Symbiosis of smart objects across IoT environments

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symbIoTe Trials, Deployments & Assessment

The symbIoTe Consortium

Intracom SA Telecom Solutions, ICOM, Greece
Sveučiliste u Zagrebu Fakultet elektrotehnike i računarstva, UNIZG-FER, Croatia
AIT Austrian Institute of Technology GmbH, AIT, Austria
Nextworks Srl, NXW, Italy
Consorzio Nazionale Interuniversitario per le Telecomunicazioni, CNIT, Italy
ATOS Spain SA, ATOS, Spain
University of Vienna, Faculty of Computer Science, UNIVIE, Austria
Unidata S.p.A., UNIDATA, Italy
Sensing & Control System S.L., S&C, Spain
Fraunhofer IOSB, IOSB, Germany
Ubiwhere, Lda, UW, Portugal
VIPnet, d.o.o, VIP, Croatia
Instytut Chemii Bioorganicznej Polskiej Akademii Nauk, PSNC, Poland
NA.VI.GO. SCARL, NAVIGO, Italy
Universität Zürich, UZH, Switzerland

For more information on this document or the symbIoTe project, please contact:
Sergios Soursos, INTRACOM TELECOM, souse@intracom-telecom.com

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Editor(s): João Garcia

E-mail: jmgarcia@ubiwhere.com

Author(s): João Garcia (UW), Matteo Pardi (NXW), Raquel Ventura Miravet (S&C), Digu Aruchamu (S&C), Luca De Santis (NAVIGO), Lorenzo Neri (NXW), Reinhard Herzog (IOSB), Michael Jacoby (IOSB), Szymon Mueller (PSNC), Karl Kreiner (AIT), Aleksandar Antonić (UNIZG-FER), Martina Marjanović (UNIZG-FER), Svenja Schroeder (UNIVIE), Mario Drobics (AIT), Antonio Paradell (WLI)

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1 Executive Summary

The symbIoTe middleware has been designed in order to accommodate various types of use cases revolving around IoT, where multiple platforms need to interoperate to offer valuable services to users. As such, to validate the developed system, the various use cases involved in the project planned and performed trials with real users in real locations. The assessment of these trials allows for the evaluation of the symbIoTe middleware as a whole, and its specific use cases.

The current document, entitled “symbIoTe Trials, Deployments & Assessment”, aims at providing an overview of the various use cases and the performance and results of their trials. Additionally, it is explained how the various use cases benefit from using symbIoTe, how the different involved stakeholders benefit from the different trials and how the various partners can use the results of the developed work for future exploitation.

The document starts by describing how the core components were deployed and tuned to handle the various trials to be performed. Moreover, certain software optimizations are described based on the initial feedback received from the trial sites after some preliminary tests.

The document continues with a summary of each trial. The *Smart Residence* use case involved three different trials within the same domain. The Smart Home use case showed how a user can access his/her home devices, operated by different platforms, under the mediation of the symbIoTe Smart Space Middleware. It was possible to see the good responsiveness of the system and how symbIoTe has a general good performance when a large set of resources are registered in the environment. The Smart Indoor Air Quality trial was able to leverage indoor and outdoor air quality sensors to provide useful information and services to residents. The Smart Mirror trials were successful, being able to leverage several IoT devices to monitor and guide the health of elderly people.

The *Smart Mobility* use case was able to reach a large number of participants (more than 200), obtaining good user feedback, using a cross-domain use case. Through symbIoTe L1 compatibility, and the use of enablers, it was able to leverage the data and services from three different platforms to provide useful services to citizens.

The EduCampus use case was able to use the concept of symbIoTe federations to provide IoT services between different campuses. One important outcome of this trial is the usage of semantic mapping, permitting the interoperability between platforms without the need to speak the same language.

The *Smart Stadium* trial was able to provide quality of service to the users, who found the experience enjoyable. This use case showed how symbIoTe could be used to provide services to retailers.

The results of the *Smart Yachting* trials obtained good user feedback, using symbIoTe capabilities to provide mooring and automatic supply chain services to the yachting industry.

All in all, the symbIoTe solution was extensively tested under different types of use cases, with different requirements, with real-world settings, involving real end users and real-life environments. The obtained results demonstrate the usefulness of symbIoTe in the aforementioned use cases. The involvement of commercial IoT platforms in some cases, or close-to-market IoT prototypes in other cases, further support the technical

achievements of the project, since the developed Open Source middleware was able to interact and facilitate all the different types of involved platforms.

2 Introduction

This section aims at providing information regarding this document, which encompasses all the work done in tasks T5.4 and T5.5.

2.1 Purpose of the Document and Scope

Being the final document of WP5, this document concludes the work done in regards to the various use cases. It mainly focuses on the effort performed for tasks T5.4 and T5.5, although they are dependent on previous WP5 tasks. As such, the document aims at finalizing the use cases, more specifically, their trials planning, deployments and corresponding assessment.

2.2 Document Structure

Section 3 describes the preparations done to the Core components of symbIoTe in order to be able to handle the demand of the different use cases. Section 4 includes the description of all the uses cases, their value proposition, the benefits for the involved stakeholders and the exploitation plans for each partner. Section 5 concludes the document. The annexes of Section 8 provide more details about the deployment and assessment of the trials.

3 symbIoTe Trial Preparation

3.1 symbIoTe middleware

The implementation focus in the months preceding trials was put to prepare and facilitate functionalities required by the trials and use cases. The result of this work has been release *version 2.0.0* of the symbIoTe middleware[1]. It was the first public release that offered L2-compliance software modules of the symbIoTe Cloud as well as support for L3- and L4-compliance usage in symbIoTe SmartSpace environment. It also provided bug fixes and other improvements to the existing L1 components.

Moreover, middleware documentation with a detailed description of the integration process with symbIoTe middleware as well as examples has been provided in the form of Github wiki pages:

- symbIoTe Cloud:
  - https://github.com/symbiote-h2020/SymbioteCloud/wiki
- symbIoTe Enabler:
  - https://github.com/symbiote-h2020/SymbioteEnabler/wiki
- symbIoTe Smart Space:
  - https://github.com/symbiote-h2020/SymbioteSmartSpace/wiki

3.2 Deployment of Core services

3.2.1 Technical specification

symbIoTe Core services are hosted on a virtual machine running on PSNC's Open Stack cluster. It uses 8 virtual CPUs (Intel Xeon E312xx series), 16GB of RAM and 160GB of HDD storage. The machine is running the Linux operating system (Ubuntu 16.04 LTS). Each Core Service component runs within a separate instance of the Apache Tomcat servlet container.

3.2.2 Deployment and configuration

Version 2.0.0 of symbIoTe Core components have been deployed on the above machine and configured to provide a central access point for all trial participants to register their platforms, services and resources.

The two external interfaces are available:

- Core Interface, which provides security, search and access request functionalities https://www.symbiote-open.man.poznan.pl/coreInterface

[1] https://www.symbiote-h2020.eu/blog/2018/05/24/new-symbiote-middleware-release-v-2-0-0/

- Cloud Core Interface, which provides platform and resource management functionalities, including resource registration, modification and deletion, passing monitoring information etc.

  https://symbiote-open.man.poznan.pl/coreInterface/

3.3 Software improvements from preliminary trial tests

The project performed a number of preliminary trial tests to check the operation and performance of the middleware. During these tests, certain issues have been successfully addressed by providing software updates. These updates led to subsequent software releases (namely v.3.0.0 and v.3.0.1) which were used for the full-scale conduction of the trials. The following table summarizes the respective actions taken.

Problem description	Status	Solution
Desynchronization issues between Core and Cloud layers leading to inconsistencies between the status of resources on the platform side (Cloud) and on the central side (Core).	Fixed	A special synchronization method has been introduced that allows a platform side to update its status based on the status persisted on the core side.
Resource registration (and update) request executed a remote SPARQL query (from Semantic Manager to Search) to retrieve a potentially existing location definition in the Jena triplestore used in the Search component.	Fixed	A caching mechanism has been introduced to the Semantic Manager component, which holds the information about the locations registered by the platforms and their resources in the repository, which can be accessed directly.
Security checks were done per resource and not per result set, which resulted in repeated validation of credential requests sent to the Authentication and Authorization Manager component.	Fixed	New methods have been introduced to the SymbIoTeSecurity library, which allows the component using the library to store partial map of validated credentials locally and to pass it to the validation method. This way no extra messages are exchanged between Search and AAM components above the necessary ones.
Sub-query used for observed property checks during the search operation was executed on secured graph (with low performance).	Fixed	Replacement of secure with unsecured graph for the sub-query, since security checks are done on the resource level and are not needed on the reading property level.
Concurrent query support on the Jena triplestore have not been properly configured and implemented.	Fixed	Apache Jena provides multiple-reader/single-writer concurrency support (MRSW). Concurrent access to stored model has been introduced and implemented in the Search component, allowing thread pool with configurable size to serve multiple read requests.

		However, due to MRSW, in situations where a use cases requires many write access operations on their resources additional solutions are recommended such as load balancing of multiple Search instances.

4 Use Cases

Each Use Case performed one or more trials in order to test the integrated symbIoTe system and use-case specific components on a technical level, as well as the developed applications from an end-user point of view. In this section for each use case, a description is provided, its value proposition is explained, the benefits for the various stakeholders are described and the relevant exploitation plans are presented.

4.1 Smart Residence

The Smart Residence use case aims to demonstrate interoperability across different smart home IoT solutions: symbIoTe is used to dynamically combine different services and sensors and actuators so as to provide a natural and homogeneous user experience for smart homes across platforms. To demonstrate this, three applications are implemented that offer comfort, automation, security, energy efficiency and healthcare services. All of them use advanced and ubiquitous technologies including sensors and other devices integrated in the residential infrastructure.

Table 1: Smart Residence Use Cases

	Smart Home	AAL	Indoor Air Quality
Platforms Involved (CL)	2 (L3)	1 (L1)	2 (L1)
Gateways / devices	8	4	5 / 64
Apps	2	1	1
Enabler	1	0	1
Test Sites	Pisa (IT)	Vienna (AT), Graz (AT)	Barcelona (ES)
No. Of Users	15	25 (18, 7)	5

4.1.1 Smart Home (Pisa)

4.1.1.1 Use Case Description

The Smart Home use case showcases how to control IoT devices located in a physical space. With that goal in mind, two applications have been developed: Smart Area Controller and Home Comfort. Both applications leverage on a specific enabler, which gives them the possibility to filter the devices in the space, basing on their position (building, floor, room, etc.). In this way, the application has to query the symbIoTe enabler in order to retrieve the list of smart devices (sensors and actuators) in a selected area and then to allow a user to control them.

Smart Area Controller

With Smart Area Controller, users interact with the resources of the Smart Space (SSP) with an application installed in their smartphones. The application connects to the Smart

Space and gathers data from resources through an Enabler that is able to search and filter resources on the Core based on their location.

Home Comfort

Home Comfort scenario showcases a situation where devices are automatically controlled in order to keep user's predefined comfort values. A user pre-configures the desired targets in the application, and the system will automatic control of the environment. For instance, lux levels have been pre-set to a desired value: the system acts on dimmer lights and on automated curtains to control luminance. Moreover, it also sets the fan coils to reach and maintain the requested temperature.

4.1.1.2 symbIoTe Value proposition

From a symbIoTe viewpoint the use case is compliant to L3 level: homes and buildings are seen as Smart Spaces (running the symbIoTe Smart Space Middleware, S3M) and thus home resources can be registered from different Platforms or can be Smart Devices.

The main benefit of using symbIoTe is the ability to allow platforms to interoperate. This enables different home IoT devices (e.g. Philips Hue, Netatmo, etc.) to easily interoperate with fully-fledged platforms, such as Symphony, just with a minimum effort of implementation. The second big advantage of symbIoTe in this use case, is the presence of an enabler that handles indoor locations. The GPS system is not suitable for indoor location purposes; therefore, this property must be addressed as symbolic locations (i.e. room, floor, etc.) and not by coordinates. The enabler facilitates the implementation of Smart Residence applications by offering such service for all the platforms involved.

4.1.1.3 Benefits of the adoption of symbIoTe

The work on Smart Residence use case has allowed to validate the symbIoTe solutions and their benefit. In particular, the trial has further demonstrated the feasibility of interoperability scenarios between platforms (i.e. Symphony by Nextworks) and third-party IoT devices (i.e. lights, dimmers, presence sensors, etc.) without the need of any extension, but simply using symbIoTe core services and SSP enablers to access and control resources provided by other IoT platforms and devices in the same Smart Space. Furthermore, the trials have demonstrated that resource access and control functionalities through symbIoTe are complete.

4.1.1.4 Exploitation plans

Based on the results of the symbIoTe validation activities, Nextworks intend to continue developing a market strategy for Symphony empowered with symbIoTe solutions.

Per se, symbIoTe will not change the business model for Symphony but rather consolidate its penetration in the Smart Residence and Smart yachting markets through enlarged interoperability and technology support features.

We also aim to expand the Symphony marketability to new customers with large smart residences (e.g. Smart Mall, Smart Resort) up to the Smart City. It is hard to quantify the exact market size that can be developed through symbIoTe adoption in Symphony:

however, it can be considered in line with the public market analyses by specialized consulting firms[2,3].

The network of contacts established through the symbIoTe project in public communication and dissemination events (e.g. IoT Week, ETSI IoTWeek, etc.) will be used together with the existing network of commercial contacts of the company to implement a market scouting and elaborate offers.

4.1.2 Smart Healthy Indoor Air

4.1.2.1 Use Case Description

The Smart Healthy Indoor Air application is based on the indoor/outdoor air quality monitoring and pursues to improve indoor air quality. Indoor air quality (IAQ) refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health, comfort and performance of occupants. It is important to ensure that the air inside the building people inhabit on a daily basis is of a good quality. Outdoor generated air pollution is relevant for indoor air quality and health. Exposure to indoor air pollution has been linked to the development of different diseases from infections to asthma or to poor sleep. It can also cause less serious side effects such as headaches, dry eyes and nasal congestion[4].

Sensing and Control Systems SL partner's (S&C) roadmap aims to create a smart home/office connected with the city. The current S&C's platform, nAssist[5], monitors, controls a number of direct parameters related to indoor air quality, such as CO_2 levels, humidity and temperature. In addition, this platform monitors and controls other factors that are important for indoor environmental quality considerations such as light and noise since they also affect occupants. The idea is to increase this framework by considering platforms providing outdoor measurements so as to understand how indoor and outdoor sources of pollution, heat and humidity, together with the ventilation and air conditioning systems, affect the indoor air quality in buildings. The nAssist platform registers these parameters in the symbIoTe platform.

Five different locations inside Barcelona city were evaluated. The indoor equipment available for each location include the following products:

- 1 gateway for communication
- 1 multi-sensor 4x1 (motion, temperature, humidity, and luminosity)
- 1 CO2 sensor
- 1 Electricity energy consumption
- 2 smart energy plug (electricity measuring and on/off for towel heater and TV)

[2]Mapping the Smart-Home Market by Sonny Ali and Zia Yusuf, available online at: https://www.bcg.com/publications/2018/mapping-smart-home-market.aspx

[3] BPIE, Is Europe Ready For The Smart Buildings Revolution?, available online at: http://bpie.eu/publication/is-europe-ready-for-the-smart-buildings-revolution

[4] Quantifying the Performance of Natural Ventilation Windcatchers. Jones, B; (2010) Quantifying the Performance of Natural Ventilation Windcatchers. Doctoral thesis , Brunel University

[5] http://www.sensingcontrol.com/solutions/customizable-iot-platform.html

In addition, the platform registers a set of sensors (O3, NO2, PM10) located in seven different outdoor fixed stations in Barcelona. The interpolation function from the Enabler provides interpolated values for O3, NO2 and PM10 for a specific house location given the GPS coordinates of the fixed stations.

The smart home reacts to changes in indoor parameters such as temperature, humidity, CO_2 levels and noise to maintain a healthy and safe indoor environment by recommending actions to the user such as using air purifiers, ventilation systems and opening/closing the windows to eliminate unpleasant impacts.

4.1.2.2 symbIoTe Value proposition

The purpose of the show-case 'Healthy Indoor Air' is to apply the L1 interoperability functionality of symbIoTe in the nAssist smart home platform of S&C. The end objective is it to monitor and improve the Indoor Air Quality (IAQ) in buildings based on real time quality of outdoor air.

The main value of symbIoTe here is letting platforms access outdoor air quality data like in this show case, from the platform of Generalitat de Catalunya. In addition, the interpolation function of the symbIoTe Enabler provides more accurate spatial data on outdoor air quality for each home based on limited number of fixed air quality monitoring stations spread across a city or region.

This show-case has a general value proposition to establish healthier indoor spaces, and from a business perspective to create new opportunities which is reflected by the intended customer relationships, new customer segments, and marketing channels used. It also allows the creation of new value-added services using the air quality data coming from private/public outdoor air quality data providers. The Interoperability and Enabler functionalities of symbIoTe can further improve the market competitiveness of platforms similar to nAssist.

4.1.2.3 Benefits of the adoption of symbIoTe

The benefits of using the L1 and Enabler functionality of symbIoTe are many folds. It lets smart home or similar platforms to integrate third party data seamlessly. In addition, the application of symbIoTe interpolation enabler can help to improve the accuracy of data like air quality on a spatial scale. For air quality data providers, integration of symbIoTe components can help generate additional revenue streams and further reuse of the data. For the end customer, symbIoTe components can help them have an improved user experience and access better value-added services in their day today lives. These can be extended to other data sources and their applications in smart cities.

4.1.2.4 Exploitation plans

From an exploitation perspective, this show case is in line with S&C's roadmap to create a smart home/office connected with the city and provide more robust solutions with focus on clean environment and optimised energy use. It sees enormous business potential in the different interoperability functionalities and value-added components of symbIoTe in general. It has actively engaged in exploitation efforts during the symbIoTe project phase.

From a short-term perspective, S&C foresees exploiting the L1 functionality of symbIoTe to provide air quality recommendations/warning to its smart home platform users. Before

participating in symbIoTe, nAssist platform had a TRL of 6-7 and after the validation of the new services with interoperability, it has reached TRL 7. The planned revenue stream follows the approach of license fee-based business model and having additional agreements in place allowing the customers to further use the collected data.

S&C actively participates in various International trade events to promote its solutions and its participation in symbIoTe. Notable among these are the Mobile World Congress, World IoT Congress & Expo, and World Smart City Congress & Expo, etc. which are held annually in Barcelona. It will continue to participate in such events and utilise its commercial and marketing teams to further commercially exploit this show case results and other relevant symbIoTe components.

4.1.3 Smart Mirror

4.1.3.1 Use Case Description

In the year 2050 every third European will be older than 60 years. This demographic change has implications for the European health system, as chronic diseases increase with age and have a dramatic impact on life quality and hospitalization rates. Studies showed that ICT solutions in mobile health (mHealth) and telehealth services contribute to increase quality of life and support elderly people in their health management. This use case explored the use of a smart voice-enabled bathroom mirror guiding end-users through simple workflows to track vital parameters and record information on quality of life. The smart mirror – developed on a tablet app hidden behind a one-way-mirror – identifies end-users by Bluetooth-enabled wristbands or commercially available fitness trackers. It records weight measurements through a BLE-enabled body scale, personal well-being through voice-enabled questionnaires and provides feedback on physical activity. The smart mirror interacts with the symbIoTe-enabled KIOLA health platform developed at the Austrian Institute of Technology and health data recorded through Fitbit® wristbands.

4.1.3.2 symbIoTe Value proposition

The smart mirror interacts with two health platforms, the KIOLA health platform and the Fitbit® platform. Both platforms provide their own Application Programming Interfaces (APIs). Within the implementation of the use case, both platforms were made level 1-symbIoTe-compliant. The smart mirror app can now communicate to two health IoT platforms using one unified interface. Moreover, if more IoT platforms get symbIoTe enabled, wristbands can easily be exchanged without changing the app itself.

4.1.3.3 Benefits of the adoption of symbIoTe

The key benefit of using symbIoTe in the healthcare domain is interoperability. Platform owners benefit from ready-made symbIoTe components allowing programmers to quickly provide interoperable and secure APIs. App developers benefit from a unified view on IoT-platforms without having to worry on technical details of a single platform.

4.1.3.4 Exploitation plans

Based on the positive user feedback from the initial trial, new modes of interaction with the smart mirror and integration of further devices will be explored. Moreover, AIT investigates how the smart mirror can be used as a supplemental user interface for a telehealth

platform supporting management of chronic diseases using a deeper symbIoTe-integration level (symbIoTe Level 3/4) to ease the communication between medical devices.

4.2 Smart Mobility & Ecological Routing

4.2.1 Use Case Description

The Smart Mobility and Ecological Routing Use Case addresses the problems regarding environment pollution and air quality in the major European cities. It does so by collecting air quality data from multiple IoT platforms in different countries and uses such measurements for runners, joggers and cyclists in order to plan the best routes to their destination.

Through symbIoTe, air quality measurements are obtained from different platforms. This data is obtained from fixed stations already existing in the cities and from specifically deployed mobile sensors which were carried by the users.

This air measurement data is aggregated and interpolated using a symbIoTe enabler and associated to the map's street segments. With the streets correctly classified by their air quality, routing engines can take that information into account when computing the most ecological routes to the application's users. These paths can also benefit from other factors such as traffic and available parking, in case the platforms have access to these kinds of sensors.

Finally, users are able to search for Points of Interest (POIs) following certain criteria, including data from sensors such as available parking or noise levels. Routes for the selected POI can be computed using the previously mentioned service.

Table 2: Smart Mobility Use Case

Platforms Involved (CL)	3 (L1)
Gateways / devices	56 wearable + 20 stationary devices
Apps	2
Enabler	1
Test Sites	3 (Zagreb, Vienna, Porto)
No. of Users	60

Three members of the consortium participated in the development of this use case: AIT, UNIZG-FER and UW. UNIZG-FER provides wearable sensor data through OpenIoT. AIT, through an extension of their openUWEDAT platform, exposes air quality data from fixed air quality stations in Croatia and Zagreb and, additionally, provide a routing service for the city of Vienna. UW, through the MoBaaS platform, provides air quality readings from fixed and wearable sensors, as well as their routing service. More details about the work done for this specific use case can be found in Annex 8.1.2.

The main outcomes of the use case were the trials performed in the cities of Vienna, Zagreb and Porto, with real users. This allowed for the validation of the concept and the

developed work. In total, more than 80 users actively participated in the trial, and more than 230 users at least once tried the routing application. Participants liked the idea behind the use case, namely the ecological routing and the idea behind using wearable sensors to get a better coverage of the city's air quality, which could have useful applications. Additionally, users liked using the SMEUR routing app, stating that its simplicity and quickness to provide the routes were appreciated.

4.2.2 symbIoTe Value proposition

The clear benefit of using symbIoTe for this use case is the offered interoperability. This is clear by looking at the easiness of collaboration between the MoBaaS, openUWEDAT and OpenIoT platforms, where they could use the provided data and services seamlessly. One example of this is that MoBaaS could use air quality data from the other two platforms to compute green routes. This is not only limited to this collaboration, what could be considered the big advantage of this interoperability is that it becomes very easy to start offering this service in a different city, even if they have a different air quality provider, as long as they offer their data through symbIoTe. It's basically plug and play.

Another big advantage of symbIoTe is the ability of creating enablers that abstract certain logic from whoever is using these data and services, and additionally creating services (e.g. data analytics) over the symbIoTe-enabled platforms. This way, it was possible to create a service over these platforms (the SMEUR routing app) that does not have to worry about specific symbIoTe logic. As such, the enabler itself can be offered to app developers, who can develop mobility apps using the data and services offered by these platforms, without having to worry about and symbIoTe specifications.

4.2.3 Benefits of the adoption of symbIoTe

Platform owners benefit from making their platforms symbIoTe-compliant since it eases the interoperability with other platforms. Not only that, it can make it easy to work with services already implemented over the symbIoTe middleware and/or enablers.

App Developers, through the implementation of enablers, can develop apps over the offered services through symbIoTe, without having to worry about specific technicalities of the middleware.

Municipalities can offer mobility services to their citizens without being locked-in to a specific vendor.

4.2.4 Exploitation plans

4.2.4.1 UNIZG-FER

UNIZG-FER plans to become an active member of the future symbIoTe Alliance in order to use and enhance the developed open source software for educational activities and prospective projects. It also plans to continue publishing relevant research results related to the developed work in this project.

4.2.4.2 AIT

AIT plans to integrate crowd-sensing software developed for this use case in AIT‘s environmental monitoring solution (openUWEDAT) utilizing symbIoTe to integrate external

measurements and services. Furthermore, AIT plans to initiate projects based on the results of this project, with public bodies such as the city of Vienna.

4.2.4.3 UW

The easiness provided by symbIoTe middleware to interoperate with other IoT platforms allows UW to adapt its solution to work with other partners and cities, making it easy to deploy the developed services in other locations and augment the current solution to involve other sources of information and services. As such, UW plans to use the results of this use case to reach new clients and implement MoBaaS in new locations.

4.3 EduCampus

4.3.1 Use Case Description

The EduCampus use case is inspired by the eduroam (EDUcation ROAMing) initiative, an international roaming service for users in research and education. The key idea behind both concepts is to agree on a common framework to harmonize infrastructure services in order to provide researchers, teachers and students easy and secure access to campus services when visiting campuses other than their own. While eduroam focuses on network access, the EduCampus use case aims for IoT middleware services.

The vision behind the EduCampus is the following. When looking at the rapidly growing market for sensors included in smart devices, used in or attached to smart buildings, establishing smart campus infrastructures, there will be rich offerings of services based on IoT middleware installations on a campus. Examples are climate control systems in workplaces, electronic access control systems, indoor location and navigation support, guidance systems for handicapped people, location-based collaboration support, or room information and reservations systems as used in the EduCampus use case.

Such services will be offered by a multitude of specialized IoT-platforms, each dedicated to its own purpose but at the same time making use of associated resources and services provided by other IoT platforms. The goal of this use case is to demonstrate that individual platforms can be integrated into cooperating federations without the need for major code adaptations and changes within their platform information models and the depending application logic, and at the same time being open and extendable to be federated with new IoT platforms, enriching the federation with new types of resources and services. The key idea is to be as independent as possible from single point of failures, like centralized infrastructures and common data models with limited applicability.

Table 3: EduCampus trials

Platforms Involved (CL)	4
Gateways / devices	80 BLE beacons
Apps	2
Enabler	0
Test Sites	2 (KIT Karlsruhe, IOSB Karlsruhe)
No. of Users	~35 (planned)

The EduCampus use case included four different IoT-platforms:

- Room reservation system by Fraunhofer IOSB
- Indoor navigation system by Karlsruhe Institute of Technology (KIT)
- Security Patrol tracking system by QR-Patrol
- Smart virtual key system by Vizlore

The room reservation and the indoor navigation systems are sharing resources that are semantically identically, like rooms and indoor location beacons, but are modeled in a slightly different way. The use case demonstrated that both systems can be made interoperable by introducing a semantic mapping service for resource discovery and data translation. Furthermore, the evaluation showed that the performance scales very well with increased data size and complexity.

As an extension to this use case, the security patrol system as well as the smart virtual key system have been integrated into one common federation, which is sharing indoor location beacons, owned and managed by different IoT platforms. The resulting integrated use case was then able to share indoor location information managed by the room reservation system and from the smart virtual key system to the security patrol system. That extended the outdoor tracking capability for the security patrol to indoor tracking. Another integration feature was the provision of virtual keys to the participants of a meeting organized by the room reservation system. This extended use case showed the openness and flexibility to enrich existing federations by adding new services and new resources.

4.3.2 symbIoTe Value proposition

The two main benefits of using symbIoTe for this use case are its unique approach to semantic interoperability and the support of decentralized federations.

symbIoTe's semantic interoperability approach supports semantic mapping, which means platforms do not have to agree on a common/shared information model to exchange information. They rather can expose their data using different information models and provide declarative mappings between them and symbIoTe will do the translation between them in a transparent manner. Using this feature allows our use case to dynamically integrate new platforms using different information models without requiring any chances in code or redeployment of components.

The second major benefit from using symbIoTe is its concept of federations. On a technical level, federations provide a decentralized and failsafe way for multiple platform to interact with equal rights. This allows them to form a strong and diverse ecosystem and provides the flexibility to realize individual business models, by forming partnerships and sharing IoT resources in a controlled environment.

4.3.3 Benefits of the adoption of symbIoTe

The barrier for platform owners to join is much lower because they do not have to write any code to adapt their information model to any common model but can simply expose their data and service the way they want and just provide a mapping to other models. This suits the requirements for agile development very well and is less error-prone as it does

not require any code to be written. Combining this feature with federations allows for easy and quick creation of new business relations and cooperation to provide a service to customers.

4.3.4 Exploitation plans

The EduCampus use case demonstrated a way to achieve interoperability without enforcing a common language. We see that as the main asset within our exploitation plan. The semantic mapping service is available as an integrated service within symbIoTe and we plan to make it available as a Minimal Viable Product (MVP) to be used outside the symbIoTe framework as well.

The capability to connect two individual IoT platforms by making their resources and services discoverable and interoperable without interfering with their internal information models, is requested in many application domains. Our exploitation plan is to present this approach to other domains we are currently working on, like the industrial automation, smart farming and smart cities. As this solution is quite unique among current IoT integration frameworks, this requires some explanations and demonstrations. First contacts with potential business partners have signified the interests in the symbIoTe capability to establish federations of interworking IoT-platforms without a central system integrator as an organizational bottleneck.

The fist steps in our exploitation have been done by publishing papers to communicate the concepts and by approaching standards developing organization in order to prepare the groundwork for semantic enriched IoT resource description and to enable a standardized semantic mapping approach. This will be continued in the next future.

4.4 Smart Stadium

4.4.1 Use Case Description

The Smart Stadium use case aims at showcasing the feasibility, advantages and added value of smart objects for a solution that, in this particular case, is focused on retailer services for the visitors of a stadium. The use case is based on three main applications, the visitor application, the retailer application and the promowall application, all of them discovering and taking advantage of the different symbIoTe enabled smart objects deployed throughout the stadium (remote ordering devices for retailers, symbIoTe-enabled visitor mobile devices and promowall screens).

All smart objects have also indoor location capabilities by means of the symbIoTe-enabled BLE beacons platform that has been deployed throughout the stadium. The number of beacons, density, transmission power and indoor location accuracy are adapted in each case to the specific needs of the stadium manager. Thanks to the beacons platform, any application can seamlessly get from symbIoTe a list of the registered smart objects ordered by proximity to any given location inside the stadium.

Visitors are identified through their smartphones, provided they have installed the corresponding smart stadium visitor app, while remote ordering devices and beacons allow identifying retailers (both moving carts and physical shops). Both visitors and remote ordering devices are registered into symbIoTe. From the visitor’s point of view, Smart Stadium brings the opportunity to detect the closest retailers through symbIoTe, place

orders independent of where they are, or receive products that they bought directly in their seat.

Additionally, retailers can broadcast through symbIoTe their offers and promotions to all visitors inside the stadium, or those that are moving near specific areas inside the stadium. Retailers can send their promotions to large SmartTVs (Promowalls), which have been strategically located throughout the stadium and have also been registered into symbIoTe.

Table 4: Smart Stadium Use Case

Platforms Involved (CL)	4 (L1)
Apps	3
Test Sites	1 (Atlètic Terrassa Hockey Club)
No. of Users	> 250 users downloaded APP

The Smart Stadium trials took place at the premises of Atlètic Terrassa Hockey Club (ATHC, http://athc.cat/), a sports club located just outside the city of Terrassa, about 30 km NW from the city of Barcelona. The trials took place during events attended by more than 1000 people, from whom more than 250 downloaded the visitor application, as shown in the following video: https://youtu.be/Db9bVpurP_o. ATHC and its supporters were very satisfied with the three applications (visitor, remote ordering and promowall) and the features that symbIoTe provided to them in the form of location and remote ordering. symbIoTe provided the ability to discover and dynamically access new devices ordered by proximity, as well as known and preregistered ones, and it was used to develop the next evolution of customer immersion in stadiums.

4.4.2 symbIoTe Value proposition

Concerning the value proposition of symbIoTe for the Smart Stadium use case, the unique selling point is clear: symbIoTe helps any Smart Stadium solution provider to improve selling services in a more flexible and extensible way thanks to the symbIoTe L1 interoperability features. As a result, the solution provider can:

a) add new services to enable rapid and flexible service co-creation from various IoT platforms (e.g., on-demand media vs catering), and

b) broaden data collection and interaction from a bigger number of IoT devices/platforms/solutions extracted from various abstracted underlying platforms with symbIoTe (e.g., localization information provided by multiple infrastructures for low & high resolution).

In particular, once the four Smart Stadium platforms (location platform, visitors' platform, remote-ordering platform and promowall platform) have been made symbIoTe-compliant, the development of symbIoTe-enabled applications is quick and straightforward, thus allowing the solution provider to provide high added-value services to their clients in an unprecedented quality, time and cost.

4.4.3 Benefits of the adoption of symbIoTe

The Smart Stadium use case involves three main types of different users that take advantage of the benefits that symbIoTe brings to them:

- Visitors: Visitors are the consumers of all the services provided either directly by the stadium manager, or by service providers licensed by the stadium manager. The main benefits that they get from symbIoTe are an improvement in services and an enhanced visitor experience, with a reduction in queues and waiting times, as well as an easier location of available services and points of sale in the stadium.
- Service Providers: Services providers provide complementary added-value services to stadium visitors, such as food, kiosks, general information, etc., and they benefit from symbIoTe by improving the efficiency of their services, with a quicker service that reaches a larger number of customers. In addition, they also improve the acceptance ratio of their promotions and offers, since they get the capability of specifically targeting the customers that, at any time, are located closer to them.
- Stadium Managers: The stadium manager has the responsibility of managing all stadium services, from the most basic ones (ticketing, access, emergency medical services, security staff…), to the added-value services. The Stadium Manager benefits from symbIoTe by taking better advantage of the large number of visitors to improve revenues through retailers installed in the stadium, and offering a more complete and personalized information to visitors, and all of it without generating any additional burden to them.

In addition to the direct benefits that symbIoTe brings to Smart Stadium stakeholders, there is also a clear benefit for application developers in how easy is to develop and deploy the solution, since symbIoTe hides to them all the complexities related to platform interoperability.

4.4.4 Exploitation plans

The value of symbIoTe for Worldline and ATOS is the possibility to use symbIoTe technologies to enhance Worldline Connected Solutions to make possible to sell services in a flexible and extensible way from various IoT platforms. Additionally, symbIoTe also increases the portfolio of Worldline and ATOS solutions for indoor location-based services in several markets: in addition to stadiums, the solution is applicable to museums, commercial centres, airports, and exhibition centres

From the abovementioned services, it is worth mentioning the highly demanded solution for remote-ordering in stadiums, which had not been included until now in Worldline solution for stadiums due to its complexity and difficulty to integrate very diverse IoT platforms, and which is now available and can be easily deployed at any symbIoTe-enabled stadium.

Regarding Smart Stadium app, the idea is to use the improvements done through symbIoTe as a PoC for other external stakeholders, showing the benefits of the application in a real environment. In fact, the close collaboration with ATHC has given Worldline an important reference for Smart Stadium solutions, opening a new market for mid-range stadiums and premises that can benefit from this type of solution, and which can be practically shown now to interested stadium managers or any other stakeholder.

4.5 Smart Yachting

4.5.1 Use Case Description

Smart Yachting aims at testing symbIoTe's potential in the context of the Yachting industry. This is a sector with a growing importance in Europe, with an estimated yearly turnover of almost EUR 20 billion, involving approximately 32,000 companies which directly employ over 280,000 people.

Table 5: Smart Yachting Use Case

Platforms Involved (CL)	2 (Navigo Digitale, Symphony)
Gateways / devices	2 Yachts as "Smart Devices"
Apps	2
Enabler	2
Test Sites	2 (Viareggio, Marina Cala De' Medici - Italy)
No. of Users	6

Smart Yachting focuses on two specific showcases, Smart Mooring and Automated Supply Chain, which exploit data from IoT sensors to automatically acquire information from the yacht and to pass them to the business applications connected to the port infrastructure.

Smart Mooring in particular aims to automate the mooring authorization procedure of the port, in itself a quite bureaucratic and tedious process, since Marinas operate in strongly regulated contexts.

Automated Supply Chain (ASC) assumes that the yacht is berthed at the port and aims at automatically identifying the needs for goods and services on board, so that automated requests for offers can be issued on the marketplace web platform of the port.

From a symbIoTe viewpoint, the use case is compliant to L1, L3 and L4 levels: yachts in fact are seen as Roaming Smart Devices (SDEV – Level 4), registered in the Core together with their resources, while ports are seen as Smart Spaces. A yacht connects in symbIoTe through the port's Smart Space Middleware (S3M – Level 3 & 4). Each port exposed a S3M which is integrated with the Navigo Digitale IoT Platform (Level 1): the use case applications – Navigo's Portnet, the mooring workflow management system, and Centrale Acquisti, the web marketplace, – are connected in symbIoTe through two dedicated Enablers (Level 1).

4.5.2 symbIoTe Value proposition

Smart Yachting's general vision is to connect ports' applications and IoT services in order to expose them as a unique infrastructure, exposing data and common services. Thanks to symbIoTe, it is possible to facilitate visiting yachts (but also tourists coming from inland) to:

- easily and transparently connect and interact with ports' applications and IoT platforms

- find and exploit services offered by the ports
- automate whole workflows and tedious manual procedures.

The focus of Smarty Yachting is therefore on the interoperability between ports and yachts. With symbIoTe, incoming vessels can easily and transparently connect to the port's infrastructure, to find and use services offered by the harbor.

In particular, for Smart Mooring we aim to intercept a specific phase of the mooring process that starts when the yacht is approaching – at a distance – the destination port and ends when it finally berths into one of the piers. When approaching the port, the vessel is first detected through LoRaWAN, allowing to send alerts to the port personnel in the piers to wait for the incoming boat. When it enters the port area, a Wi-Fi connection is initiated between the yacht and the S3M: this way yacht data that must be specified in the mooring authorization procedure can be automatically acquired and there is no need to manually copy them on paper forms; last but not least, there is no need for the yachtsman to physically go to the Port Authority's offices, unless any problem arises.

With Automated Supply Chain instead, the yacht is berthed at the port and steadily connected – through WiFi – to the port's S3M. The yachtsman connects to the Centrale Acquisti web marketplace application through a common web browser: he/she gives the authorization to Centrale Acquisti to connect through symbIoTe to the machine data of the boat, that automatically provides indication about what is needed on board, whether of maintenance or resupply nature. Needs are expressed by identifying the categories of the possible suppliers that might fulfil them by using the schema.org ontology (e.g. the *schema:Electrician* class is used when maintenance on the electric systems of the yacht is needed).

4.5.3 Benefits of the adoption of symbIoTe

The trials done in the project allowed to assess the benefits of Smart Yachting for the involved users, including: workflow simplifications, reduction of paperwork, automated notifications, more accurate and up-to-date information retrieval. Smart Yachting involved different types of users, who obtained specific kinds of benefits from the technological solutions proposed in the project.

For Smart Mooring:

- Yachtsmen, who are completely freed from manually performing the mooring authorization request, avoiding therefore to fill-up paper forms to present to the Port Authority office
- Port Authorities' operators using Mooring Workflow Management Systems. They obtain on the one hand the simplification of their work and the reduction of the amount of paper forms that must be filled each time a yacht arrives in the port; on the other they are automatically informed of the arrival of the yacht in the port area (when still at a distance) and when it has finally berthed.
- The workers in the Port Area, that can automatically receive notifications (e.g., on their phones) when the yacht is arriving or has berthed, with the possibility to access in real-time all the useful information about the yacht. This is also extremely beneficial from a customer support viewpoint, since workers can know beforehand the characteristics of the boat and can anticipate the possible needs of the incoming yachtsmen.

For Automated Supply Chain:

- Yachtsmen, who can automatically identify the needs on boards and find a suitable supplier in the port area, even at their first visit in the harbour.
- Local suppliers that can have a boost of their sales driven by the automatic requests for offer received through the Smart Yachting integration.
- Port Authorities' managers, that see the availability of such "high-tech" services as extremely beneficial for the reputation of their ports. Promoting themselves as "smart" and "modern" can in fact potentially attract more customers in a high-end/luxury business like Yachting.

4.5.4 Exploitation plans

Smart Yachting allowed to successfully develop a full automated, open, general-purpose and interoperable platform for the integration of yachts and ports. Trials and user assessments carried on in the project demonstrated encouraging results in this sense. In particular Smart Yachting paves the way to create an interoperable standard amongst IT/IoT solution providers in the Yachting Industry.

On the one hand in fact, symbIoTe's partners Nextworks and Navigo actively work with important yacht manufacturers and several ports and port associations in Italy, Malta and Montenegro. On the other, the project's Open Calls showed an interest in symbIote by IoT system integrators that offer solutions for the Yachting industry. In particular, the Greek company OptionsNet made their SaMMY IoT platform for marinas symbIoTe-L1 compliant.

This is therefore a promising opportunity that we can expect to fulfil with a medium/long-term strategy. The maximum benefit in fact can be obtained only if a significant number of yachts and ports complies with the Smart Yachting technology.

In the short-term, the participation in symbIoTe allowed Navigo to significantly boost its marketing proposition of technological solutions for ports. Its commercial suite of software for marinas, Marina+, now officially includes the Navigo Digitale IoT platform, used in symbIoTe. Moreover, the experience on IoT technologies acquired in symbIoTe allowed Navigo to participate as a partner in the Mosè research project, funded by Regione Toscana in Italy, which aims to develop an innovative Pedestal system for marinas.

5 Conclusions

Throughout this document, the various performances of the use cases were reported, along with the benefits of using symbIoTe for each case, the benefits for the different stakeholders, and how symbIoTe and the worked developed for each use case can be exploited.

The diverse number of trials provided different types of challenges for the system. While the Smart Residence use case trials were performed in contained locations, trials such as Smart Mobility operated through the whole cities. Different levels of integration were tested under different domains, with the Smart Residence and Smart Yachting putting to test the Smart Spaces' components. Semantic Mapping was put to test in order to provide another tool to improve platforms' interoperability.

Table 6: symbIoTe trials total numbers

Platforms Involved (CL)	18
Gateways / devices	239
Apps	13
Enabler	5
Test Sites	12
No. of Users	~400

All in all, the system responded well to the workload put upon it, and various symbIoTe functionalities were tested successfully. Not only was the system validated, but the various specific enablers and applications developed for each use case were also put to test, with good results. Additionally, it was proved during the Smart Mobility trials that the system can handle a large number of users at the same time.

The trials showed how symbIoTe can support rea-life use cases in various domains and how this can improve the flexibility of the applications and increase the utilization of existing IoT environments.

6 References

[1] symbIoTe project Deliverable D9.1 – POPD Requirement No.2; February 2016.

[2] Brooke, John. "SUS-A quick and dirty usability scale." *Usability evaluation in industry* 189.194 (1996): 4-7.

7 Abbreviations

AAL	Ambient Assisted Living
GA	Grant Agreement
HCI	Human-Computer-Interaction
ICT	Information and Communications Technology
IoE	Internet of Everything
IoT	Internet of Things
KPI	Key Performance Indicator
POPD	Protection of Personal Data
QoE	Quality of Experience
S3M	symbIoTe Smart Space Middleware
SSP	symbIoTe Smart Space
WTP	Willingness-To-Pay

8 Annexes

8.1 Smart Residence

8.1.1 Smart Home (Pisa)

8.1.1.1 Definition of the Test cards and Questionnaires

The procedure followed to evaluate Smart Area Controller and Home Comfort applications is articulated in three phases described in three different main Test Cards:

Platform Registration
This test card illustrates the procedure to evaluate the correct registration of the SSP resources and locations provided by two separated symbIoTe L3 compliant IoT platforms.

The first one organizes its devices in locations modelled as Rooms, the second one in locations modelled as Floors. The user should then be able to define the topology of the environment and the consequential hierarchy between locations through the Enabler.

The test verifies the correct operation of the basic registration process and the feasibility of interoperability between resources registered by different platforms. One further objective is to verify the capability of the symbIoTe Enabler of correctly managing the topology.

This test is run by a unique tester, producing a single test card, since the registration procedure needs to be run once, and users are not intended to face it.

Smart Area Controller
This card evaluates the correct functioning of Smart Area Controller App developed for Android devices to control all the devices registered in the SSP. It should be possible for a user to navigate through the hierarchical tree of locations to reach any registered device, while remaining unaware of a platform that registered it.

The application leverages on a specific enabler, which gives the possibility to filter the devices in the space, based on their position (building, floor, room, etc.). In this way, the application has to query the symbIoTe enabler in order to retrieve the list of smart devices (sensors and actuators) in a selected area and then to allow a user to control them.

The tests have been run by 10 end users (Nextworks employees) producing functional evaluation Test Cards. The 10 resulting Test Cards has been summarized in a general one. After completing the functional tests, the users were asked to complete a questionnaire about usability and appreciation of the application.

Home Comfort
This card evaluates the correct functioning of Home Comfort App, consisting of a Back-end, running on a server (that monitors the sensors and activates the actuators) and a Front-end (accessible via a web interface for creation of scenarios and configuration).

The tests verify the interoperability between resources registered by different platforms and their capability to cooperate in a scenario.

With Home Comfort App, a user interacts with any resource and navigates through locations being completely unaware of the platform that registered it.

Similarly to the Smart Area Controller App, the tests have been run by 10 end users (Nextworks employees) producing a functional evaluation Test Cards. The ten resulting Test Cards have been summarized in a general one. After completing the functional tests, the users were asked to complete a questionnaire regarding the usability and appreciation of the application.

8.1.1.2 Deployment

The tests have been executed within the Nextworks' offices in Pisa. The location does not need a special preparation since the sensors and actuators are already installed. Nevertheless, the commercial IoT platform from Nextworks, called Symphony, was made symbIoTe compliant, in order for the smart devices to be exposed.

The devices involved in the trial are sensors and actuators controlled by two instances of the same IoT platform, i.e., Symphony, and, as specified in the previous paragraph, they were organized in locations modelled as Floors and Rooms.

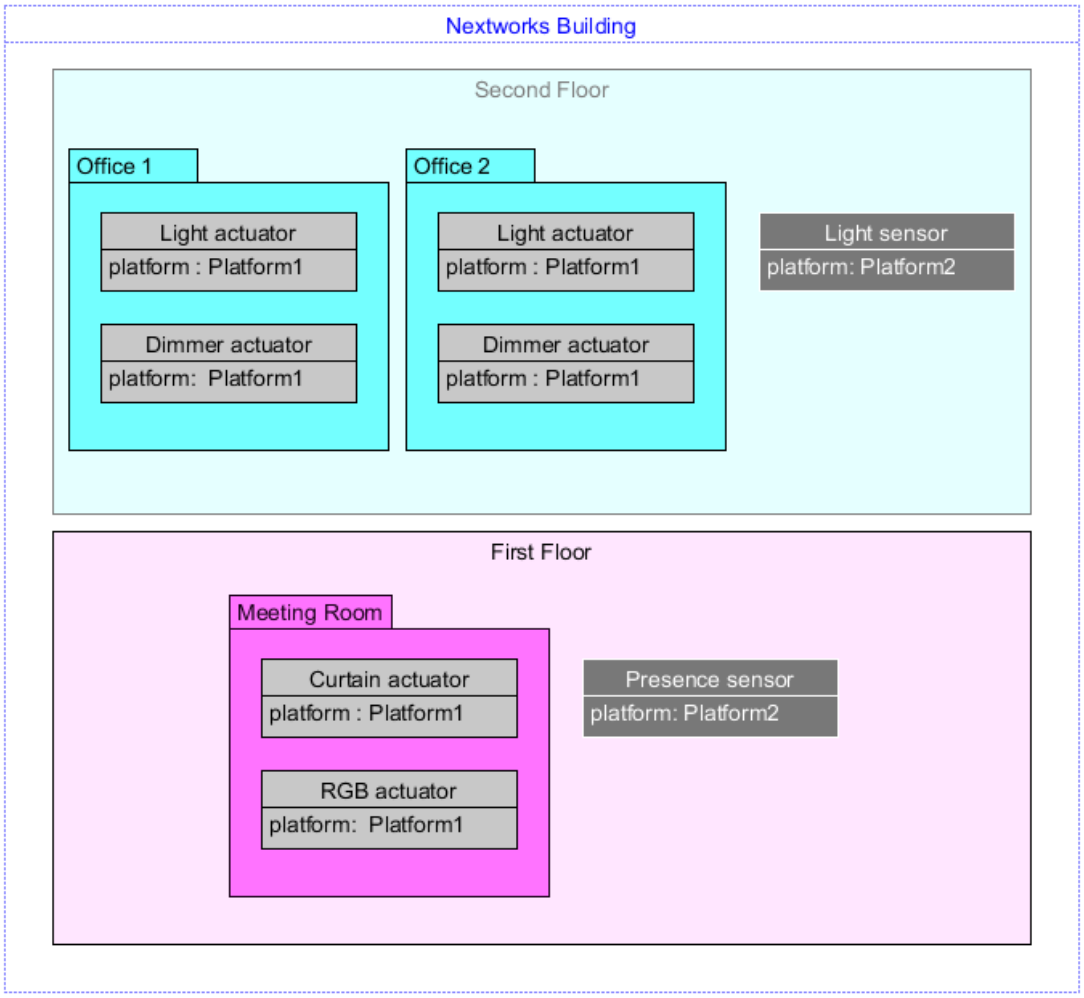


Figure 1: Topology

From the architectural point of view the deployment of the system is shown in Figure 2:

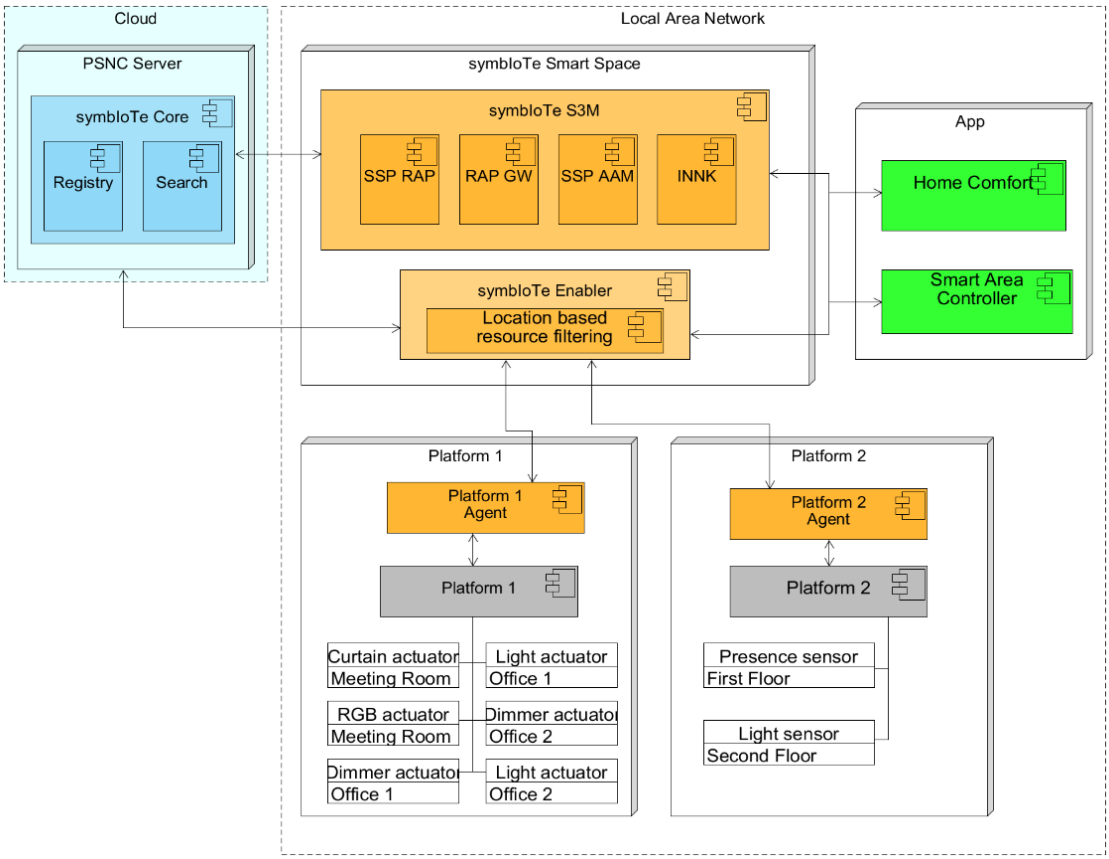


Figure 2: Architecture

8.1.1.3 KPIs

KPIs have been set for both the Home Comfort and Smart Area Controller app.

The procedure shown in **Platform Registration** refers to the preliminary work done to have Home Comfort and Smart Area Controller running.

Application	No. of Users	Description	Target Value
Smart Area Controller	10	Percentage of showed devices (in the right location);	
		Percentage of accessible/controllable devices (depending on the device);	>80%
		Percentage of locations showed, correctly positioned in Hierarchical tree and navigable.	
Home Comfort		Percentage of showed devices (in the right location);	

		Percentage of locations showed, correctly positioned in Hierarchical tree and navigable;	>80%
		Percentage of availability of devices in creating a scenario;	
		Percentage of respect of scenarios rules.	

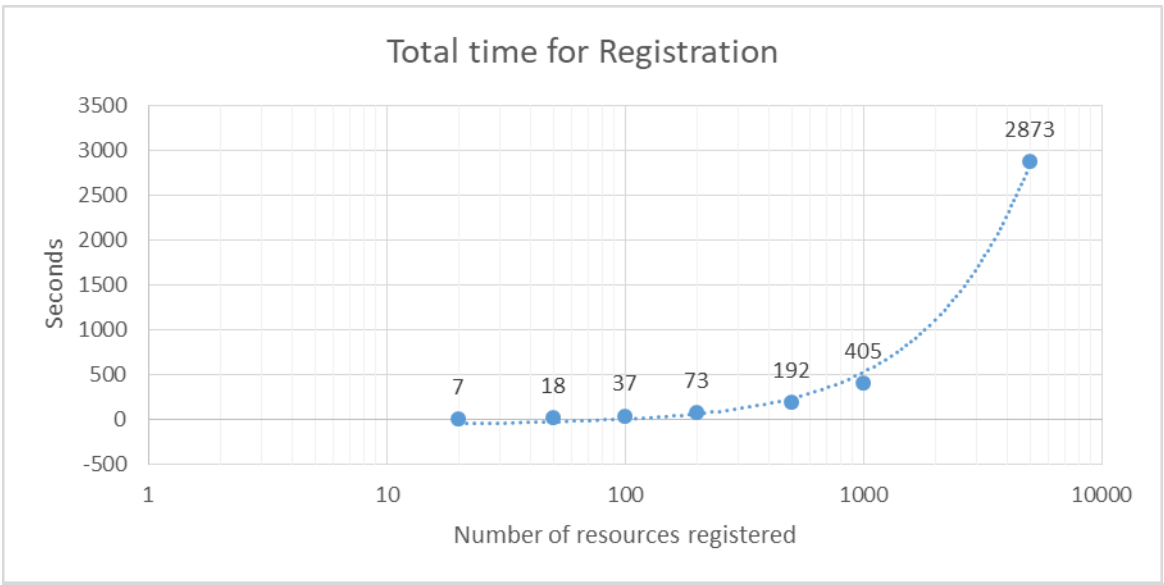
8.1.1.4 Functional tests – Status and Results

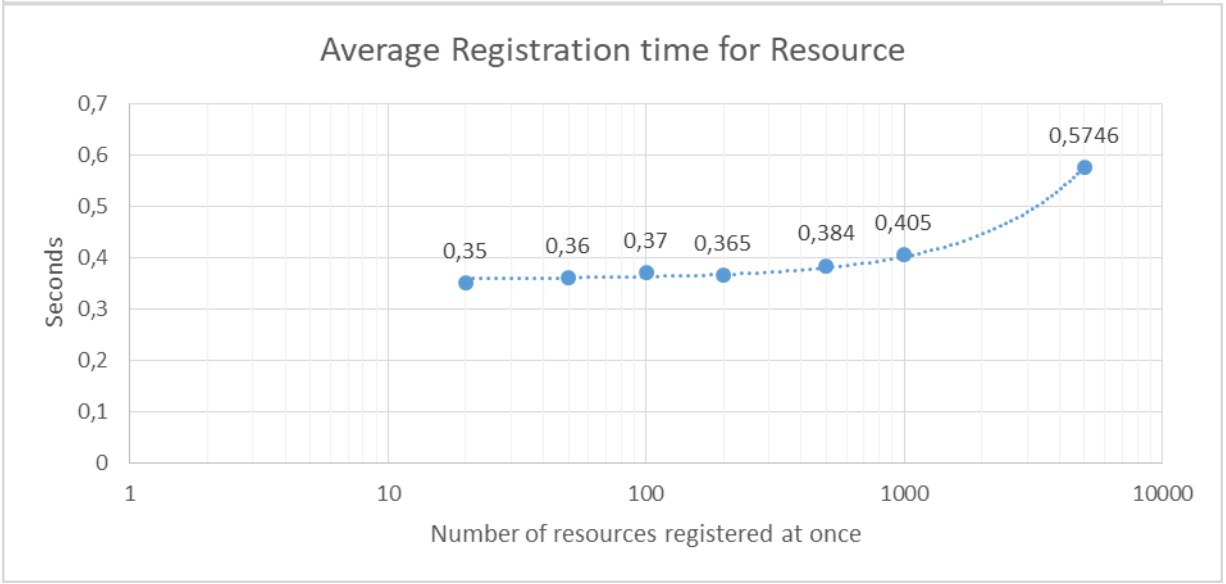
With the **Platform Registration**, a test is done to verify the correct functionality of the basic registration process and the possibility of resources registered by separated platforms to interoperate in the same SSP. It is also verified the capability of the symbIoTe Enabler of correctly managing the topology.

Test Description	Status	Results
Registration of the first Platform (Symphony):	Passed	No errors during registration process in symbIoTe Agent logs
Inspect registered resources and locations on SSP from the first Platform (Symphony)	Passed	All Platform 1 resources and locations are correctly registered, searchable and their information accessible:
Inspect registered resources and locations on SymbIoTe Core	Passed	All Platform 1 resources and locations are correctly registered, searchable and their information accessible
Registration of the second Platform (Symphony):	Passed	No errors during registration process in symbIoTe Agent logs
Inspect registered resources and locations on SSP from the second Platform (Symphony)	Passed	All Platform 2 resources and locations are correctly registered, searchable and their information accessible:
Inspect registered resources and locations on symbIoTe Core	Passed	All Platform 2 resources and locations are correctly registered, searchable and their information accessible
Verify the SSP registered locations on the Enabler: All the locations registered by both of the platforms should be displayed in the Enabler interface. The enabler is completely agnostic about which Platform has registered a specific location.	Passed	All the locations registered by both of the platforms are displayed in the Enabler interface.

Check of the SSP registered locations hierarchy: The Enabler provides a GUI that allow the user to create a hierarchical tree between the locations registered by both of the platforms. This tree must be navigable.	Passed	After the hierarchy has been created it is tested to be actually saved in the SSP database.

A Stress Test has also been run over the system, registering a growing number of resources within the SSP.





It is possible to see that the number of resources do affect the average registration time of devices but it still remains acceptable (about 0,5 s) even when up to 5000 registrations are carried out at the same time.

8.1.1.5 Execution of the trials with users – Status and Results

For Smart Area Controller

Test Description	Status	Results
Navigation through Locations: Verify that every location that appears in the topology is displayed and selectable in Smart Area Controller APP (for each correctly displayed location one point has been given by each operator).	Passed	50/50
Navigation through Locations, hierarchy verification: Verify that the hierarchical order of locations shown in the topology is reflected into the Smart Area Controller APP interface (for each location correctly collocated in the hierarchical tree one point has been given by each operator).	Passed	50/50
Navigation through Locations up to resources: Every resource in the Smart Area Controller APP must be accessible and correctly reachable through any locations it is registered in (for any correctly displayed and collocated resource one point has been given by each operator).	Passed	80/80
Navigation through Locations, resource functioning: Verify that every resource that appears in the topology is readable (sensors) or writable (actuators) in Smart Area Controller APP (for each correctly behaving resource one point has been given by each operator).	Passed	80/80

For Home Comfort

Test Description	Status	Results
Navigation through Locations: Verify that every location that appears in the topology is displayed and selectable in Smart Area Controller APP (for each correctly displayed location one point has been given by each operator).	Passed	50/50
Navigation through Locations, hierarchy verification: Verify that the hierarchical order of locations shown in the topology is reflected into the Smart Area Controller APP interface (for each location correctly collocated in	Passed	50/50

the hierarchical tree one point has been given by each operator).		
Navigation through Locations up to resources: Every resource in the Smart Area Controller APP must be accessible and correctly reachable through any locations it is registered in (for any correctly displayed and collocated resource one point has been given by each operator).	Passed	80/80
Scenarios creation: At the moment of a new scenario creations rules must be empty and every possible condition/action combination (depending only on sensors and actuators in the location) must be selectable. (Each operator defines an Example Scenario setting conditions on any available sensor and actions on any available actuator, one point is given for any correctly set scenario).	Passed	10/10
Scenarios rules check: Once scenario's rules are set their correct execution must be checked creating the desired conditions on sensors and verifying the correct reactions of actuators (one point is given for any correctly reacting scenario).	Passed	10/10

8.1.1.6 Test Cards

Platform Registration

Test-card #	**Symbyote_SR_NXW_1**	**Execution Status**	***PASSED***
Test Name	Registration of resources and locations from two IoT platforms		
Objectives	The aim of these tests is to verify the correct registration of all the SSP resources and locations provided by two IoT platforms L3 compliant to symbIoTe architecture. For the test, two separated platforms are used which register resources and locations on the same SSP: • Platform 1 registers a set of actuators located into rooms: o #1 Meeting room ▪ #1 RGB actuator ▪ #1 Curtain actuator		

<table>
<tr><td></td><td>

#1 Office 1

#1 Dimmer actuator
#1 Light actuator

#1 Office 2

#1 Dimmer actuator
#1 Light actuator

Platform 2 registers a set of sensors located into floors:

#1 First floor

#1 Presence sensor

#1 Second Floor

#1 Light sensor

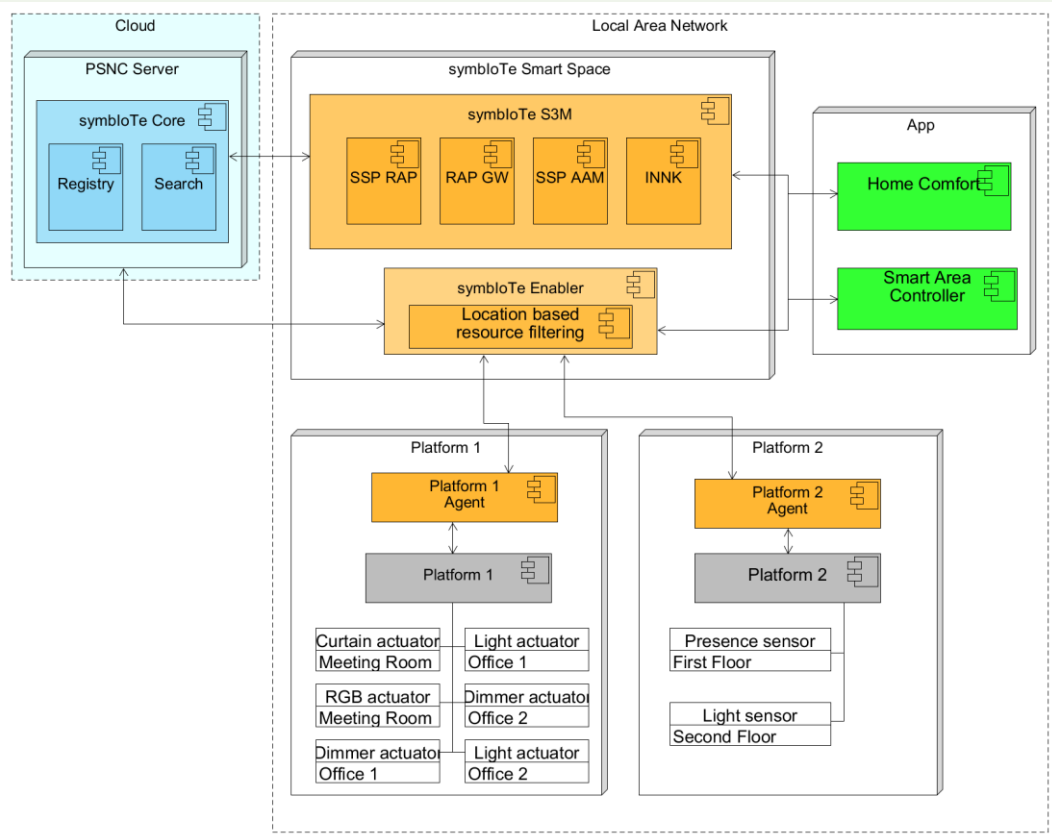
The resources are divided this way in order to emulate the behaviour of two different Platforms controlling different kind of devices and organizing locations on different levels:
Platform 1 controls actuator devices and organizes them into locations modelled as Rooms.
Platform 2 instead, controls sensor devices and organizes them into locations modelled as Floors.
The definition of the topology of the environment and the consequential hierarchy between locations is set by the Enabler.

The objective of the test is to verify the correct operation of the basic registration process and the feasibility of interoperability between resources registered by separated platforms. One further objective is to verify the capability of the symbIoTe Enabler of correctly managing locations when a hierarchical tree is created.</td></tr>
<tr><td>KPIs to measure</td><td>
<table>
<tr><th>DESCRIPTION</th><th>PROCEDURE</th><th>TARGET VALUE</th></tr>
<tr><td>Correctly registered resources on SSP</td><td>Rest call to the Innkeeper</td><td>#2 Dimmer actuator
#1 RGB actuator
#1 Curtain actuator
#2 Light actuator
#1 Presence sensor
#1 Light sensor</td></tr>
<tr><td>Correctly registered locations on SSP</td><td>Rest call to the Enabler</td><td>#1 Meeting room
#1 Office 1
#1 Office 2
#1 First floor
#1 Second Floor</td></tr>
</table>
</td></tr>
</table>

	Correctly registered resources on Core	*Check via WebApp*	*#2 Dimmer actuator #1 RGB actuator #1 Curtain actuator #2 Light actuator #1 Presence sensor #1 Light sensor*
	Correctly registered locations on Core	*Check via WebApp*	*#1 Meeting room #1 Office 1 #1 Office 2 #1 First floor #1 Second Floor*
	Correct hierarchical registration of locations	*Rest call to the Enabler*	*First Floor -> Meeting Room Second Floor -> Office 1, Office 2*
	Correct access to resources	*Check via WebApp*	*#2 Dimmer actuator #1 RGB actuator #1 Curtain actuator #2 Light actuator #1 Presence sensor #1 Light sensor*
Related Use Cases	Smart Residence		
Designers	*Gino Carrozzo, Matteo Pardi, Luca Tomaselli, Lorenzo Neri*		
Related Test-cards	Symbyote_SR_NXW_2, Symbyote_SR_NXW_3		
Attachments	None		
Additional Comments	This Test card refers to the preliminary work done to set up the symbIoTe environment (based on two L3 Platforms registered on the same SSP) on which the Home Comfort and Smart Area Controller app are tested. These test aren't meant to be run by users and are illustrated in this Test Card to show the necessary workflow to have Home Comfort and Smart Area Controller running.		

Trial resources and topology	

Required resources	Symphony L3 Agent on Platform 1 (Symphony);
	Symphony L3 Agent on Platform 2 (Symphony);
	Controlled devices over both Platforms;
	• Platform 1 resources:
	  ○ #2 Dimmer actuator
	  ○ #1 RGB actuator
	  ○ #1 Curtain actuator

	○ #2 Light actuator • Platform 1 locations: ○ #1 Meeting room ○ #1 Office 1 ○ #1 Office 2 • Platform 2 resources: ○ #1 Presence sensor ○ #1 Light sensor • Platform 2 locations: ○ #1 First floor ○ #1 Second Floor Home Comfort Application Smart Area Controller Application
Topology details	

Test description

St	Step description and expected results	Status

ep #		
1	**Description**: Registration of the first Platform (Symphony): **Expected Results:** • Successful registration process **Measured Results:** • No errors during registration process in symbIoTe Agent logs **Comments**:	*Passed*
1.1	**Description**: Inspect registered resources and locations on SSP from the first Platform (Symphony) **Expected Results:** • All Platform 1 resources are correctly registered, searchable and their information accessible: o #2 Dimmer actuator o #1 RGB actuator o #1 Curtain actuator o #2 Light actuator • All Platform 1 locations are correctly registered, searchable and their information accessible: o #1 Meeting room o #1 Office 1 o #1 Office 2 **Measured Results:** • Search and retrieve information for Platform 1 resources via Rest call to SSP: o #2 Dimmer actuator o #1 RGB actuator o #1 Curtain actuator o #2 Light actuator • Search and retrieve information for Platform 1 locations via Rest call	*100% Passed*

	to SSP: ○ #1 Meeting room ○ #1 Office 1 ○ #1 Office 2 **Comments**:	
1.2	**Description**: Inspect registered resources and locations on symbIoTe Core **Expected Results:** • All Platform 1 resources are correctly registered, searchable and their information accessible: ○ #2 Dimmer actuator ○ #1 RGB actuator ○ #1 Curtain actuator ○ #2 Light actuator • All Platform 1 locations are correctly registered, searchable and their information accessible: ○ #1 Meeting room ○ #1 Office 1 ○ #1 Office 2 **Measured Results:** • All Platform 1 resources are correctly registered, searchable and their information accessible: ○ #2 Dimmer actuator ○ #1 RGB actuator ○ #1 Curtain actuator ○ #2 Light actuator • All Platform 1 locations are correctly registered, searchable and their information accessible: ○ #1 Meeting room ○ #1 Office 1	*100% passed*

- #1 Office 2

Comments:

http://10.0.10.11:3000/innkeeper/public_resources


```
[
  {
    "resource": { … }, // 6 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 6 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 6 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 6 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 6 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
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    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 7 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  },
  {
    "resource": { … }, // 7 items
    "resourceType": [ … ], // 1 item
    "locationName": "NEXTWORKS SSP PISA"
  }
]
```
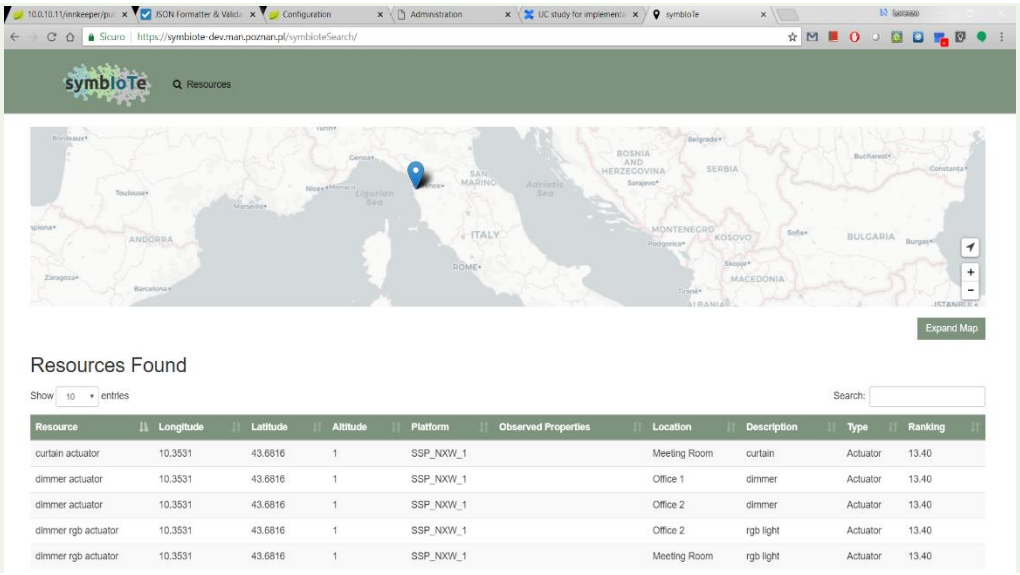



Resource	Longitude	Latitude	Altitude	Platform	Observed Properties	Location	Description	Type	Ranking
curtain actuator	10.3531	43.6816	1	SSP_NXW_1		Meeting Room	curtain	Actuator	13.40
dimmer actuator	10.3531	43.6816	1	SSP_NXW_1		Office 1	dimmer	Actuator	13.40
dimmer actuator	10.3531	43.6816	1	SSP_NXW_1		Office 2	dimmer	Actuator	13.40
dimmer rgb actuator	10.3531	43.6816	1	SSP_NXW_1		Office 2	rgb light	Actuator	13.40
dimmer rgb actuator	10.3531	43.6816	1	SSP_NXW_1		Meeting Room	rgb light	Actuator	13.40

2	**Description**: Registration of the second Platform (Symphony) **Expected Results:** • Successful registration process **Measured Results:** • No errors during registration process in symbIoTe Agent logs **Comments**:	*Passed*
2.1	**Description**: Check of the Second Platform (Symphony) registered resources and locations on SSP **Expected Results:** • Platform 2 resources: o #1 Presence sensor o #1 Light sensor • Platform 2 locations: o #1 First floor o #1 Second Floor **Measured Results:** • Platform 2 resources: o #1 Presence sensor o #1 Light sensor • Platform 2 locations: o #1 First floor o #1 Second Floor	*100% passed*

Comments:

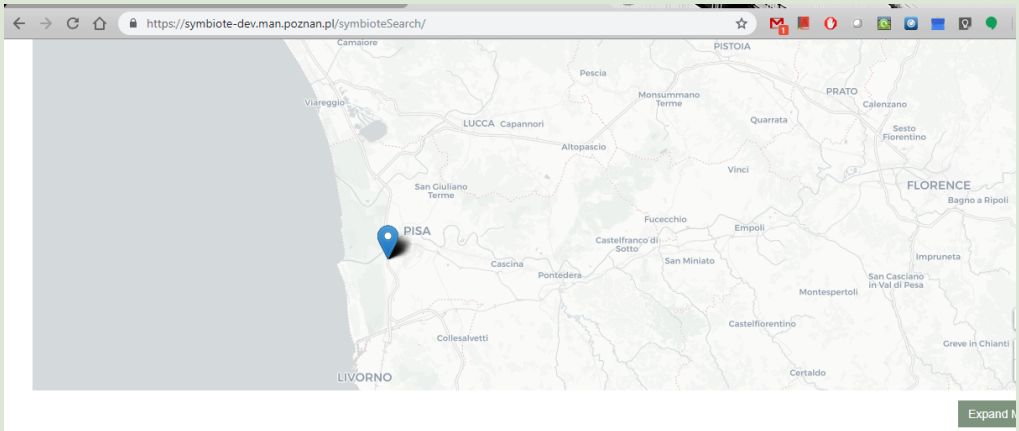
2.2	**Description**:
	Check of the Second Platform (Symphony) registered resources and locations on Core
	Expected Results:
	• Platform 2 resources:
	  ○ #1 Presence sensor
	  ○ #1 Light sensor
		100% passed

- Platform 2 locations:
  - #1 First floor
  - #1 Second Floor

Measured Results:

- Platform 2 resources:
  - #1 Presence sensor
  - #1 Light sensor
- Platform 2 locations:
  - #1 First floor
  - #1 Second Floor

Comments:



Resources Found

Show 10 entries Search:

Resource	Longitude	Latitude	Altitude	Platform	Observed Properties	Location	Description	Type	Ranking
brightness sensor	10.3531	43.6816	1	SSP_NXW_1	illuminance	Second Floor	Sensore luminosita	StationarySensor	13.40
curtain actuator	10.3531	43.6816	1	SSP_NXW_1		Meeting Room	curtain	Actuator	13.40
dimmer actuator	10.3531	43.6816	1	SSP_NXW_1		Office 1	dimmer	Actuator	13.40
dimmer actuator	10.3531	43.6816	1	SSP_NXW_1		Office 2	dimmer	Actuator	13.40
dimmer rgb actuator	10.3531	43.6816	1	SSP_NXW_1		Meeting Room	rgb light	Actuator	13.40
dimmer rgb actuator	10.3531	43.6816	1	SSP_NXW_1		Office 2	rgb light	Actuator	13.40
presence sensor	10.3531	43.6816	1	SSP_NXW_1	surface density	First Floor	sensor	StationarySensor	13.40
sensor sensor	10.3531	43.6816	1	SSP_NXW_1	power	First Floor	sensor	StationarySensor	13.40

3

Description:
Verify the SSP registered locations on the Enabler:
All the locations registered by both of the platforms should be displayed in the Enabler interface.
The enabler is completely agnostic about which Platform has registered a specific location.

Expected Results:

- #1 Meeting Room

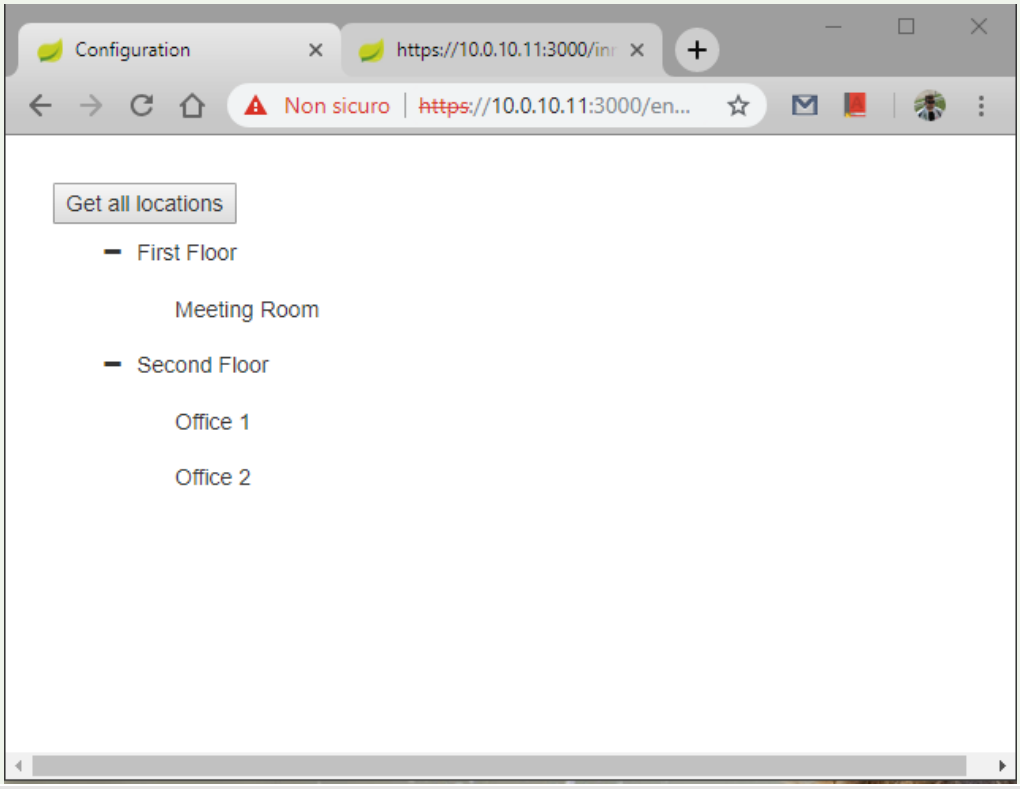
100% Passed

- #1 Office 1
- #1 Office 2
- #1 First Floor
- #1 Second Floor

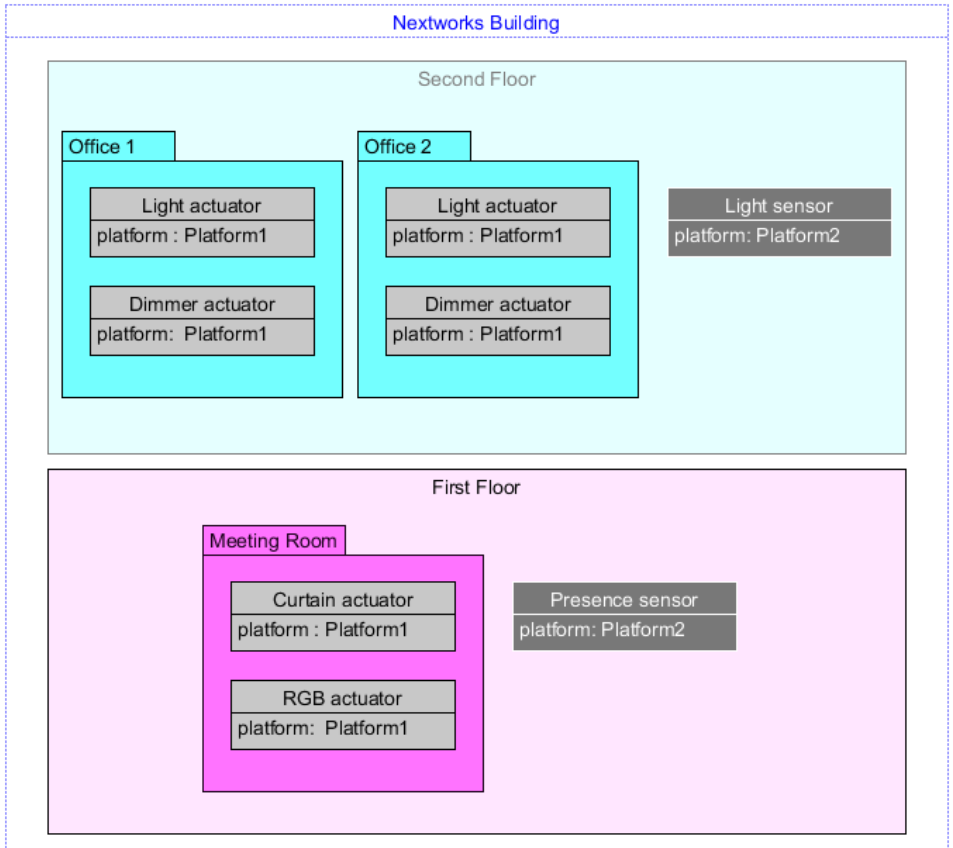
Measured Results:

- #1 Meeting Room
- #1 Office 1
- #1 Office 2
- #1 First Floor
- #1 Second Floor

Comments:



4	**Description**: Check of the SSP registered locations hierarchy: The Enabler provides a GUI that allow the user to create a hierarchical tree between the locations registered by both of the platforms. This tree must be navigable. After the hierarchy has been created through a GET call to the SSP is possible to verify that it is actually saved in the SSP database. The topology set for these test is illustrated in the image below.	*100% Passed*



Expected Results:

- Location's hierarchy illustrated in the topology saved in SSP
  - First Floor -> Meeting Room
  - Second Floor -> Office 1, Office 2

Measured Results:

- Location's hierarchy illustrated in the topology saved in SSP
  - First Floor -> Meeting Room
  - Second Floor -> Office 1, Office 2

Comments:

Smart Area Controller

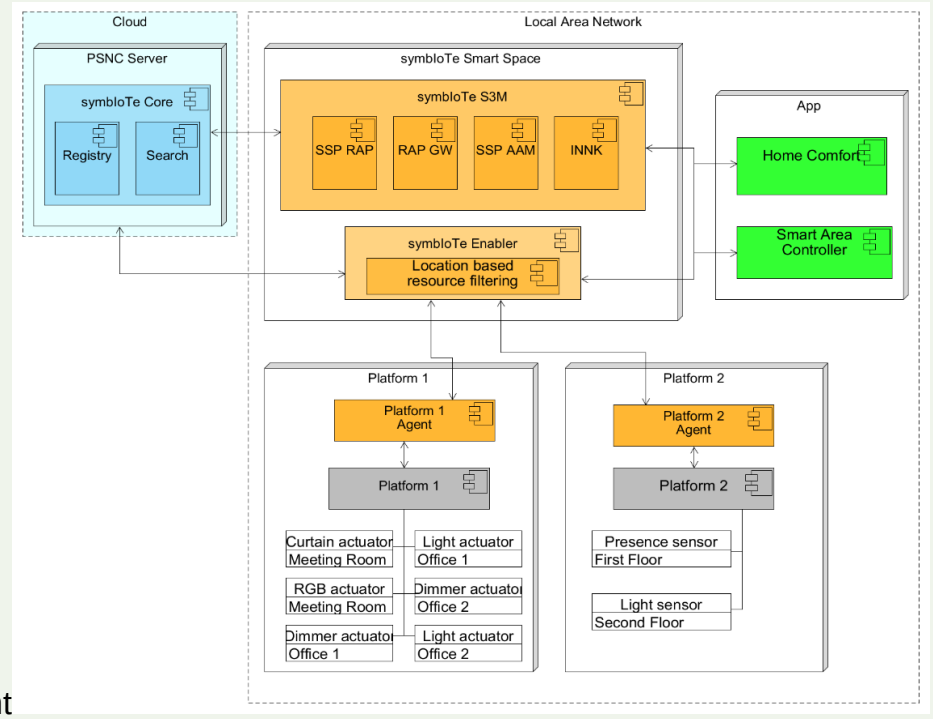
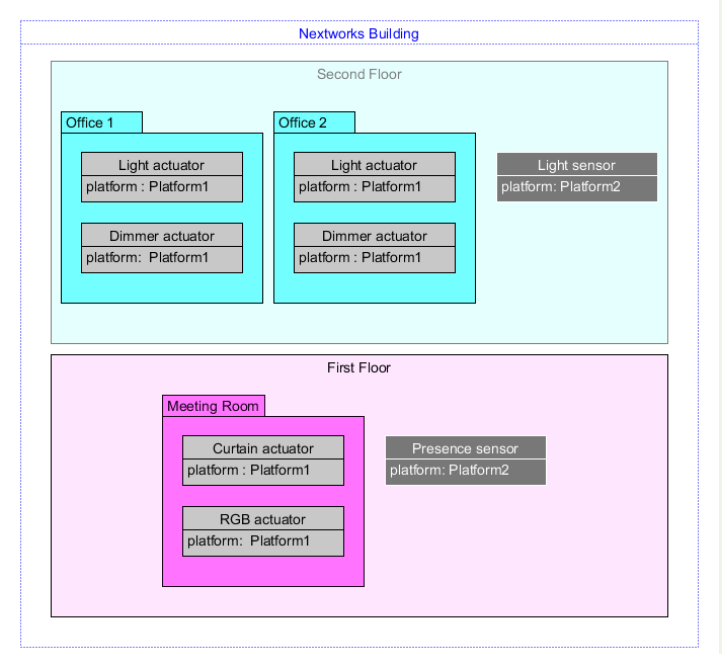
Test-card #	Symbyote_SR_NXW_3	**Execution Status**	*PASSED*
Test Name	Smart Residence – Smart Area Controller APP		
Objectives	Verify the correct functioning of Smart Area Controller APP The mobile app should be capable of controlling devices all the devices registered in the SSP. It should be possible for the user to navigate through the hierarchical tree of locations		

<table>
<tr><td></td><td>to reach any devices (registered by both the platforms).

The application leverages on a specific enabler, which gives the possibility to filter the devices in the space, based on their position (building, floor, room, etc.). In this way, the application has to query the symbIoTe enabler in order to retrieve the list of the CPSs in the selected area and then to allow the user to control them.</td></tr>
<tr><td>KPIs to measure</td><td>
<table>
<tr><th>DESCRIPTION</th><th>PROCEDURE</th><th>TARGET VALUE</th></tr>
<tr><td>Correctly displayed locations</td><td>Each operator running the test gives one point for any location described in the topology and correctly displayed in the Smart Area Controller APP</td><td>50 points
(5 locations x 10 operators)</td></tr>
<tr><td>Correct hierarchical positioning of locations</td><td>Each operator running the test gives one point for any location described in the topology and correctly collocated in the hierarchical tree in the Smart Area Controller APP</td><td>50 Points
(5 locations x 10 operators)</td></tr>
<tr><td>Correctly accessible resources through locations</td><td>Each operator running the test gives one point for any resource described in the topology that appears and is collocated in the correct location in the Smart Area Controller APP</td><td>80 Points
(8 resources x 10 operators)</td></tr>
<tr><td>Correctly readable and writable resources</td><td>Each operator running the test gives one point for any readable sensor and writable actuator in the Smart Area Controller APP</td><td>80 Points
(8 resources x 10 operators)</td></tr>
</table>
</td></tr>
<tr><td>Related Use Cases</td><td>Smart Residence</td></tr>
<tr><td>Designers</td><td>Gino Carrozzo, Matteo Pardi, Luca Tomaselli, Lorenzo Neri</td></tr>
<tr><td>Related Test-cards</td><td>Symbyote_SR_NXW_1, Symbyote_SR_NXW_2</td></tr>
<tr><td>Attachments</td><td></td></tr>
<tr><td>Additional Comments</td><td></td></tr>
</table>

Trial resources and topology	

Required resources	Symphony L3 Agent on Platform 1 (Symphony);
	Symphony L3 Agent on Platform 2 (Symphony);
	Controlled devices over both Platforms;
	• Platform 1 resources:
	  ○ #1 Dimmer actuator
	  ○ #1 RGB actuator
	  ○ #1 Curtain actuator
	  ○ #1 Dimmer actuator
	  ○ #1 Light actuator
	  ○ #1 Light actuator
	• Platform 1 locations:
	  ○ #1 Meeting room
	  ○ #1 Office 1
	  ○ #1 Office 2
	• Platform 2 resources:
	  ○ #1 Presence sensor
	  ○ #1 Light sensor
	• Platform 2 locations:
	  ○ #1 First floor
	  ○ #1 Second Floor
	
	Smart Area Controller APP installed on 10 android devices
	10 operators to run the tests

Topology details	Deployment  Topology 

Test description		
Step #	**Step description and expected results**	**Status**
1	**Description**: Navigation through Locations: Verify that every location that appears in the topology is displayed and selectable in Smart Area Controller APP, for each correctly displayed location one point has been given by each operator.	50/50

	Expected Results: • #1 Meeting Room • #1 Office 1 • #1 Office 2 • #1 First Floor • #1 Second Floor **Measured Results:** • #1 Meeting Room • #1 Office 1 • #1 Office 2 • #1 First Floor • #1 Second Floor **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_3.1** to **Symbyote_SR_NXW_3.10**	
2	**Description**: Navigation through Locations, hierarchy verification: Verify that the hierarchical order of locations shown in the topology is reflected into the Smart Area Controller APP interface, for each location correctly collocated in the hierarchical tree one point has been given by each operator. **Expected Results:** • First Floor -> Meeting Room • Second Floor -> Office 1, Office 2 **Measured Results:** • First Floor -> Meeting Room • Second Floor -> Office 1, Office 2 **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_3.1** to **Symbyote_SR_NXW_3.10**	50/50
3	**Description**: Navigation through Locations up to resources: Every resource in the Smart Area Controller APP must be accessible and correctly reachable through any locations it is registered in, for any correctly displayed and collocated resource one point has been given by each operator. Expected Results:	80/80

- First Floor ->
  - Meeting Room ->
    - #1 Curtain actuator
    - #1 RGB actuator
  - #1 Presence sensor
- Second Floor ->
  - Office 1->
    - #1 Dimmer actuator
    - #1 Light actuator
  - Office 1->
    - #1 Dimmer actuator
    - #1 Light actuator
  - #1 Light sensor

Measured Results:

- First Floor ->
  - Meeting Room ->
    - #1 Curtain actuator
    - #1 RGB actuator
  - #1 Presence sensor
- Second Floor ->
  - Office 1->
    - #1 Dimmer actuator
    - #1 Light actuator
  - Office 2->
    - #1 Dimmer actuator
    - #1 Light actuator
  - #1 Light sensor

Comments:
These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_3.1** to **Symbyote_SR_NXW_3.10**

4	**Description**: Navigation through Locations: Verify that every resource that appears in the topology is readable (sensors) or writable (actuators) in Smart Area Controller APP, for each correctly behaving resource one point has been given by each operator. **Expected Results:** • #2 Dimmer actuator - Writable • #1 RGB actuator - Writable • #1 Curtain actuator - Writable • #2 Light actuator - Writable • #1 Presence sensor - Readable • #1 Light sensor - Readable **Measured Results:** • #2 Dimmer actuator - Writable • #1 RGB actuator - Writable • #1 Curtain actuator - Writable • #2 Light actuator - Writable • #1 Presence sensor - Readable • #1 Light sensor - Readable **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_3.1** to **Symbyote_SR_NXW_3.10**	80/80

Results

KPI DESCRIPTION	ACTUAL VALUE	TARGET VALUE
Correctly displayed locations	50	50 points (5 locations x 10 operators)
Correct hierarchical positioning of locations	50	50 Points (5 locations x 10 operators)
Correctly accessible resources through locations	80	80 Points (8 resources x 10 operators)
Correctly readable and writable resources	80	80 Points (8 resources x 10 operators)

Home Comfort

<table>
<tr><td>Test-card #</td><td>Symbyote_SR_NXW_2</td><td>Execution Status</td><td>PASSED</td></tr>
<tr><td>Test Name</td><td colspan="3">Smart Residence – Home Comfort APP</td></tr>
<tr><td>Objectives</td><td colspan="3">Verify the correct functioning of Home Comfort APP
Home Comfort App consists of
• Back-end running on a server, that manages core operations monitoring the sensors and activating the actuators
• Front-end accessible via web for scenarios creation and configuration

The purpose is to set conditions on comfort environmental parameters like luminosity, temperature etc. in order to reach the desired comfort state.
These tests verify the interoperability between resources registered by separated platforms and their capability to cooperate in a scenario.
The Home Comfort APP interacts with any resource and navigates through every locations being completely unaware of the Platform that registered it.</td></tr>
<tr><td rowspan="5">KPIs to measure</td><td>DESCRIPTION</td><td>PROCEDURE</td><td>TARGET VALUE</td></tr>
<tr><td>Correctly displayed locations</td><td>Each operator running the test gives one point for any location described in the topology and correctly displayed in the Home Comfort APP</td><td>50 points
(5 locations x 10 operators)</td></tr>
<tr><td>Correct hierarchical positioning of locations</td><td>Each operator running the test gives one point for any location described in the topology and correctly collocated in the hierarchical tree in the Home Comfort APP</td><td>50 Points
(5 locations x 10 operators)</td></tr>
<tr><td>Correctly accessible resources through locations</td><td>Each operator running the test gives one point for any resource described in the topology that appears and is collocated in the correct location in the Home Comfort APP</td><td>80 Points
(8 resources x 10 operators)</td></tr>
<tr><td>Scenarios Creation</td><td>Each operator creates his own scenario setting conditions on sensors and operations on actuators.</td><td>10 Points</td></tr>
</table>

		The operator gives one point if the scenario is correctly created.	
	Scenario Working	Each operators controls the correct functioning of the created scenario creating on sensors the expected conditions and verifying the correct behaving of actuators. One point is given if the scenario works properly.	10 Points
Related Use Cases	Smart Residence		
Designers	Gino Carrozzo, Matteo Pardi, Luca Tomaselli, Lorenzo Neri		
Related Test-cards	Symbyote_SR_NXW_1, Symbyote_SR_NXW_3		
Attachments	None		
Additional Comments			

Trial resources and topology	

Required resources	Symphony L3 Agent on Platform 1 (Symphony);
	Symphony L3 Agent on Platform 2 (Symphony);
	Controlled devices over both Platforms;
	• Platform 1 resources:
	  ○ #2 Dimmer actuator
	  ○ #1 RGB actuator
	  ○ #1 Curtain actuator
	  ○ #2 Light actuator
	• Platform 1 locations:
	  ○ #1 Meeting room
	  ○ #1 Office 1
	  ○ #1 Office 2
	• Platform 2 resources:

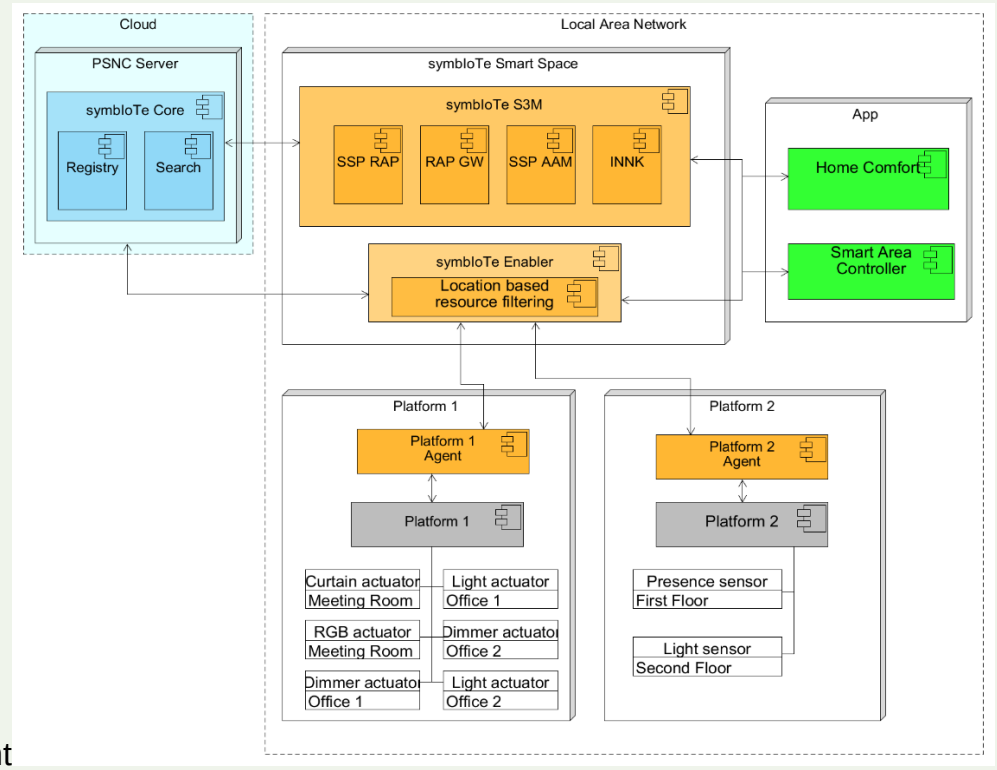
- #1 Presence sensor
- #1 Light sensor

- Platform 2 locations:
  - #1 First floor
  - #1 Second Floor

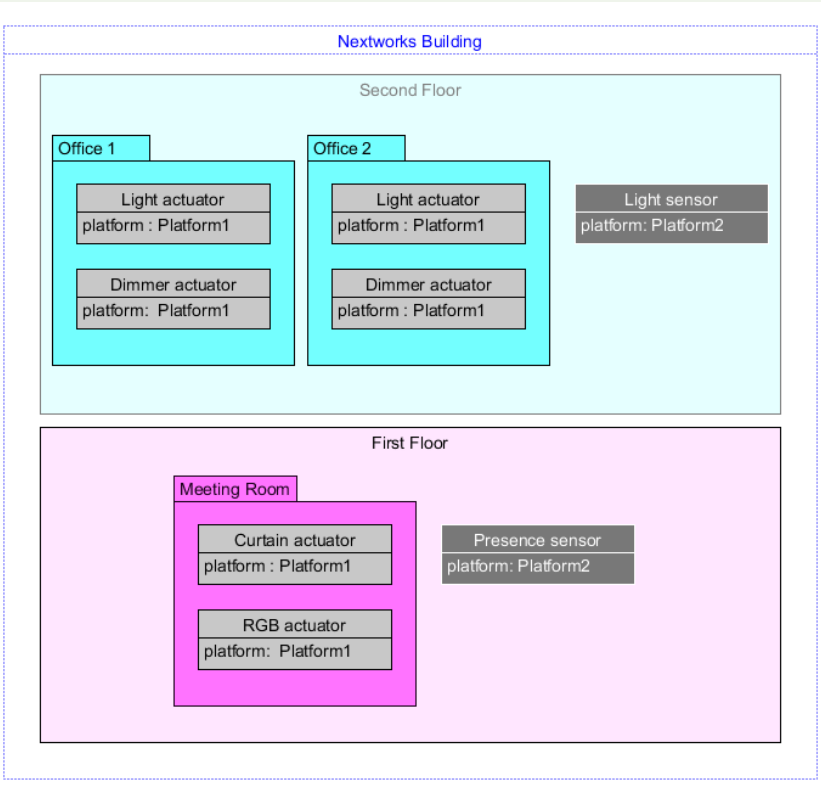
Home Comfort APP installed on 10 devices

10 operators to run the tests

Topology details



Deployment Topology



Test description		
Step #	**Step description and expected results**	**Status**
1	**Description**: Navigation through Locations: Verify that every location that appears in the topology is displayed and selectable in the Home Comfort APP, for each correctly displayed location one point has been given by each operator. **Expected Results:** • #1 Meeting Room • #1 Office 1 • #1 Office 2 • #1 First Floor • #1 Second Floor **Measured Results:** • #1 Meeting Room • #1 Office 1 • #1 Office 2	50/50

	• #1 First Floor • #1 Second Floor **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_2.1** to **Symbyote_SR_NXW_2.10**	
2	**Description**: Navigation through Locations, hierarchy verification: Verify that the hierarchical order of locations shown in the topology is reflected into the Home Comfort APP interface, for each location correctly collocated in the hierarchical tree one point has been given by each operator. **Expected Results:** • First Floor -> Meeting Room • Second Floor -> Office 1, Office 2 **Measured Results:** • First Floor -> Meeting Room • Second Floor -> Office 1, Office 2 **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_2.1** to **Symbyote_SR_NXW_2.10**	50/50

3	**Description**:
	Navigation through Locations up to resources:
	Every resource in the Home Comfort APP must be accessible and correctly reachable through any locations it is registered in, for any correctly displayed and collocated resource one point has been given by each operator.
	Expected Results:
	• First Floor ->
	  ○ Meeting Room ->
	  ▪ #1 Curtain actuator
	  ▪ #1 RGB actuator
	  ○ #1 Presence sensor
	• Second Floor ->
	  ○ Office 1-> ▪ #1 Dimmer actuator
	  ▪ #1 Light actuator
	  ○ Office 1->
		80/80

	▪ #1 Dimmer actuator ▪ #1 Light actuator o #1 Light sensor **Measured Results:** • First Floor ->: o Meeting Room ->: ▪ #1 Curtain actuator ▪ #1 RGB actuator o #1 Presence sensor • Second Floor ->: o Office 1->: ▪ #1 Dimmer actuator ▪ #1 Light actuator o Office 2->: ▪ #1 Dimmer actuator ▪ #1 Light actuator o #1 Light sensor **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_2.1** to **Symbyote_SR_NXW_2.10**	
4	**Description**: Scenarios creation: At the moment of a new scenario creations rules must be empty and every possible condition/action combination (depending only on sensors and actuators in the location) must be selectable. Define an Example Scenario setting conditions on any available sensor and actions on any available actuator. **Expected Results:** • Every possible condition/action combination available (given the topology) • Scenario correctly created with the rules chosen by the operator: scenario 'ExampleXXX' appears with the expected rules in the scenario's list of the app **Measured Results:** • Every possible condition/action combination available (given	10/10

	the topology) • Scenario correctly created with the rules chosen by the operator: scenario 'ExampleXXX' appears with the expected rules in the scenario's list of the app **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_2.1** to **Symbyote_SR_NXW_2.10**	
5	**Description**: Scenarios rules check: Once scenario's rules are set their correct execution must be checked creating the desired conditions on sensors and verifying the correct reactions of actuators. **Expected Results:** • Respect of scenario's rules **Measured Results:** • Scenario rules respected **Comments**: These results are expected for every operator and registered in test cards from **Symbyote_SR_NXW_2.1** to **Symbyote_SR_NXW_2.10**	10/10

Results	KPI DESCRIPTION	ACTUAL VALUE	TARGET VALUE
	Correctly displayed locations	50	50 points (5 locations x 10 operators)
	Correct hierarchical positioning of locations	50	50 Points (5 locations x 10 operators)
	Correctly accessible resources through locations	80	80 Points (8 resources x 10 operators)
	Scenarios Creation	10	10 Points
	Scenario Working	10	10 Points

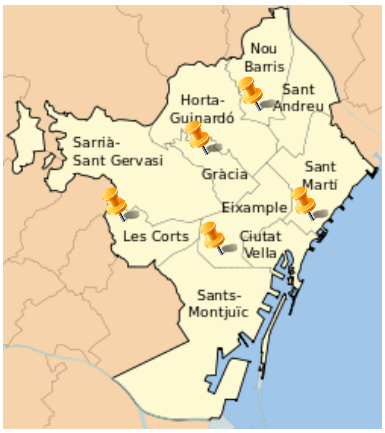
8.1.2 Smart Healthy Indoor Air

8.1.2.1 Deployment

Five different locations inside Barcelona city were evaluated. The indoor equipment available for each location include the following products:

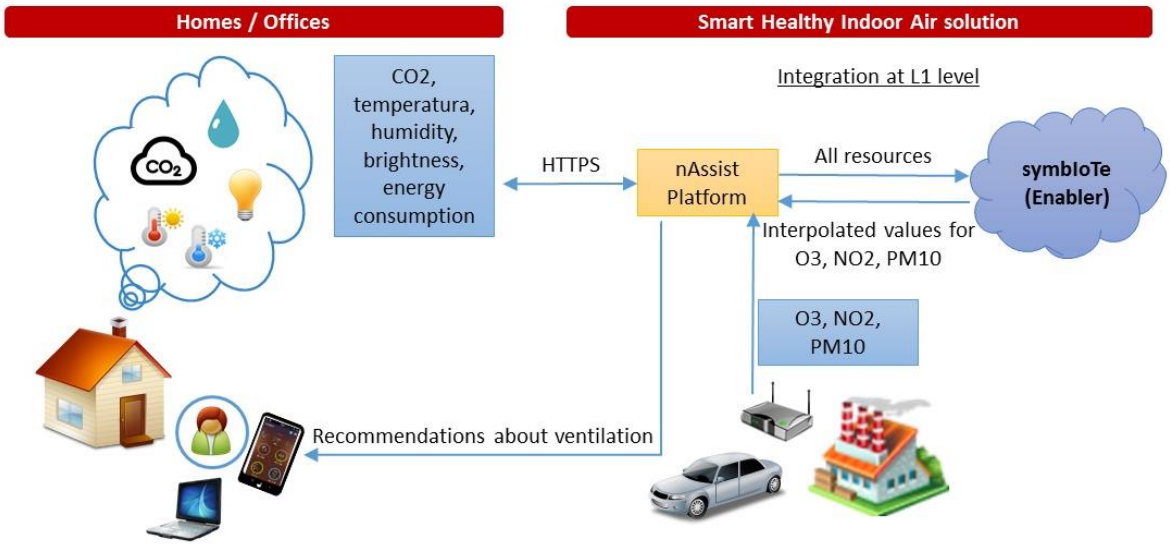
- 1 gateway for communication
- 1 multi-sensor 4x1 (motion, temperature, humidity, and luminosity)
- 1 CO2 sensor
- 1 Electricity energy consumption

- 2 smart energy plug (electricity measuring and on/off for towel heater and TV)



In addition, the interpolation function from the Enabler provides interpolated values for O3, NO2 and PM10 for a specific house location given the GPS coordinates of the fixed stations. The platform registers a set of sensors (O3, NO2, PM10) located in seven different outdoor fixed stations in Barcelona: Ciutadella, Eixample, Gracia, Palau Reial, PobleNou, Sants, and Vall Hebron. The next diagram shows the overall architecture deployed by each house.

Participants were recruited among those who were familiar with the enControl system and live in different areas of Barcelona city. We evaluated the same five subjects from April to November 2018. Since the five subjects are familiar with the system, it was not necessary a training session to explain them the system. We asked them to carry out their normal routines.



8.1.2.2 KPIs

We have defined KPIs to measure the functionality of the application from the user point of view and from a technical point of view:

Type of KPIs	Description	Target Value
Integration	Seven resources registered by each indoor installation (five houses)	35 resources registered
	Three resources registered by seven outdoor fixed stations	21 resources registered
	Interpolated values for each installation (O3, NO2 and PM10) being updated hourly	Values from 15 resources being updated hourly from enabler
	Generation of recommended ventilation strategies when indoor air quality is low	Creation of messages by the notification system. The rule engine detects that the indoor air quality is lower than a threshold, then notification system creates a message with a recommended ventilation strategy
	Values from all sensors are being updated	Updated values hourly
Application	State of sensors	On-state for all sensors and actuators
	Connectivity of the gateway	Ping received every 4 minutes
	State of the database	All resources stored and values updated according to the sending frequency for each type of sensor
	Functioning of the rule engine	Recommendations generated when indoor air quality level is bad
	Functioning of the notification system	Recommendations visualized in the user application
	System usability assessment	Usability assessment above 68 according to the SUS tool and two or more affirmative answers to indicate that the system can increase the quality of life.

8.1.2.3 Issues & Risks

The main issue during pilots was the sensors monitoring to make sure that all of them were reporting correctly. The battery management was the main constraint for the indoor

sensors. On the other hand, some outdoor sensors ever stopped working for some days but we did not have any direct control over them to fix the problem.

8.1.2.4 Functional tests – Status and Results

The following tests were carried out in order to validate the integration of the nAssist platform with the symbIoTe core:

Test Description	Status	Results
Registration of the nAssist platform	Passed	nAssist platform listed
Registration of the resources	Passed	A total of 64 resources were registered: • Three sensors (O3, NO2, PM10) for 7 fixed stations • Eight sensors (CO2, temperature, humidity, energy consumption, brightness, O3, NO2, PM10) for 5 houses • Three actuators (tower heater, TV, wall plug) for 2 houses
Interpolation function updates hourly values for O3, NO2, PM10 for each house by taking into consideration the GPS coordinates and values of the fixed stations and GPS coordinates of the houses	Passed	• Interpolation function finds fixed stations through a search in the core • Checking manually the output of the interpolation function
Data exchange between the interpolation function and nAssist platform. Resources are required to be found through a search in the core	Passed	• Interpolation function finds fixed stations through a search in the core • Output from the interpolation function matches with the data visualised in the user application

8.1.2.5 Execution of the trials with users – Status and Results

The following tests were carried out in order to evaluate the functionality of the application and the user experience:

Test Description	Status	Results
To guarantee the correct functioning of sensors and actuators through the application.	Passed	Monitoring of the list of sensors and actuators through the Devices functionality. All values were updated according the sending frequency configuration of each sensor.

To guarantee the correct functioning of the gateway. The gateway sends a ping to the cloud every 4 minutes to indicate that it is working fine. If there is not any ping received after 10 minutes, the notification system sends an alert.	Passed	A ping command sent from the gateway every 4 minutes. When the gateway lost its connectivity, an automatic notification was sent to the application.
To validate the correct storage of the data coming from sensors in the database of nAssist platform.	Passed	Database updated with values from all resources.
To validate the correct functioning of the rule-based reasoning engine. The rule engine generates the recommendation to the user when the indoor air quality is not good according to some rules.	Passed	Generation of recommendations when the indoor air quality was modified manually to check the rule engine functionality.
To validate the notification system which will send a recommendation to the user through the application when the rule engine detects a bad indoor air quality.	Passed	Recommendations received by the user when a bad indoor air quality was detected.
To measure the user acceptability. Two different questionnaires were provided to the user to complete after the trial. One questionnaire is for measuring the usability of the system (System Usability Scale, SUS) and the other one is to measure the effectiveness of the recommendations to improve the user's quality of life.	Passed	• The SUS score was calculated for each user. Three participants got a score above 68 and 2 participants below 68. • Two or more affirmative answers from the dichotomous questionnaire indicates that the system helps to improve the quality of life. Two participants got two or more affirmative answers and three participants had less than two affirmative answers.

8.1.2.6 Conclusions

Two different sets of tests were carried out to evaluate the integration of the nAssist platform into the symbIoTe system and the functionality of the application, from a technical and a user experience point of view. The use of the user questionnaires were intended to measure perceived ease-of-use and perceived improved quality of life, distinguishing between unusable and usable systems. One critical point was the small number of

participants and, therefore, the limited number of trials that does not allow us gain conclusions about the user acceptability and the functionality of the application in terms of improving the participants' quality of life. However, the evaluation of the integration of the platform into the symbIoTe system did not depend on the number of trials.

8.1.3 Smart Mirror

SMILA was deployed to AIT offices in the Smart Business Center in Graz, Austria for a period of one month starting with Oct 5th, and the trial ended on Oct 22nd. 7 people (3 female, 4 male) were recruited from offices in the Smart Business Center over the course of two weeks. Participants signed an informed consent in agreement with European General Data Protection Regulation (GDPR) following a personal information conversation. Moreover, participants were handed out smart phones with de-identified google accounts for privacy reasons. Actual weight measurements were de-identified as well before data got stored in the database.

Figure 3: Smart Mirror SMILA

Following inclusion and exclusion criteria where used for interested participants:

Inclusion criteria:

1. Participants are older than 18 years

Exclusion criteria:

1. Participants wears active or passive implants (e.g. pacemaker, stents, insulin pumps)
2. Participants suffering from cardiac arrhythmia
3. Pregnancy
4. Participants suffering from EMF syndrome
5. Participants taking beta blockers or antiarrhythmic medication
6. Participants suffering from rheumatism
7. Known allergies against product materials as found in common fitness trackers (especially in wristbands)

User interaction was not explained or shown to end-users. Finally end-users were are asked to keep a personal “interaction diary” in order to document any successful or failed interaction.

A total of 35 interactions with the mirror were recorded over the time of four weeks. 28 (80%) interactions were successful (meaning the whole workflow could be completed) and 7 interactions failed. Compliance with respect to daily measurements was 94.28%.

Test Description	**Status**	**Results**
Number of correctly recorded weight measurements	Passed	28/35 (80%)
Number of correctly recorded measured personal well-beings	Passed	22/28 (78,5%)
Average confidence for speech recognition	Passed	0,83 (±0,07)
User compliance	Passed	94,28%
User acceptance (for use in daily life)	Passed	SUS Score 74.17 (B-)

8.1.3.1 KPIs

We have defined KPIs to measure the functionality of the application from the user point of view and from a technical point of view:

Type of KPI	**Description**	**Target**
Integration	Number of correctly recorded weight measurements	>80%
Integration	Number of correctly recorded measured personal well-beings	>80%
App	Average confidence for speech recognition	>75%
App	Number of repeated weight measurements	< 20 %
App	Number of repeated questions for personal wellbeing	< 20 %
Usability	User compliance	>50%
Usability	User acceptance (for use in daily life)	>50%

8.2 Smart Mobility & Ecological Routing

8.2.1 Deployment

The use case is deployed across three consortium members (AIT, UNIZG-FER and UW), where each member is responsible for its own components and maintains its own platform. The SMEUR Enabler is running at the UNIZG-FER site, but it is a joint work of all three involved partners (UNIZG-FER, AIT and UW). The overall architecture is depicted in Figure 4.

The use case deployment relies on the two mobile applications published in Google Play store: 1) CUPUS crowdsensing application[6] that gathers data from mobile sensors (UNIZG-FER sensors and DunavNet sensors); and 2) the symbIoTe SMEUR routing application[7] which offers POI search and green routing information. The CUPUS app is a pure OpenIoT application which uploads sensor data acquired by mobile phones and wearable air quality sensors to the OpenIoT platform. It exposes collected sensor data using symbIoTe L1 components (mainly RAP). Similarly, AIT created an extension for the openUWEDAT platform to expose data collected from stationary stations across Austria and Croatia) using symbIote middleware, and UW's MoBaaS platform exposes sensors deployed in Porto. For Vienna, the routing service used was developed by AIT and, for Zagreb and Porto, MoBaaS routing engine, developed by Ubiwhere, was used. symbIoTe core services are running on PSNC's servers, supporting the use case with services for registration and discovery of resources (i.e., data sources).

[6] https://play.google.com/store/apps/details?id=hr.fer.tel.cupusmobileapp
[7] https://play.google.com/store/apps/details?id=com.ubiwhere.symbiote

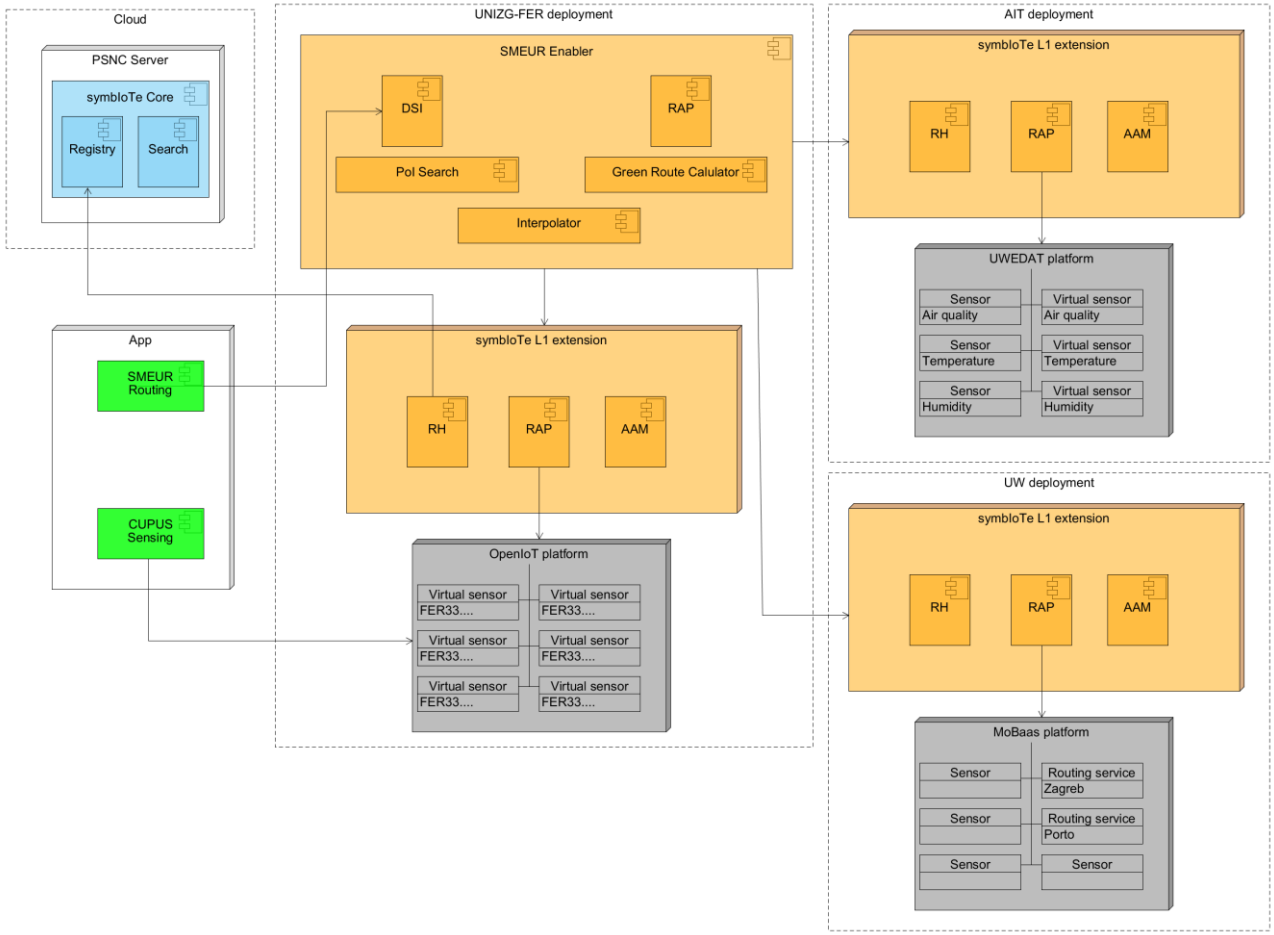


Figure 4: SMER use case deployment

Vienna

To obtain official air quality data for Vienna, the official source for air quality data in Austria provided by the UBA was used. The UBA data was pulled from their server and stored in a system, hosted by AIT (openUwedat). This system was integrated as a L1 platform in symbIoTe and the 17 sensors were registered in the core. The routing enabler was then able to find these sensors and provider their data for the interpolator. To provide smart ecological routing for Vienna, AIT's routing engine was updated to use the air quality data provided by this interpolator as an additional parameter for the route calculation.

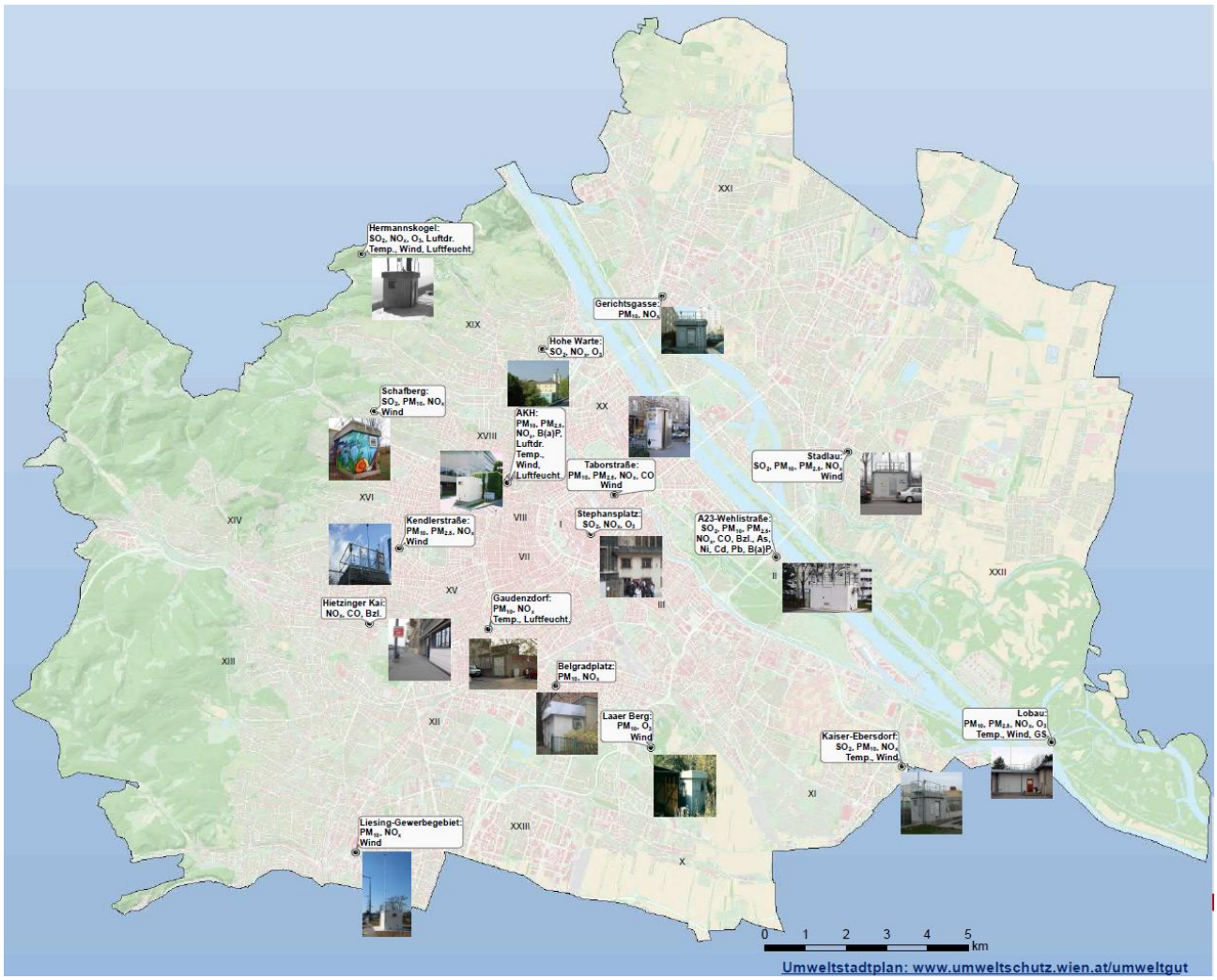


Figure 5: Stationary air quality stations in Vienna

Wearable sensors for the trial participants were built by DunavNet, based on the specification of AIT and FER. Overall 20 mobile sensors were used in the trial, from which ten were provided to the participants, and the other 10 sensors were used for testing and stationary measurements.

Figure 6: Mobile air quality sensors used in Vienna

Zagreb

The city of Zagreb is covered by observations gained from fixed environmental stations (integrated through the openUWEDAT platform) and wearable sensors that we carried by end users. Wearable sensors were connected to mobile phones acting as gateways to transmit air quality readings to the OpenIoT platform. The mobile sensors used in Zagreb, both by UNIZG-FER students and volunteers recruited by our OC2 winner Sindikat Biciklista are shown in **Figure 7**. The trials in Zagreb started in June (organized by UNIZG-FER) and were organized by Sindikat Biciklista from September to November 2018). Wearable sensors sense CO and NO_2 gas levels, temperature, humidity and atmospheric pressure, and end user mobile phone gathers the noise level and luminescence. On average, 10 to 20 volunteers were actively acquiring air quality data during the trials, and each volunteer was carrying a wearable sensor for a duration of one to two weeks, depending on his/her availability. Volunteers were asked to acquire sensor data during their normal daily activities.

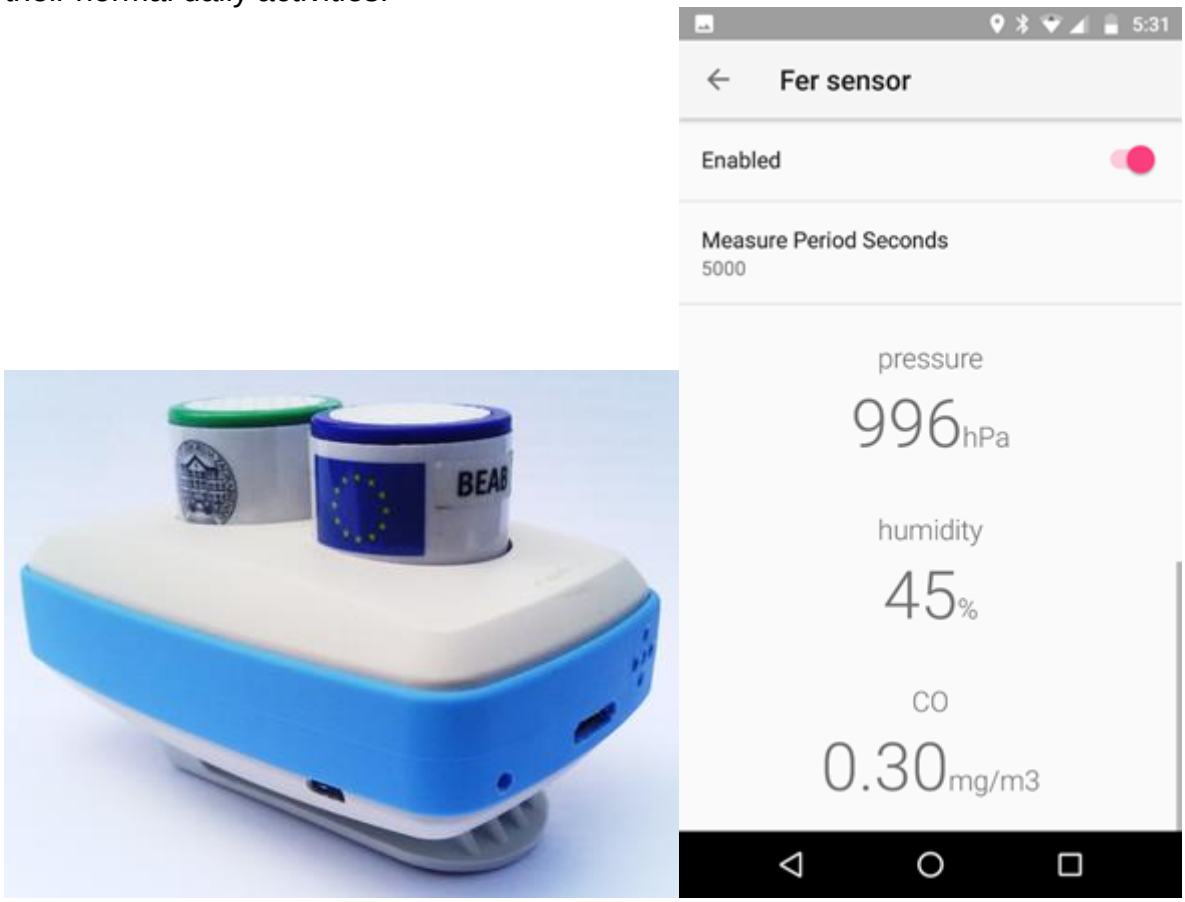


Figure 7: Wearable sensors used in the trials in Zagreb

Volunteers have collected air quality readings covering almost the whole city of Zagreb, as depicted in Figure 8, and the total of 56 stationary FER sensors were registered to convey readings from wearable sensors during the trials.

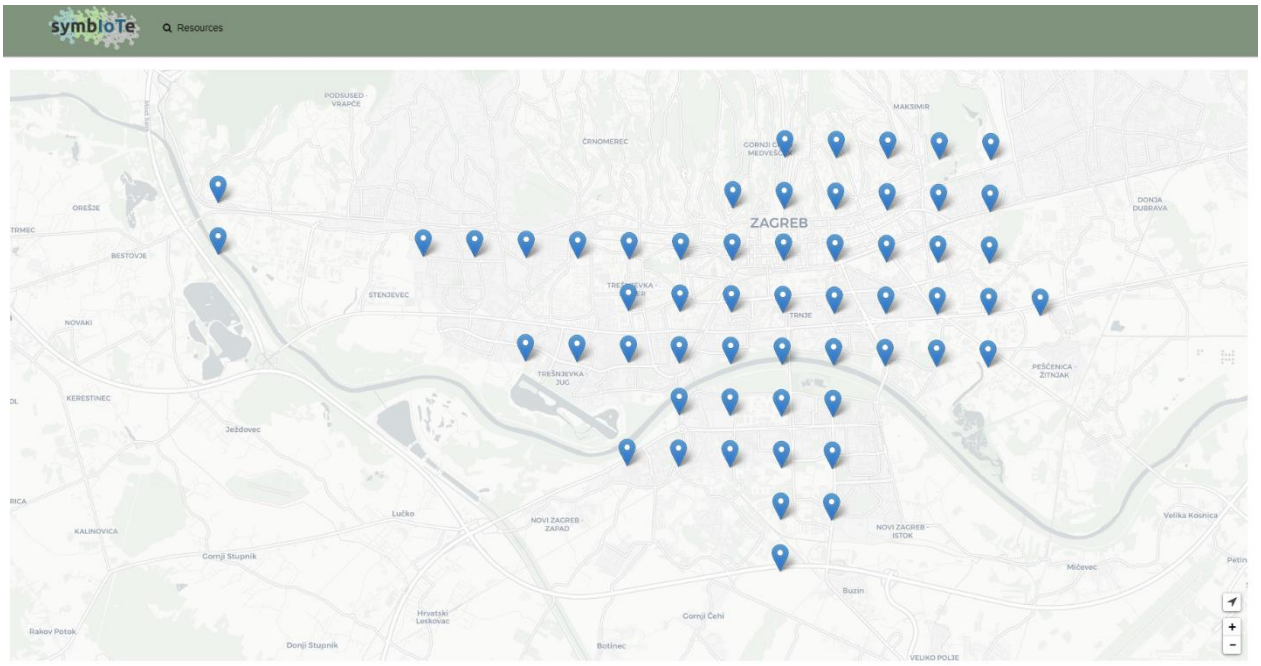


Figure 8: OpenIoT sensors registered in symbIoTe for the city of Zagreb

Porto

The air quality readings for the city of Porto comes from the MoBaaS platform, which gathers data from fixed air quality stations and wearable sensors (mainly the ones used in the OC2 extension for trials by Monitar). The sensors gather data about temperature, precipitation, noise levels, carbon dioxide, nitrogen dioxide, ozone, humidity, wind speed, light, solar radiation, carbon monoxide, PM1, PM2.5 and PM10. Trials were run during November and December, where 20 users used the developed application and reported their experiences.

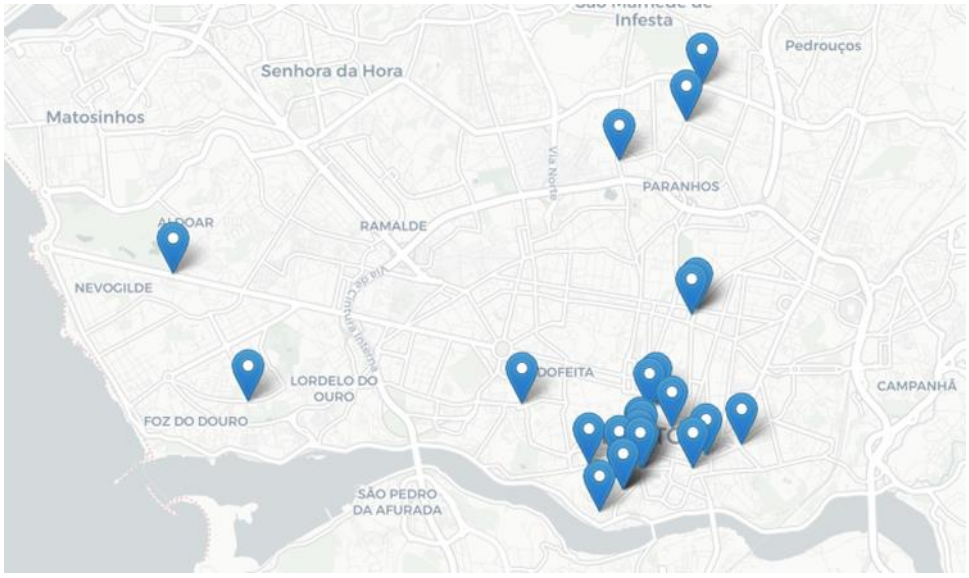


Figure 9: Air Quality Sensors in Porto

The trials were organized in a way that they could be done at the same time as the OC2 extension winners MONITAR trials. This way, more air quality data could be gathered at the same time, both from fixed and mobile sensors.

Figure 10: Air Quality sensor in Porto

8.2.2 Execution of the trials with users – Status and Results

8.2.2.1 Test Flow

Vienna

For the end-users, weekly training sessions where organized to introduce the system and to obtain their consent for participation and data handling. Prerequisites for taking part in the trial were regular walks by foot or commute by bike in the inner ring of Vienna. Participants then were asked to install both CUPUS as well as SMEUR app on their private smartphone and receive a mobile sensor provided by the AIT. Related material (user manual, GDPR consent, trial consent form, rental agreement) were prepared and handed out to the users. The trainings took place at AIT and UNIVIE between 20. August and 17. September.

Each participant received a compensation in the form of an external USB battery pack. All of these users had a sensor box for the duration of the trial and installed the SMEUR app, as well as the smart ecological routing app installed on their own mobile phones.

Zagreb

As already stated, the second trial in Zagreb was organized by the OC2 winner Sindikat Biciklista. In order to encourage volunteers, mostly cyclists, from different parts of the city to participate in a real-world trial, Sindikat Biciklista organized four workshops and three promo events in coordination with UNIZG-FER to inform users about the project and demonstrate the usage of both applications. The organized events had a high impact on the audience and resulted with an increased number of both CUPUS as well as SMEUR application downloads in the following days. In total 53 volunteers from Zagreb downloaded the CUPUS Crowdsensing App, and 189 volunteers downloaded the SMEUR

Routing App. Altogether, the recruited volunteers collected 123,309 different measurements about their environment during the three months period as shown in Table 7. The most measurements were obtained during October which confirms that the organized promo events had a great success among volunteers in Zagreb.

Table 7 Number of measurements which were collected during the trial period

Measurement type	September	October	November
ambientLight	2840	15413	9549
noise	8536	15413	9687
CO	3596	6410	2593
humidity	3683	6084	2813
NO2	3353	5898	2585
pressure	3696	6544	2734
temperature	3697	5471	2714

Porto

The trials in Porto started in November and provided good results and valuable feedback, to the developed application and enabler, and symbIoTe in general.

Users either used their personal mobile phones or were provided a phone by Ubiwhere, and used the app between the 5th of November and 7th of December.

In overall 48 participants across all sites filled out the questionnaire. While in Zagreb as well as in Vienna participants used both apps and the sensor pack, in Porto only the routing app was tested:

Table 8 - Trials' Participants

Location	Participants	Questionnaires obtained	Apps
Zagreb	~40	8	CUPUS + Routing
Vienna	26	26	CUPUS + Routing
Porto	~20	14	Routing

The majority of participants were 25-34 years old, some were older (35-44), while only a small percentage was either under 25 or over 45. All of the participants were skilled Android users, since owning a private Android phone was a prerequisite. Most of the participants did walk or bike regularly in their respective cities (see Figures 10 - 12).

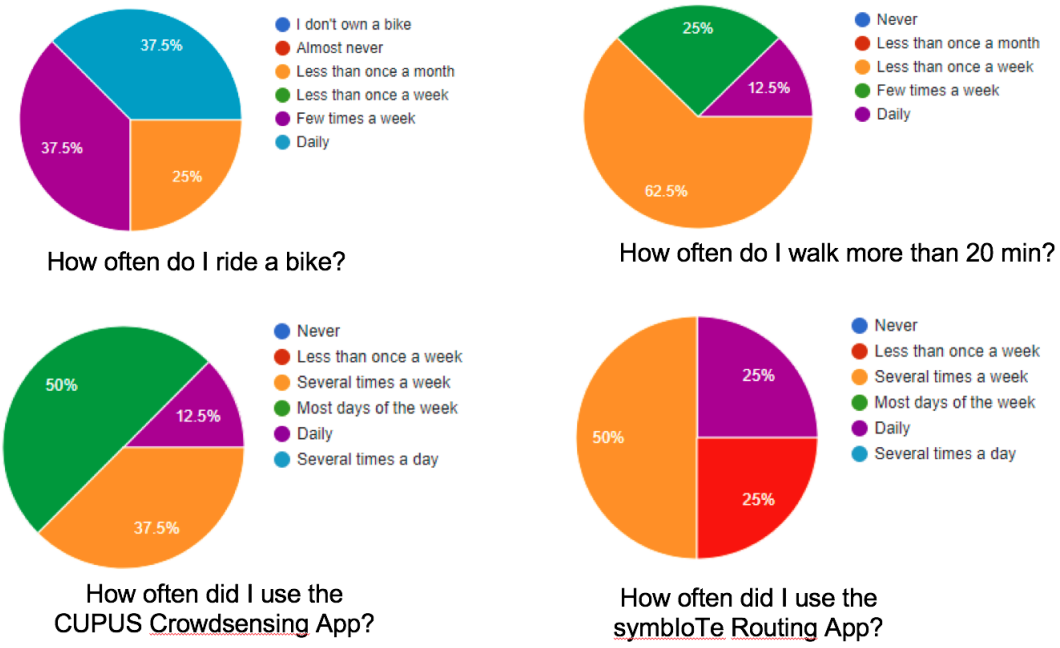


Figure 11: Commuting behaviour and app usage in Zagreb

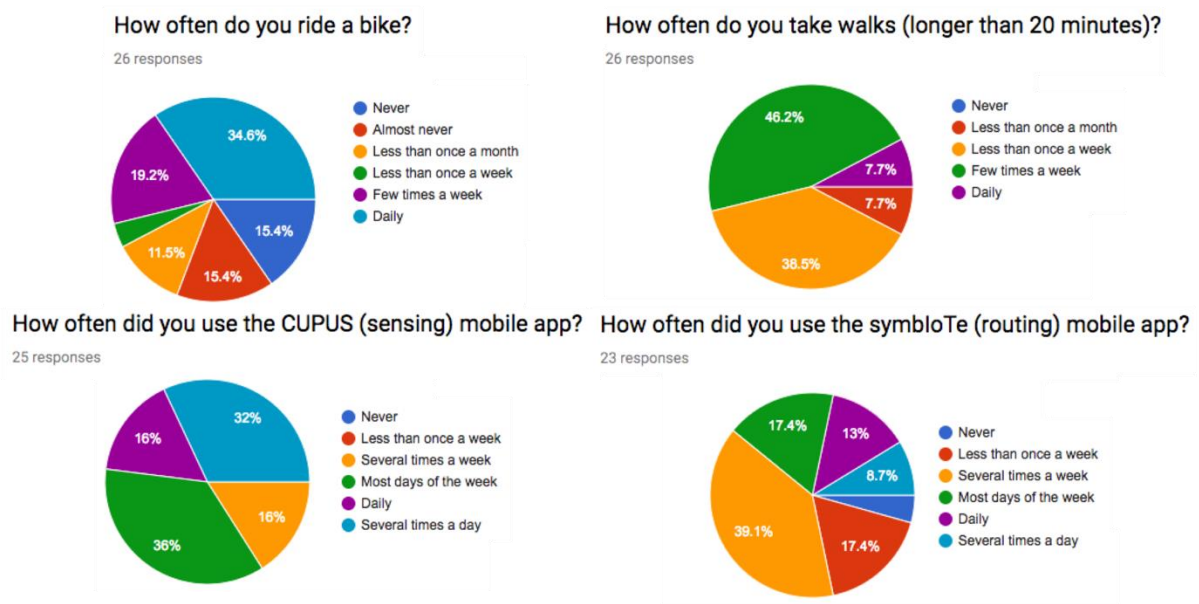


Figure 12: Commuting behavior and app usage in Vienna

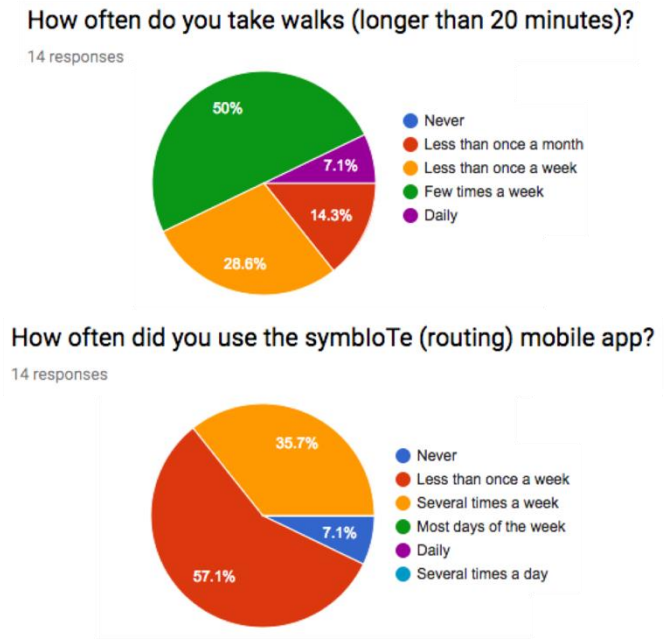


Figure 13: Commuting behaviour and app usage in Porto

8.2.2.1.1 Likes

Participants **liked many aspects of the system**. Especially the idea behind the use case, namely ecological routing, was something many end users were interested in and found it highly valuable. Participants saw a high value in routes through their city with good air quality and said that not only routes, but also other higher-impact decisions would profit from better knowledge about air quality. One Participant stated: *"I think just having a detailed map of air quality data would be more interesting though, seeing as I would probably want to choose destinations based on air quality"*. Another end user said that air quality maps often contain large gaps, and that portable sensors could fix this issue at the root. Other use cases like the real estate market, city-wide traffic routing and environmental monitoring in general were mentioned.

Despite certain usability issues, participants praised the simplicity and the clean design of the **SMEUR routing app**. One participant stated that *"finding routes between current location and POIs is very easy to do"*. Also fast response and non-existent delay of route calculation and presentation on the smartphone was mentioned. Participants also said that they found the POIs nearby interesting and that they learned something about their surroundings.

For the **CUPUS sensing app** the end users especially liked that they could directly observe the gathered data in real time. Thus, they could monitor the air quality on their daily routes and gain insights into the air pollution they encountered during their day: (I like to…) *"Get (almost) instant feedback on air quality for the routes I take quite often"*. It seemed to appeal their scientific curiosity.

8.2.3 Conclusions

The SMEUR use case was developed by UNIZG-FER, AIT and UW in cooperation with their local communities and OC2 winners, Sindikat Biciklista and MONITAR. The main

goal was to address the problem of urban pollution in European cities and offer “green” ecological routes to the end-users. To achieve this goal, citizens of Zagreb, Vienna and Porto were utilized to participate in real-world trials, and collect dense spatio-temporal data about their environment, as well as to use the routing application to their destinations. In total, more than 80 users actively participated in the trial, and more than 230 users at least once tried the routing application. After the trial, participants were asked to respond to a questionnaire and provide their feedback regarding both applications.

8.3 EduCampus

8.3.1 Deployment

The backend application for the IOSB room reservation application and the KIT campus navigation application has been deployed on virtual machines within the DMZ areas in IOSB and the KIT data center.

Figure 14: EduCampus deployment shows the two virtual machines with the main components. For both installations, the dockerized symbIoTe Cloud deployment was used.

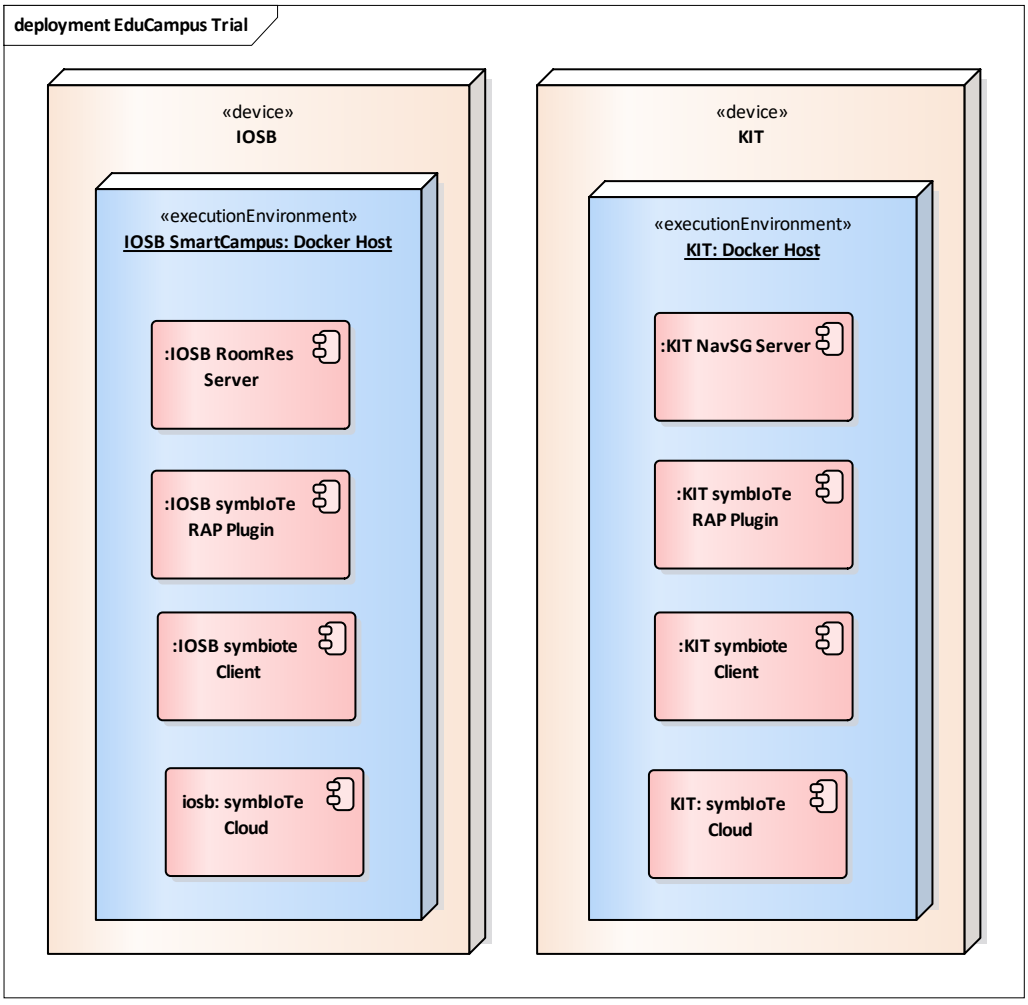


Figure 14: EduCampus deployment

It turned out, that the requirements on the virtual machine in terms of memory and CPU usage, was rather high. The KIT administration suffered from long loading times (up to 30 min) and very high RAM utilization, which caused problems in system response times for the server administration.

The KIT navigation application is based on an Android App, which is shown in Figure 16. It provides information on the current location, which either is derived on GPS location in case the user us outside a building or based on BLE triangulation if the user is inside a building.

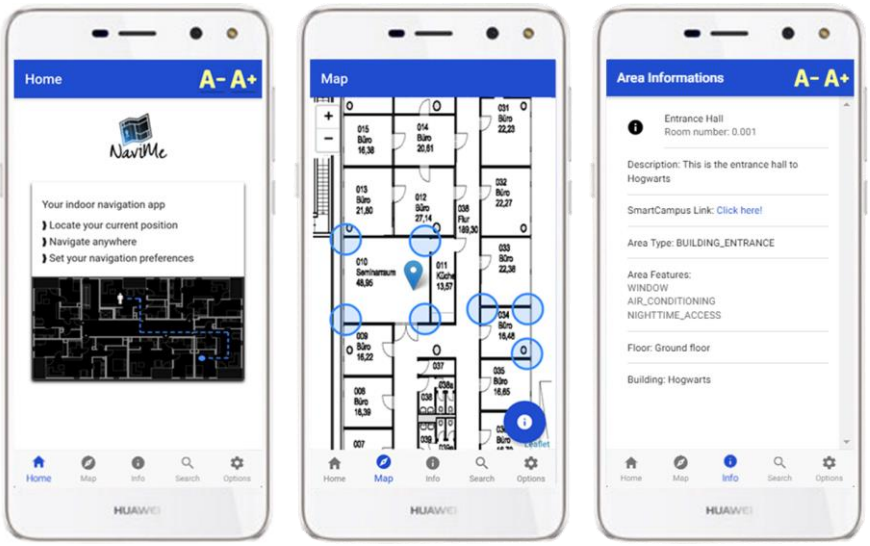


Figure 15: KIT Mobile Navigation Application

The IOSB room reservation application shown in Figure 17 is also based on an Android App. It gives information on nearby rooms, based on BLE signal strength. The reservation feature is based on a calendar that allows reservation of room and the creation of meetings with other users.

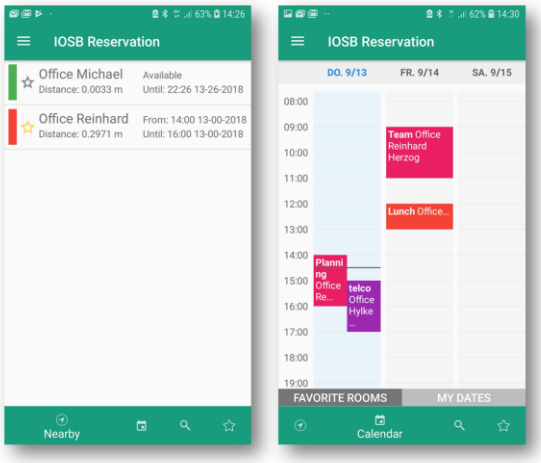


Figure 16: IOSB Mobile Reservation Application

In general, both applications and their backend services are ready to be integrated via symbIoTe but as the needed functionality for semantic mapping in symbIoTe is not released at time of writing they remain separate applications for now.

8.3.2 Federation with Open Call 2 partners

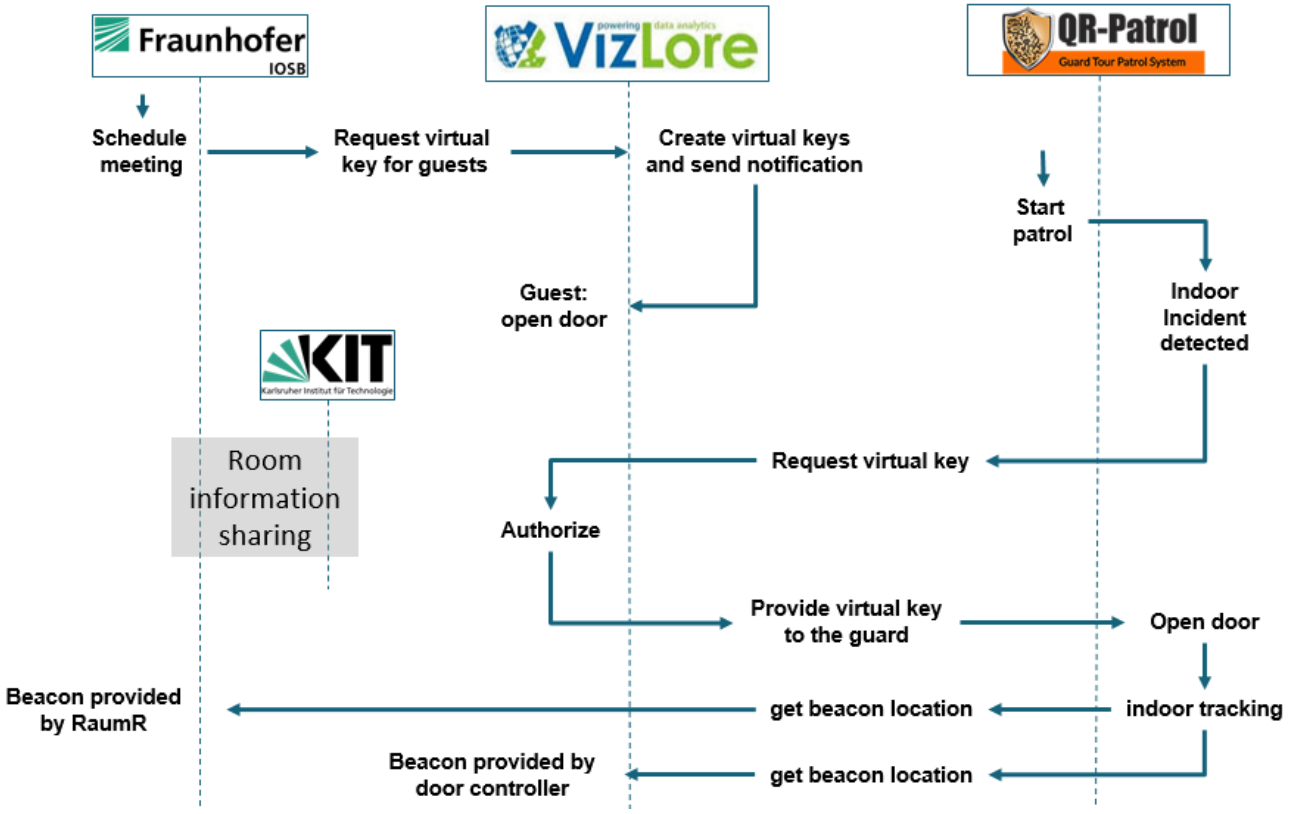


Figure 17: Use Case workflow on federation with OC2 partners.

Additionally to the federation with KIT we added two of the OC2 winners to the federation and realized an integrated use case shown in Figure 17. The workflow is as follows. Once a meeting via the Fraunhofer IOSB app is scheduled for a certain room and guests, a virtual key for all the external guests is generated by calling the *createVirtualKey* service from VizLore application. Upon entering the IOSB premises, external guest can unlock only the doors required to get to the meeting room using the default VizLore application. The second part of the workflow deals with external security patrols using the QR-Patrol app and outdoor BLE beacons to document they are actually monitoring the desired area. Before creating this federation, tracking was only possible outside and they had physical keys to enter the building when they detect an incident inside the building. For the time the security guards went inside the building, tracking was not possible. Now, with the functionality newly added by this federation, they do not require physical keys but are granted access through virtual keys as soon as they report in inside incident via the QR-Patrol mobile app. Once inside, their position can be monitored using the existing indoor BLE beacons from IOSB and VizLore platform.

The federation is using symbIoTe L2 and a shared custom information model including BLE beacon descriptions as well as services (e.g. create virtual keys) and actuators (e.g. open door). From a user's point of view, the use of symbIoTe is completely transparent

meaning users only see the mobile apps they have been using before. All the integration and interoperability between the systems happens on backend-side.

8.3.3 Functional tests – Status and Results

As integration of semantic mapping into symbIoTe core components was delayed far after the time the trials should be run, we decided to at least provide some functional and performance tests for the semantic mapping components itself.

The tests were divided into three parts:

- Performance test for data translation using the symbIoTe client API (mocking all external requests)
- Performance test for data transformation using different sizes of data
- Performance test for SPARQL Query rewriting

All tests were executed as a JUnit tests on a laptop with Intel Core i7-4720HQ CPU with 16GB RAM running Win10 Enterprise Edition and Netbeans IDE. Each test was run 50 times. Calculated times are the median execution time in milliseconds with a drop of 20% (i.e. 10% fastest and 10% slowest runs were dropped).

Performance test for data translation using the symbIoTe client API

Goal of this test is to validate functionality of the semantic client library and performance of the semantic mapping in a way it would be used in any real application. All calls to other symbIoTe components (namely Search and ResourceAccessProxy) were mocked. The scenario for the test was as follows. There are two L1 platforms registered in the Core, platformA and platformB. Each of the platform uses its own PIM, i.e. platformA uses modelA and platformB uses modelB. Both PIMs have an overlap in domains, i.e. there are classes in one of the PIMs that semantically align with the other PIM and vice versa. They are referred to as classA and classB thereafter (see Figure 18). Furthermore, a mapping between modelA and modelB is registered in the Core mapping classA to class B and vice versa (see Listing 1 for an example). PlatformB offers a service that takes an instance of classB as parameter and returns an instance of classB, i.e. the method signature looks like service(classB) → classB. Now platformA (or someone else only knowing modelA) wants to use the service but without knowing (and caring), that it uses modelB. Furthermore, the caller of the service wants to use Java classes as in- and output of the service to deliver himself of the burden to manually en-/decode them to/from String (which is the only format RAP supports). The function call is shown in Listing 2.

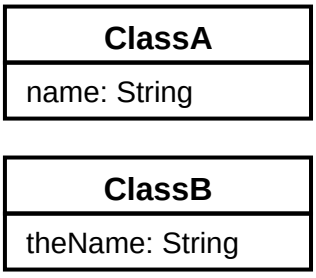


Figure 18:
Class diagram for modelA and modelB

```
BASE <http://example.org/A#>
PREFIX b: <http://example.org/B#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>

RULE
  CONDITION
    CLASS :ClassA
      :name TYPE xsd:string
  PRODUCTION
    CLASS b:ClassB
       b:theName VALUE REFERENCE :name
```

Listing 1:
Mapping from modelA to modelB

```
ClassA result = semanticRapClient.invokeServiceWithMapping(
      RESOURCE_ID_SERVICE,        // symbIoTe ID of service to call
      new ClassA(),               // service input, class must use
                                     provided JSON-LD annotations
      ClassA.class,               // result type, also needs
                                     JSON-LD annotations
      true,                       // server validation (from RAP client)
      HOME_PLATFORM_IDS);         // home platform IDS
```

Listing 2: Example call to symbIoTe semantic client library.

In the following, we explain in detail what steps happen in the semantic client library when executing this function call.

1. The ID of the PIM used for the input parameter is determined by either HOME_PLATFORM_IDS (if possible) or by finding a PIM containing the used semantic classes and properties.
2. The ID of the PIM used for the service is resolved based on the resource ID of the service.
3. Both mappings (forward, i.e. from modelA to modelB, and backward, from modelB to modelA) are fetched from the Core.
4. The actual input (i.e. new ClassA()) is converted to JSON-LD based on annotations in ClassA.
5. The forward mapping is parsed and executed.
6. The actual service is called via RAP from platformB with the result from previous step as payload.
7. The backward mapping is parsed and executed.
8. The resulting JSON-LD is parsed to an instance of ClassA and is returned.

Steps 1 to 3 are executed as SPARQL queries to the Search component. For the test they are mocked, i.e. no real connection to the Search happens but the result is provided locally. The actual resource access in step 6 is also mocked. The semantic mapping library is used in step 5 and 7 for parsing and execution.

Two different scenarios were tested. The simple scenario uses very simple PIMs with only one class and the most trivial mapping (renaming a property). The EduCampus scenario works with the information models prepared in the use case for KIT and IOSB. They contain multiple classes and three mapping rules including a custom JavaScript transformation function. The simple scenario uses only one instance of a class as payload, the EduCampus scenario uses three instances (one beacon and two locations).

Table 9 – Performance results for the simple scenario (in ms).

find PIMs		Access	Mapping						Overhead	Total
service (by resource ID)	client (by platform ID)	invoke service	client -> service			service -> client				
			get	parse	execute	get	parse	execute		
0,40	0,50	0,08	0,42	0,88	4,78	0,59	0,91	5,34	11,30	25,38
0,90			12,92							

Table 10 – Performance results for the EduCampus scenario (in ms).

find PIMs		Access	Mapping						Overhead	Total
service (by resource ID)	client (by platform ID)	invoke service	client -> service			service -> client				
			get	parse	execute	get	parse	execute		
0,34	0,41	0,07	0,36	2,88	25,43	0,55	2,86	13,72	12,68	59,36
0,76			45,79							

There are a few things to keep in mind when interpreting these results. Finding and getting PIMs as well as invoking the service are mocked. This explains why they only take less than 1ms. In reality, such a SPARQL query takes around ~600ms as tested manually. The most interesting results are the time for actually transform the data (highlighted in red) which is roughly ~20ms for the simple scenario and ~50ms for the EduCampus scenario. As a RAP call takes around 800-1200ms (based on manual tests), this is reasonable cheap to be used in real-world scenarios.

In reality, each call to find a PIM as well to get a mapping is a SPARQL query to the Search that takes ~600ms. This has an important impact on performance in reality. Calls to find PIMs are only added for convenience and can be left out (by manually providing the PIM IDs) wherever more performance is needed. The call to get mappings from the Core is essential but caching could be implemented to reduce the costs.

It is to note, that execution time of mappings will increase with the amount of data to transform but the same applies to sending/fetching data to/from RAP. The following figure shows how execution time for executing one-way mappings scale with size of the data.

Performance test for data transformation using different sizes of data

Figure 19 shows how execution time of data transformation increases with size of input data. For each of the two scenario multiples of the original test size is used. It is shown, that for the simple scenario the execution time is almost linear but in fact, it is just increasing very slowly. For the complex mapping, it shows that execution time is scaling linear with the size of the input. These results indicate that semantic mapping through data transformation is feasible in the real world.

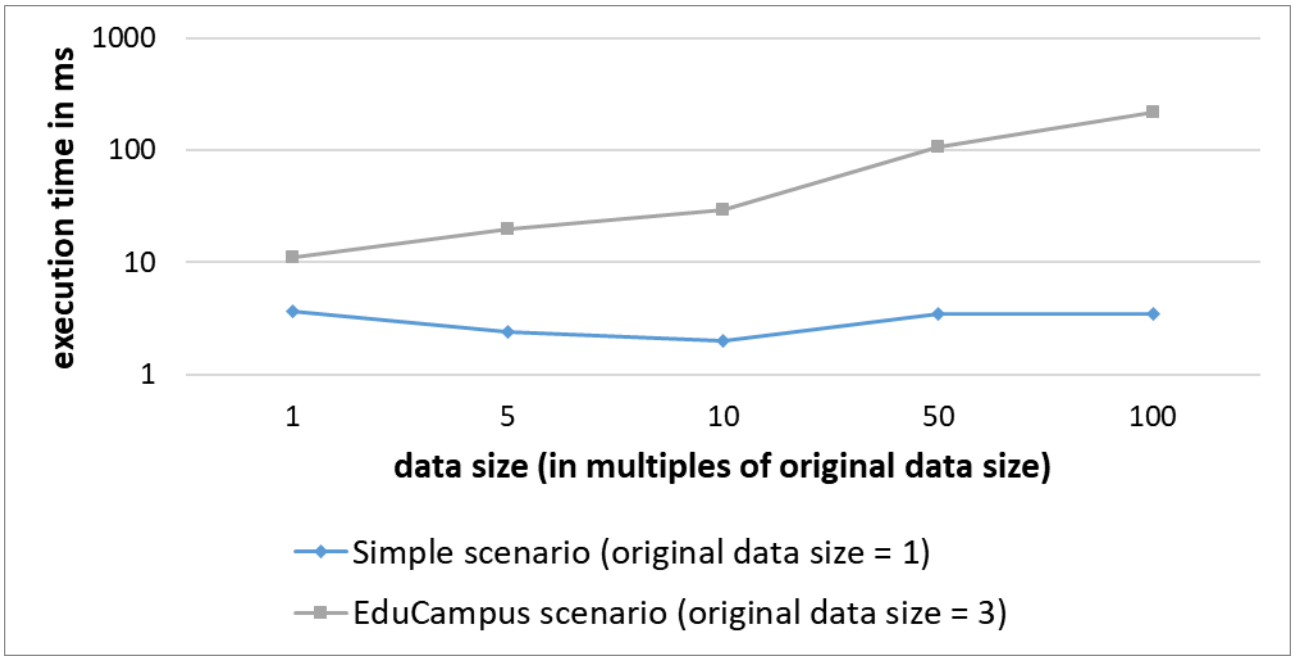


Figure 19: Performance for executing semantic mapping with varying data size.

Performance test for SPARQL Query rewriting

For federated resource lookup, symbIoTe Search needs to identify available mappings and for each mapping found, rewrite the original search query, execute it and merge the results. Tests show, that it takes 10.6 (mean) ± 3,6 (st.dev) ms to do such a query rewriting for the EduCampus scenario. Performance of query rewriting only depends on query and mapping length/complexity. As the rewritten queries can the executed in parallel in symbIoTe Search, this approach seems very promising.

8.3.4 Conclusions

The federation with OC2 partners shows how synergy effects can easily be achieved once there is a technical framework like symbIoTe reducing the technical overhead of implementation.

The performance of semantic mapping has shown to be good enough to be integrated into real-life systems with adding roughly an overhead between 0.5% (simple scenario) and 2% (EduCampus scenario) to regular RAP access (for data size of 10). Currently, finding used PIMs/mappings, which are just syntactic sugar, introduces overhead. However, with some minor additional work, this can easily be reduced dramatically e.g. by introducing caching.

8.4 Smart Stadium

8.4.1 Deployment

The Smart Stadium trials took place at the premises of **Atlètic Terrassa Hockey Club** (ATHC, http://athc.cat/), a sports club located just outside the city of Terrassa, about 30 km NW from the city of Barcelona.

Figure 20: Atlètic Terrassa Hockey Club logo

The picture below shows a map of ATHC premises.

Figure 21: Map of ATHC premises

ATHC is running a team of field hockey that participates in the Spanish national league, and which is also usually participating in the European championships, the Euro Hockey League.

For simplicity, Smart Stadium solution is deployed in a single virtual machine instance, as the following diagram depicts:

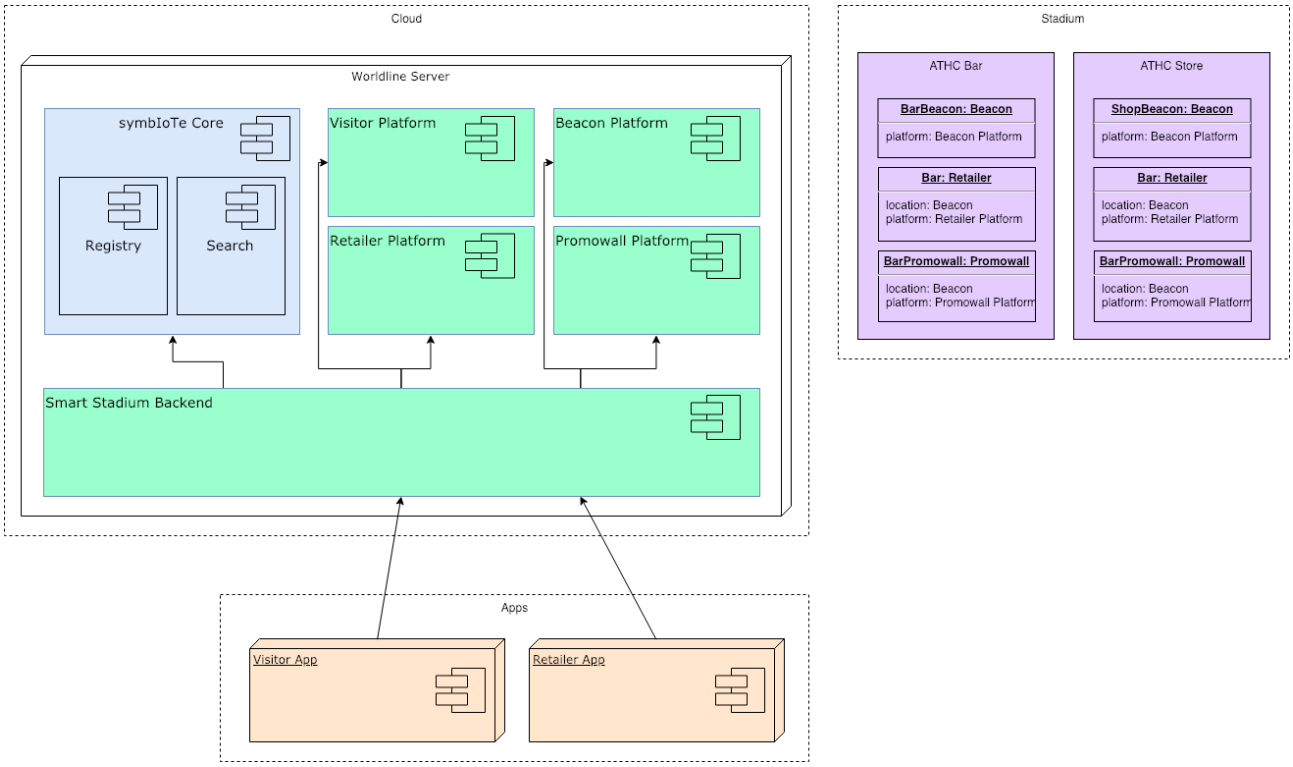


Figure 22: Smart Stadium deployment diagram

Client applications connect to Smart Stadium Backend and interact with physical beacons located in two selected areas in the stadium: ATHC Bar and ATHC Store.

8.4.2 Execution of the trials with users – Status and Results

The trials took place during two important special events in ATHC facilities with several matches from different categories (men and women, child and senior):

- End of season social event: 17 June 2018
- Spanish Junior Hockey Championship: 21 - 24 June 2018

More than 1000 people met at the stadium in each of these events, and more than 250 of them downloaded the symbIoTe-enabled ATHC official application. This application is considered as a short-period usage application, since its purpose is to provide sports information, location information and retail information. Due to that, user session lives for a short period of time (2 to 3 minutes average at most). Hence, concurrency is not a key problem in a regular app usage, unless a promotion is sent to all users and all of them feel curious to read it as soon as they receive the notification in their app. In any case, the trials demonstrated that symbIoTe performance was optimum for this use case.

Finally, the many users that provided their feedback about symbIoTe-powered features felt impressed because of the power it provided to them, being remote ordering and location the most appreciated new features.

The following figures shown how positive were the answers that the stadium visitors provided through the app questionnaire:

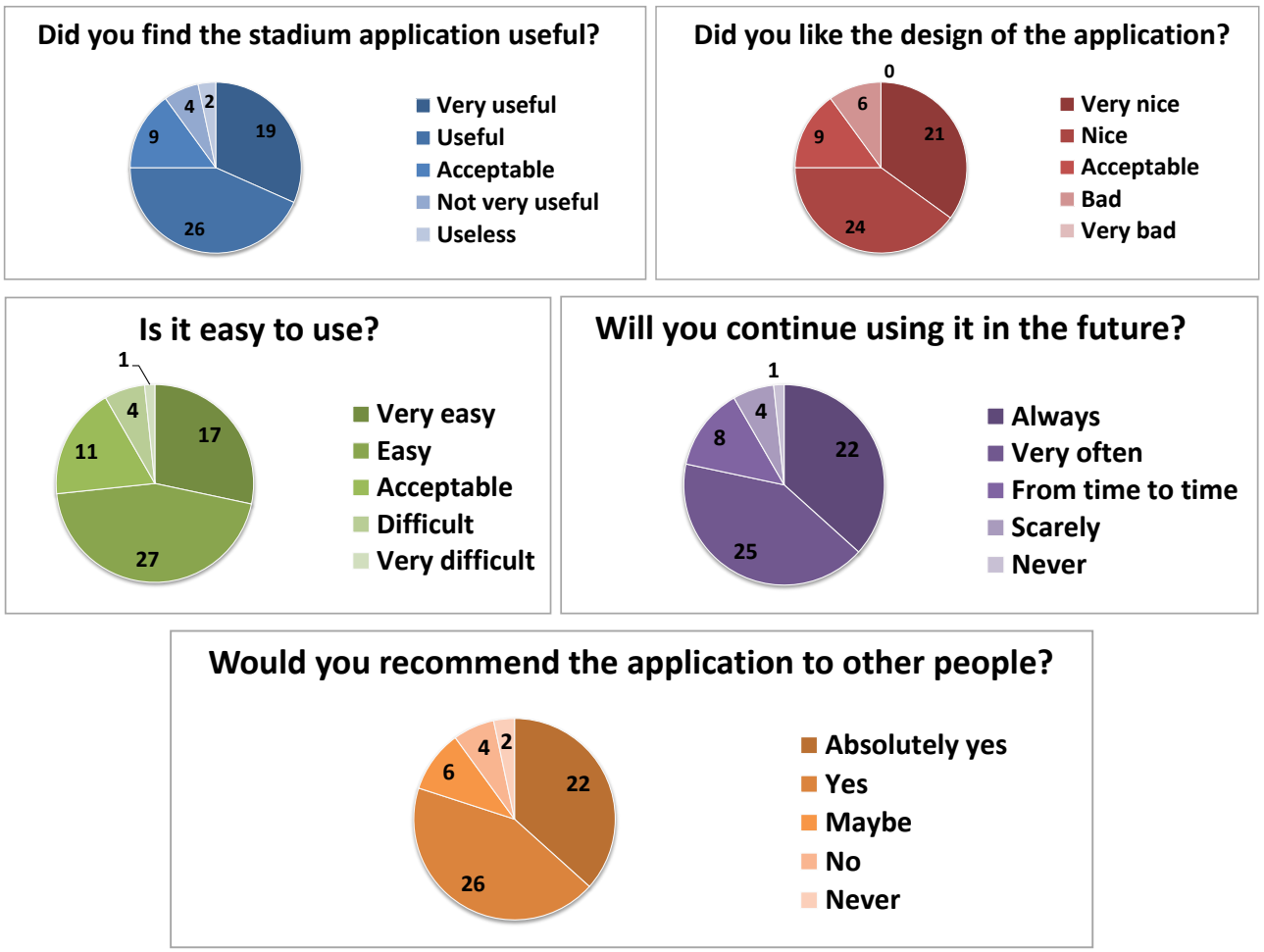


Figure 23: Summary of answers from Stadium visitors

8.4.3 Conclusions

ATHC and its supporters were very satisfied with the three applications (visitor, remote ordering and promowall) and what symbIoTe provided to them in the form of location and remote ordering features. The visitor mobile app (Atlètic Terrassa Oficial) is available both on Play Store (Android) and App Store (iOS).

The overall user and team satisfaction proves that the pilot was a complete success. The trials took place during events attended by more than 1000 people, from which more than 250 downloaded the visitor app. From these users, almost 70 answered the questionnaire, and they gave a qualification of more than 85% of positive scores. symbIoTe provided the ability to discover and dynamically access new devices ordered by proximity, as well as known and preregistered ones, and it was used to develop next evolution of customer immersion in stadiums.

8.5 Smart Yachting

8.5.1 Definition of the Test cards and Questionnaires

Two different test cards have been defined for the Smart Yachting use case, one for each of its two showcases. They include the general objective of the tests, the steps to take to perform validations, a description of the software components deployed for the tests and the KPIs to measure. Their complete description is available in two separate documents:

- For Smart Mooring: SY-TESTCARD-Smart_Mooring
- For Automated Supply Chain: SY-TESTCARD-Automated_Supply_Chain

After pilots, users were asked to complete an on-line questionnaire based on Google Form. The target users were the Port operators which were involved in the trials (they also "simulated" the role of Yacht owner, since the Yachts that have been used belong to the Ports).

The Questionnaire consists of 11 questions which center around the users expectations and experience during the trial. Users were also asked to express their opinions about the possibility offered by the new technologies introduced by symbIoTe. It was possible to collect the feedbacks of 5 out of the 6 users involved in the trial.

8.5.2 Deployment

Smart Yachting's trial took place in two Italian ports, Viareggio and Marina Cala De' Medici, in the Tuscany coast. The execution of the trial has been influenced by the availability of the SymbIoTe Smart Space Middleware (S3M), since Smart Yachting was a Level 3/Level 4 compliant use case and relied on this component. General validation started in late Spring/early Summer 2018, initially assuming that the Yacht was a "normal" L1 platform, and continued later on, when S3M has been released, till the month of October 2018.

From a technically viewpoint, each port exposed a S3M: their applications – Navigo's Portnet and Centrale Acquisti – were connected in symbIoTe through two dedicated Enablers. For simplicity's sake, the same deployment – shown in the diagram below – has been used for the two Ports, with minimal reconfigurations when the trial was performed in the second Harbour. This didn't spoil the generality of the trial, since all the tests of the use case involve only a single Port at the time.

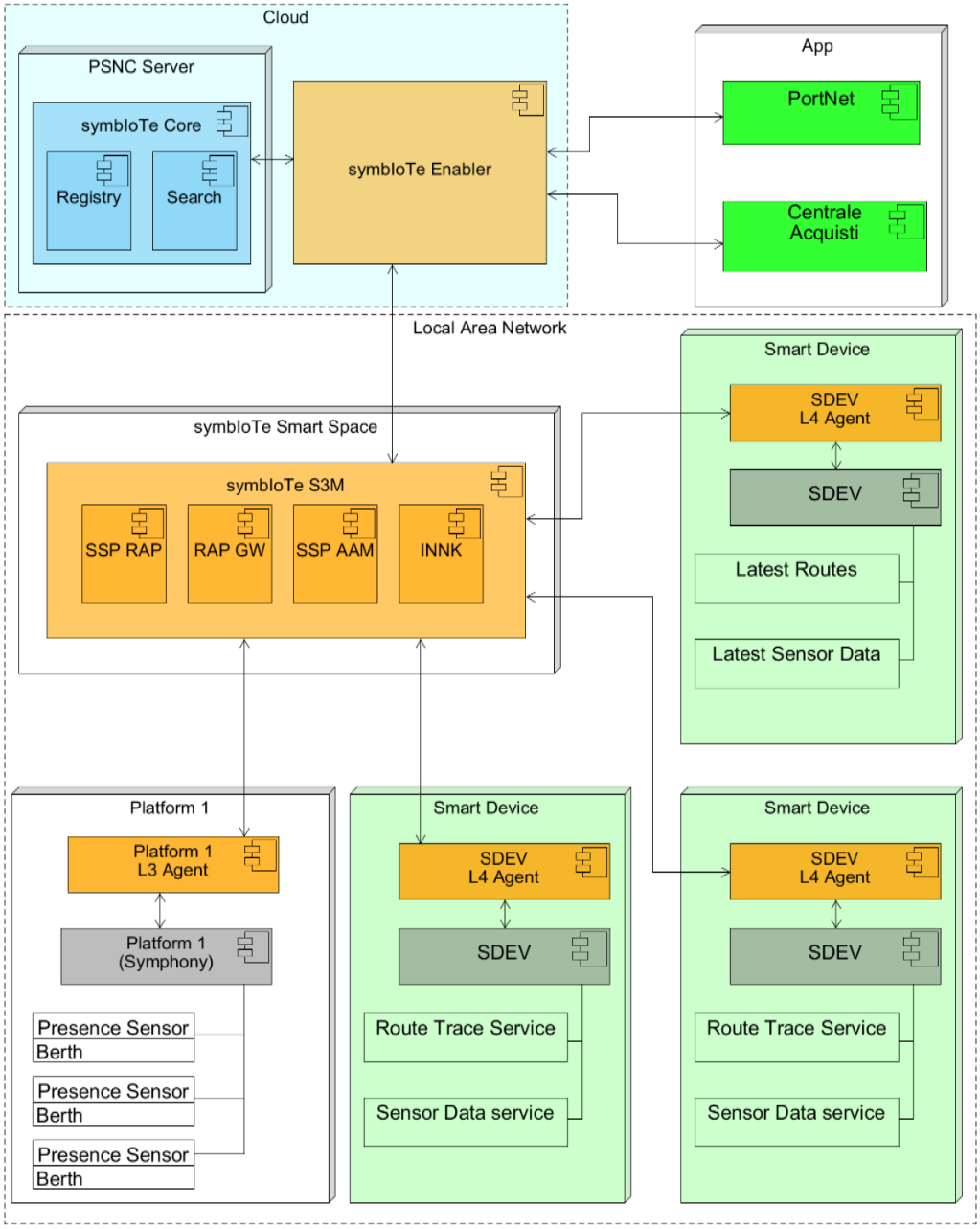


Fig. 1 – Smart Yachting trial deployment diagram

Separate set-ups, for each of the two showcases foreseen for the use case – Smart Mooring and Automated Supply Chain (ASC) – have been arranged.

For Smart Mooring the trial involved a real yacht to navigate towards Viareggio and berth in its port, while the Portnet mooring management application can automatically advance its workflow through the acquisition of data from several sensors.

The assessment involved:

- one Yacht

- 2 Port operators, one in the office, and one in the Pier. The former supervised the correct advancement of the mooring workflow in the Portnet App, while the latter was expecting the Yacht arrival on the destination Pier and could testify when it finally berthed (in order to verify if the presence sensor correctly detected the arrival of the boat).

The set-up included a LoRaWAN antenna installed in the Viareggio port, a LoRaWAN tag and various machine sensors on board of the yacht and LoRaWAN presence sensors in the Pier. Wi-Fi connectivity was also available for the berthing Yacht.

Automated Supply Chain required a simpler set-up, since its aim was to automatically identify the maintenance and supply needs on board of a Yacht, berthed on the Port and connected to the Internet via the Port's Wi-Fi. Services were exposed by Navigo's Centrale Acquisti market-place web application, where the services of 10 local companies are offered.

We arranged two separate trials, one in Viareggio and one in Marina Cala De' Medici, each one with a Yacht and two users (a Yacht owner and a Centrale Acquisti operator)

8.5.3 KPIs

Separate KPIs have been defined for the two showcases, as described in the table below.

Type of KPIs	**Description**	**Target Value**
Smart Mooring	Approval rating regarding the ease of use of the solutions prepared for Smart Yachting, as experienced by port personnel	> 90%
	Average global time spent by the port authority operators in managing a mooring procedure through symbIoTe	< 5 min (at present for the manual procedure it's more than 30 min)
	Percentage of data automatically acquired from the boat respect those managed manually	100%
	Percentage of extra data automatically acquired from the boat	> 50%
	Approval rating regarding the ease of use of the solutions prepared for Smart Yachting, as experienced by port personnel (as assessed through the questionnaires)	>90%
Automated Supply Chain	Number of possible suppliers to fulfill the yachts needs in the two ports	At least 10
	Percentage of the most common	>60%

	resupply yacht's needs that can be mapped through IoT sensors	

8.5.4 Issues & Risks

Smart Yachting was not an easy use case to assess, since for its actual execution a lot of different things had to be prepared.

First and foremost, the availability of a working implementation of S3M in late Summer pushed forward the timing initially foreseen for the trial. This wasn't a major issue anyway, since earlier technical tests were performed assuming the Yacht was a "normal" symbIoTe L1-compliant platform. This allowed the team to identify all the issues regarding the development of the Enablers and the actual interactions amongst the Yacht's IoT platform and the Navigo's Applications.

The yachts in the two ports had to be booked in advance and especially during touristic season their availability was very limited. In Summer also the personnel of the two Ports was often too busy to be involved in the trial. This forced to reschedule the final tests of the trial in late October.

Despite these issues, the Smart Yachting trial was successfully completed.

8.5.5 Functional tests – Status and Results

Several tests were carried out in order to validate the technical components of Smart Yachting. Some of the most significant validations carried out for the trial follow.

For Smart Mooring

Test Description	Status	Results
The mooring procedure is started by PortNet APP. PortNet APP expects a specific Smart Device registration over port SSP and it contacts the Enabler, which in turn starts polling periodically the Core for the Smart Device to connect to the SSP and register the services: • Latest routes • Latest sensor data	Passed	After Mooring procedure is started in the PortNet APP, the port SSP starts to receive periodic requests for Smart Device presence through its enabler.
As soon as the Smart Device is connected to the Port Wi-Fi (meaning that the Yacht has reached the harbour) it automatically starts the registration of two services: • Latest routes • Latest sensor data In order to verify this the SSP innkeeper is checked through a REST GET.	Passed	The Smart Device services are correctly registered and the Latest routes and Latest sensor data services are available and can be read by the enabler.

The innkeeper has also to register the new services on symbIoTe core. The core status is controlled through the WebApp.	Passed	All Smart Device services are correctly registered in the core, they are also searchable and their information accessible.
The Enabler starts polling for the services, and when it receives data from the Latest routes and Latest sensor data services, it informs the PortNet APP with the newly read data.	Passed	The Enabler received data and updated the PortNet APP with the information read
PortNet APP starts polling the proximity sensor on the berth to detect when the approaching yacht has finally docked	Passed	Proximity sensor status received in PortNet via the Enabler
Once the proximity sensor detects the presence of the expected yacht to the right berth, PortNet APP closes the mooring procedure.	Passed	Proximity sensor triggered and PortNet updated the workflow status

For Automated Supply Chain

Test Description	**Status**	**Results**
The procedure is started in the Automated Supply Chain APP by the yacht owner. Automated Supply Chain APP offers a set of goods and services suppliers which the yacht owner can contact for his/her needs and get offers on the requested goods or services. The Yacht (Smart Device) is contacted by the Automated Supply Chain (via the Enabler) and communicates its readings for consumable and/or maintenance needs. The APP shows the yacht owner the data gathered and prepares offer requests to be sent to the suppliers and get offers for them.	Passed	All Yacht's needs are translated into offer requests and correctly registered in the APP. The offer requests have been correctly received by the suppliers.
The IoT platform on board successfully detect the resupply needs on board through sensors	Passed	In the trial the following supply/maintenance needs were detected: • Fuel • Engine faults • Electric faults. Since the yachts used for the trial have limited electronics on board

		(they were both below 15 mts and quite old), these were the only possible needs that could be detected for the trial.

8.5.6 Execution of the trials with users – Status and Results

The following tests were carried out in order to evaluate the functionality of the application and the user experience.

For Smart Mooring

Test Description	Status	Results
Ease of use: the Portnet application, already known by the operators, have been extended to support the use case	Passed	The users didn't need any specific training because the general workflow of the App was respected.
Savings of time: total duration of the workflow is reduced by the introduction of the Smart Mooring functionality	Passed	The tests were repeated twice. The total timing spent for each use case by the operator has been of around 5 minutes, with a significant improvement over the current totally manual procedure.
Accuracy: all the steps of the workflow are taken in the correct order	Passed	All the steps in the Portnet workflow are correctly activated, as the Yacht arrives in the Port.

For Automated Supply Chain

Test Description	Status	Results
Ease of use: the Yacht owners should easily understand how to activate the needs detection	Passed	The Automated Supply Chain application was extended with an intuitive interface. The users involved in the trial didn't need any training nor documentation to use it.
Savings of time: the functionality must significantly reduce the time spent by the yacht owner to deal with local suppliers	Passed	Any need detected on board automatically generated a Request for offer at the right supplier.
Accuracy: As the yacht owner receives offers from the suppliers, he/she can arrange an agreement with the ones he/she chooses and make orders. The suppliers receive the offer requests and reply to them with their offer. The communication goes back and forth between the yacht	Passed	The offer requests generated are correctly received by the suppliers, which can make offers; the yacht owners are able to create orders out of them.

owner and the suppliers until an agreement is reached		

8.5.7 Conclusions

SmartYachting trial aimed to validate the vision of seeing a touristic port as a symbIoTe's Smart Space and the Yachts in transit as Roaming Smart Devices. All the Port's applications can interact with the symbIote ecosystem through enablers: in the project two specific kinds of software systems – the Mooring Workflow Management System and the Port Marketplace – have been considered.

Feedbacks from users, both in the form of answers to the questionnaire, feedbacks from functional testing and KPIs analysis, have been all positive.

The limits of the trial are in the use case inherent complexity, that doesn't allow to involve a significant number of users (e.g. Ports, Port operators, Yacht owners, Port Application developers, etc.).

Even with this relatively simplified set-up (that in any case involved 2 Ports, 2 Yachts, 2 Applications and 6 operators) the results of the trial confirmed the soundness of the vision described above, that of course can become commercially viable once a significant number of Ports and Yacht manufacturers embrace this approach and technology.