Document: Executive Summary Report

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1. Contents

2. List of Reference Documents

[RD-1]	4000140623- Final report (FR).pdf

3. Acronyms

5G	-	5 generation mobile
AoA	-	Angle of Arrival
CD	-	Concept Demonstrator
DL	-	Downlink
GLONASS	-	Global Navigation Satellite System
GNSS	-	Global Navigation Satellite System
GPS	-	Global positioning System
HW	-	Hardware
I/F	-	Interface
LOS	-	Line-Of-Sight
LS	-	Least Squares
N/A	-	Not Applicable
NR	-	New Radio
PVT	-	Position Velocity Time
R&D	-	Research and Development
RD	-	Reference Document
RF	-	Radio Frequency
RTT	-	Round-Trip-Time
SoW	-	Statement of Work
SW	-	Software
TDoA	-	Time Difference of Arrival
UL	-	Up Link
UWB	-	Ultra Wide-Band

4. Executive Summary

Indoor tracking and navigation, despite almost two decades of trying, continues to be one of the last remaining challenges associated with providing spatial and location awareness to Enterprise transactions and activities, especially when absolutely referenced to a global geo coordinate system. For such ubiquitous indoor positioning relatable accuracies in the order of 1 to 10 m is still a significant challenge when only partial GNSS coverage and sparse local reference infrastructure are available.

In such cases – which are attractive from an User adoption perspective, in that no or little extra capital costs or infrastructure needs to be deployed – how various new location aware radio technologies can be exploited (UWB, Wi-Fi RTT, or 5G NR) to supplement and assist in enabling indoor location is a major topic of interest both technically and commercially. Such radios have certain capabilities, radio channel characteristics and Impulse response measurement means, which allow for another set of abilities to be broad to bear on this problem set, in concern with GNSS. The derivation of ranging and/or direction of arrival (DoA) / direction of departure (DoD), Time difference of Arrival (TDoA) measurements coupled with GNSS signals/observables across a range of realistic and representative conditions. Understanding the trade-offs in performance, across a given set of these radios, when processed in a collaborative manner, when various degrees of local infrastructure are available are the main tenets of investigation, assessment and demonstration in the current project.

As well as the accuracy performance (relative to ground truths) and availability of the position solution, the scalability of the available radio interfaces (I/F) as well as the techniques used to orchestrate the ranging or time measurements (e.g., multiple users in a shopping mall) need also to be considered, especially when collaborative positioning exploiting peer-to-peer estimations are also considered. This is especially the case for radios such as UltraWideBand (UWB), which is aggressively penetrating certain core market areas, such as the Connected Car and the SmartPhone.

Through a rigorous iterative approach towards the realisation of a concept demonstrator that addresses the above, danalto has:

- Reviewed, characterised, tested or emulated (where necessary) the underlying performance scale and relation of the main terrestrial location aware radios (signal-based) and how different combinations of these radios, when fused with various (snapshot or tracking) GNSS (observable based), can potentially work together to deliver indoor positioning;
- Commercial Off the Shelf hardware has been the focus, so as to assess the real on the ground capabilities available in the short term and which can be readily scaled, whilst keeping an eye to economic, cost-efficient solutions to the problem.
- The accuracies possible have been assessed, through various processing chains (through data playback functions of the CD) has been implemented for widely different scenarios.
- A broad range of different Algorithms and filtering (Kalman FIlter, Particle Filter and Unscented Kalman Filters) have been implemented, allowing the assessment of each radio participating into a collaborative approach to be traded off in terms of implementation complexity and performance benefit.
- At each iteration of the CD, the overall has been fine-tune through design, implementation and testing, fully exploiting the lessons learnt from each iteration;
- Where feasible, the overall efficiency, practicality and cost of the implemented solutions have been tuned.

The concept demonstrator realised consists of a cloud software platform that collects and stores a large dataset of measurements from a physical layer which consists of reference range information from a device to an anchor, or groups of anchors, as well as GNSS receiver observables. This also includes how measurements taken for processing to infer a device location are configured and orchestrated through software control. Reference anchor sets are employed that are absolutely referenced to coordinate frame to allow performance accuracies to be assessed in a quantitative manner. Anchors have been built with abroad range of different location aware radios, all or some of which can be controlled to participate in a given test, whilst the anchors themselves are mobile and mounted on tripods, so that different physical layouts, aligned to different Use Cases where sparse infrastructure are important (e.g. for Office, Warehouse or Emergency Services Use), can be tested and evaluated.

The CD is a standalone system that allow further tests and scenarios to be explored, presents the accuracy estimations for a test, the underlying time series data gathered and deployed in the estimations, as well as KPIs of the number and type of measurements employed for a given test/estimation. Configuration data for a test can be flexibility created and uploaded for a test, which output data can be downloaded for further offline processing. All raw data is logged to a time series database allowing replayed and repeated p[processing of a single dataset for comparative testing of different processing approach. This is quite a powerful approach, especially when considering the context of each of the Use Cases, accuracies required to make the technology useful and to refine and fine tune algorithms and filtering approaches.

In conclusions, terrestrial radios, that are location capable, have made huge steps forward in terms of energy , propagation distances and ranging accuracies performance – particularly UltraWideBand – and through the appropriate collaboration and filter techniques show significant promise in bringing the ubiquity of GNSS to the indoor settings. Despite these advances, these radios are still early on their commercial journey and have significant adoption hurdles, particularly on prices and economics, to drive adoption, though this is happen through adoption in parallel large scale market uses of the radios (e.g. Connected Car access control). Meanwhile Wi-Fi, which has had ranging capabilities for several years, has been slow to be adopted, due to the limited accuracies of the narrow bandwidth channels available to date and the lower carrier frequencies. However, with the emergence of higher channel bandwidth driven by next generation SmartPhone bandwidth needs) the ability to bring this critical radio into the mix for indoor location has accelerated. Indeed, with the new advances in low power WiFi, the possibility of WiFi not only being a SmartPhone navigation radio, but a radio for indoor asset tracking, looks to be gaining momentum.

Automated absolute referencing of indoor location requires continuity and extension of GNSS referencing indoors. Both tracking and Snapshot receivers have been considered, but results to date suggest only the former is useful for automatic indoor anchor self-referencing, which is a must for real world scalable commercial deployments and use. Snapshot GNSS has some value for collaborative solution in asset tracker, but the computational complexity of snapshot vs traditional tracking GNSS receivers, is still to be largely worked out in the market place.

No additional or sparse additional infrastructure is key for broad market adoption of indoor tracking and navigation. Indeed, reuse of existent infrastructure is the most likely ultimate scalable solution (i.e. WiFi access points). In either cases, it is our view that GNSS has two core roles to play. One, to reference the infrastructure (access points) using collaborative positioning where the GNSS can absolutely reference local coordinate indoor technology systems. Second, providing the outdoor to indoor location continuity lead when infrastructure is sparse. Currently, the optimum technology for sparse infrastructure is considered to be provided by Two Way ranging and AoA, as a single anchor with these technologies with some assistance from GNSS can provide good positioning, but may not be the most scalable for navigation (e.g in large public settings such as airports), where other more infrastructure hungry approaches will be needed e.g. Downlink Time Difference of arrival.