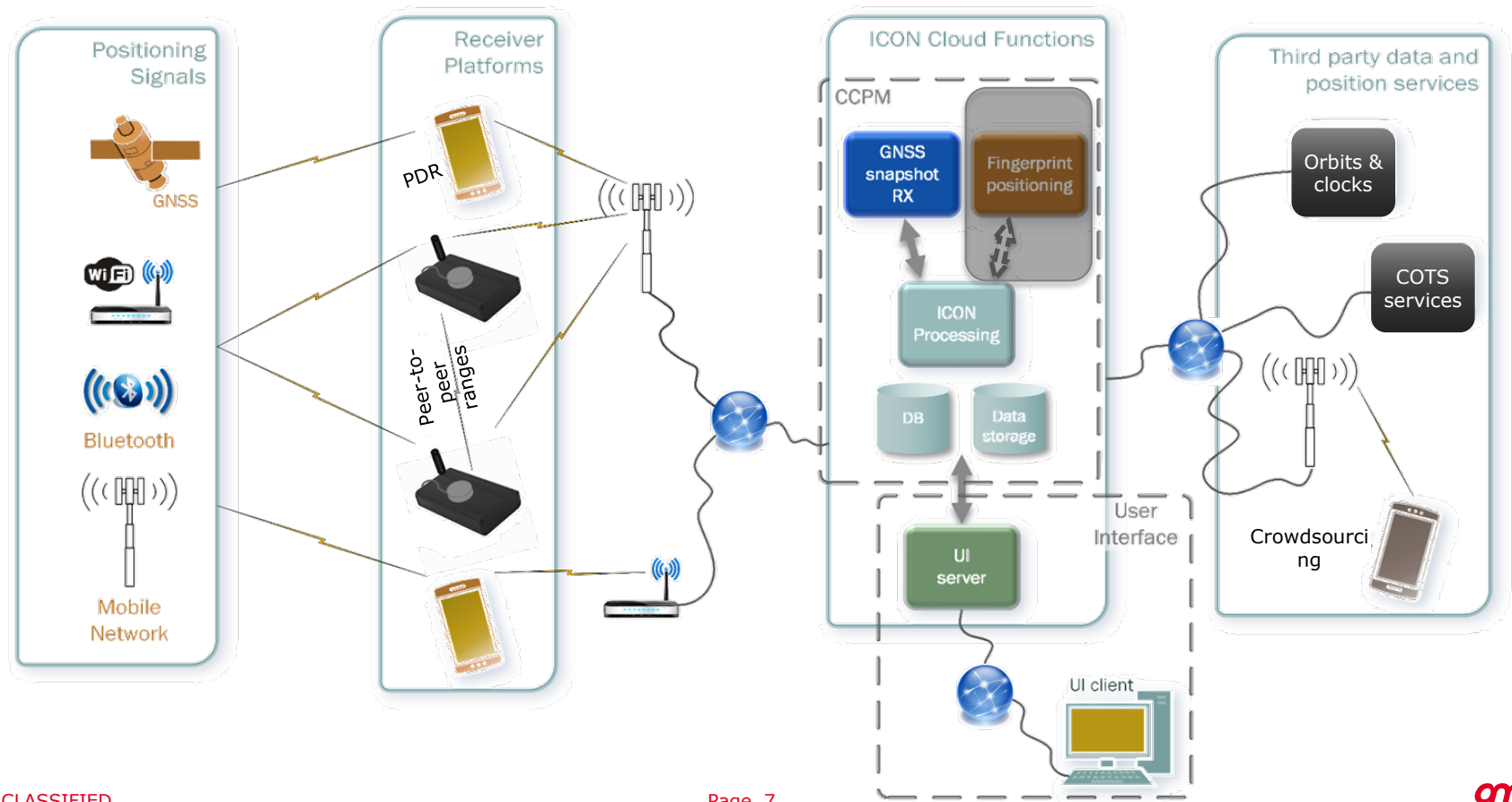
Introduction to ICON

Description of concept demonstrator

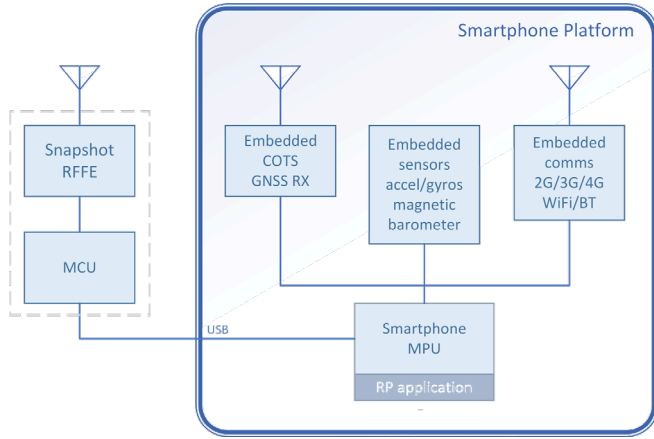
Validation testing

Conclusions

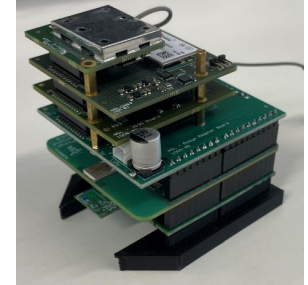
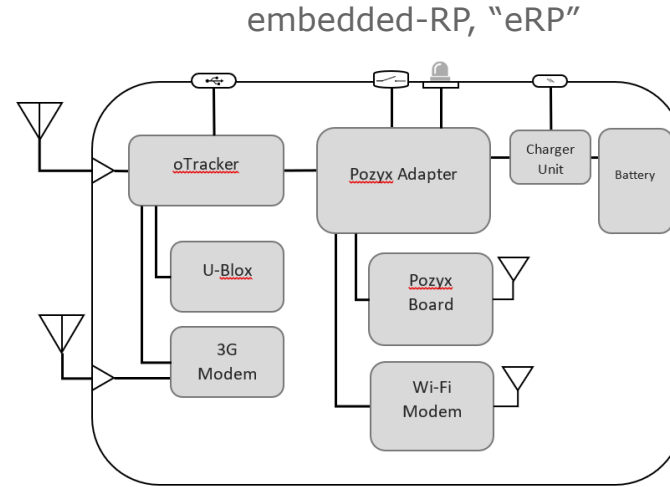
Functional Architecture



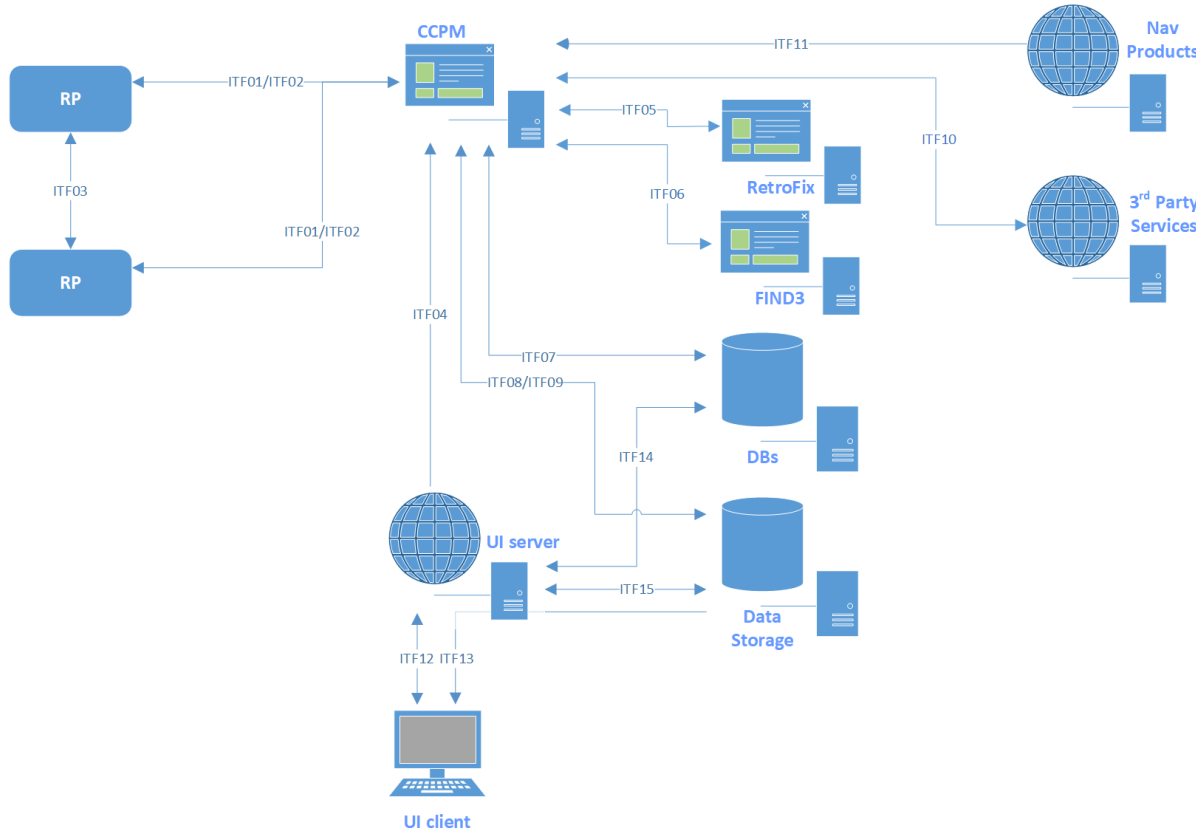
Receiver Platforms for both Use Cases



phone-RP, "pRP"



Architecture for ICON CCPM



Cloud Cooperative Processing Module (CCPM)

- CCPM server
- Configuration reading
- Data input
- Data output
- Results output
- Snapshot GNSS positioning
- SoOp fingerprint positioning
- SoOp Geolocation services
- Pedestrian dead reckoning
- COTS GNSS raw observations
- Barometric height calibration
- Peer Ranging positioning
- Fused PVT Solution

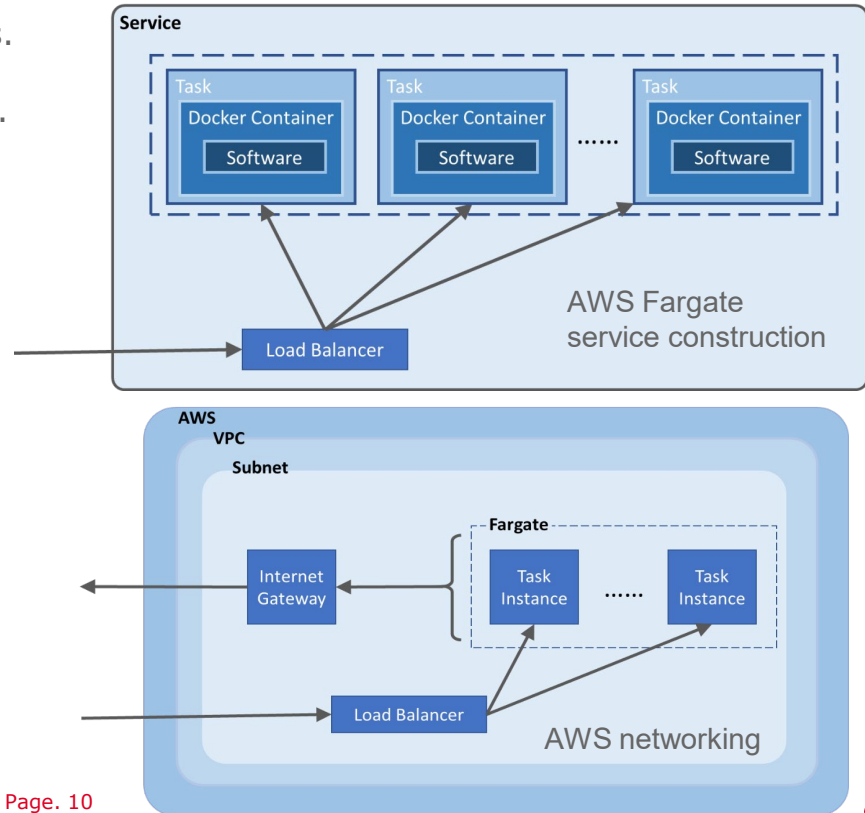
ICON Cloud Hosting

The ICON processing is hosted on the Amazon's AWS cloud using the following AWS functionality:

1. Server software hosted as AWS Fargate services.
2. Database tables stored in an Aurora database.
3. Output files and input data stored in S3 buckets.
4. User interface runs as an AWS Fargate hosted http server with PHP support

Multiple services are hosted:

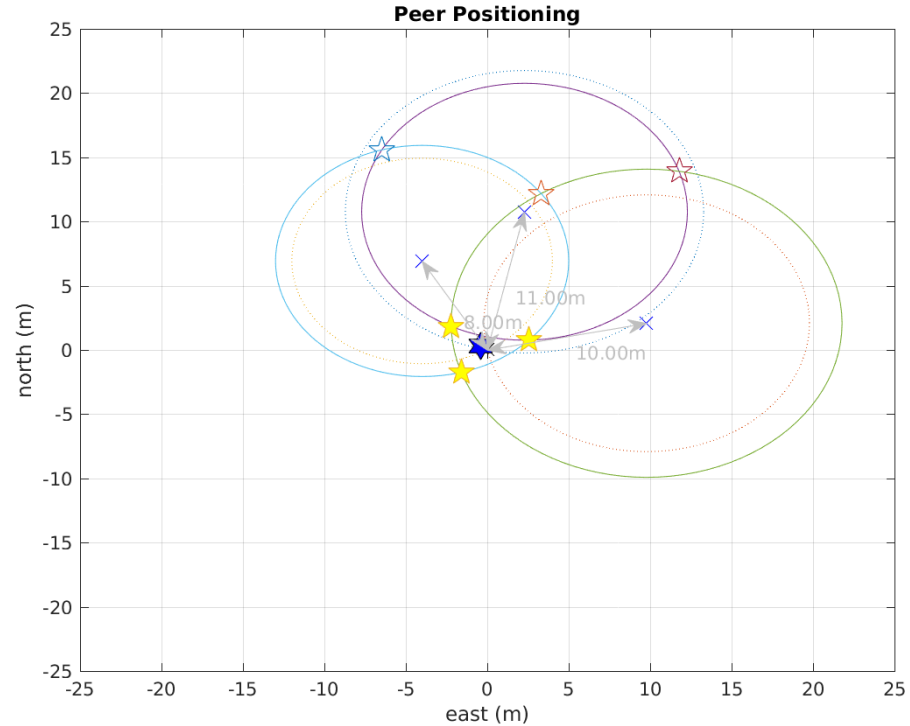
- ICON CCPM
- RetroFix snapshot GNSS software receiver
- FIND3 SoO fingerprint matching
- ICON UI
- Navigation data retrieval
- Reprocessing task



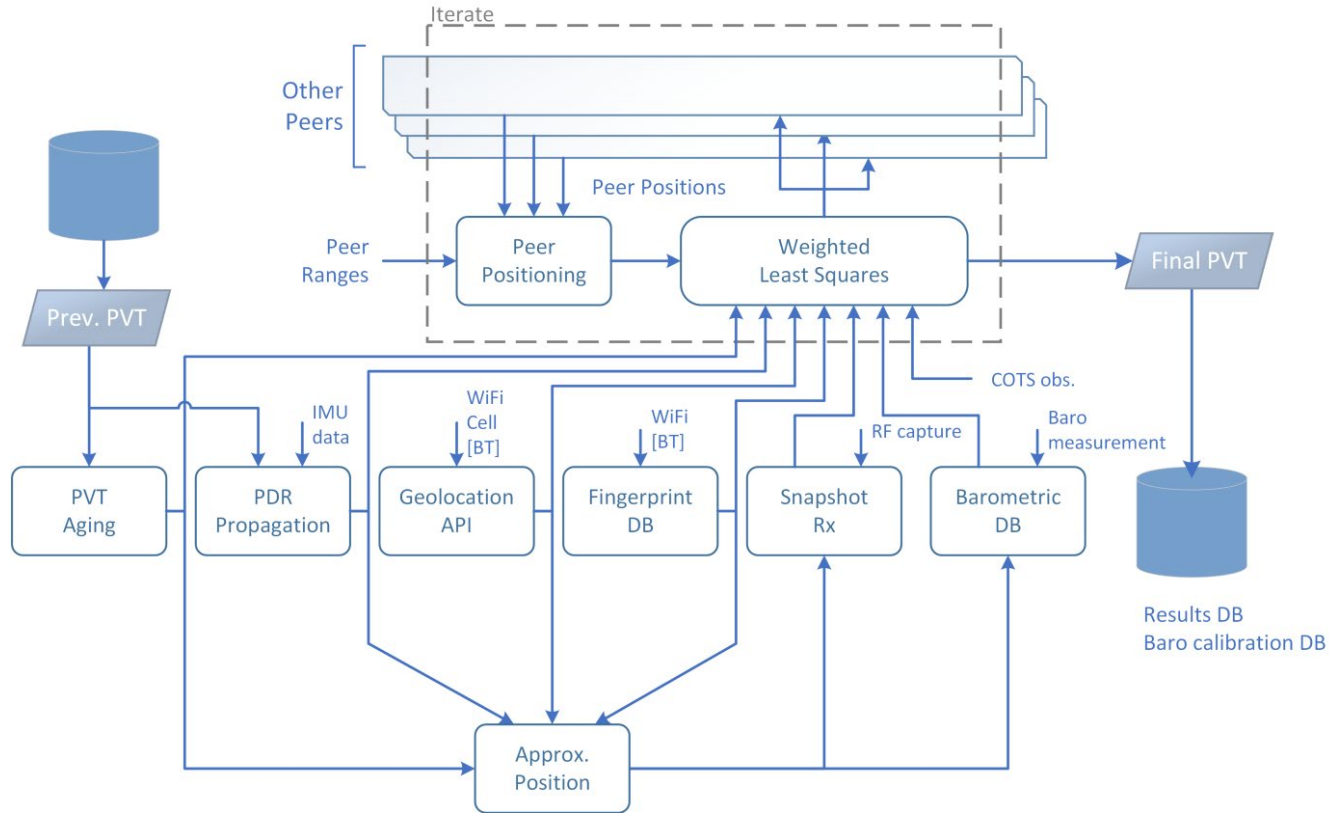
Peer Ranges Positioning

2D peer position solution from peer ranges + latest peer position

- Peer position and ranges with both uncertainties used in fused solution
- Impacted by accuracy of range and peer position and age of position estimate
- 3D coordinates of peer devices and height used
- Collaboratively iterate position of network of devices
- Improved PVT estimates for all the peers, including peers initially with no/poor PVT, is sufficient peer to peer measurement to peers with a PVT
- Evaluation of intersection of pairs of range circles with outlier elimination found more tolerant of errors and biases than direct combination of all the circles in a single system of equations



ICON Fusion Filter



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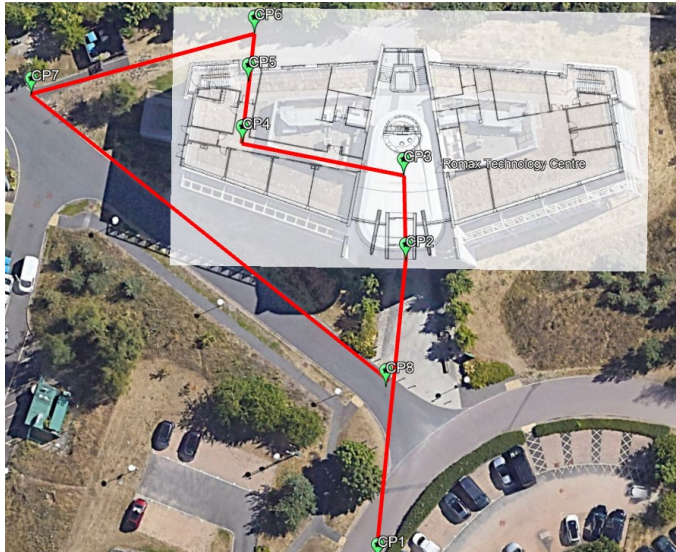
Conclusions

Validation Tests – LBS use case

pRP indoor positioning evaluation

Test Routes:

- a) Enterprise centre ground floor
- b) Enterprise centre ground & first floor



(a)



(b)

Validation Tests – LBS use case

pRP indoor positioning evaluation

Error measures obtained over all laps

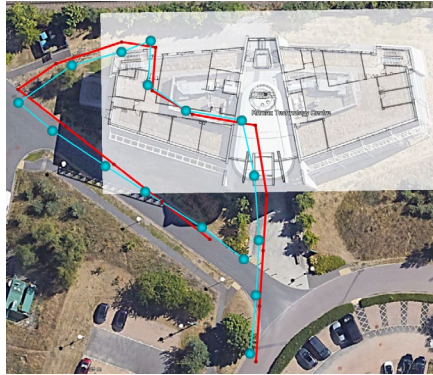
Route	PVT type	Availability (epoch)	Availability (%)	2D			3D or Vertical Error (only for Barometer)		
				CEP (m)	1Sigma (m)	2Sigma (m)	CEP (m)	1Sigma (m)	2Sigma (m)
Enterprise A	Final PVT	431/435	99%	3.4	4.2	9.9	4.2	5.2	10.6
	COTS	431/435	99%	4.2	5.3	25.2	5.3	7.0	25.8
	Snapshot	310/435	71%	7.1	9.2	26.4	11.8	13.9	49.5
	PDR	425/435	98%	4.4	5.3	12.2	5.4	6.4	12.4
	Barometer	431/435	99%	N/a	N/a	N/a	1.8	2.5	9.0
Enterprise A & B	Final PVT	456/460	99%	5.1	6.4	14.0	6.1	7.9	15.7
	COTS	456/460	99%	5.8	8.9	28.7	7.0	9.9	28.9
	Snapshot	247/460	54%	5.6	7.3	21.8	10.0	12.1	38.4
	PDR	450/460	98%	7.4	8.7	15.8	8.7	10.1	16.7
	Barometer	456/460	99%	N/a	N/a	N/a	2.9	4.0	9.0

Validation Tests – LBS use case

pRP indoor positioning evaluation

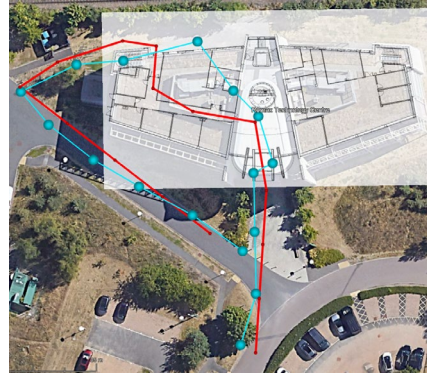
Example results from both routes (Single lap)

Final PVT

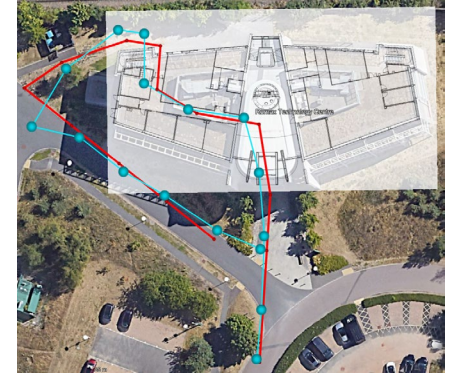


Enterprise
Floor A

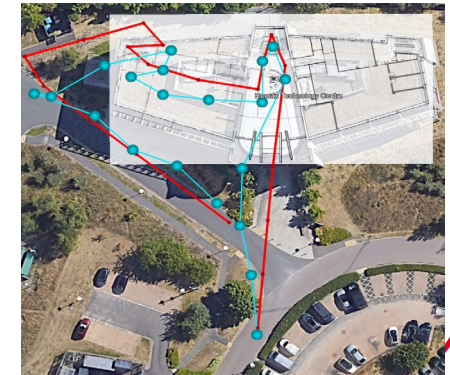
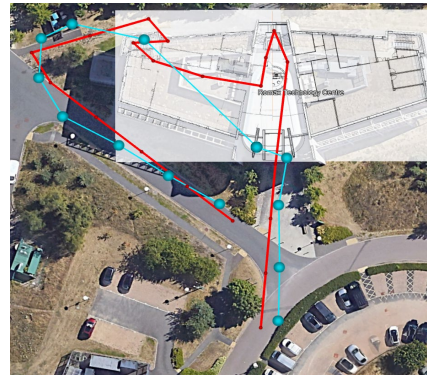
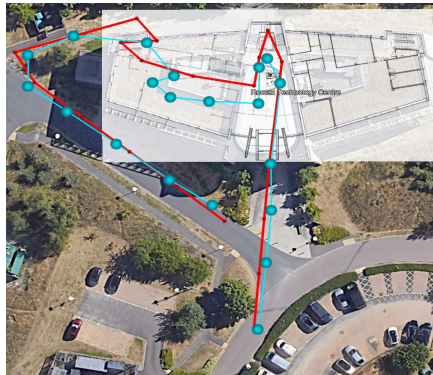
COTS PVT



PDR



Enterprise
Floor A & B



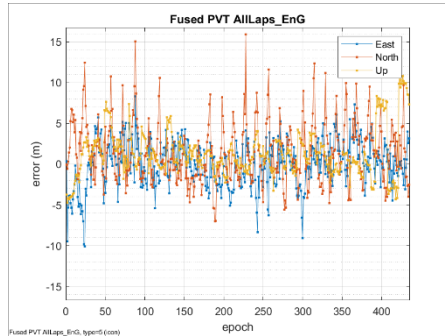
Validation Tests – LBS use case

pRP indoor positioning evaluation

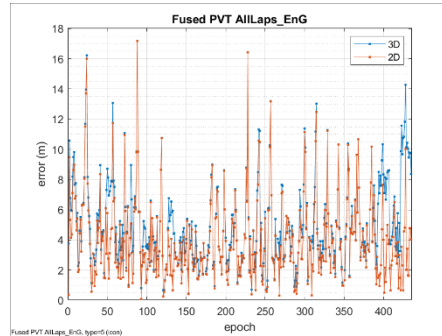
Example results from Enterprise ground floor route (including all laps)

Final PVT:

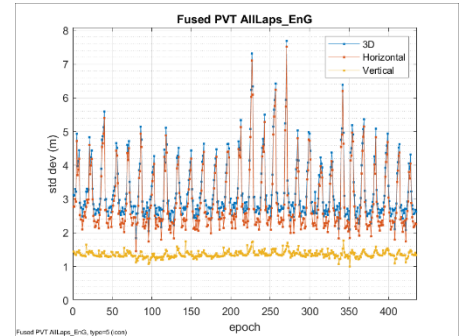
ENU time series



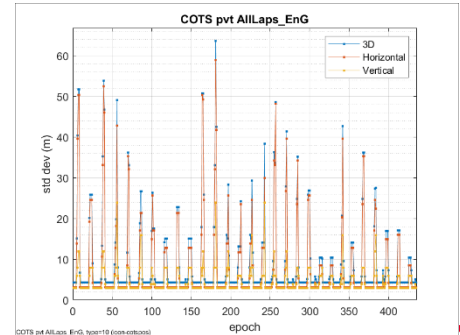
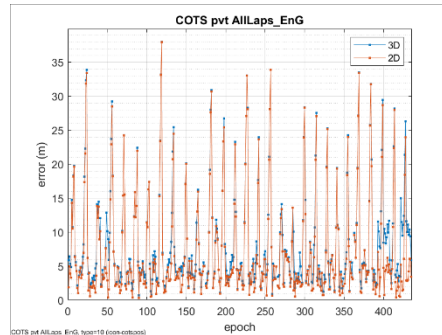
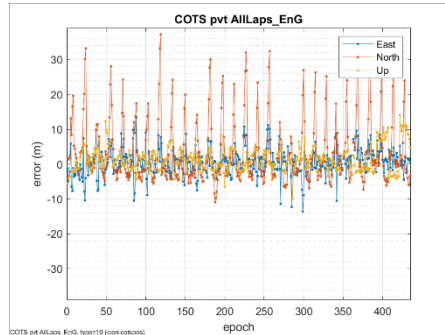
2D/3D error time series



2D/3D uncertainty plot



COTS PVT:



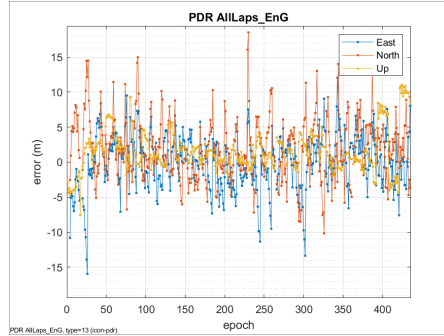
Validation Tests – LBS use case

pRP indoor positioning evaluation

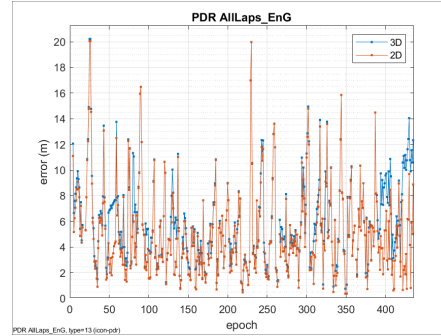
Example results from Enterprise ground floor route (including all 15 laps)

PDR:

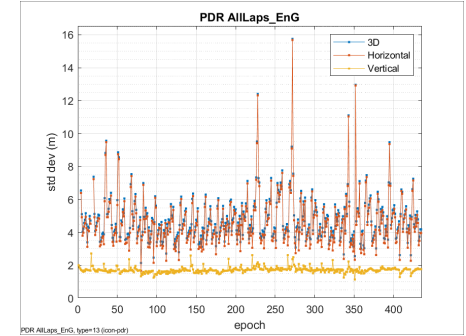
ENU time series



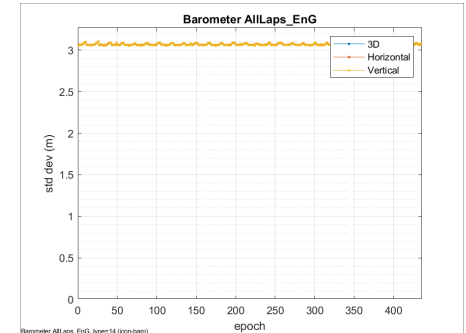
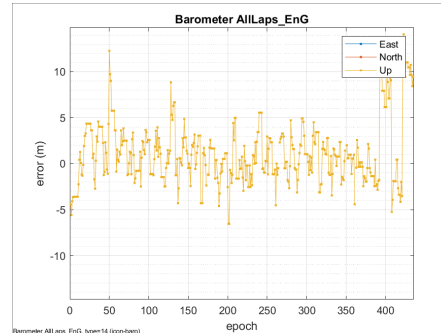
2D/3D error time series



2D/3D uncertainty plot



Barometer:

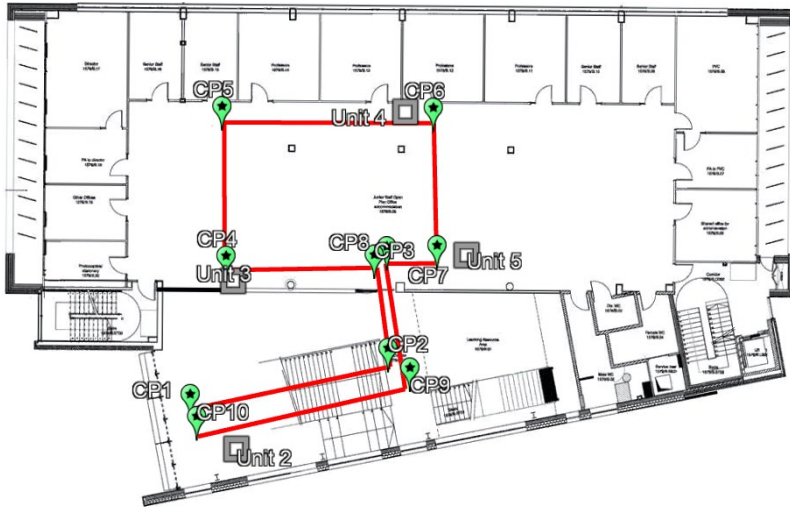


Final Tests– Results

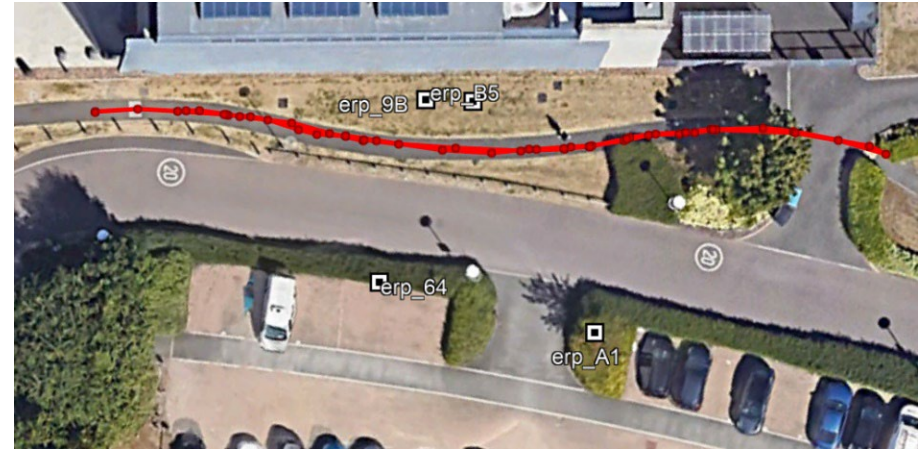
eRP indoor/outdoor positioning evaluation

Test Routes:

- a) Nottingham Geospatial Building (NGB) ground and first floor
- b) Walking path near NGB (outdoors)



(a)



(b)

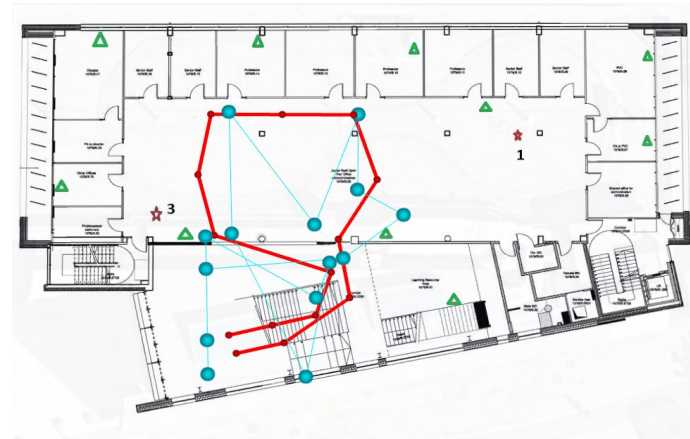
Final Tests– Results

eRP indoor/outdoor positioning evaluation – Trials error measures



Route	PVT type	Availability		CEP (m)	1Sigma (m)	2Sigma (m)
NGB Indoors	Co-op	101/107	94%	2.7	3.8	9.1

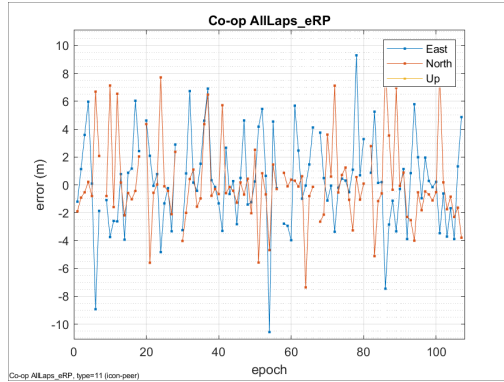
Example Lap Performance over map



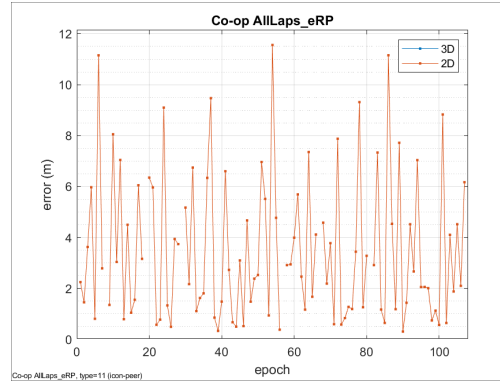
Final Tests– Results

eRP indoor/outdoor positioning evaluation - Indoor positioning performance results

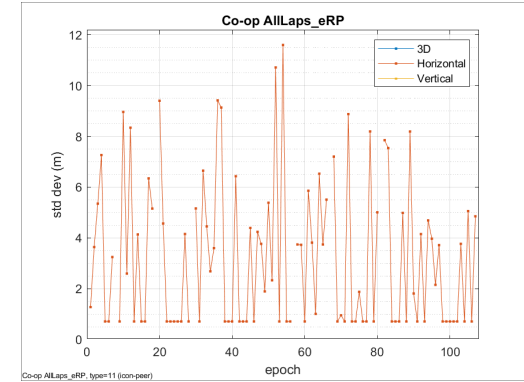
Peer position: ENU time series



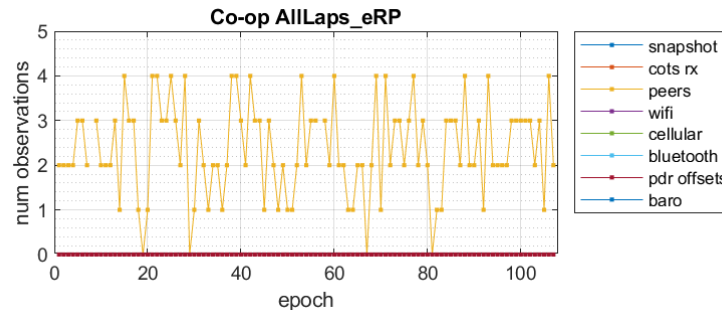
2D error time series



2D uncertainty plot



Number peer observations



Final Tests– Results

eRP indoor/outdoor positioning evaluation

Error measures obtained throughout the trials:

Route	PVT type	Availability		CEP (m)	1Sigma (m)	2Sigma (m)
NGB outdoor Path	Co-op	154/167	92%	10.1	12.8	22.5

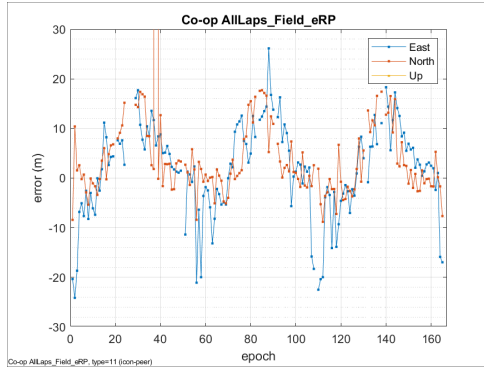
Example Lap Performance over map



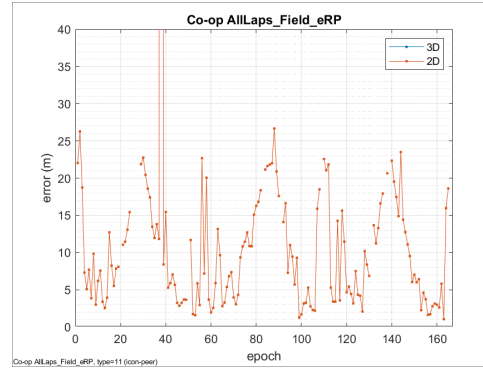
Final Tests– Results

eRP indoor/outdoor positioning evaluation - Outdoor positioning performance results

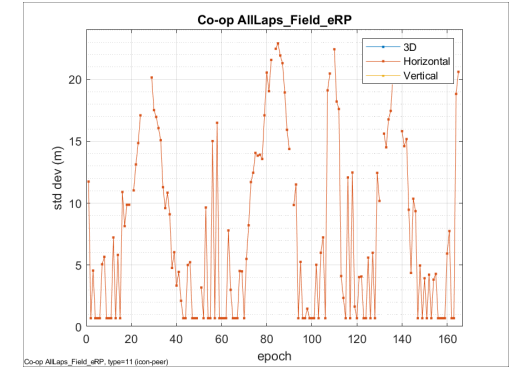
Peer position: ENU time series



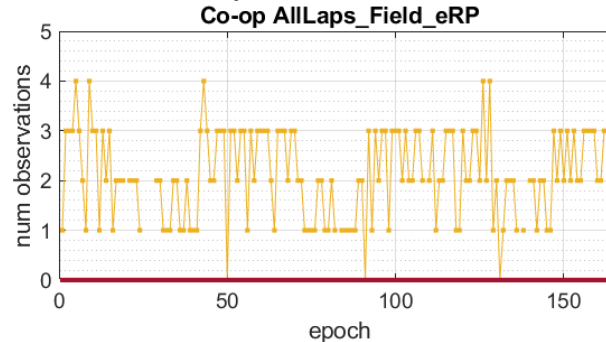
2D error time series



2D uncertainty plot



Number peer observations



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Conclusions

The ICON cloud-based CCPM is an advanced and sophisticated development showing robust performance over extended validation.

- Cloud computing implementation is a template and reference for other GMV developments

ICON activity also developed key technologies like PDR positioning, peer-to-peer positioning and sensor fusion

- Performed well within the constraints of the environments and measurement quality employed
- Some of these used in subsequent projects, others remain for future opportunities

Valuable insight and know-how for the future for technologies employed and other evaluated

Wi-Fi RTT for peer-to-peer measurements was not successful. New technologies, like UWB in mobile handsets may supersede this → Potential to bring improvements for collaborative positioning in difficult environments

The ICON concept demonstrator has shown valuable capabilities and performance for further development.

- Over the project term, technologies have moved on and could benefit from updating

Looking to the future, the snapshot GNSS receiver could be further developed to process the new generation GNSS signals offering gains in low power operation and higher sensitivity at lower energy cost

Thank you

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L. Enrique Aguado

