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Innovative navigation solutions

Hansel Testbed

Executive Summary Report

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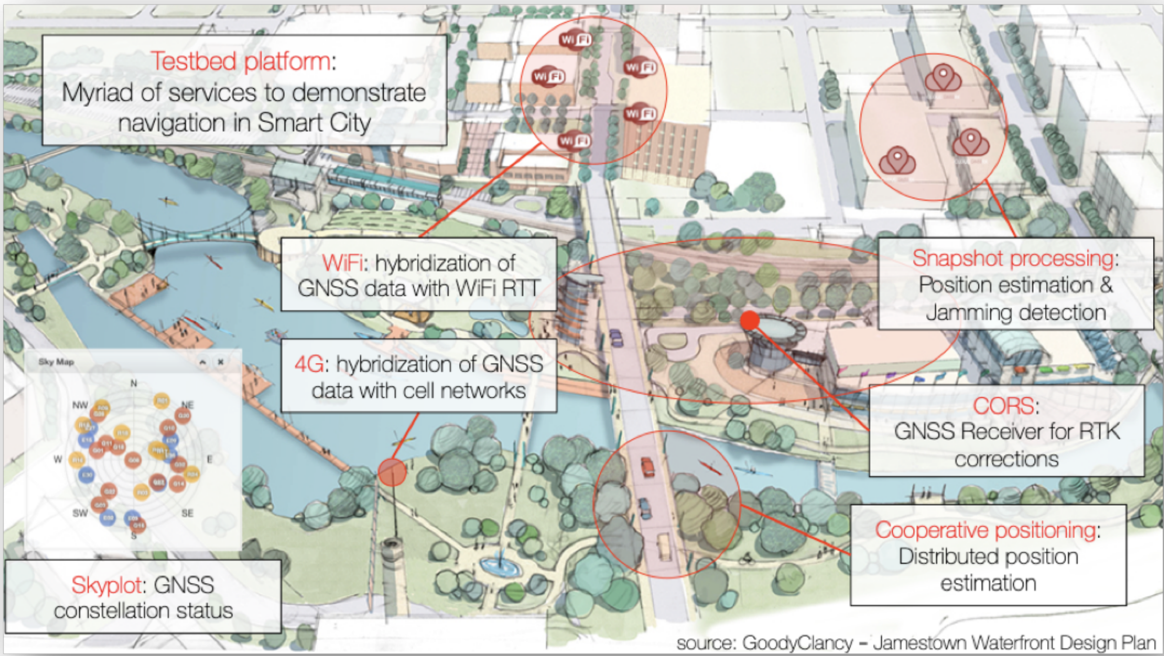
VERSION CHANGE HISTORY

Date	Version	Author	Brief Comment
2020-12-10	1.0	ROK	First version
2020-12-16	1.1	ROK	Add programmatic aspects

HANSEL - “*Testbed GNSS navigation in Smart cities*”, is a Testbed platform being developed under the ESA contract #4000126230, as a joint effort among the following companies: Universitat Autònoma de Barcelona (Spain), TrafficNow (Spain), Politecnico di Torino (Italy), Links Foundation (Italy) and Rokubun S.L. (Spain, acting as prime of the consortium).

The prime goal of the Hansel Testbed demonstrator is to integrate various technologies in the field of navigation and applicable in the context of Smart cities. it is intended to be a navigation infrastructure that will serve an area (city). A summary of HANSEL capabilities is summarized in the following figure



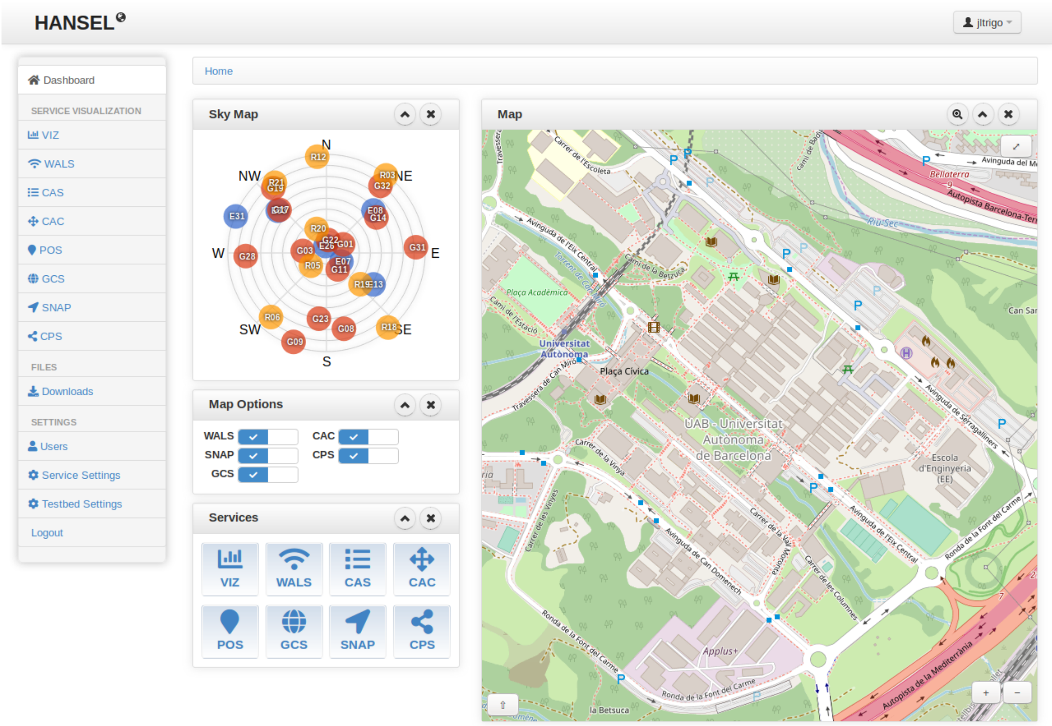
HANSEL provides navigation infrastructure in the context of Smart Cities

In particular, HANSEL provides the following services:

- **Accurate GNSS navigation** (centimetric level) will be achievable thanks to the reference GNSS receiver of the tested, that streams its data to the Hansel NTRIP caster, so that users of the Testbed can perform Real Time Kinematics (RTK). In the future, additional reference GNSS receivers can be added without hassle, just by configuring them to stream their data to the caster, which will broadcast it to the users.

- **Resilient and robust positioning** will be possible thanks to the non-GNSS infrastructure that will be used for navigation. This non-GNSS infrastructure covers both 4G ranging (which is being simulated in this testbed) as well as WiFi ranging (provided by the 802.11mc-compliant routers deployed in the testbed). This data can be hybridized at the user terminal and thus complement GNSS-based positioning in events of lack of GNSS visibility (indoors or tunnels) or even provide assistance in severe disruption of GNSS signal (multipath or interference).
- A HANSEL smartphone application has been developed that allows to grab both GNSS and WiFi ranging data. This data is uploaded into the **WiFi Access point Location Service** (WALS) of HANSEL, which then discovers and locates WiFi Access Points with (potentially) metric accuracy. The same service provides users with the necessary information required to use WiFi ranging for navigation.
- The testbed features several **Software Defined Receiver** (SDR) nodes that take **snapshots** of the GNSS signal and use UAB's Cloud Receiver service to both monitor the location of these nodes as well detecting possible events of **interference**. SDR are specially suited for IoT applications, where power consumption is scarce and the positioning capabilities are usually deferred to an external entity (in this case the external service provided by UAB).
- The testbed has been designed with mobile terminals in mind, in particular **smartphones**, which are ubiquitous in Smart cities. In this context, a smartphone app has been developed to provide the users with **Cooperative positioning**, sharing data between them (through the server) in order to maximize the positioning accuracy.
- In addition, the testbed features a **command and control** service that centralizes all locations of both the users and testbed sensor nodes. Moreover, if the user wishes, she/he/it can upload a route (track) and instruct the service to provide notifications in order to follow it at a later time. This feature allows the users to receive notifications from the server such as "accelerate", "turn left", "stop" , … thus enabling platooning or managing fleets or swarms of unmanned rovers that need to maintain a certain formation or need to be at a certain place at a certain time.

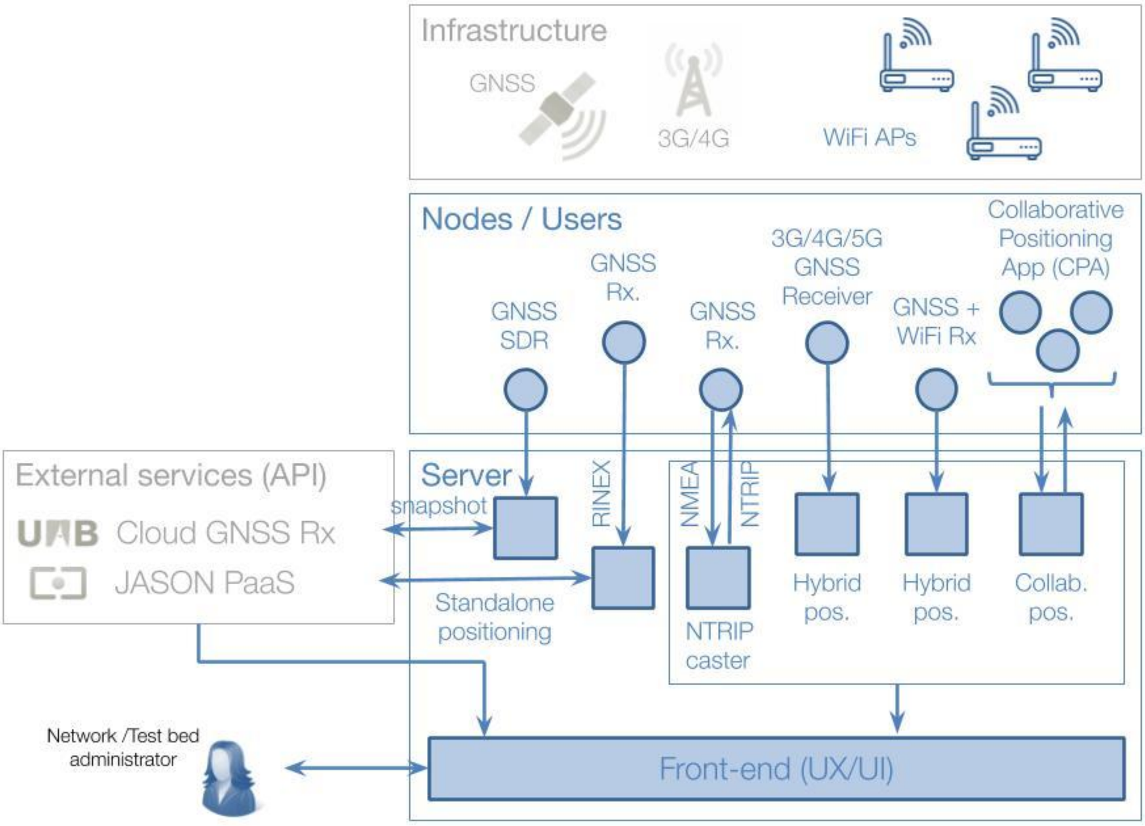
Last but not least, HANSEL features a front-end that centralizes all information of the testbed and allows the operator to monitor, at all times, the position of the users, location of the nodes, status of the GNSS constellation, …



The HANSEL server features a front-end that centralizes all the testbed information and allows to visualize all nodes and users present in the Testbed

The architecture of the testbed is shown in the following figure, that contains the basic logical elements of HANSEL:

- **Infrastructure** covers the necessary providers and enablers for navigation: GNSS satellites, cell towers and WiFi RTT routers that are compliant with the 802.11mc protocol. Some of these elements can be controlled by the tested operator (i.e. Wifi routers) while others will not (GNSS satellites and cell towers)
- **Nodes (or sensors)** are the elements that provide data to the testbed, examples of nodes are Software Defined Receiver dongles, the base GNSS receiver providing data to perform RTK or even the smartphones that have the HANSEL apps, which provide with data to the server such as location or WiFi ranging data (so that WALS can compute the location of the WiFi access points)
- **Users** make use of all the features provided by the server (consume the positions computed by WALS to perform hybrid GNSS+WIFi location, ...), perform collaborative positioning, ...
- **External services**, are third party services (UAB's Cloud GNSS Receiver and Rokubun's Jason positioning service) that augment the capabilities of the testbed,
- **Server** is the physical entity (computer or even instance in the cloud) that orchestrates the different services of the testbed and has the front-end to monitor the activity of the testbed in real time.

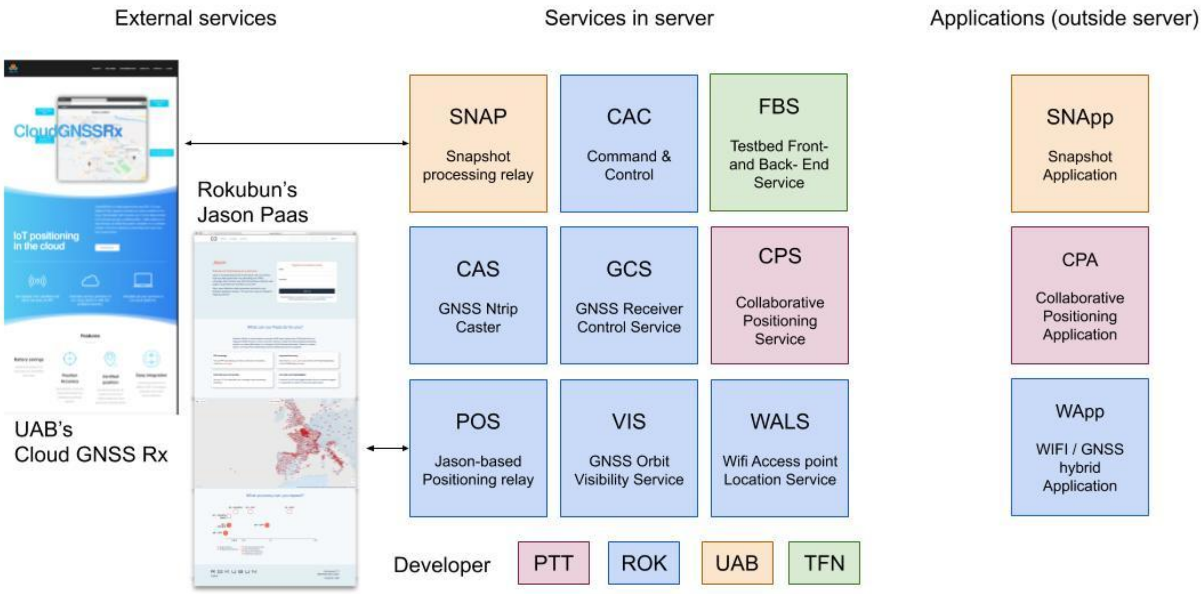


HANSEL architecture is structured in a series of key elements: infrastructure providing the navigation capabilities, sensors/nodes that provide the necessary data to the server, users of the testbed and external services that extend the testbed capabilities.

The different HANSEL services have a **microservice architecture** philosophy with the following rationale in mind:

- Enforce a uniform communication protocol both external (from users/nodes to server and vice versa) and internal (between services). The **communication is performed via API that has a RESTful** protocol. This not only ensures uniformity but also ease of expandability with new features and ease of integration with other technologies (smartphone apps, other external services, …)
- Each service is encapsulated into a Docker container (virtualization) so that dependencies are easily traceable and do not affect other services (i.e. changes of dependency version of service A will not affect service B that has the same dependency but with another version). This is especially critical when different development teams are involved in the testbed (which has been the case for this contract, where up to 4 different teams were contributing to the software of the server).
- **Expandability and Flexibility** of the testbed for future applications is ensured with this approach because a new feature can be covered by a new encapsulated service.

Moreover, the implementation of the server has been done in a Continuous Integration and Continuous Development environment, which offered a very agile way to include new features to the server (new software updates done by the developers were automatically pushed to production after all software tests passed, with minimal manual intervention). A diagram covering all the microservices embedded in the Hansel server are shown below.



HANSEL is structured as a set of microservices that encapsulate the key features of the testbed.

Regarding the programmatic aspects of the project, the project ran from February 15th 2019 (Kick Off) to December 16th 2020 (Final Review). The planned date for project termination was May 2020, however, the COVID-19 pandemic impacted the execution of the deployment and demonstration of the tested, and they had to be postponed. A total of 6 work-packages covered the execution of the work:

- WP1 System design, to critically review the requirements that need to be met in the activity and define the use cases and Testbed based on the objectives of the project. The milestone that closed this WP was the SRR (System Specification Review).

- WP2 Design and implementation, which contained the bulk of the project. This package was divided in various sub-workpackages that tackled the design and implementations of the algorithms, protocols, techniques and equipment of each service in the testbed. The different sub-workpackages (with partner assignations) are as follows: WP2.1 Concept Design (LINKS), WP2.2 Snapshot processing (UAB), WP2.3 Collaborative processing (PoliTo), WP2.4 Infrastructure fusion (Rokubun) and WP2.5 Server design and Implementation (TrafficNow). The midpoint of the WP contained the DDR (Detailed Design Review) milestone to prepare the WP3, which overlapped during the last phase of the development.

- WP3 Test Specification, to define the tests that were to be performed during the validation campaign. This WP ended with the TRR (Test Readiness Review) milestone, which kicked off the testing campaign.

- WP4 Experimentation Campaign, where the tests were executed and the resulting data was analyzed by the different members of the consortium. This workpackage contained the experimentation campaign that was carried out at the UAB Campus, and the results were presented during the TAR (Test Acceptance Review) milestone.

- WP5 Conclusions and recommendations, to wrap-up the activities of the project and concluded with the current FR Final Review milestone.

- WP0 Project management.

The project resulted in the following dissemination and evolution activities:

- Paper published in the MDPI Smart cities journal

  Minetto, Alex, et al. "A Testbed for GNSS-Based Positioning and Navigation Technologies in Smart Cities: The HANSEL Project." Smart Cities 3.4 (2020): 1219-1241.

- Presentation of the project at the Smart City Expo held at Barcelona, November 2019.
- Execution of the BANSHEE PoC to perform a performance assessment in the position of WiFi Access Points using various smartphones and under different conditions. This project was executed in the framework of the Technology Transfer Proof of Concepts (Contract number 4000131075/20/NL/MH/KDJ)
- In the context of Indoor navigation and resilience of navigation in urban environments, Rokubun has been granted a GSA contract to develop a market oriented operational system that successfully hybridizes GNSS and WiFi RTT measurements.
- Patent on automated WiFi discovery and positioning based on RTT and GNSS raw measurements submitted by Rokubun to EPO on September 2020.
- An extension of the cooperative framework demonstrated in the HANSEL project was proposed by Politecnico di Torino to support GNSS-based navigation and positioning in space applications for the context of the next ESA missions (e.g. Lunar Communications and Navigation System). The research proposal was succesfully accepted on Dember 15, 2020 and it will co-fund a Ph.D. program for the feasibility study of “GNSS-based cooperative positioning in space”.

In summary, HANSEL offers an intelligent infrastructure to serve its urban area with heterogeneous services and applications related to navigation and positioning and not limited to GNSS. The services provided by HANSEL can be ultimately used to automatically manage the city, provide support to decision makers and optionally produce a set of open data to start a wave of third-party service and application developments. The HANSEL project, while developing a testbed for diverse positioning algorithms well presented in the different deliverables of the project, has designed, developed and tested an architecture (for positioning and timing services) that easily fits in the aforementioned smart city infrastructure adding relevant value. Indeed, the HANSEL architecture, once integrated in a Smart City, can be augmented with new services (i.e. expandability) in a scalable fashion. The development and first validation of such architecture is an important result, indeed not less important than having built the testbed itself, because it represents a concrete and viable solution that overcome today limitations of many technologically advanced solutions on the market today, namely the verticality, the impossibility of reuse and their vendor lock-in nature, which allows only the manufacturer to make changes and evolutions.