Symbiosis of smart objects across IoT environments

688156 - symbIoTe - H2020-ICT-2015

D5.3 – End User Validation

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

Document Control

Title: D5.3 – End User Validation

Type: Public

Editors: C. Löw, A. Rafetseder and S. Schröder, UNIVIE

E-mail: christian.loew@univie.ac.at, albert.rafetseder@univie.ac.at, svenja.schroeder@univie.ac.at

Authors: Aleksandar Antonić (UNIZG-FER), Luca De Santis (NAVIGO), Gerd Dünnebeil, Mario Drobics, Karl Kreiner, Kurt Edegger (AIT), Reinhard Herzog, Michael Jacoby (IOSB), Christian Löw, Albert Rafetseder, Svenja Schröder (UNIVIE), Adam Olszewski (PSNC), Toni Paradell (Worldline/ATOS)

Doc ID: D5.3-v2.9.docx

Amendment History

Version	Date	Author	Description/Comments
v0.1		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Add preliminary structure; contents for Smart Residence use case; Appendix / questionnaires for use case
v0.2		Aleksandar Antonić (UNIZG-FER)	Content for SMER use case, questionnaire for the use case in appendix
v0.3		Adam Olszewski (PSNC)	Extend the description of Section 2, Objective, Structure
v0.4		Luca De Santis (NAVIGO)	Content for Smart Yachting use case.
v0.5		Adam Olszewski (PSNC)	Description for Section 3.3 Approach
v0.6		Reinhard Herzog (IOSB)	EduCampus evaluation approach.
v0.7		Svenja Schröder (UNIVIE)	Restructured chapter on use cases. Added Acronym section.
v0.8		Karl Kreiner (AIT)	Added more background information on how SMILA can benefit for elderly people; added health background and SMILA figure
v0.9		Adam Olszewski (PSNC)	Extended sections specifying purpose, objectives and addressed comments
v0.10		Toni Paradell (Worldline/Atos)	Content for the Smart Stadium use case.
v0.11		C. Löw, A. Rafetseder (UNIVIE)	Complete references, proofread Use Case sections
v0.12		Adam Olszewski (PSNC)	Added section on platform owners' perspective, extended approach description, contributed to use case section
v0.13		C. Löw, A. Rafetseder (UNIVIE)	Editing; Introduction, Terminology/Approach
v0.14		C. Löw, A. Rafetseder (UNIVIE)	Version for internal review
v0.15		Corinna Schmitt (UZH)	Internal review
v0.16		Ilia Pietri (ICOM)	Internal review
v0.17		Luca De Santis (NAVIGO)	Incorporation of remarks from internal review
v0.18		C. Löw, A. Rafetseder (UNIVIE)	Incorporation of remarks from internal review
v0.19		C. Löw, A. Rafetseder (UNIVIE)	Reworked chapters 6, 7
v0.20		C. Löw, A. Rafetseder (UNIVIE)	Further corrections in chapters 1, 2, 3
v0.21		Svenja Schröder (UNIVIE)	Incorporation of reviewer remarks in chapter 5
v0.22		Adam Olszewski (PSNC)	Incorporation of reviewer remarks in chapters 3, 4

V0.50		Aleksandar Antonić (UNIZG-FER)	Address internal review comments
v0.51		C. Löw, A. Rafetseder (UNIVIE)	References Check, Proof-Reading
v0.2.0		Aleksandar Antonić (UNIZG-FER)	Updated SMER results
V0.2.1		Adam Olszewski (PSNC)	Update Platform Owner Perspectives with latest results; update figures and tables per internal review comments
V0.2.2		Reinhard Herzog (IOSB), Albert Rafetseder (UNIVIE)	Update EduCampus results
V0.2.3		Danilo Giacomi (NAVIGO), Albert Rafetseder (UNIVIE)	Update Smart Yachting results
V0.2.4		Zvonimir Zelenika (VIP)	Add indoor positioning results
V0.2.5		Adam Olszewski (PSNC)	Port over earlier edits
V0.2.6		Albert Rafetseder (UNIVIE)	Integration and cleanup
V0.2.7		Adam Olszewski (PSNC)	Extract key points of latest surveys, add captions to figures and move them to the Appendix
V0.2.8		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Integration, cleanup
V0.2.9		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Check of Terminology, small fixes, intregration
V0.3.0		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Remove Winword markup
V0.3.1		Toni Paradell (Worldline/Atos)	Update for Smart Stadium evaluation
V0.3.2		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Join campus-related evalutions
V0.3.3		Zvonimir Zelenika (VIP)	Campus use case review and editing
V1.0		C. Löw, A. Rafetseder, S. Schröder (UNIVIE)	Update conclusion

Legal Notices

The information in this document is subject to change without notice.

Table of Contents

1 Executive Summary

The symbIoTe project works to research and create a rich and federated IoT ecosystem of practical relevance and usability. To reach this goal, its concepts and artefacts must be put to test, enabling the intended audiences to express their views on the state and feature spectrum of the system. This provides valuable feedback across partners and work packages and helps to validate both current assumptions and plans, and also strategies and projections regarding future directions of symbIoTe.

This Deliverable D5.3 reports on the findings of Task 5.3 with respect to end user validation. Its validations are based on symbIoTe's five use cases and their respective developments and prototypical implementations:

1. Smart Residence with validation scenario using a Smart Mirror device for self-care,
2. Smart Mobility and Ecological Routing with validation scenario for environmental sensing and routing for bicyclists,
3. Smart Stadium with validation on coordination of stadium operators, shops and visitors,
4. EduCampus with validation on novel reservation and navigation approaches and enabler-based indoor positioning, and
5. Smart Yachting with validation on workflow optimization in marinas.

The notion of end users is correspondingly broad and spans from casual consumers to expert users and a diverse set of possible stake-holders. In addition to the validation scenarios, the perspectives of platform owners and other stake-holders thus are evaluated using a combination of living lab tools, such as interviews, validation boards, value network analyses, Saint-Gallen business model innovation, Design Thinking sessions, and participatory workshops. This extends the value proposition feedback to stakeholders other than end-users and augments the end user-based frame of reference with viewpoints from a business background. This can support further validation efforts in WP5 and the overall business model definition in the symbIoTe project. The validation results presented in this Deliverable D5.3 indicate that end users see symbIoTe and the applications it enables as generally favourable, with valuable proposed augmentations. For instance, the study conducted on the Smart Mirror prototype supports the feasibility of home-based smart objects for health care self-management while pointing out possible ways of improvement from a usability perspective.

Regarding the other prototypes developed in symbIoTe, intermediate assessments show the basic aptness of the designs. Further and more detailed results will be reported in the upcoming Deliverable D5.6 scheduled for M36, with an encouraging outlook, taking into account positive feedback gathered, e.g. from Open Call 2 (OC2) winners regarding the Smart Mobility and Ecological Routing prototype as well as from Port Authority Operators regarding the Smart Yachting prototype.

2 Introduction

The symbIoTe project aims at researching and creating conceptual and technological ground work for an ecosystem of networked IoT device families[1]. In relation to current IoT technologies that behave, to varying extent, as insular products in a fragmented landscape of vertical solutions, symbIoTe provides the means for a unified foundation and language of IoT technology.

Research and development efforts undertaken in the course of the symbIoTe project encompass various challenges and focal points around distributed technology architecture, security and user-centric design efforts, among others. In relation to the latter, symbIoTe's WP5 ("Use-case based Trials & Deployments") combines evaluation and validation efforts surrounding the symbIoTe platform solution and builds on prior conceptual work completed in WP1 ("Ecosystem Definition") as well as predefined use cases.

Task 5.3, which this Deliverable D5.3 reports on, addresses symbIoTe's end user validation. It takes on use case developments and prototypical implementations as undertaken in Tasks 5.1 and 5.2, plans and executes validations around the use cases of symbIoTe and contributes definitory ground-work in pursuit of meaningful conceptualizations of what "end-users" are, specifically in respect to a specific use case as well as generally in the scope of a unified ecosystem such as symbIoTe.

In respect of the heterogeneous nature of practical applications aimed to be supported by the unified solution of symbIoTe, this definitory ground-work is bound to be conducted "bottom-up" in order to be grounded in the practice of involved end users and stakeholders and yield a diverse set of mindfully curated notions of such important players. Following this, the validation of a unified, interoperable, and federated IoT ecosystem presents various possible and necessary perspectives to be taken; be it the larger picture of diverse stakeholders that surround an application of symbIoTe in practice or the focused view on a specific user-group to be supported by intricately networked IoT devices. Such overall end-user validation combines different views into a report that aims to capture symbIoTe's unity through diversity.

This Deliverable yields a description of validation efforts around several symbIoTe use cases. Just as the use cases differ in their scope and breadth, the validations focus on different aspects of symbIoTe's offerings; irrespective of the various specific constraints, it is worth noting that every use case saw a practical validation. The evaluation of use cases within the symbIoTe project continues past this Deliverable. End user trials will be realized and reported on also in subsequent tasks and Deliverables in WP5, in particular Deliverable D5.6 on Trials, Deployments and Assessment. Not least, the work on T5.3 has already yielded two publications that detail on different aspects of this task [1, 2].

2.1 Purpose and Scope of Document

Deliverable D5.3 describes and summarizes activities of Task 5.3 on end user validation, carried out from month 19 to month 29 of symbIoTe project. Its main purpose is to evaluate proceedings of symbIoTe from an end user perspective and enable a realistic validation of the overall architecture as well as the concrete implemented use cases, as

---

[1] symbIoTe Vision: https://www.symbiote-h2020.eu [last accessed: 01-06-18]

outlined in the Description of Work (DoW). By analysing use case specific symbIoTe usage scenarios, subject to a number of living lab methodologies and user centric validation tools, a broad and cross-domain overview of potential new values for stakeholders is drawn.

Furthermore, this Deliverable works towards a realistic validation of the overall architecture, prototypes, and applications under specific use cases, represented by Minimum Viable Products (MVPs), to be delivered under WP7. Moreover, the present Deliverable outlines user-specific challenges within symbIoTe use case scenarios against the end user requirements.

2.2 Task T5.3 Objectives

The major objective of T5.3 on end user validation in symbIoTe is to explore the expectations and actual needs of symbIoTe middleware end users and other key stakeholders in order to support the process of turning technical components into sustainable services. The expected impact of the studies realized in T5.3 is to provide end user evaluations and recommendations for other tasks, for instance in WP6 in relation to the Open Call process and WP7 in relation to dissemination and exploitation activities. Furthermore, platform-related end-user research is conducted to improve symbIoTe sustainability planning based on business model related feedback from key parties involved in new symbIoTe enabled scenarios.

Moreover T5.3 aims to outline market niches for the value proposition of symbIoTe as a whole. The task shall also support symbIoTe use cases in designing communities of users and early adopters and tools for ongoing validation during the timeframe of T5.3 and beyond, with special attention to end user trials carried out under WP5 business models being designed under WP1 and community building under WP7. On this account, while macro and meso level activities such as definition of KPIs or organization of events and workshops going across all use cases are concluded within T5.3, some micro level use case specific activities (e.g., Smart Stadium trials + evaluations), built on top of T5.3 feedback, continue beyond T5.3 accordingly with the realization manner of each use case.

This Deliverable attempts to constitute common grounds for the five addressed implementation areas in order to support a quantitative and/or qualitative selection of the most promising symbIoTe elements that have the potential to be pursued after completion of the symbIoTe project. On this account, this Deliverable identifies and narrows down common Key Performance Indicators (KPIs) as well as confronts WP6 value propositions against end user expectations. Playing a cross-WP interconnecting role, this Deliverable also contributes to unifying end user related terminology. Moreover, this Deliverable sets the stage for end user involvement in testing of use case applications and reinterprets building blocks within WP1 value network analysis of symbIoTe business models. In this respect, this Deliverable provides examples and structures of user driven Value Network Analyses (VNAs) that may suggest an augmentation of WP1 VNA diagrams and business models, as specified in Deliverable D1.3 [3].

The starting point of T5.3 was to create and apply dedicated living lab tools accordingly with the actual realization manner of the overall project as well as use case related applications. Based on this, T5.3 living labs and usability studies in symbIoTe focus on the very final evaluation stage of service co-development, namely end user validation. As indicated in Figure 1 (T5.3-related focal aspects in bold letters), T5.3 builds on previous

living lab phases (see Section 3.1 for an introduction), such as Co-creation and User testing.
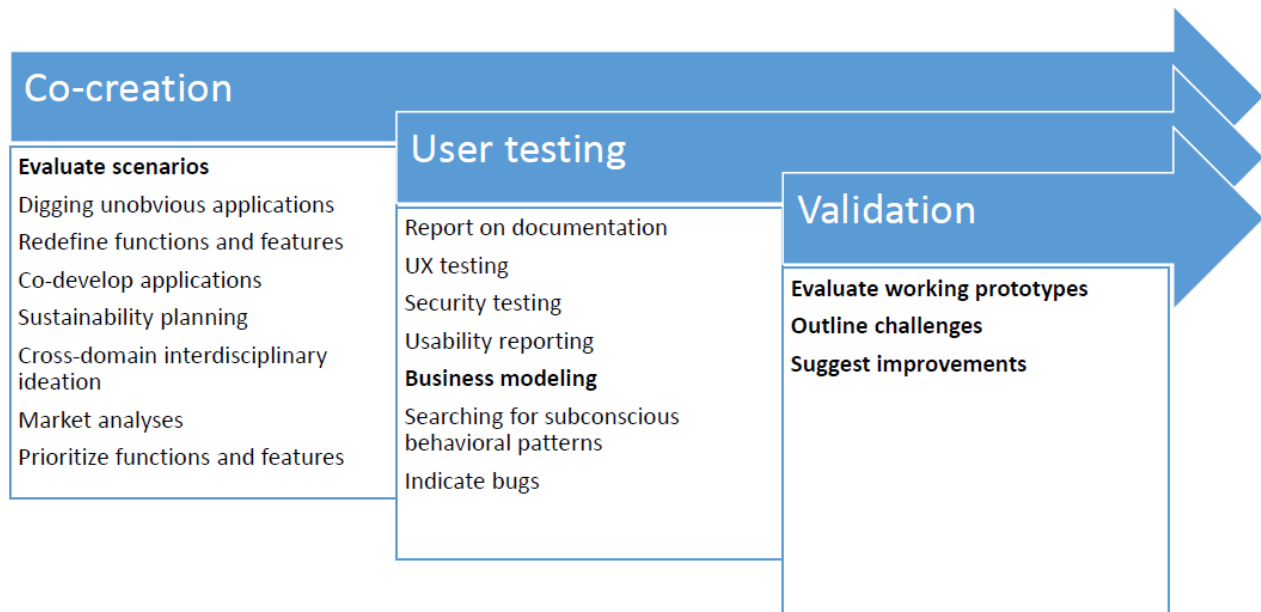
Figure 1: symbIoTe kick-off meeting overview of planned T5.3 activities.

2.3 Document Structure

The remainder of this document is structured as follows: Chapter 3 introduces the terminology and approach taken on in the course of T5.3. Chapter 4 details on several user studies conducted in the course of WP5. Chapter 5 is concerned with the meso-level perspective previously described and identified stakeholders and value flows in this respect. Chapter 6 summarizes the results and concludes this Deliverable.

3 Terminology and Approach

3.1 Terminology

One important aspect of Task 5.3 was to clarify and define the terminology to build upon during the planning of the evaluation. This happened in accordance with other work packages and Deliverables throughout the project, which have already defined relevant terminology.

End User

In symbIoTe End User denotes "an individual user of a symbIoTe-supported IoT application" (cf. Deliverables D1.2 [4] and D1.4 [5]). Basically D5.3 follows this definition, but in some places, especially usability and feasibility-related studies conducted in the course of T5.3, the definition is extended to address *individual users*, representing not just themselves and their own personal perspectives, but also broader interests and requirements of organizations behind them, such as IoT platform owners, integrators and client organizations (e.g., bike rentals, restaurants, yachts, marinas) referred to in this document as *stakeholders*.

Beside this general definition, which is used in the use-case related studies reported on in chapter 4, the platform-related end user research conducted in the course of T5.3 and reported on in chapter 5 yielded a more specific notion of a user in the context of symbIoTe, disambiguated by awareness of symbIoTe technology:

- User – organizational (company) or individual (developer) user of symbIoTe tools aware of using symbIoTe,
- End User – organizational user of applications built on top of symbIoTe tools hardly aware of using symbIoTe,
- Final End User – individual user of applications built on top of symbIoTe tools hardly aware of using symbIoTe.

End User Validation

Establishing documented evidence, which raises the degree of assurance that a specific process or prototype will meet user and business needs by producing a service meeting, its predetermined specifications and addressing requirements of end users.

Stakeholder

According to prior statements in D1.3 [3], a *Stakeholder* "can be actively or passively affected by the technology (e.g., protocols, symbIoTe)". In D1.3 this includes the aforementioned end users as a more specific subset, while allowing a broader examination approach of all individuals and groups affected by the technology developed in symbIoTe. Pursuing that approach, we propose the following definition of stakeholder: *A Stakeholder is a person or organization actively or passively affecting or affected by symbIoTe technologies.*

Living Lab

As defined by D. Schuurman et al. [6] a living lab is "a real-life test and experimentation environment where users and producers co-create innovations". Since the technology

developed in symbIoTe aims at providing a seamless usage experience from core to end users, testing in realistic environments is crucial. Thus, we define a "living lab" in the scope of symbIoTe as follows: *"Experimentation environment where symbIoTe users and creators co-perform the validation of symbIoTe business models, components, and functionalities in real-life-like settings".*

Living Lab Panel

A group of test users, selected for a specific living lab activity (co-creation, testing, validation). Panel participants are normally selected from a larger group of volunteers. Stakeholder profiles of panel participants (technical expertise, usage maturity and intensity, business perspective) need to match with requirements and goals of the specific project and its planned living lab activities in order to provide relevant feedback from users. After completing their living lab activities, panel participants may become early adopters and/or community members around the tested solution.

3.2 Approach

Task 5.3 builds on top of functional and non-functional requirements of symbIoTe components and applications predefined by the project consortium under other WPs and tasks until month 19. On this account, Task 5.3 integrates sustainability and exploitation related findings of other WPs, namely D1.3 [3], D1.4 [5], D3.1 [7], D5.2 [8], D5.5 [9], and D7.4 [10], to extend them beyond technical requirements by adding an end user perspective layer and contrasting general business scenarios against real-life business and user expectations of stakeholders.

As sketched in Figure 2, the task included multiple research steps taking place on micro, meso and macro levels:

On the **micro level**, specific use cases were addressed to dig deeper into the requirements and business opportunities of each use case and specific business scenarios within use cases, as well as overall usability and user experience of associated symbIoTe prototypes.

On the **meso level**, or the symbIoTe project level, data from consortium participants and open calls participants were gathered to compare, contrast and unify requirements and approach within the project as a whole. Furthermore requirements for symbIoTe components functionalities, value propositions and MVPs were analysed.

On the **macro level** comprehensive and general activities were carried out going beyond the strict scope and audience of symbIoTe project, such as EPI IoT idea challenge events, conference demonstrations, etc. where generic results were gathered.

While macro and meso level activities are involved using living lab tools and audiences, the micro level requires dedicated tools and participants. Therefore, each use-case-related validation effort was set up to select specific participants as well as to define the most promising validation problems, business scenarios and tools that use case leaders deemed relevant.
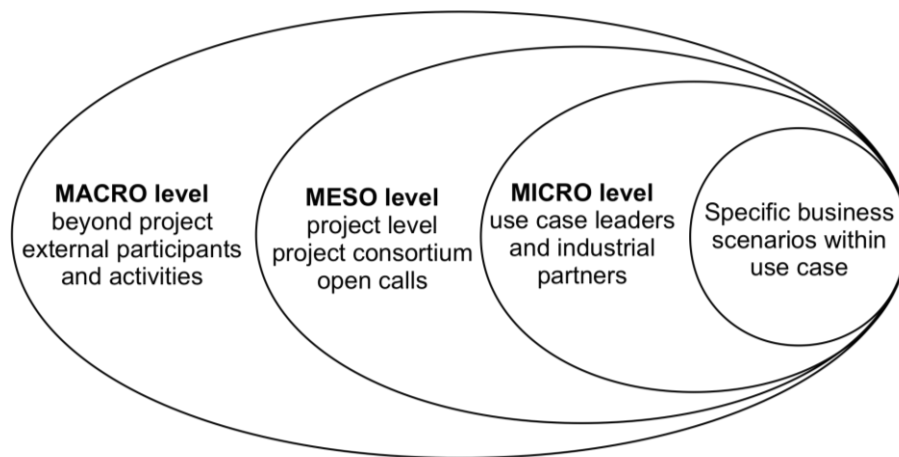
Figure 2: T5.3 levels of research steps.

The broad range of business areas, addressed by symbIoTe, called for dedicated end user validation tools designed per use case to deeply analyse potential business scenarios at micro level. At the same time a unified approach, terminology and tools were necessary to enable collaboration and evaluation across use cases and components at the meso or project level. Therefore, this Deliverable focuses mainly on meso and micro levels with merely slight variations beyond. On this account, end user validation micro level activities individually designed within every use case were carried out (described under Section 4), while symbIoTe shared middleware components underwent common validation meso level activities (described under Section 5).

Therefore, T5.3 consists of general and use case specific activities. Micro-level-related results are documented in Section 4 of this Deliverable. Micro level and use case specific activities engage mainly individual end users, such as yacht port workers, patients, and urban citizens, to provide application level feedback targeting selected business scenarios within use cases. General level activities, further described in Section 5, address mainly meso level, project related issues and the platform-owner perspective. Meso level activities engage mainly organizational stakeholders, such as representatives of IoT platform owning companies, in order to embrace elements common for symbIoTe components and applications.

4 Use Case Perspectives

This section presents activities and results of micro level living lab activities performed within the use cases focusing on specific business scenarios selected within each use case. Since the deployment and evaluation of the use case scenarios is a continuous and task spanning work, ongoing as well as completed evaluation activities are reported here.

4.1 Use Case: Smart Residence

4.1.1 Overview

For this use case, UNIVIE and AIT tested interactions with a "Smart Mirror" device in a mock-up bathroom setting in UNIVIE's lab rooms, and both general health/fitness related opinions and feedback about the smart device through questionnaires. The end users employed for this test included young adults (students aged 20-35) and older adults (aged 50-69).

The Smart Mirror is constructed from a stock Android tablet computer, mounted inside a custom wooden frame with semi-transparent mirror. The display of the tablet (and thus the screen contents of the symbIoTe-enabled app running on it) is visible through the mirror and provides one part of the interface. Other interactions are triggered by Bluetooth: The app's interaction process starts when a Bluetooth Low Energy (BLE) beacon that the user wears which is recognized by the mirror in proximity (in this case a bracelet). Then, the user is prompted to interact with the device via text-to-speech in- and output, and the user's reply to a question about their subjective well-being is recorded. Furthermore, a Bluetooth scale is connected to the tablet device and records the user's body weight.

This interaction scenario is specifically designed for elderly people with low computer literacy. As chronic diseases become more common as age advances, an interaction with medical devices for self-monitoring health might have a beneficial impact on life quality. Especially weight is a critical health indicator in chronic heart failure and sudden changes in weight over the course of 2-3 days might indicate severe health deterioration. Regular weight measurements and transfer to a central database where clinical experts can review data might help to reduce hospitalization rates as therapy adjustments can be quickly made. Aside from initial tests long-term studies could show how this technology could be particularly used in retirement homes to assist care processes.

4.1.2 Goals

The purpose of the test was to validate the Smart Mirror prototype and check the feasibility of the interaction model from the perspective of end users. A symbIoTe-enabled backend was used during the tests, thus also revealing platform owner-oriented aspects to the SMILA operators.

4.1.2.1 Device under test

The device tested for this use case was a Smart Mirror nicknamed SMILA (short for "Smart Mirror Integrated Living Assistant"). The device contains a Samsung Galaxy Tab A 10.1 Android tablet behind a semi-transparent mirror inside a wooden frame of approximately 40x30x4cm with a gross weight of about 2.5kg. The tablet is padded by black paper, and the lack of light within the wooden frame leads to the user experiencing a regular mirror

when no information is shown on the tablet. This simple design and using only widely available materials we kept the total costs for one prototypical below EUR 300.

When SMILA is powered on, it connects to a configured Wi-Fi network, retrieves its location using Google's services, and displays the current date and time alongside the current weather and city name. The minimum amount of information, compared to commercially available smart mirror solutions featuring daily news or stock charts, has been chosen to prevent information overload on our target audience. Additionally, we keep power consumption and data usage to a minimum by showing only the minimum amount of contextual relevant information.

Whenever a user, equipped with a Bluetooth Low Energy (BLE) beacon, is in vicinity of the mirror, SMILA tries to identify the user by reading the non-personal ID of the beacon and resolves it to a specific person by querying the symbIoTe enabled backend. In this case the beacon was embedded in a bracelet worn on the user's wrist but could also be incorporated in other forms of jewellery or everyday clothing. When the beacon is known to the backend, the device can use the per-user configuration (e.g., the first name) and storage (e.g., for measured values) in interactions.

SMILA can connect to nearby BLE enabled smart body weight scales (e.g., Wahoo Balance BLE weight scale) and retrieve the current measurements. The weight measurement is stored only temporarily within the mirror and is sent to the symbIoTe enabled backend as a new sensor reading. Another task, SMILA can perform, is to ask the present user about her current physical wellbeing. This is done by voice output, and the user is expected to answer in a free text form via voice input. SMILA recognizes and interprets the voice input using Google's services and notifies the user if there is no input or too much background noise and the user cannot be understood clearly. The recognized answer is sent to the symbIoTe-enabled backend.

Since SMILA does not permanently store data nor needs to know any user in advance, this setting is suitable for multi-user applications like nursing homes or even public places where the vital data of a large number of different people must be stored in different platforms. The symbIoTe enabled infrastructure acts as an intermediate between the BLE beacons (wristband, bracelet or necklace) and the specific platform the user wants their data delivered to.

4.1.3 Methodology

A study was carried out with a total of 18 participants from two age groups (18-35 and 50-69), on two separate occasions in November 2017 (younger participants) and March 2018 (elder participants). The study consisted of questionnaires and user interactions with the Smart Mirror prototype in a mock bathroom setup in UNIVIE's lab. In order to improve the turnout, the elderly participants were also interviewed after their test runs.

4.1.3.1 Setting

The UNIVIE lab room was set up to imitate a small bathroom-like setting (towels, toothbrush, shower curtain) in the corner of a lab room. The Smart Mirror was mounted on the wall, the Bluetooth-connected scale was on the floor. Figure 3 depicts the setup as used for the test.

Figure 3: The SMILA prototype (top centre) as used in the living lab evaluation setting.

To monitor the participants' actions in the test space and interactions with the device in an unobtrusive way and support later evaluations, a camera and audio recorder were placed behind the shower curtain. Participants were asked in writing for their consent before recordings were started.

4.1.3.2 Questionnaires

The test included pre- and post-interaction questionnaires. Both were presented to participants either in a web browser on a computer, or on paper to be filled out by hand. The questionnaires included free-text fields, single-choice- and multi-choice questions. No time limit was given for filling out the questionnaires. The questionnaires asked about

- The participant's demographical information,
- Smartphone/tablet usage,
- Prior experience with health and fitness related apps, devices, advice, and success (or lack thereof),
- General health self-awareness,
- The perceived properties of the Smart Mirror prototype, including its
  - complexity, integration, difficulty to learn,
  - user interface aspects such as font size and voice output, and
- Privacy awareness and constraints of sharing the Smart Mirror's data.

For the younger age group, some questions specifically asked the participants to put themselves into the position of an elder friend or relative, and imagine to be answering on their behalf.

The full pre- and post-interaction questionnaires (translated to English from the German version used in the lab tests) are available in Section 9.3 in the Appendix.

4.1.3.3 Test Flow

Each test was carried out by at least one test supervisor and included exactly one participant. Before a test run, the supervisor configured the Smart Mirror's backend so that the participant's first name could be used during the interaction with the prototype. After asking the participant in, the supervisor

- Briefly introduced the test flow,
- Asked the participant to sign the consent form for audio and video recordings of the test run,
- Let the participant draw a pseudonymous label for correlating the participant's pre- and post-interaction questionnaire, and
- Asked for the pre-interaction questionnaire to be filled out.

Once the participant finished the first questionnaire, the supervisor handed out the Bluetooth Low Energy wristband and instructed the participant to change rooms, thus entering the bathroom setting with the Smart Mirror prototype. There, the device…

- … "recognized" the participant via a BLE beacon as he or she approached.
- … verbally greeted him or her by first name (as configured in the backend beforehand).
- … instructed the person to use a scale, situated on the floor.
- … read out (and stored in the backend) the person's measured weight.
- … asked the person for their personal well-being and recorded the person's reply.
- … said goodbye.

The supervisor then passed the post-test questionnaire to the participant.

For the older adult participants, the test supervisor also conducted free interviews of 15 to 60 minutes to increase the turnout for matters not explicitly addressed by the questionnaires.

4.1.3.4 Participants

The lab test was done with participants from two different age groups. Out of the 11 younger participants (8 between 18 and 25, 3 between 26 and 35) four were female and seven male. All of those participants were students of computer science at UNIVIE and were recruited over a lecture and received compensation in form of points for the course. Seven of the participants had an Android smartphone, three had an Apple iPhone and one participant had both Android smartphone as well as an iPhone. Of the younger participants, four used their smartphone 1-3 hours daily, six of them 3-6 hours, and one person each 6-9 hours and more than nine hours daily. All but one already heard of the Internet of Things.

For older adults, six female and one male participant (1 between 50 and 54, 1 between 55 and 59, two between 60 and 64, and 3 between 65 and 69) took part in the second test. Five of those were retired; two were working at the university in administration. Three had an Android smartphone, three a Microsoft Windows smartphone, one person had both, and one had no smartphone at all. Three used their smartphone 1-3 hours a day and three less than one hour. Five out of seven participants haven't heard of the Internet of Things yet.

4.1.4 Evaluation

As already mentioned, the tests took place in the lab facilities of UNIVIE in two parts: 11 younger participants participated in November 2017, while in the beginning of 2018 the 7 older adult participant group was invited into the lab.

4.1.4.1 Fitness and Health

When being asked how much they cared about their health ("How much do you care about your health?", answerable on a Likert scale from 1 to 7, where 1 meant "very much" and 7 meant "not at all"), both the younger and older participants leaned towards caring for their health (μ=2.86, σ=2.48 for the older participants and μ=3, σ=1.83 for the younger). Both groups had similar fitness goals (see Figure 4 and Figure 5).

Figure 4: Fitness Goals of the Younger Generation.

Figure 5: Fitness Goals of the Older Generation.

Both groups had experiences with fitness trackers. Four of the younger and two of the older participants mentioned Runtastic[2]. Furthermore two of the younger participants said they had experiences with Google Fit[3]. Despite of that three of the younger and none of the older participants were using a fitness tracker at the time of the test.

Weight (among other measurements) seemed to be an important indicator for achieving their fitness and health related goals, as could be seen in Figure 6 and Figure 7 respectively.
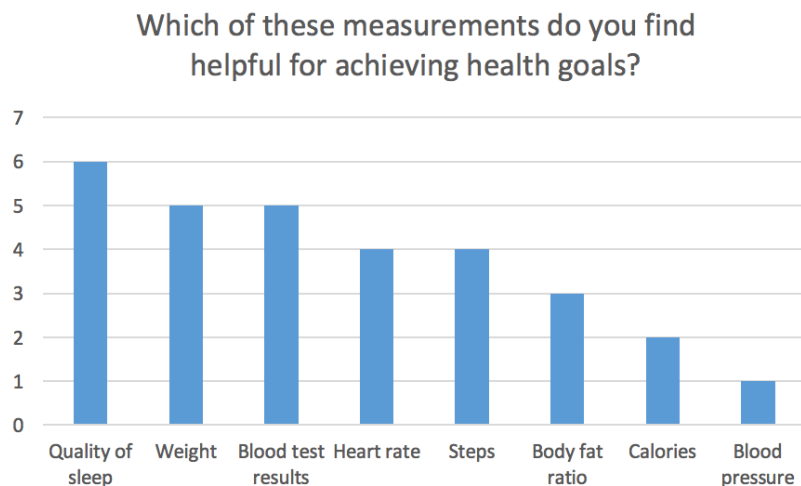
Which of these measurements do you find helpful for achieving health goals?

Figure 6: Measurements perceived as useful for achieving their fitness goals of the older generation.

Which of these measurements do you find helpful for achieving your goals?
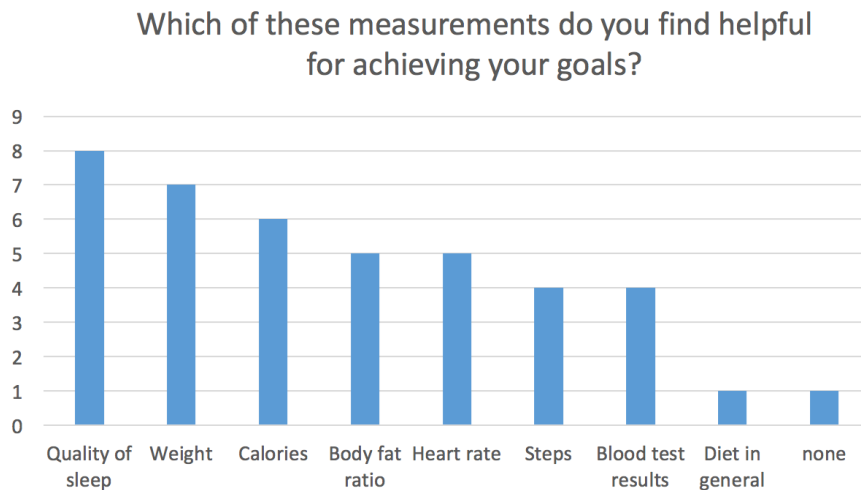
Figure 7: Measurements perceived as useful for achieving their fitness goals of the younger generation.

4.1.4.2 Privacy Concerns

Privacy as a concern was a very prominent topic mentioned multiple times by the participants regarding the collection of fitness and health related data. The younger

---

[2] Runtastic: Running, Cycling & Fitness GPS Tracker: https://www.runtastic.com [last accessed: 2018-05-22]

[3] Google Fit: https://www.google.com/fit [last accessed: 2018-05-22]]

participants were being asked about reasons why they would not use fitness trackers. The prevalent reasons were privacy issues, namely privacy and surveillance, the sensibility of health-related data or the permanent tracking.

We asked the participants if they could imagine sharing their data with others and if they answered yes with whom they would share it. From the younger participants one answered that she/he would share it without any restriction and one said that she/he would maybe share it with their family and friends. Another one said that she/he would only share their data to a certain degree. Six said that they would only share the data in anonymized form and four answered that they would never share their data. All of the older participants stated that they would only share the data in anonymous form.

When being asked, with whom they would share this fitness respectively health related data, eight younger participants answered they would share it with family members and another eight said with doctors (multiple mentions were possible with this question). Four answered they would share it with friends, three with research institutions and two with care facilities. From the older participants, seven could imagine sharing their data with doctors, five with research institutions, and one each said they would give their data to care facilities, family or friends.

4.1.4.3 Supportive Tasks

Younger participants described their interest in self-quantifying features such as SMILA supporting them via steps-taken, nutrition and water intake and other related info. Older participants mentioned blood pressure information (4 of 7 participants).

Older participants mentioned interest in self-management-related support, such as keeping up with medication or measurement tasks such as blood sugar or blood pressure, getting reminders of and scheduling doctor's appointments as well as situative support with more complex self-care tasks. One participant, a sufferer of scoliosis, described their difficulty with self-care tasks prescribed by her physical therapist: *"There are lots of different possible exercises, it depends a lot on day-to-day differences. [..] I struggle with getting this right. My therapist said that this was normal for most of her patients."*

A theme that emerged from the semi-structured interview as significant to the older participants, albeit not imagined by the younger ones, was one regarding SMILA's conceptual position in relation to fitness goals and health self-management. Four older participants described the upholding of their own self-determination in relation to such tasks as important for them in their assessment on whether they could see themselves using technology for these purposes. Technological agents as either intermediaries between them and their attending health-care professionals and supporters for their own fitness goals should not undermine their independence, e.g. as an "extended arm" of health care professionals, but uphold their personal agency, be a supportive friend rather than a masked form of surveillance or a collection of "should-dos".

4.1.4.4 Interaction with the Mirror

Overall, the older as well as the younger participants found the mirror easy to use and hardly encountered any problems. They found the system to be simple and usable without any help. A need for improvement was observable around the aspect of delays: Sometimes, the BLE bracelet would not be discovered by the mirror in time. Also, the delay between a voice message generated by SMILA and its active listening for responses

seemed to be too short and participants answered too soon for SMILA to understand their responses. One of the major critiques evolved around the computer voice, which was perceived as "robotic" by some participants. When being asked whether they found the voice output enjoyable, the younger answered with µ=2.62 and σ=2.09 on a Likert scale from 1 to 5, where 1 meant "fully agree" and 5 meant "don't agree at all". Surprisingly, the older participants were less critical with µ=2 and σ=1 on the aforementioned Likert scale.

We asked both groups of participants about design preferences regarding the system, specifically if they wished to have another form of BLE beacon or another way of authenticating in general. Eight of the thirteen younger participants did not want another form of BLE beacon and liked the bracelet. Two wanted to include the beacon into a pendant and one suggested the form of a brooch. One participant mentioned that the BLE beacon could also be attached to the smartphone. From the older participants five out of seven did not want to change the form of beacon. The other two suggested the form of a pendant. In overall the participants seemed to like the idea to incorporate the BLE beacon in some form of jewellery.

When being asked if the participants liked another form of authentication than then bracelet, the younger ones clearly preferred biometric authentication: Nine suggested voice recognition, seven face recognition and one fingerprint authentication. One younger participant mentioned to use password or pin authentication. Two did not want to change the form of authentication. The older generation as well preferred biometric authentication: Both fingerprint authentication and face recognition were suggested three times, while one participant liked the bracelet as is.

We then asked why they would choose another form of authentication over the bracelet. The most prominently mentioned reasons were convenience and safety. Both older and younger generation mentioned that wearables could be forgotten, while they could under all circumstances use their bodily features for authentication. Especially in a bathroom situation, before dressing, any worn artefact could be forgotten. Another reason was, that a wearable artefact could be used by another person, either non-deliberately, e.g. by another family member, or maliciously.

4.1.5 Results

This formative user study supports the feasibility of the Smart Mirror SMILA as a tool for fitness and health self-management. Participants reacted positively to the proposed prototype and found it feasible to use in their daily lives for purposes of fitness/self-care and health self-management. The study yields an overall positive and encouraging picture while pointing at possible improvements.

Weight was reported as relevant for the pursuit of fitness goals, supporting the initial feature-set of SMILA. The participants described a differentiated perception of required privacy in sharing data with medical care-givers and professionals or family, pointing at the necessity of differentiated sharing and visibility restriction functionality in SMILA. The participants furthermore mentioned several possible self-care related tasks they could see themselves to be supported with by SMILA, with especially the older participants highlighting that such technology needs to support and uphold their self-determination. The interaction design of SMILA was well received, and several possible improvements to user authentication were suggested, mostly for reasons of convenience and safety.

The younger participants reported an overall rather positive impression, while the older participants were also curious and interested, but, in all, more reserved. We asked the

participants whether they could imagine using the smart mirror in their own home. Seven younger participants answered with yes, four with maybe and two said no. From the older participants three said yes while four answered with maybe. When being asked whether the participants would recommend the mirror to their friends and family, seven out of thirteen younger participants answered yes and six said maybe. From the older participants three answered they would recommend the mirror and four voted for maybe.

Most of the younger participants could imagine using the mirror regularly: 10 of the 13 agreed or even fully agreed, while one was indecisive and two disagreed. The older participants were more hesitant: Three out of seven could imagine using the mirror regularly, while two were indecisive and two disagreed.

4.2 Use Case: Smart Mobility and Ecological Routing

4.2.1 Overview

The Smart Mobility and Ecological Routing (SMER) use case is developed by UNIZG-FER, AIT and UW in cooperation with their local communities. The SMER use case will utilize citizens of Zagreb, Vienna and Porto to collect dense spatio-temporal data in urban environments, mainly air quality measurements such as the CO_2 and NO_2 gases, temperature, humidity and atmospheric pressure. Collected readings are used to interpolate missing values, so that end users can obtain detailed environmental data from the symbIoTe ecosystem in focus cities. Interpolated data also serves as main input to routing service, which is based on the ecological parameters, i.e., in addition to the fastest route a user is offered with the route between two locations that has the best air quality. The routing functionality is extended with the Point of Interest (PoI) suggestion, offering to an end-user the possibility to choose a PoI, and simultaneously receive the routing instructions according to the user preferences and current urban environment status.

The SMER use case results in an application, which is available to be used by anybody that has an Android device, but the real benefit of the application offerings will be available to the citizens of Zagreb, Vienna and Porto. Data collection is performed through all the three involved platforms; the UWEDAT platform [11] integrates the fixed environmental measurement stations from Austria and Croatia, while the OpenIoT[4] and MoBaas[5] platforms integrate data collected through mobile wearable air quality devices using an end user smartphone which serves as gateway for the measurement device. The wearable sensor is the key technology of the use case, because in collaboration with end user movements it offers a unique view on the environmental status of urban area throughout a day.

End users of the SMER use case are primarily citizens of urban areas with a healthy lifestyle and which are environmentally responsible individuals. End users can be divided into two groups: the first group that consists of citizens who voluntarily collect data when they are on the move, and the second group which comprises of regular citizens that are users of the SMER application. The SMER application users benefit from the data gathered and processed in the symbIoTe ecosystem, which is presented through the

---

[4] Open Source cloud solution for the Internet of Things: https://www.openiot.eu [last accessed 2018-06-08]
[5] Mobility@Ubiwhere: https://mobility.ubiwhere.com/ [last accessed 2018-06-11]

application functionalities. The first group is crucial because they collect environmental data so that a value-added service, such as the ecological routing service, can be offered to all citizens. The target group of citizens for this group is primarily environmentally aware citizens, who actively work on the improvement of the quality of life in their cities. Also young people who spend some time outdoors every day are good candidates because they can collect data at disperse location without interrupting their daily routine. The second group of end users are all citizens that live in the city which participate in active communities that collect environmental data. The key factor is to advertise as much as possible the offerings from the SMER application in order to make the largest possible impact on local communities.

4.2.2 Goals

The goal of the tests is to validate the SMER use case and check the user satisfaction with the novel service that is provided, especially in terms of a single application integrating functionalities that were typically available through multiple applications installed on an end user device. In the tests and post-test questionnaire we focus on the technical perspective of the implemented use case and on the novel offerings available through symbIoTe (e.g., presentation of cross-platform data or integration of routing service with air quality measurements).

4.2.2.1 Smart Mobility and Ecological Routing Validation Setup

The Smart Mobility and Ecological Routing validation covers the complete information flow of the SMER use case, and is currently deployed as real-world scenario in the three focus cities: Zagreb, Vienna and Porto. It includes two aspects of the use case: (I) data acquisition using wearables sensors and (ii) usage of PoI search and routing service that is based on collected and processed data. The interaction overview is shown in Figure 8. End users use the application which communicates with the Smart Mobility and Ecological Routing enabler that comprises of three functionalities: (I) Interpolator logic interpolating missing values of ecological parameters, (ii) PoI Search suggesting PoI to end users, and (iii) Green Route Calculator calculating the route between two locations taking into account environmental data (both collected environmental readings and interpolated values). The enabler greatly benefits from the symbIoTe ecosystem, because the symbIoTe Core services returns all available resources, which are accessible using the unified interface, no matter to the underlying platform.
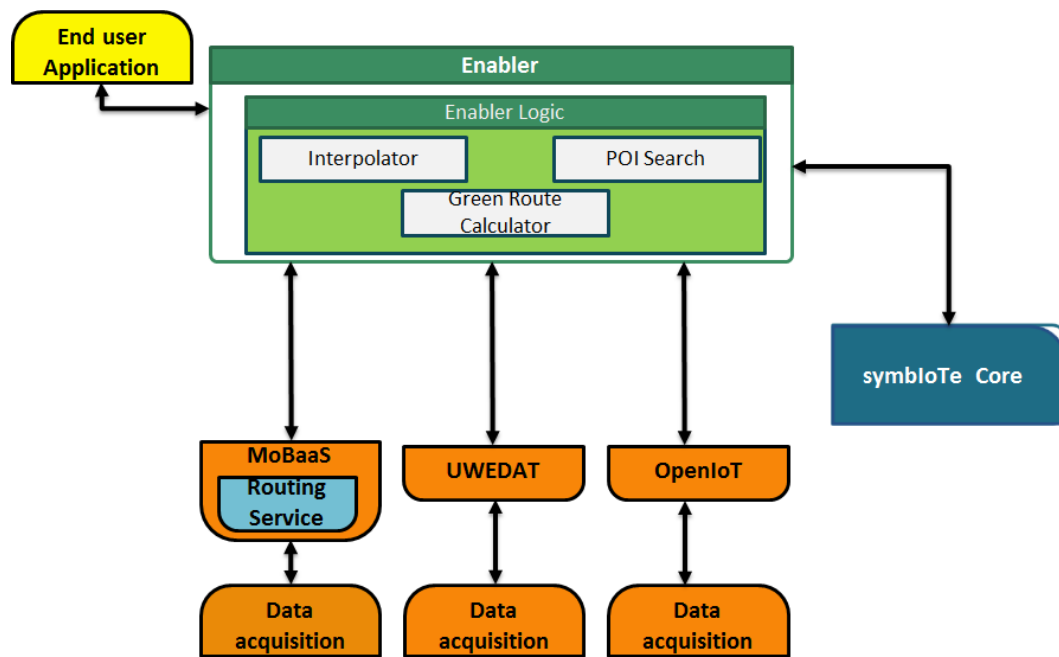
Figure 8: The SMER use case interaction.

The data acquisition process is in control of individual platforms and uses platform native interfaces. The UWEDAT platform integrates validated data from fixed stations, while MoBaaS and OpenIoT use small wearable sensors and regular citizens to acquire data in areas that are not covered by fixed environmental stations. Data measurements are stored in the platforms, while the enabler stores only data related to its services, thus not duplicating data. An example of wearable sensor and corresponding application, developed in the OpenIoT project, is shown in Figure 9. The application is designed to work in the opportunistic mode, i.e., it does not require any action from an end user during the data acquisition process, only to start the application and connect a wearable sensor with a mobile device, because the mobile device serves as a gateway between the sensor and the platform. End users gathering environmental data are also encouraged to use the SMER application to benefit from collected data. It is important to note that the SMER application is available to all citizens and not just to those that contribute data regularly, because only a small number of users wearing the sensor is enough to achieve sufficient coverage of urban area in order to be able to implement services such as ecological routing.

Figure 9: Wearable sensor and OpenIoT data acquisition application

Following the initial validation and its results, the evaluation of the use case is performed mostly through organized trials in Zagreb, Vienna and Porto. In the cities of Zagreb and Porto trials run by symbIoTe consortium members are extended with the OC2 winner third-parties that applied for the trial organization. Zagreb hosts two trials, one from UNIZG-FER and a second organized by Sindikat Biciklista, a not-for-profit organization that focuses on the cyclist community, while in Porto in addition to the trial organized by UW, the symbIoTe consortium supports the OC2 winner Monitar. The trial in Vienna is organized by AIT.

All trial organizers split end users in two groups, the first group has a primary task to collect as much data as possible, and the second group uses the SMER application to receive route suggestions. End users from the data collection group can also use the SMER application for routing and PoI search. Each trial has dedicated time slots for data collection, when all end users in charge of collecting environmental readings are active and move through the city. These slots can be considered as a guided measurement campaign. Such a short-term campaign is very important, because it provides the extensive real-world data set with environmental readings, available to symbIoTe users to develop new end user applications and to experiment with the collected data set (i.e., calculate correlation between sensor readings or determine minimal number of readings needed to interpolate city-wide values). Apart from the guided campaign, end users are expected to collect data whenever they are outdoor without interrupting their daily activities.

The trial organizers monitor the end user activity depending on the group they belong. Data collection users are evaluated primarily based on the number of collected environmental readings, distinct locations where they collected measurements, length of path they took while collecting the environmental data and total activity time. On the other

hand, users using the routing and PoI search service are evaluated by tracking the actual route taken by a user. This data can serve two purposes: (I) to observe how often users are taking the suggested route, and (ii) to improve the routing algorithm based on the actual route taken.

4.2.3 Methodology

The validation of the SMER use case consists of practical use of the sensors and SMER apps, and a post-test questionnaire. The goal is to perform a final check on the equipment, test all features and anticipate possible problems during field trials.

To contrast, the trials will be conducted with environmentally aware volunteers (i.e., end users), which receive a symbolic compensation for their effort.

4.2.3.1 Setting

The SMER use case should be validated in a real-world scenario, so the tests are running in parallel while end users are executing their daily routine, i.e., moving through an urban area such as: commuting to work, taking an afternoon walk, etc. The applications can be used anywhere, but due to the lack of an established user base, i.e., citizens carrying wearable sensors and sending environmental data, the symbIoTe consortium and OC2 winners are focusing on the urban areas of Zagreb, Vienna and Porto.

4.2.3.2 Questionnaire

A questionnaire is given to all end users after they complete the test run. The questionnaire is divided in five sections:

- General demographic information about end user and their equipment,
- Questions related to the wearable sensors and data acquisition process,
- Questions related to the routing and PoI search services,
- Questions related to the overall Quality of Experience (QoE), and
- other comments.

Questions related to the data acquisition are filled in only by users that are using the wearable sensor, and all users fill in all other questions. The questionnaire examines the user opinion for both the implemented use case and the offerings of the symbIoTe ecosystem, such as: sharing its data outside of its home platform or whether he/she feels beneficial to combine cross-platform data to achieve a service. Also, it is investigated whether end users are willing to invest some of their time and money to provide environmental data outside of such test run.

4.2.3.3 Test Flow

Preparation of the symbIoTe components and SMER application involved in the use case were done by end of May 2018. May and June 2018 were used to run the validations.

Once equipped with a sensor and a smartphone that runs the SMER app, users tested the basic usability and viability of the system and the planned trial evaluation method. The use case is focused on the outdoor air and environmental data quality, and all users are warned to turn off wearable sensors while they are indoor, but no penalties apply in case they forget to turn off the sensor. All transmitted data is anonymized and no user-specific data is stored. Additionally, all users are informed about which data is collected during the briefing, and they are expected to give the consent to participate.

Apart from the guided measurement campaign, no specific instruction were given to the end users, simulating a real-world scenario. All users were encouraged to also participate in the longer-term trials by using the use case symbIoTe application for routing and PoI search.

4.2.3.4 Participants

The validation runs focused sessions mostly with consortium members and people from the consortium institutions. The first test run was held in Zagreb during June 2018, with 15 participants carrying sensors and collecting data for three weeks. The validation users self-reported to be mostly students (90% younger than 25) and females (80%).

4.2.4 Evaluation

The SMER use case is evaluated on two levels:

1. Software offerings enabled by symbIoTe and
2. Citizen impact of the SMER use case.

The offerings enabled by symbIoTe addresses questions regarding the cross-platform data integration and number of usages of the use case application. Citizens' impact will address questions regarding the number of involved users, willingness to invest some of their time and money to continue supporting such tests and their opinion regarding the overall quality of experience of the use case implementation.

To summarize, the use case will be evaluated through the following KPIs:

- Number of users of the use case application,
- Number of collected environmental readings (including all three involved IoT platforms),
- Number of route requests,
- User acceptance of offered ecological routes (by tracking whether a user follows suggested route)
- User experience regarding the Android applications,
- The use case application usefulness, and
- Overall use case quality of experience.

4.2.5 Results

The SMER validation questionnaire was filled in by 10 participants of which 9 of them used the CUPUS sensing application and 1 participant used the SMEUR routing application. A single user reported usage of the SMEUR sensing application because the application was in the final phase of testing, with frequent updates so usage was focused on resolving all open issues and improving quality of presentation rather than to user satisfaction. The assessment of the SMEUR routing application will be gathered during future trials and will include all improvements based on this trial run.

Users reported using devices from Motorola, HTC, Huawei and Samsung (share 50%) and device OS was Android versions 6.0 – 8.0. General habits regarding riding a bike and walking are shown in Figure 10 and Figure 11. We can notice that only 20% of users are

riding a bike frequently, and others are riding a bike less than once a month. In contrast to, taking longer walks where 90% of users are doing that activity multiple times a week. This numbers are quite expected, because we looked for volunteers that regularly ride a bike or take longer walks, in order to cover larger areas of a city.
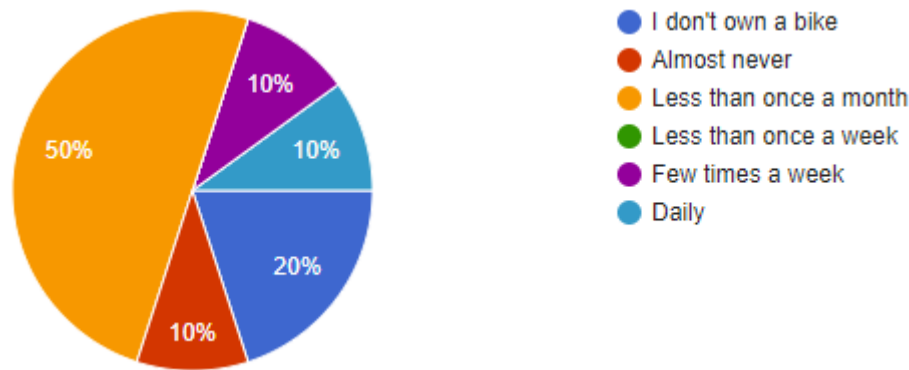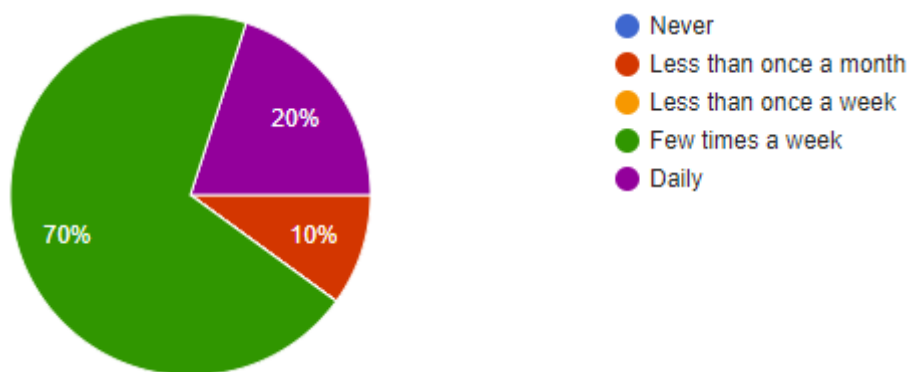

Figure 10 Bike riding frequency

Figure 11 Walking (longer than 20 minutes) frequency

Table 1 presents overall results of the questionnaire regarding the CUPUS sensing application used in the trial. All questions have offered answer in the scale 1 – 10, where 1 represents claim "I do not agree" and value 10 represents the answer "I completely agree". The table shows average value of user answers, and standard deviation so that we capture spread of the values in answers. Users think that the app is easy to use (average 8.33) and can be quickly learned (8.44). The similar conclusion can be drawn if we study the low average on questions regarding necessary support to use app (1.78) and complexity (2.56). The highest average value had the questions regarding willingness of users to share data with other users, which was very high 9.22 and their interest to contribute data during their day-routine 7.44. This high average drops significantly if user needs to buy sensor node (average drops to 2.44). Finally, average value of interest to collect data outside of trials is 4.67, showing that users are not clearly determined whether they are willing to perform such activities on the long run. Wide spread of answers to this question is positive, because small subset of users are willing to use it in the long-term, and since small number of users is sufficient to cover large urban geographical areas the long-term run of the data collection campaign is feasible.

Table 1 Results of the sensing application questionnaire for trial in Zagreb

Question	Average	Standard Deviation
I think that I would like to use this app frequently	5.70	2.33
I found the app unnecessarily complex	2.56	1.34
I think the app was easy to use	8.33	0.81
I think that I would need the support of a technical person to be able to use this app	1.78	1.87
I found the various functions in this app were well integrated	7.22	1.62
I think there were too many inconsistencies in this app	4.11	2.69
I would imagine that most people would learn to use this app very quickly	8.44	1.83
I found the app very cumbersome to use	3.56	1.71
I felt very confident when using the app	8.22	1.31
I had to learn a lot of things before I could get going with this app	2.56	1.71
I am satisfied with the ease of process of connecting a wearable sensor to the mobile application and starting the data acquisition process	5.67	2.36
I would share data that I have collected with other users	9.22	1.62
If I would share my data, it would be important for me that data is anonymized	3.56	2.67
I am interested in contributing and publishing the air pollutant measurements during my day-routine	7.44	2.75
I am interested in buying an air quality sensor to be able to contribute the air pollutant measurements	2.44	1.17
I am interested in using this app outside of this trial	4.67	2.58

The last part of the questionnaire was free text form where users could provide other comments regarding the application and overall use case experience. Users reported most problems with volatility of Bluetooth connection with a sensor device, and inability to use a sensor device during rain (i.e., a sensor device should not get wet). Also, users reported that they find interesting to see air quality around them, and the fact that data from all users contributing are visible with simple subscription. Figure 12 shows overall recommendation of the use case to friends and/or family. It is encouraging that none of the users reported that the system should not be recommended. Users find the use case useful and possibly very interesting to their friends and family.
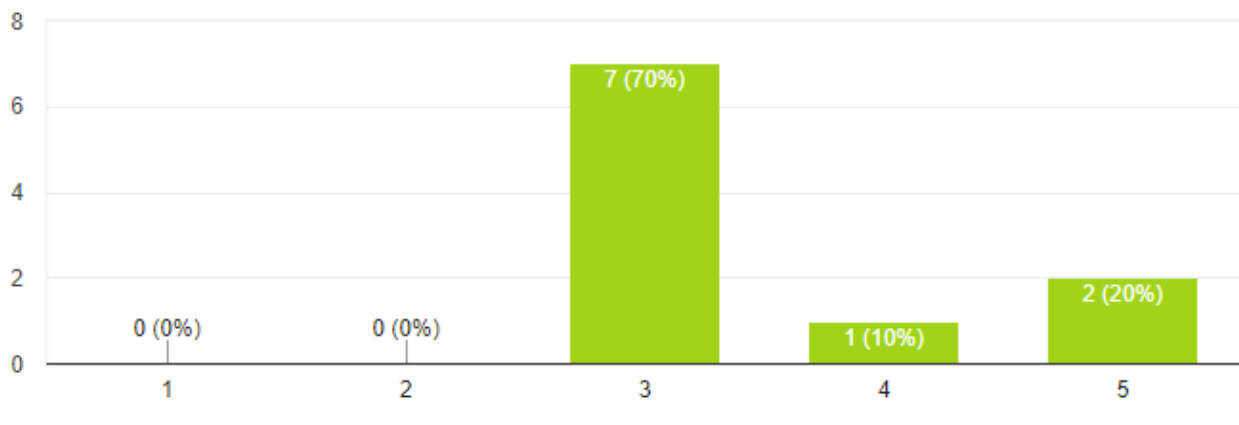
Figure 12 Question regarding overall recommendation of the use case

Results for trials based on this first validation will be available upon the end of all trials in Zagreb, Vienna and Porto and they will be reported in Deliverable D5.6 focused on trials and deployments. Interest shown during symbIoTe OC2 is encouraging, and resulted in the organization of additional trials in two (Zagreb and Porto) out of three focus cities. OC2 winners consider that such a use case can have an impact on their local communities and it will include more citizens to promote ecological awareness in urban areas.

The SMER use case also helped in development and validation of the symbIoTe software components and supporting documentation in order to improve quality of presentation of the symbIoTe framework to non-consortium members. All three involved platforms are integrated in the symbIoTe ecosystem and platform owners offered pre-release evaluation of the symbIoTe software.

4.3 Use Case: Smart Stadium

4.3.1 Overview

The Smart Stadium use case aims at testing symbIoTe in the framework of sports infrastructures, typically attended by large numbers of people during a delimited time to watch a sports event or any other type of show or recreational activity.

A Smart Stadium solution intends to provide visitors with a complete experience around the event. Stadium managers are perfectly aware of the direct and indirect benefits that they can get through the provision of added value services that enhance the visitor experience. The provision of those services requires the use of several technologies based on different IoT infrastructures, either permanently installed in the stadium or deployed or made available for a specific event, in any case perfectly integrated and powered through symbIoTe-enabled applications. The Smart Stadium use case is focused on the enhanced stadium visitor experience in the following areas:

- *Visitors services:* Taking advantage of the specific location of the visitor to make specific promotions, provide location-based information, information on available services, their location, how and when to reach them, their conditions and cost.
- *Stadium promotional services*: Third parties operating the added value services have the possibility to make general promotions, or specifically and contextually driven campaigns. In addition to the direct information in the different applications, visitors may become aware of these promotions through notification systems.

● *Remote ordering services*: Visitors may send orders to the providers of the added value services, which receive and process them in advance. These services are key to optimize the stadium operation, for example by dramatically reducing the queues of people trying to access the added value service.

All these services require the interaction with different IoT independent platforms that would require very complex programming and adaptation to the characteristics of the specific platforms deployed in each stadium. For example, any location-based service will require interacting with a geolocation/indoor location service, the implementation of which may dramatically change from one stadium to another (open air stadiums where at least some areas are covered with GPS or closed halls/arenas that fully require indoor location service), while this will happen seamlessly with symbIoTe enabled platforms.

4.3.2 Goals

The Smart Stadium use case involves three main types of users with completely different roles, expectations and potential benefits from the Smart Stadium solution:

● *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 provided services will require that the visitor owns a smartphone and has downloaded the stadium application. The attendance, characteristics and number of visitors to the stadium are totally unpredictable. For certain events, an estimate can be made regarding the number of attendees based on previous events with similar characteristics. Still, in no case it will be possible to contact and interact with visitors in advance, and since their participation in the use case requires that the stadium app be downloaded, it will be necessary to carry out a promotional campaign that encourages them to download it. The main advantages of the Smart Stadium solution expected for visitors are improvement in services 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* provide complementary added value services to stadium visitors, such as food, kiosks, general information, etc. They may be third parties contracted by the stadium manager, or be directly provided by the stadium manager itself. This type of user of the Smart Stadium solution is somewhat more predictable than the visitors of the stadium, since they will have to establish in advance some type of contract with the Stadium Manager. Even so, it will usually be difficult to contact them in advance, and the interaction with them will only be possible once they come to the stadium to provide their services. Retailers expect to improve the efficiency of their services with a faster service that can reach a larger number of customers. In addition, they also expect to improve the acceptance ratio of their promotions and offers, as they are specifically targeted at the closest customers.

● *Stadium Managers* have the responsibility of managing all stadium services, from the most basic ones (e.g., ticketing, access, emergency medical services, security staff etc.) to the added value services. They setup the stadium infrastructure for service providers. The Stadium Manager is the main stakeholder in symbIoTe-based services, is usually going to be easily accessible, and can provide feedback whenever necessary, i.e., before, during and after the events. The Stadium Manager expects to improve the use of its facilities, taking better advantage of the large number of visitors to improve revenues through retailers installed in the

stadium. Regarding stadium visitors, the Stadium Manager expects to offer more complete and personalized information, which will result in an enhanced visitor experience, so that they will be open to come back to the stadium for other events and recommend the experience to other potential visitors.

The final purpose is to show the benefits of a Smart Stadium solution to visitors and retailers, but most remarkably to Stadium Managers, which are the ones that will be contracting this type of solution. In addition to the benefits themselves, the use case will also show how easy it is to develop and deploy the solution, demonstrating to Stadium Managers that these solutions do not generate any additional burden to them.

4.3.3 Methodology

The validation methodology consisted in two phases:

- As a first phase, Worldline employees that were not involved in the symbIoTe project tested the three applications: visitor, retailer and promowall applications, providing their feedback with the perspective of end users.

- As a second phase, we took advantage of a hockey match between ATHC and F.C. Barcelona on 13 May 2018 which had a very limited number of visitants and employees. The visitor application was showed to visitors, the retailer and the promowall applications were showed to stadium employees, and the three applications were showed to the stadium manager.

4.3.3.1 Setting

The validation took place first at Worldline premises in Barcelona, and then at the sport facilities of Atlètic Terrassa Hockey Club (ATHC)[6], located in the village of Terrassa, 30 km from Barcelona, Spain. Their facilities include the main hockey stadium, several hockey training fields, tennis and paddle courts, swimming pools, gym and fitness centre, bar and restaurant, and other complementary services.

The number and distribution of all involved devices, beacons, remote ordering devices and promowalls, was decided to allow for a suitable validation of the applications, testing all the available functions of the different applications.

4.3.3.2 Questionnaires

Informal interviews were done for all types of users. However the approach was different for each of them and adapted to their characteristics and potential expectations.

- *Visitors*: Even if in general the stadium manager considered that direct interviews with visitors would be too intrusive, he authorised some informal interviews to selected visitors for the purpose of application validation.

- *Stadium employees, acting as service providers*: They were asked by means of a direct interview on their perception of the services provided through symbIoTe. The interviews were focused on asking about the advantages that the solution was

---

[6] Club esportiu a Terrassa, centre esports, fitness, natació, activitats I cursos: https://www.athc.cat/ [last accessed: 2018-05-22]

going to bring to them, the easiness to use the application on the remote ordering and promowall devices, and the perceived problems, if any.

● *Stadium Manager*: A first informal interview to the stadium manager took place after the previously mentioned hockey match. It was an initial interview before the trials, in which the Stadium Manager was asked to give his opinion and feedback on the three applications, focusing on usability and potential of the solution aspects.

4.3.3.3 Test Flow

The validations were conducted before and during the event previously specified. Before starting any test, the required infrastructure had to be installed and configured (beacons, remote ordering devices and promo walls). This installation and configuration was done prior to the event, and was concluded with all devices registered into symbIoTe core.

The tests essentially consisted in the execution of two main flows, the promotions flow and the orders flow. Each of these flows involved several IoT platforms and several types of end users.

Promotions flow

One of the service providers at the stadium decides to issue a promotion, and in order to have a quick response, decides that the promotion must be sent only to the stadium visitors that are in the same area of the stadium and also the promo walls in that area. The service provider prepares the promotion in his symbIoTe-enabled device and sends the promotion. The promotion is immediately received by all visitors in that area that have downloaded the stadium app, and in all promo walls of that area that immediately show the promotion in their panels.

Orders flow

One of the visitors would like to order some food. She launches the stadium app and looks for food service providers around her. She selects the closest service provider, gets the offering from that service provider, selects one of the products, and sends the order to the service provider. The service provider receives the order in his symbIoTe-enabled device, accepts the order and the visitor receives the acceptance from the service provider. The visitor just has to wait for her order to arrive. The service provider receives the location of the visitor that placed the order, and once the food is ready, he goes to the visitor location and finishes the purchase.

Both flows were repeated during the validation tests under different conditions and with different end users in order to get a representative diversity of results.

4.3.4 Evaluation

After the end of the validation tests, the informal interviews were analysed in order to evaluate user satisfaction for all different types of users as defined before. The user satisfaction evaluation was done in accordance to the following KPIs:

● Usability of the solution and design of the application,
● Usefulness and effectiveness of the solution,
● Ease of use of the solution,
● Potential of the solution in the future, and
● Potential of the solution in other scenarios or types of events

4.3.5 Results

The results of the evaluation, derived from the informal interviews, can be summarized as follows:

- Visitors: We showed the visitor app to ten stadium visitors, known and selected by the Stadium Manager. These ten visitors had the opportunity to use the visitor application during and after the hockey match. No initial instruction was given to them, they had full freedom to use the application in the way they wanted, discovering the functionalities by themselves. After some time playing with the application, personnel from Worldline talked to them, not only to get their impressions but also to check if they were using the application as expected or they were missing or not appreciating the value of some features. Their impressions were very positive in general, from design and usability perspectives we just received some few advises and requests, all of them very minor. Regarding the offered features, they also agreed in that they looked very useful to them, even if the reduced visitors' and retailers' assistance to that specific match made it more difficult for them to figure out the full potential of the application.

- Stadium employees, evaluating as Service providers: We showed the retailer and promowall applications to three stadium employees, all of them related to the provision of different services in the stadium facilities. They all find the application very useful for those matches and events with a large number of visitors coming to the stadium, providing them with an easy way to create awareness and interest in their products and to make offers to interested visitors. They provided some few recommendations related to the design of the application that have already been considered and implemented.

- Stadium Manager: He had the opportunity to look at the three applications, also while selected visitors and employees were using them, and agreed to the comments already provided by them. His main concerns were more related to requirements towards the stadium (installation of devices such as beacons, remote ordering and promowalls) rather than the applications, which he found well-designed, easy to use, and with good business potential for the stadium during the most important matches and championships in which they are participating. He committed to provide more comments and analysis after the trials, with a higher base of users and real retailers taking advantage of the applications.

4.4 Use Case: EduCampus and Enabler-Based Indoor Location

The validation for this use case comprises two parts with complementary focus. The first part, starting with Section 4.1.1 right below, validates system aspects of integration capabilities offered by symbIoTe at two educational campuses (KIT and IOSB). The second part in Section 4.4.6 and onwards evaluates enabler-based indoor positioning at an office space. It is scheduled for later use at another educational campus (UNIZG-FER).

4.4.1 EduCampus Overview

The EduCampus use case aims at testing the symbIoTe potential to provide an interoperability framework for integration IoT platforms. The platforms to be integrated support indoor localization for navigation in campus and office spaces, and room information and reservation.

The first focus area of this use case is to evaluate the conceptual approach of symbIoTe, where federated platforms are able to expose own resources and use exposed foreign resources, with minimal impact on the platform applications. The second focus area is the resulting application behaviour of a federated platform. The challenge in this second area is to use the existing end-user services of a legacy platform in an extended application scope, namely on a foreign campus with IoT resources managed by a federated platform.

4.4.2 Goals

Based on the two different focus areas of this use case, different end users are addressed. For the conceptual evaluation, the goal is to evaluate the applicability of the symbIoTe interoperability concept. This will address the application designers and system integrators.

The second goal is to evaluate the user experience of an extended legacy application. This will address the end users of the existing applications and the administrative users with extended responsibilities.

4.4.2.1 Conceptual Evaluation

The integration of two individually designed and operated IoT installations provides challenges on many levels. This evaluation starts with the question whether the conceptual approach of symbIoTe is efficiently applicable to integrate platforms that are using different information models; each one designed to serve individual application needs and was initially not used to expose resource to an external application. The efficiency will be measured based on the task to be done to archive such integration. These tasks are the exposition of the information elements to be used by a federated application, and the mapping of data elements from one application to another. symbIoTe provides a framework to model resources, by having a generic Base Information Model that can be extended by an application specific model. For the mapping symbIoTe introduces a language to define rules that need to be applied by system integrators without specific background on semantic technologies. The conceptual evaluation will measure how effective system integrators are able to apply these methods.

4.4.2.2 Data Translation Efficiency

During the execution time the resource discovery of remote resource, the data transfer between IoT platforms and finally the translation of data encodings will affect the performance of the applications. The goal of the second part of the EduCampus evaluation is to measure the impact of these performance costs.

4.4.2.3 End-User Experience

The evaluation topic will also aim at the user experience of the final end users. It is expected that the mapping to two independent application models will never be complete in the sense that every aspect of one legacy application can be mapped to another legacy application. The question is how well the two EduCampus applications from Karlsruhe Institute of Technology (KIT) and IOSB are able to deal with missing information, in case of incomplete mappings. To quantify this evaluation, the end users in the trials will be asked how they experience the behaviour of the legacy applications when operated in a remote campus in contrast to the standard operation in the native campus.

4.4.3 Methodology

There will be two different areas for the evaluation. For the conceptual and the user experience evaluation the KPIs will be based on subjective assessment of persons. The main instrument for this evaluation will be interviews and questionnaires. For the performance evaluation there will be latency and execution time measurements. The build in monitoring features in the symbIoTe framework will be used for the performance evaluation.

As a specific aspect for the conceptual evaluation, we will investigate how well the IoT interoperability framework of symbIoTe can be used within the Behaviour-Driven Development (BDD) and Domain-Driven Design (DDD) methods used within the KIT development team.

4.4.4 Evaluation

The EduCampus Trial will be executed in cooperation with the Karlsruhe Institute of Technology (KIT), specifically with the Research Group Cooperation & Management (C&M)[7], led by Professor Dr. Abeck. A group of 5 students has been tasked to extend the NavSG application of the C&M department. For the trials an additional team will be installed to get user experience from the end user perspective.

On the Fraunhofer IOSB side the integration is done by the personnel assigned to the symbIoTe project for the end user trials. Additional IOSB personnel will be invited to take part in the evaluation on a voluntary basis.

The focus for the EduCampus use case will be the indoor location using BLE beacons for the purpose of navigation and room information and reservation. The focus will be the navigation for the KIT application and the reservation for the IOSB application. The foreseen KPIs are:

- Efforts for vocational adjustment to the method of exposing an information model (Time and perceived complexity).
- Effort to formulate the exposed information model (Time and perceived complexity).
- Effort to formulate the mapping rules between KIT and IOSB information model (Time and perceived complexity).
- Effort to integration the symbIoTe framework (Time and perceived complexity).
- Performance for resource discovery (Service latency and CPU load).
- Performance for data transfer including encoding translation (Service latency and CPU load).

4.4.5 Results

From the first part of the evaluation on the conceptual aspects, we got some early observations. The students tasked with the symbIoTe integration had no to very little background on semantic technologies. While none of them had used ontologies before, the familiarization with an ontology editor and understanding of the Base Information Model took only very little time. The exact time will be provided after evaluation of the students' time sheets but it was in the range of few hours. For the formulation of the exposed data model the students had some general questions related to data modelling

---

[7] Willkommen bei Cooperation & Management (C&M, Prof. Abeck): http://www.cm.tm.kit.edu [last accessed 2018-06-08]

techniques, but otherwise the task seems to be easy and was done within one working day.

The mapping language was not finished at the time while the first group was working on it. This evaluation will be done with a second group.

4.4.6 Enabler-Based Indoor Positioning Overview

An additional implementation in the Edu Campus use-case is an indoor positioning system which is designed and tested by VIP and will be implemented on VIP main campus. As system utilizes multiple-available wireless technologies, it is implemented as an enabler and can be applied to various different campus or other large indoor environments (business, hospital and educational campuses, large shopping centres and parking garages, closed sport arenas, transport hubs such as airports and in general any large closed space).

Positioning and subsequently, navigation in outdoor space has been well developed and implemented thanks to satellite positioning systems such as GPS, Galileo[8], BeiDou[9] or GLONASS[10] which provide high level of accuracy when there is an unobstructed view of the sky above. All such systems and dependent applications fall short when the sky is not visible (primarily in Indoor or in cases of deep urban canyons with limited sky visibility.

While specialized and custom solutions do exist primarily providing precision positioning within constrained industrial spaces (Ultra Wideband Indoor Positioning), there are no widely available and standardized ways to deliver usable indoor positioning. Based on the specification defined in D2.6 [15] an indoor positioning system and accompanying user and server application is in development and their architecture. An early version has been shown in D5.4 [16].

The system utilizes fingerprints from various wireless network infrastructures including 3GPP-standard mobile network, 802.11 Wireless LAN and Bluetooth (BLE) beacons to determine physical position by utilizing the trilateration algorithms (calculating position based on measured distance to pre-defined fixed points). After determining the physical location by aggregating the information from different Specific Location Enablers (one per each wireless infrastructure present), the system converts the physical location into a symbolic location by utilizing a dedicated component of Symbolic Location Enabler.

---

[8] Official Galileo-Website by the European Commission: http://ec.europa.eu/growth/sectors/space/galileo/ [last accessed: 2018-10-29]
[9] Website of BeiDou Navigation Sattelite System by the Chinese National Space Administration: http://en.beidou.gov.cn [last accessed: 2018-10-29]
[10] Website of GLONASS by the Roscosmos State Corporation for Space Activities, Russia: https://www.glonass-iac.ru/en/ [last accessed: 2018-10-29]
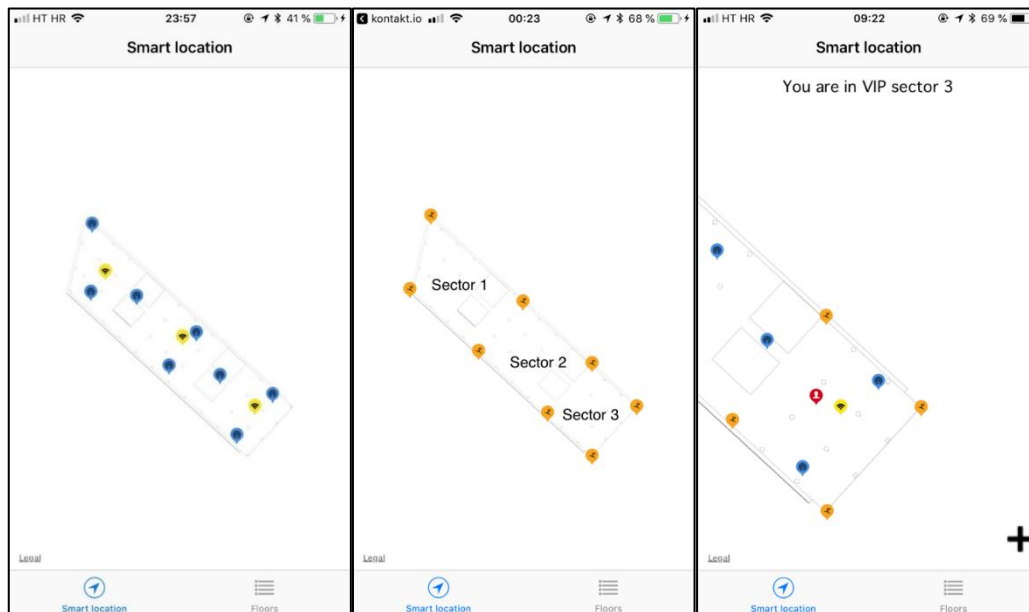
Figure 13: Example showing floorplan, sensors, defined sectors and positioning result

From the end-user perspective, an avatar is positioned on the provided indoor maps (on correct floor level and at appropriate location), and the user is provided with a symbolic location (building, floor, room, area). The quality of the positioning should relate to number and type of wireless transmitters present in the certain area where best results are expected in areas augmented with Bluetooth (BLE) beacons and those where all wireless infrastructure is installed having indoor positioning in mind.

Validation of the concept and actual working of the system has been done on the prototype implementation of the solution, with primary goals of determining the functionality of the solution itself (physical precision, application usability) and determining the required number of Bluetooth beacons to achieve required precision.

Final end-user trials (not in the scope of this deliverable) will be performed on VIP main office and technical campus (Zagreb Žitnjak), which is currently undergoing extensive reconstruction to improve various aspects of the office space, including the deployment of various smart building systems and supporting the more modern and flexible seating and work arrangements.

4.4.6.1 Goals

With rather frequent migrations and re-grouping of work teams, number of outside workers temporarily working on campus and recent mergers and acquisitions, tracking and locating teams and various resources (meeting rooms, videoconferencing and collaboration rooms, network printers, departments etc) has become a serious challenge, which we aim to solve with indoor positioning.

A prototype of the implemented system has been validated on one 1000m2 floor with three existing WiFI access points augmented with total of 8 Bluetooth beacons. The main office building consists of eight floors of same layout, thus validation on one floor is considered sufficient. Key goals of the validation were confirming:

- The usability and responsiveness of end-user smartphone applications on iOS and Android platform, comparison of precision between iOS and Android.

- The location precision with more or fewer wireless transmitters (WiFi-only floors compared with Bluetooth augmented floors, different transmitter topologies)

The primary validation point is the achieved precision and the time until which the precision is achieved, thus validating the usability of the application and the system. Another validation point is determining the required number and optimal positions of the Bluetooth beacons to achieve required precision, i.e. a greater accuracy than 3m of horizontal physical positioning at 99% availability and 100% vertical positioning.

4.4.6.2 Methodology

Various measurement methodologies have been used in for measurement of quality of radio technologies (mobile and fixed telecom services being our core business), thus tools for signal propagation simulations[11] and measurement[12] have been used to determine the quality of the WiFi and other wireless coverage on the floor where validation was taking place.

Based on the simulated wireless network propagation, walk-through tests have been performed to measure signal coverage from existing WiFi and mobile network infrastructure and adjust the locations and power levels of Bluetooth beacons used to augment the positioning precision. Figure 14 overviews the WiFi coverage map at the campus building.

Also, walk-through tests have been performed to validate the correct identification of wireless transmitters (WiFi access point MAC addresses and network identifiers, mobile network cell penetration and IDs, Bluetooth beacon IDs) and exact demarcation of rooms and defined spaces.
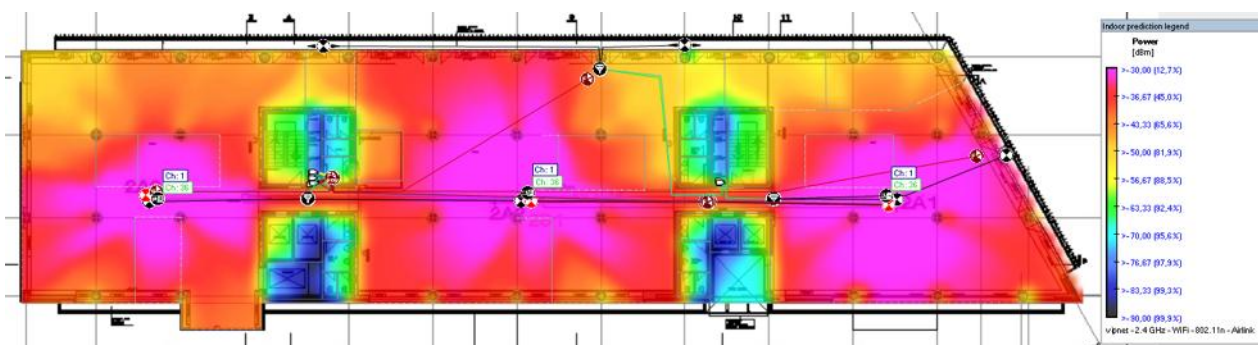

Figure 14: Indoor WiFi coverage map (2.4GHz) in Žitnjak campus building

Finally, a walk-through test with the Indoor Positioning application has been performed to measure the precision of the solution. This walk-through test predefines the route taken and defines measurement position on which the difference between the actual position and one offered by the application is evaluated.

---

[11] In-building wireless network design planning and deployment solutions : http://ibwave.com [last accessed 2018-10-01]

[12] Nemo Wireless Network Solutions | Keysight (formerly Agilent's Electronic Measurement): https://www.keysight.com/en/pc-2767981/nemo-wireless-network-solutions [last accessed: 2018-10-01]

4.4.6.3 Evaluation

Parameters by which system operation and usability are evaluated according to the requirements defined in *5G Study on positioning use* cases [17] which defines the positioning requirements that are planned for the implementation of 5G mobile networks, as our goal is to create a system that is in line as much as possible with the future 5G positioning implementation.

Horizontal accuracy is expected to the level of "High Accuracy Positioning Service" with Enhanced positioning, providing accuracy of less than 3m with 99% of availability in both indoor and outdoor area (requirement PR-009) and same level of vertical accuracy (3m) which is enough to distinguish the floor in indoor use (requirement PR-010).

Also, the time in which the positioning is provided is observed where the "time to first fix" (TTFF) should be below 30s or under 10s with reduced horizontal precision (requirement PR-013). Other requirements from the study are also taken into account where applicable (some are defined for different use-cases or for outdoor areas).

4.4.6.4 Results

Measurements were completed during two days, during work hours (09:00-17:00) to get most relevant results (presence of people also affects the wireless propagation) and with two different platforms (iOS on iPhone 7 using only Bluetooth beacons and Android on Samsung Galaxy A5/2016 using combination of WiFi and Bluetooth beacons).

On six predefined points (and after the adjustments to the positioning of the BLE beacons) multiple measurements have been performed with precision of the average location between 1m and 3m on various test-points, with better results in the (south) part of the building where more Bluetooth beacons have been added.

Precision has been better with the Android implementation compared to the iOS implementation. However, we could not determine if this is the result of Bluetooth-only implementation on iOS compared to the hybrid implementation on Android which takes into account both the positions of the Bluetooth beacons and positions of fixed WiFi infrastructure. Translation of the physical location to a logical location (i.e. one of three sectors that the physical floor was divided into) worked correctly and without delay.

Table 2: Measurement results

		Point 1	Point 2	.Point 3	Point 4	Point 5	Point 6
Measurement result	lon/E	16.031750	16.031658	16031491	16.031551	16.031436	16.031263
	lat/N	45.785315	45.785404	45.785471	45.785503	45.785582	45.785670
Exact location	lon/E	16.031760	16.031685	16.031473	16.031585	16.031415	16.031225
	lat/N	45.785321	45.785395	45.785470	45.785493	45.785558	45.785679
Acccuracy	m	1.05	2.33	1.36	2.86	3.14	3.10

Vertical accuracy has been 100%, the system always correctly identified the floor on which it was located, which was expected as the wireless signal penetration between the floors is low and system quickly recognized the closest transmitters and calculated the floor accordingly.

Further end-user testing and results will be documented in Deliverable D5.6, updated with the results available at the time. As construction work on upgrading of the campus will continue in 2019, interim available results and experiences will be documented, based on the segments of the campus where construction upgrade works and deployment of navigation augmentation beacons have been completed.

4.5 Use Case: Smart Yachting

4.5.1 Overview

Smart Yachting aims at testing symbIoTe potential in the context of the Yachting industry. This is a sector with a growing importance in Europe (see also the long-term strategy Blue Growth[13] of the European Commission), with an estimated yearly turnover of almost EUR 20 billion, involving approximately 32,000 companies which directly employ over 280,000 people[14].

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 procedure of the port, in itself a quite bureaucratic and tedious process, since Marinas operate in strongly regulated contexts. For the use case, the workflow logic is provided by the Navigo application Portnet[15].

Automated Supply Chain (ASC) on the other hand assumes that the yacht is berthed at the port, and therefore steadily connected – through Wi-Fi – to the port's Smart Space (SSP). The showcase aims to automatically identify the needs for goods and services on board of the yacht, so that automated requests for offers can be issued on the Marketplace platform of the port, provided by another application of the Navigo infrastructure (Centrale Acquisti[16]).

From a symbIoTe viewpoint, the use case is compliant to L1, L3 and L4 levels in accordance to Deliverable D1.4 [5]: yachts in fact are seen as Roaming Smart Devices (SDEV), 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).

A detailed description of the use case is provided in the D1.3 Deliverable [3].

---

[13] Blue Growth | Maritime Affairs: https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en [last accessed: 2018-06-04]

[14] Facts & Figures: http://www.europeanboatingindustry.eu/facts-and-figures [last accessed: 2018-06-04]

[15] PORT NET: IL SISTEMA DIGITALE DEL PORTO DI VIAREGGIO: http://www.navigotoscana.it/port-net-sistema-digitale-del-porto-viareggio/ [last accessed: 2018-06-11]

[16] NAVIGO PARTECIPA AL PROGETTO UE SYMBIOTE. Nel programma Horizon 2020 - Navigo: http://www.navigotoscana.it/navigo-partecipa-al-progetto-ue-symbiote-nel-programma-horizon-2020/ [last accessed: 2018-06-04]

4.5.2 Goals

This use case aims to verify the expected benefits of Smart Yachting for the involved users. Benefits include workflow simplifications, reduction of paperwork, automated notifications, and more accurate and up-to-date information retrieval for the port authority and workers; insights into possible business cases for suppliers; and finally, tighter integration and new symbIoTe-based applications for yacht owners as the end users of the platform.

Smart Yachting implies the involvement of different kinds of users, each with different needs and expectations for the technological solution proposed in the project.

For Smart Mooring:

● The users of Portnet, the Mooring Workflow application, namely the operators of the Viareggio Port Authority, working in the office. They expect on the one hand to simplify their work and to reduce the amount of paper forms that must be currently filled each time a yacht arrives in the port; on the other hand to be automatically informed of the arrival of the yacht in the port area (when still at a distance) and when it has finally berthed. We involve in the validation one operator of the Viareggio Port Authority in Italy.

● The workers in the Port Area, that can automatically receive notification (e.g., on their phones) when the yacht is arriving or has berthed, with the possibility to access in real-time to 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. We involve in the validation one port area worker (port operator) of the Port of Viareggio, Italy.

For Automated Supply Chain:

● We again involve operators of Port Authorities, this time of the ports of Viareggio and Marina Cala de' Medici in Italy. We involve one user for each port, those that are managing the marketplace web application Centrale Acquisti (see Figure 15), customised for each port. Their goal is to understand the potential of IoT technology to promote the offerings of the port. Also they see the availability of such "high-tech" services as extremely beneficial for the reputation of the port that can promote itself as a "smart" and "modern" harbour and potentially attract more customers for this reason.

● At least three local suppliers for each port are being involved, chosen amongst the most active and technological-savvy companies in the marketplace.
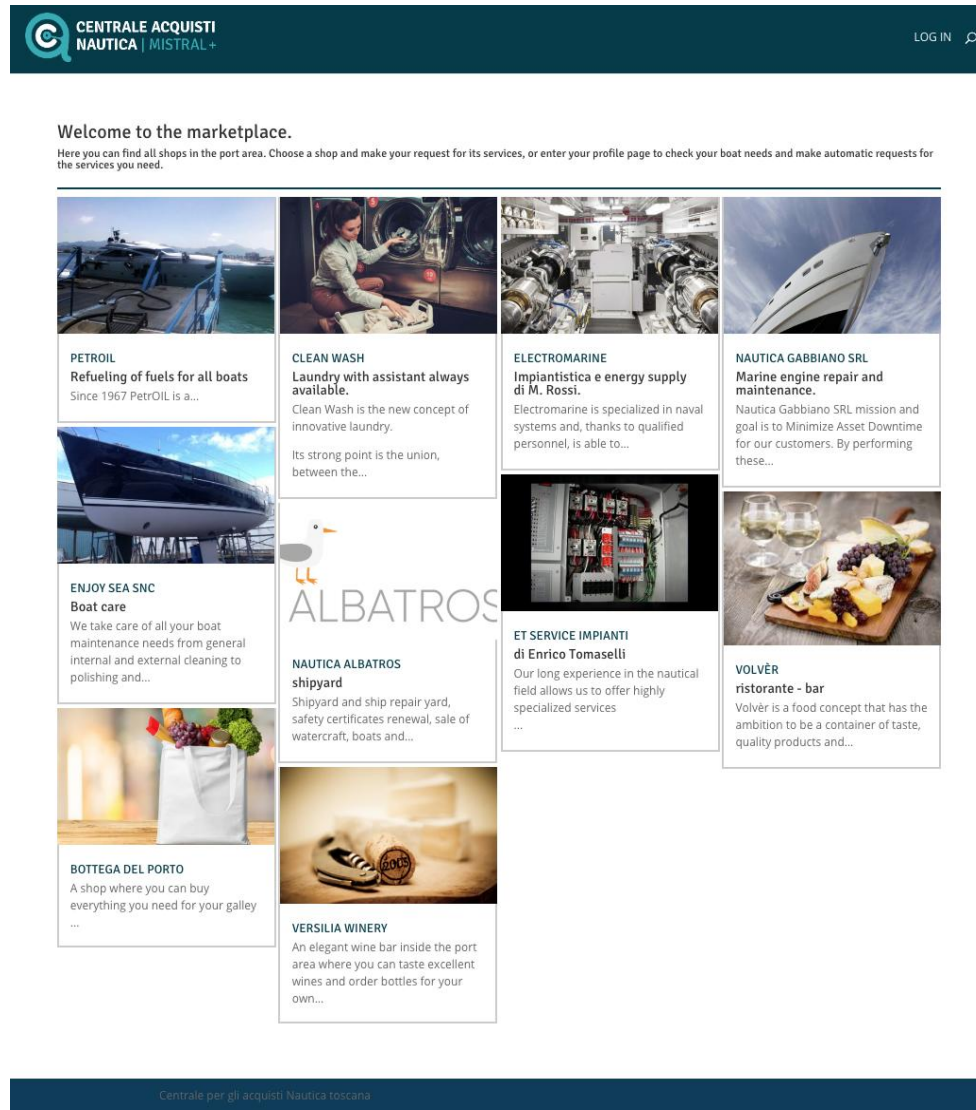
Figure 15: The Centrale Acquisti application, used in Smart Yachting[17].

For the execution of the validation, a yacht owner in each port involved, but only to help with the actual tests of the solution. The real goal here is in fact to showcase the implementations to the possible prospects of Smart Yachting, that is Port Authorities on the one hand and Yacht Manufacturers on the other.

As far as the latter are concerned, we will primarily target those that are already using Nextworks' IoT platform (Symphony[18]) on their boats. At present Smart Yachting in fact assumes that the yacht mounts Symphony on board, a platform that the Navigo's and Nextworks' teams have aptly extended and integrated in symbIoTe. Several of these manufacturers have their shipyards located in Tuscany, nearby the Ports of Viareggio and Marina Cala De' Medici (e.g., Benetti, Overmarine, San Lorenzo, Cerri, Logica, Leopard Yacht). They will be involved in some phases of the Smart Yachting trials later on, together

---

[17] Centrale aquisti: http://centrale-acquisti.navigotoscana.it [last accessed: 2018-06-05]
[18] Symphony | Nextworks: http://www.nextworks.it/en/products/brands/symphony
[last accessed: 2018-06-04]

with representatives from touristic ports, as possible prospects of the solutions developed in the project. For this purpose, a presentation event, both of technical and marketing nature, will be organised.

4.5.3 Methodology

Smart Yachting's validation is being performed by showcasing the applications to their potential users, which in our case are people working in the port (port operators, yacht captains and port authorities) that are involved in the workflows we cover in the software.

For the Smart Mooring use case, the workflow involved is the whole process that precedes the actual mooring of the boat, the documents exchange required and the data needed to be collected. Also the actual arrival of the boat at the port and the logistic required for the boat to moor.

For the automatic supply chain use case, the people involved are again yacht captains and port operators as well as services and goods suppliers operating in the port (from fuel suppliers to mechanicals and so on).

The assessment of the results will be based on:

- Software test plans, to validate the quality o the implementations,
- KPIs that will elaborate the effectiveness of the Smart Yachting solutions, and
- Users questionnaires and direct interviews to be conducted to all the people involved.

4.5.4 Setting

As described before, validations with users wereorganised in the ports of Viareggio and Marina Cala de' Medici, located in the Italian Region of Tuscany.

4.5.5 Questionnaire

Questionnaires and interviews were done with the users involved in the Smart Yachting trials, to assess their feedback.

The main points covered include:

- Expectations about the technology, before being involved in the trials
- Perceived difficulties of the user interfaces and of the workflows foreseen in the trials
- Perceived advantages of the solution
- General quality of the implementation
- Willingness to suggest the solution to other ports/companies
- Pros and cons of the use case according to their point of view.

While interviewing the users involved we've asked for their opinions regarding the point above, and what was their impression after having tried the softwares.

4.5.6 Test Flow

Separate tests for Smart Mooring and Automated Supply Chain (ASC) have been performed, the former only in Viareggio while the latter both in Viareggio and Marina Cala De' Medici ports.

For Smart Mooring a mooring workflow procedure was showcased: the processes of collecting documents and assigning the workflows to the user responsible of each step, the ability of the software to identify a boat approaching the port and later on arriving at the pier, as well as the ability to query the boat for information (i.e. latest route and various sensor reading).

People involved in this use case are as follow:

- a port operator, a man (in his early 40s) with dozens of years of expertise in the sector was involved

- a port authority, the chief of the local port authority was involved (around 50 year old)

- a yacht captain, a young (in his late 20s) but qualified man was involved

To realize the showcase, it is necessary that the following events are correctly recognized and managed by the involved systems:

- The yacht is detected through LoRaWAN[19] when still at a distance from the port; accordingly, a message is sent to the Portnet application, which successfully manages this communication by updating the workflow and alerting both the Port Authority operators and the Port Area workers.

- The yacht's IoT platform, when the vessel is near the berthing pier, connects to the port's Wi-Fi network and, through the S3M, to the symbIoTe infrastructure. Data from sensors on board are sent to Portnet and attached to the workflow of the current mooring procedure. Communications to the aforementioned users are sent: in particular Port Area workers are requested to move to the berthing pier to wait for the incoming yacht.

- The presence sensors on the pier detects when the yacht has finally berthed: a communication is sent to the Portnet application that can successfully close the workflow and inform the Port Authority operators.

ASC was tested in Viareggio and Marina Cala De' Medici: both ports already have the Centrale Acquisti marketplace application.

The test again involves yachts, this time berthed on a pier of the port and connected through Wi-Fi at the port's S3M. The yachts are configured (through real actions or simulations) to express a certain amount of maintenance or supply needs.

People involved in this use case are as follow:

- a yacht captain, the same man as the one involved in the other use case

- two port operator, one in each port, men working in the field for the last 20 years

- four potential goods and services suppliers, two fuel supplier – on in each port – one mechanical, and one food supplier

---

[19] Home page | LoRa Alliance: https://lora-alliance.org [last accessed: 2018-05-22]

The showcase consists of the following steps:

1. The yacht captain makes a request to access the yacht's machine data from the Centrale Acquisti web interface.
2. Centrale Acquisti accesses the yacht's resources – through its symbIoTe enabler – to have the list of the needs on board.
3. The application must perform a corresponding match-making with the possible suppliers in the port area (in particular of those involved in the validation).

The yacht captain and the service supplier supervised the flow of requests and the successful execution of the matchmaking actions performed by Centrale Acquisti given the machine data received from the yacht.

The local suppliers used the back-end of the Centrale Acquisti to answer to the requests of offer automatically generated by the system; in particular they could evaluate if the information acquired by sensors on board and received through symbIoTe's services are detailed enough (or simply useful) to allow them to produce an offer, without the need to directly contact the yachtsman.

The test is repeated simulating different conditions (and therefore needs) on board.

4.5.7 Evaluation

The involvement of users is assessed through interviews performed after the showcase.

Besides software tests, that focused on verifying the correctness of the implementation, a KPI-based evaluation is used to monitor the effectiveness of tests. Amongst the KPIs that have been chosen for Smart Yachting are:

- Ease of use, as experienced by port personnel, of the solutions prepared for Smart Yachting
- For Smart Mooring:
    - Savings in time by the port personnel in managing the mooring procedure through symbIoTe
    - Accuracy and completeness of the data acquired from the boat and attached to the mooring workflow, respect those managed manually
- For Automated Supply Chain (ASC):
    - Percentage of the most common resupply yacht's needs that can be mapped through IoT sensors and therefore managed by ASC
    - Usefulness of the information acquired through sensors on board to understand the needs and to prepare a complete offer without contacting the yachtsman
    - Number of possible suppliers to fulfil the yachts needs in the two ports.

4.5.8 Results

Results are extracted from informal, non-recorded interviews with the users described above. Beside asking them what was their impressions on the software as a whole and on the workflow in particular, we specifically asked for thoughts about the symbIoTe related services (automatic sensor data retrieval).

For Smart Mooring at present it was possible to simulate the automatic acquisition of information from the yacht's sensors that are attached to the mooring workflow. The

possibility to have detailed information about the vessel's route directly on the screen (not just a generic description, like those currently inserted in paper forms) plus exact data about the yacht state has been strongly appreciated by Port Authority operators. Smart Yachting in this sense will allow to measure the exact amount of black and grey water waste, plus indications about the average fuel consumption of the boat and the temperature of the exhausts emitted by the yacht: this information is crucial for evaluating the environmental impact of the incoming vessel in the port. In perspective this paves the way for some effective data analytics that could also provide predictive indications before the touristic season begins.

The ability to advance the workflow automatically when the boat reaches its pier was also considered rather convenient by the port authority, and the port operators found that having more precise information on the time of arrival would let them arrange their presence at piers more efficiently, making them able to reach the pier as soon as the boat landed, but not too much in advance (which would waste their time).

Minor concerns regarding the user interface and the user experience were expressed, which led to small adaptation of the web app itself in the suggested directions. Requests gathered were mostly based on descriptions on the web app, and small changes in the workflow which was suggested.

As far as ASC is concerned, the solution has been strongly appreciated by the Port Authority operators of the two ports. Especially Marina Cala de' Medici will officially present the marketplace to its partners. The possibility of automating the matchmaking of the yacht's needs will be especially used as a marketing lever, mostly directed to the suppliers of the area. At the same time, the more visible the offering of services and goods in a port is, the more the harbour becomes appealing as a place to stay for incoming boats.

The goods and services suppliers see the Automatic Supply Chain as an opportunity to expand their turnover, in particular the mechanicals welcomed the idea of having a detailed description of the fault provided by some sensor, as that would provide useful information a user usually is not able to provide.

The yacht captain reported that the idea of having a market place for the port would make easier for them to get information on the available services at the port.

Of course in both cases the maximum benefit can be obtained if a significant number of yachts (and ports) complies with the Smart Yachting technology: in this sense, the growing interest in applying IoT solutions in yachting, as seen for example from the number of companies with similar offerings that participated in both symbIoTe's Open Calls, is an encouraging sign in this direction.

5 Platform Owner Perspectives

In this section we are looking into activities focusing on platform owners' perspective.

5.1 Goals

In order to properly address the actual requirements of end user validation audience, i.e. symbIoTe use case owners, industrial partners and external stakeholders, our work on establishing platform owner perspectives consists of the following steps:

1. Task-specific definitions of hypotheses and assumptions for validation and related methodology;
2. Living lab panels: identification and prioritizing key stakeholders and prospective markets with a focus on cross-platform deployments;
3. Identification of living lab validation goals and construction of dedicated living lab tools, such as living lab workshops with end users, user panels, idea challenges, value network diagrams, priority matrices, user journey scenarios, surveys, and questionnaires;
4. Categorizing value propositions: KPIs, metrics, generic value propositions;
5. Provider/programmer view on component/application value/functionality;
6. End user view on component/application value/functionality;
7. User-centric value flow diagrams; Use case specific living lab end user validation reports.

After initial living lab workshops with the winners of symbIoTe Open Call 1 (OC1), eight stakeholder groups were identified and prioritized into priority group A (including 4 stakeholder profiles), priority group B (including 7 stakeholder profiles) and priority group C including all remaining stakeholder profiles. A set of User panels were created, including representatives of End User organizations, mainly developers and CEOs from IoT platform owning companies.

In contrast to the end-user focused validations in Section 4, this panel operated at different technological level (middleware instead of application) with different level of IT expertise, the participants of the User panel played different roles (co-creation instead of validation), and they took different perspectives and SymbIoTe awareness levels. While the end user validations in Section 4 reflected mainly on symbIoTe enabled applications, not emphasizing dealing with symbIoTe, the User panel focused on the requirements towards symbIoTe components on middleware level, consciously engaging in the co-creation of requirements and developments.

5.2 Platform owners' perspective results

5.2.1 Inspiration and ideation

Prior to living lab sessions due diligence of SymbIoTe assumptions was carried out in comparison with existing user scenarios. T5.3 first gathered a set of points of interest mainly in the form of usage scenarios from external stakeholders by co-organizing ideation workshops, one in Berlin and two in Poznan. In order to inspire unobvious scenarios, each of these workshops gathered from 4 to 8 interdisciplinary teams whose task was to ideate

ground-breaking IoT solutions. By interviewing participants and analysing workshop results, T5.3 compiled the following list of end user points of interest:

- control of personal data,
- security of personal data,
- single login for many usages,
- scalability / standardization,
- software documentation,
- software speed of operation,
- flexibility to embrace multiple devices,
- flexibility to embrace variety of data (including video).

The gathered points of interest were later mapped against SymbIoTe assumptions about how SymbIoTe consortium partners believe end users' interests shall be addressed. When interviewing SymbIoTe members, a set of actual market solutions was provided as inspiring examples. The result was twofold:

a) Sets of SymbIoTe values, types of data, stakeholders (listed further in this section)
b) a set of hypotheses for further validation (listed as inputs for validation results in end of this section).

5.2.2 Priority stakeholders and roles

In order to properly address business related activities, symbIoTe enabled business scenarios underwent living lab sessions and gathered feedback from living lab panels. As a result, the following types of stakeholder profiles have been identified:

- IT companies, mainly IoT platform operators and owners;
- Non-IT companies, mainly SMEs providing data-rich services to other companies;
- Public authorities, such as city councils and marina authorities;
- Individuals, such as end users of symbIoTe enabled applications.
- Consultant
- Distributor
- Smartphone provider
- symbIoTe (core administrator)
- Hotel
- Hospital
- Underground station
- Local communities
- Funding agencies
- Tourists
- Local transportation operator
- Industry
- Schools
- Research entities
- Port authorities
- Local authorities
- Software vendor

Each of these stakeholder profiles has been granted a role within the working business scenarios. In order to properly capture stakeholders' value within business scenarios, their

technological and business statuses were determined. Since symbIoTe usage and uptake is critical for the project, stakeholders' technological status was determined from symbIoTe usage perspective (column 3 in Table 3 below). Since all business scenarios pointed at IoT platform owners as critical business stakeholders, other players' statuses were determined from IoT platform owner's perspective. This way, two (technological and business) pools of stakeholders' statuses were formed. Technological status was determined by the stakeholders' relation to symbIoTe usage:

- User – organizational (company) or individual (developer) user of symbIoTe tools aware of using symbIoTe
- End User – organizational user of applications built on top of symbIoTe tools hardly aware of using symbIoTe
- Final End User – individual user of applications built on top of symbIoTe tools hardly aware of using symbIoTe
- No Status – stakeholder not using symbIoTe

Note, that when defining panels, final end users and end users were combined in a single panel.

Business statuses can be multiple per stakeholder. However, for sake of this exercise, only dominating business roles have been pointed out per stakeholder. The objective of this exercise was to determine general positions of stakeholders within business scenarios and the major directions of value flows, including money flows, among priority stakeholders. Therefore, the following statuses have been determined from platform owner's perspective:

- Direct Client – receives symbIoTe enabled service (low level), pays to provider
- Indirect Client – receives symbIoTe enabled service (high level), pays to direct client
- Prosumer – provides and receives value to/from other stakeholders
- Provider – provides value to other stakeholders

The resulting mapping of stakeholders against possible business roles enabled to prioritize stakeholders in specific business scenarios built during workshops. Three priority levels have been built:

- Priority A – stakeholder named by users and involved in 1+ business scenarios at all stages, including financial mapping,
- Priority B – stakeholder named, but excluded from scenario at financial analysis stage,
- Priority C – stakeholder named but not included in any specific business scenarios.

The resulting mapping of stakeholder types against their technical and business statuses in business scenarios (see Table 3 below), prioritizes symbIoTe business stakeholders based on working examples of possible stakeholders' roles and specific business scenarios. It is worth noticing that while the stakeholder priority matrix refers to business creation priorities only, participants stressed that there is a number of beyond financial values coming from the listed stakeholders that may be of great importance, for instance the driving force of local communities that could provide valuable feedback at testing and boost sales.

Nonetheless, when calculating MVP costs and narrowing down stakeholders to the minimum, living lab workshop participants decided to limit their scenarios' participants according to Table 3.

Table 3: Stakeholders and priority levels, as identified by platform owners.

Priority Level	Stakeholder profile	Symbiote perspective status	Platform owner's perspective status
A - Indispensable	**IT company**	user	direct client prosumer
	Non-IT company	user, end user	direct client
	public authorities	end user	direct client indirect client
	Individual citizen	final end user	indirect client prosumer
B - Important	Port authorities	end user	direct client
	Local communities	end user	indirect client
	Funding agencies	end user	indirect client
	Consultant	no status	provider
	Distributor	no status	provider
	Smartphone provider	user	provider
	Research entities	user	provider
C - Nice to have, no key value	SymbIoTe (core administrator)	user	provider
	Hotel	end user	direct client
	Hospital	end user	direct client
	Underground station	end user	direct client
	Tourists	final end user	indirect client
	Local transportation	end user	direct client
	Industry	end user	direct client
	Schools	end user	direct client
	Local authorities	end user	direct client
	Software vendor	user	provider

5.2.3 Panels of Users

Based on the priority matrix user panels were formed containing over 200 participants in total. The user panels (see Table 4) consist mainly of IT experts and platform owners, whose role was twofold: (I) To provide platform owners' perspective on symbIoTe

components, functionalities and values, (ii) to interpret and complement end users' feedback.

Table 4: User panels

Panels	Users (276 total)	Knowledge of SymbIoTe	Expertise level
ICT Cluster	53 IT companies	low	high
Future Lab	64 individual developers	low	medium to high
OC1 applicants	65 IT companies	medium	high
OC2 applicants	88 IT companies	medium	high
SymbIoTe industrial partners	6 IT companies	high	high

The panel of users includes only *users* (no "end users" or "final end uses") from Table 4 above. They are mainly IT and business experts from IT companies or IT departments, whose role is to validate assumptions addressing specific symbIoTe components as well as new business values that their companies would like to gain by implementing symbIoTe.

5.2.4 Values and value chains

This section explains a drastically narrow and user-centric view on value proposition. While the consistent and all-encompassing high-level study of value propositions takes place in other symbIoTe WPs, namely WP1 and WP7, this section disregards the broad approach and takes a narrow and scenario specific look at symbIoTe enabled new values within specific usage scenarios in order to dig deeper into actual reasons and motives platform owners' have when deciding whether or not they shall use symbIoTe in their business.

During interactive living lab sessions, end users brainstormed symbIoTe value propositions and MVPs against their actual, specific requirements and existing business models. Furthermore, they questioned their propositions in view of new opportunities enabled by symbIoTe. The exercise was performed three times semi-annually with similar groups of stakeholders with 12 teams of 3-4 real-life end users each. All living lab procedures were recorded to draw conclusions in a systemic way.
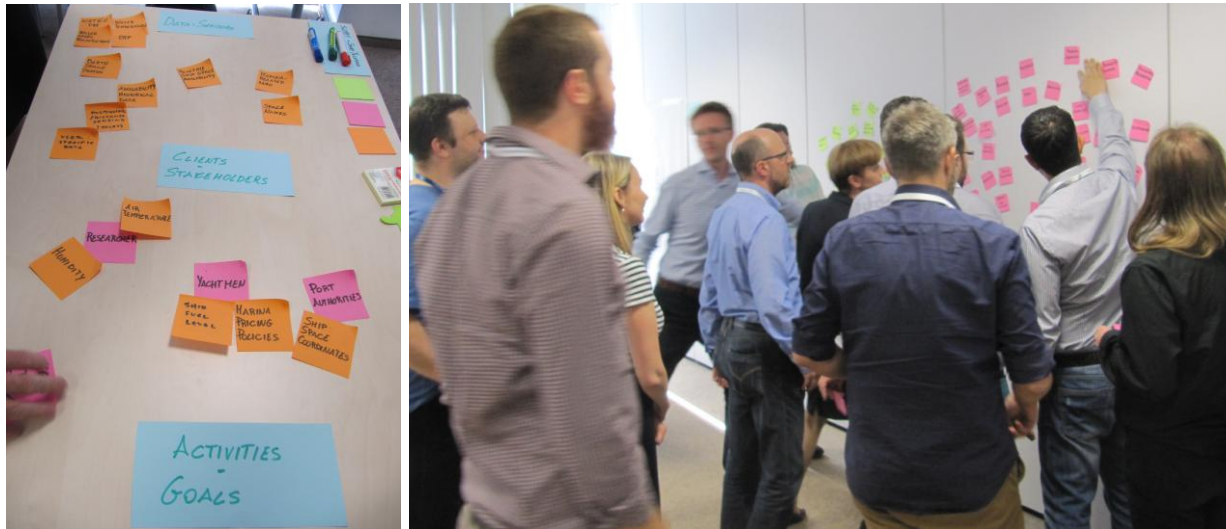
Figure 16: Living lab sessions with external participants – going beyond initial requirements and assumptions.

The interactive and business-oriented style of living lab sessions (see Figure 16) enabled symbIoTe to capture fresh and external perspectives. The post-event analyses of feedback resulted in general sustainability related recommendations for symbIoTe components as well as component-specific functional suggestions for developers. By co-creating hypothetical but reality-based specific usage scenarios, users could immediately reshape and improve symbIoTe basic concepts and assumptions. The resulting simplified business models visualized specific usage scenarios including: key stakeholders, connections and value flows between them, specific values flowing. Figure 17 below exemplifies one such visualization.

Closely federated IoT platforms business model
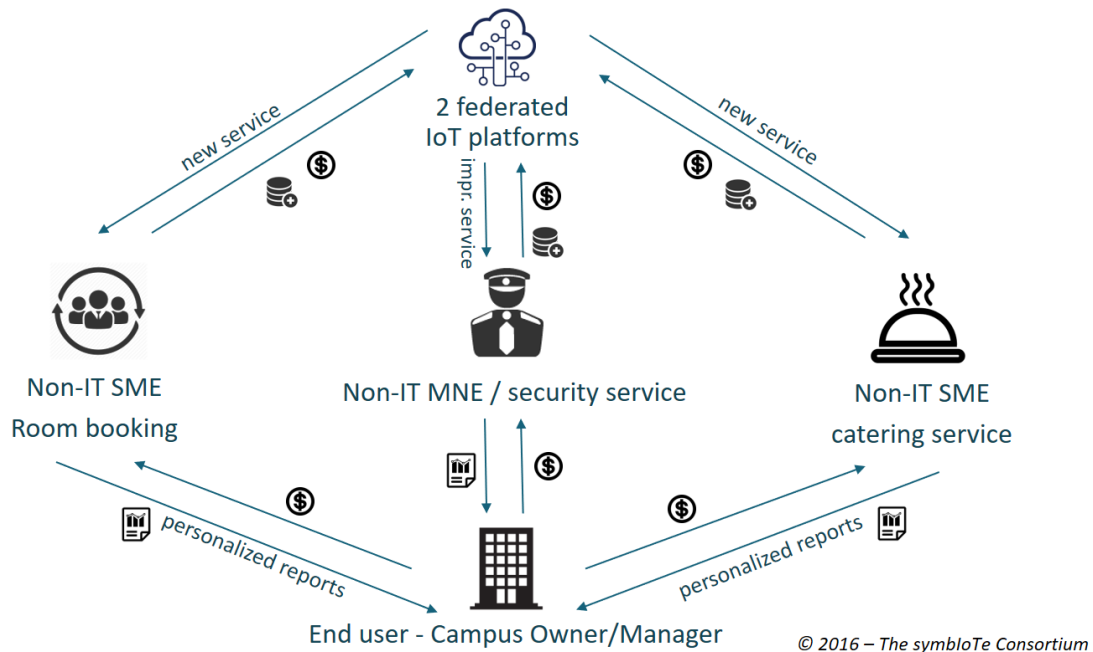
Figure 17: An example of one possible value chain model - EduCampus use case.

On the one hand, end users validated the overall concept of symbIoTe as a true enabler of new cross-platform business scenarios. On the other hand, end users prioritized the most tangible compliance models against others and expressed new component-specific requirements they deemed crucial.

Moreover, during living lab sessions users extended the primary list of generic goals, initially assumed by the symbIoTe consortium. General goals assumed by symbIoTe consortium prior to sessions were:

- To sell more services/goods,
- To install/scale infrastructure, and
- To improve provided services.

Whereas during sessions specific goals surfaced such as:

- To improve organizing estate personnel presence,
- To reduce queues in buildings,
- To improve traffic across campus,
- To improve security (personal and estate),
- To enable billing the end-users,
- To set proper (detailed) prices on services,
- To find empty rooms for meetings,
- To monitor how many people are using rooms,
- To navigate newcomers, and
- To create facility usage profiles.

Similarly, the initial pool of economically measurable values was extended. Values flowing among symbIoTe-related stakeholders identified initially by the consortium were generic:

- Sensor Data/Personal data,
- Money, and
- Services.

Whereas, values identified by business participants were business scenario specific:

- Data/Personal data/Aggregated data,
- Money,
- Knowledge,
- Service/Personalized service/Product,
- Brand/Promotion,
- Personalized information, and
- Improved policies.

Interestingly, living lab participants also introduced new datasets and sensors that had not been on the table prior to living lab sessions.

The SymbIoTe consortium assumed having close to complete knowledge about resources available from industrial partners, based on the project applications and written inputs for Deliverable D1.2. The initially assumed set of data and sensors included: indoor location, geofence alerts, event management, man-down detection, raw data from wearable sensors, beacons, user accounts, measured noise, noise level in dB, noise for a given location (latitude, longitude), noise in a given device (sensor id), noise at given time (timestamp), humidity, air temperature, pH, water temperature, ORP, water level measurements, real-time ship space availability, availability historical data, berth space occupancy status, marina-related info, ship space coordinates, space names, marina pricing policies.

The involvement of practitioners in living lab activities enabled a deeper insight and led to discovery of new data/sensors: instruction messages, pressure sensors (for seats), navigation, SOS alerts, VoIP sound, number of people passing/present, air quality (CO_2, NO_2) and ship fuel level, number of cars passing, user specific data from smartphones, position and distance sensing, ship fuel levels. Such broadened scope of operational data availability opened new testing and development scenarios and triggered a wave of fresh ideas across use cases.

5.2.5 Common KPIs and metrics

As part of coordinated efforts between WP5 and WP7 a proposition of common KPIs and metrics has been made in order to enable a comparison between the perceived value of specific MVPs and related symbIoTe components. Therefore, the initial pool of 63 KPIs and metrics for trials and validations was evaluated first by task leaders and then by industrial partners of symbIoTe project. In the first selection – Round A (Table 5 below) 22 KPIs and metrics were selected, out of which nine were approved in round B (see Table 6) by end users. In it four KPIs were unanimously deemed indispensable, while the remaining five were thought secondary.

Table 5: Round A KPIs and metrics for trials and validation

No	KPI name	KPI metric A	KPI metric B	Level of relevance for SymbIoTe (1-5)
1	Revenue potential	euro / year		5
2	Investment costs	euro total	euro / year (maintanance)	4
3	Savings	euro/year		4
4	Value proposition	Number of new/improved services (thanks to SymbIoTe)	No of new features introduced (per improved service)	5
5	Target market *growth potential*	Growth of share in existing markets	Number of new customers	4
6	Type of new revenue sources	Types of revenue sources: public, investors, clients. Ongoing VS one time.	New business cases, new types of clients	5
7	Costs optimized	Annual savings against no Symbiote years		4
8	IPR considerations	IPR transparency level 1-5		4
9	Security and privacy	Relevance of security policies for users, level 1-5		4
10	Service usage	No of existing users (per type of user/per service)		4
11	Value proposition readiness	Value proposition readiness level 1-5 (per service)		4
12	Market demand	No of organizational users expected in year 1, 3, 5 from introduction	No of individual users expected in year 1, 3, 5 from introduction	5
13	User impact	No of identified user requirements addressed (per service)		5
14	User compliance	Level of compliance (per user) 1-5		4
15	Risks	No of risks	Level of risk (per risk) 1-5	4
16	Interaction with other similar initiatives	No of initiatives engaged	Level of engagement (per initiative)	4
17	Proven replicability	Level of replicability of service across domains 1-5		4
18	Acceptance	Service validated (per		5

No	KPI name	KPI metric A	KPI metric B	Relevance level for SymbIoTe (1-5)
	validation	service, per type of user) Level of validation %		
19	Feasibilty	Feasibility level (per service)		4
20	MVP maintanance costs	euro/year (per service)		5
21	Geographical impact	Target no of countries to be covered	Target no of cities to be covered	5
22	Innovation	Level of innovation enabled (local, regional, EU, global)		4

Table 6: Round B KPIs and metrics for trials and validation

No	KPI name	KPI metric A	KPI metric B	Relevance level for SymbIoTe (1-5)
1	Revenue potential	euro / year		4
2	Value proposition	Number of new/improved services (thanks to SymbIoTe)	No. of new features introduced (per improved service)	3
3	Type of new revenue sources	Types of revenue sources: public, investors, clients. Ongoing VS one time.	New business cases, new types of clients	2
4	Market demand	No of organizational users expected in year 1, 3, 5 from introduction	No. of individual users expected in year 1, 3, 5 from introduction	4
5	Impact on user's business	No of identified user requirements addressed (per service)		5
6	Acceptance validation	Service validated (per service, per type of user) Level of validation %		4
7	MVP maintanance costs	euro/year (per service)		5
8	Geographical impact	Target no of countries to be covered	Target no of cities to be covered	5
9	Third parties' impact on SymbIoTe			4

The resulting sets of End-User-approved KPIs and metrics have been recommended to WP1, WP5, and WP7 as a starting point in deigning common grounds for business models, trial evaluations and MVPs respectively. The idea behind these proposed KPIs

and metrics is not to directly reuse them in other tasks, but rather to provide the end users' perspective for other tasks' consideration in their proceedings.

5.2.6 Platform owners' perspective on business

To continuously capture IoT platform owners' perspectives on business opportunities enabled by symbIoTe, T5.3 has prepared a continuous re-validation tool for gathering meso level user feedback. The tool evolves as symbIoTe components and awareness about their added values matures both in providers and in users of symbIoTe components. Initially the questionnaire listed the planned symbIoTe components and their technical descriptions. However, when working with living lab panels, more business-oriented objectives were brought to the table, while the tool refocused on business value propositions (each combining a number of components) rather than separate components.

Carried out on a regular basis, this questionnaire (reproduced in Table 10 in the Appendix) enables:

- Prioritization of business values,
- Validation of component creators' assumptions about market needs,
- Business contexts for functionalities, and

Specific requirements/expectations from actual users. By adding the interviews/comments column, unplanned quotations and discoveries from users were captured, to name a few:

- *"Can a video camera be considered a sensor in symbIoTe understanding?"*
- *"Scaling my platform waters down my business, while enabling new business scenarios to my existing data and clients makes a sense for us!"*
- *"We are neither fully open nor closed to publishing our data and sensors. Truth is we are in between - we wish to publish only selected categories of sensors while keeping a full control over who is using them and how."*

This type of feedback was delivered to relevant teams to work on but also it gave us hints about how to communicate symbIoTe offering when talking to business and how to improve the questionnaire itself.

5.2.7 Meso level validation

The bottom line objective of all exercises and tools described in this section was to validate symbIoTe hypotheses and functionalities.

The task was carried out in two rounds A and B. Round A, carried out in M19-M25, aimed at validating hypotheses symbIoTe business value. Round B, carried out in M26-M29, focused mainly on validating symbIoTe functionalities and usage scenarios.

As evidenced in Table 7, symbIoTe consortium had correctly identified the main objectives of its key stakeholders (IT companies) as well as had a proper assumption with regards to the need for flexibility to embrace more unverbalized goals, which were discovered after interactive interviews and workshops, but were not verbalized by the companies in formal documentation.

Moreover, symbIote had correctly expected IT companies to have clear ideas about the role symbIoTe shall play in their existing processes and services. Also, the symbIoTe had correctly expected that companies may come up with unexpected usage scenarios. On

this account, symbIoTe's consortium members' and the overall design of the platform had been in line with the major requirements of key stakeholders.

However, a number of pivots were recommended following round A validation. The major discovery here, as described in row 3 of Table 7 below, was that none of the companies involved expected a third party operator to take on the responsibility of operating symbIoTe. This discovery was populated to all other business related WPs as it might have had an impact on business modelling as well as overall sustainability planning.

Secondly, a disrupting value flow observation was made, that conversely to symbIoTe assumptions, less than 20% of symbIoTe main stakeholders declared they would sell SymbIoTe enabled services directly to end users. This had a considerable impact both on further work of T5.3 as well as other symbIoTe tasks and WPs, because a pivot of focus was necessary from final end users, such as yacht owners or individual citizens, to intermediaries, such as IT departments of tourist companies, marinas, or IT integrators.

Third, a number of minor business related discoveries were made, impacting either further business developments or technical functionalities. An example of the latter might be the development of search engine, which had incorrectly assumed that companies would be willing to advertise their lists of resources publicly. This led to focusing more on L2 federated platforms' concept that enables creating small controlled federations of IoT platforms rather than advertising one's resources publicly.

Table 7 represents selected meso layer validation results of business assumptions.

Table 7: Round A validation of hypotheses

Hypothesis/assumption	Validated	Invalidated
Common goals of SymbIoTe clients are: to sell more products to install infrastructure to improve provided services to set proper prices	All IT companies accepted these goals.	X
SymbIoTe has to be flexible enough to address other, client-specific goals.	Many client-specific goals has been listed: to organize personnel presence to reduce queues to monitor quality of life to improve traffic to change policies to provide security to bill the yachts to find empty spaces for docking to monitor how many yachts are in the port to navigate yachts to distribute transport profiles	X
Platform owners expect a third party (such as SymbIoTe association or a trusted public R&D) to maintain and operate SymbIoTe middleware.	X	All platform owners prefer to operate in environments controlled by themselves and therefore wish to maintain and operate SymbIoTe components themselves.
As long as SymbIoTe	X	Apart from technical well

works well technically, end users will use it.		operation, end users expect the middleware to be financially and legally stable in the long term before they deploy it.
End user (such as a stadium) is a direct client of SymbIoTe. When deployed, SymbIoTe operator (e.g. IoT platform) will sell directly to end users (e.g. non-IT companies).	X	End user (such as a stadium) is an indirect client of SymbIoTe. More than 80% of platform owners' usage scenarios assume sales to intermediaries (IT companies, IoT platform owners).
L1 core and L2 cloud middleware models are equally attractive from the business perspective	X	Close to all business scenarios proposed by SMEs rely on L2.
The academic aspect of SymbIoTe is not interesting for businesses.	Businesses have different goals than academia in entering SymbIoTe community.	"The academic side of SymbIoTe should be better exposed." It implies potential well structuredwell-structured and standardized access to open data and increases trust.
IoT SMEs are aware of benefits IoT middleware could bring them.	IoT SMEs have a clear idea which functionalities and how they would like to use.	X
The main objective of SymbIoTe direct clients is to share their resources in order to increase incomes.	X	More than 80% of IT companies declare they are unwilling to share their resources even when paid for.
Application areas are multiple and go beyond the five SymbIoTe use cases.	IT companies defined usage scenarios in the following areas: logistics, sales/rentals, wearables, security, smart kitchen, etc.	X
SymbIoTe client's resource list (not the data, numbers) shall be publicly available before registering to the platform.	X	1 in 10 IT companies may consider opening a limited part of their resource list publicly.

At each validation stage, direct interviews were carried out both with external stakeholders and with symbIoTe component owners in order to dig deeper the actual motivations behind replies they provided in writing.

This way, additional recommendations have been discovered while discussing weaknesses of the software f2f with respondents. Even though the majority of feedback was obvious and anticipated by symbIoTe, it is undeniable that some feedback posed a strong decision support for symbIoTe developments. Below are selected quotations, that introduced fresh perspectives to symbIoTe:

- we are unable to tell if the components work as expected after installation and setup, until a user tries to register and access resource,

- scarce user community makes it difficult to get information,

- semantic definitions are ambiguous,

- It's difficult to understand the underlying structure and the list of components to be run (which ones and why do I need to run?),

- difficult to grasp the conceptual understanding in the levels of interoperability across levels (L1, L2, L3, L4),

- We wish to use cameras as IoT end devices. Does symbIoTe support streaming as type IoT data?

- Cors gives a lot of problems when invoking services from Javascript,

- mapping custom services onto BIM models is troubling. These BIM models need to be more general and supporting more than sensors and actuators since IoT systems compose of various relevant data and context sources.

Another learning from validations carried out was setting priorities from key users' perspectives. Living lab workshops and survey results enabled SymbIoTe to distribute emphasis more appropriately across technical tasks. The corresponding detailed results are plotted in the Appendix. For instance Figure 18 shows that unlike symbIoTe initial assumptions, key users do not prioritize the ability to share data nor security, but rather expect to enable new business models and raise visibility of their existing services. Such approach was later reconfirmed in individual interviews with User panel SMEs.

An important sustainability related observation, visualised in Figure 19 was made with regards to User panel companies willingness to use SymbIoTe after the end of the project. Although the majority declared willingness or hesitation, three out of thirty respondents declared no interest. Having approached them for deepened feedback it turned out that their major concerns were of strategic nature. In particular, they lacked a long term vision of SymbIoTe developments which made it difficult for them to properly plan where in their operations SymbIoTe could properly fit.

Interestingly, those same respondents declared they expected incomes higher than € 10,000 from SymbIoTe enabled new services. As Figure 20 shows, only 3 out of 30 respondent expect incomes below € 10,000, while the average minimum expected income is above € 25,000 per year. Again, more feedback was gathered f2f to learn that SymbIoTe is repeatedly promising for companies planning to reuse traded data within their VR and AR applications, for which they would be able to go beyond their existing networks of partnering data providers and therefore develop new features and applications for their VR/AR services. That same group exclaimed their security concerns and argued that security component mechanisms in the last symbIoTe release was encouraging.

Sections 4-6 of the final validation survey addressed strictly technical issues asked by symbIoTe component owners. Therefore Table 8 and Table 9 and Figure 21: to Figure 31 represent confirmations and/or denials of assumptions about component specific user journeys, their priorities and their levels of awareness. To sum these up, while expert users widely enjoyed using those key features, such as registration and searching for data, they were mostly concerned about brokering and trading functionalities. Their concerns were twofold. While many did not know why they should be using the component, a few respondents did not find the exact features they thought would be useful for their operations. All results have been forwarded to relevant symbIoTe members to support decision making in further developments.

Last but not least an expert user satisfaction check was made, visualized in Figure 21 to Figure 37. The highest scores of average 4 (of 5 maximum) was scored by security components, whereas the most doubts in expert users were raised when using Enabler Platform Proxy. Results from this part of validation match SymbIoTe anticipations. Therefore no deeper interviews were made in relation to these six areas. However, all respondents have been invited to symbIoTe community of early adopters which enables us to reach out to them at any later time for further interviews as required.

5.3 Recommendations for other WPs and further work

Living lab panels constructed under T5.3 shall be continued after completion of the task as part of symbIoTe community of early adopters and testers, who have understanding of symbIoTe at different levels, but most importantly are open for providing further feedback about further symbIoTe developments.

Based on living lab analyses focused on platform owners' perspective, it seemed advisable for OC2 to engage, directly or indirectly, stakeholders other than those invited to OC1, namely those representing individual end users as well as data rich non-IT companies, such as marinas or estate operators/estate service companies.

The resulting overview of living lab panels' perspectives on symbIoTe components and applications provided reliable grounds to trigger the identification of the most promising symbIoTe components and/or MVP packages. However, due to the broad scope of studied application areas and markets, the performed living lab study did not allow for a measurable comparison of business potentials across components and use cases. Summing up, while platform owners' perspective living lab prioritization of symbIoTe components and offerings allowed to focus further developments on the most tangible functionalities and features, the actual economic potentials across symbIoTe components remained uncertain and requires market-specific analyses under WP1 and/or WP7.

6 Summary

This Deliverable D5.3 reports on end user validation efforts undertaken in the course of the symbIoTe project. Different perspectives are taken on the multifaceted nature of the unified IoT ecosystem proposition of symbIoTe. For this, the focus rests on symbIoTe's five use cases: Smart Residence, Smart Mobility and Ecological Routing, Smart Stadium, EduCampus and Smart Yachting.

Furthermore, a thorough participatory analysis of platform owner perspectives provides detailed definitory groundwork of relevant stakeholders and related performance metrics that can support further validation efforts in WP5 and the overall business model definition in the symbIoTe project.

The usability study conducted on SMILA, the Smart Mirror prototype (Section 4.1), generally supports the feasibility of such a device as a home-based smart object for health care self-management while pointing out possible ways of improvement from a usability perspective. In respect to the symbIoTe concept of networked IoT device ecosystems, the study confirms the need for a comprehensive data privacy model as frequently described in literature (e.g., [12], [13], [14]) and characterizes possible useful applications of SMILA as a smart companion in supportive tasks.

The SMER use case focusing on Ecological Routing (Section 4.2) helped to develop and validate the symbIoTe software components and supporting documentation in order to improve quality of presentation of the symbIoTe framework to non-consortium members. Its three underlying data collection platforms are now integrated in the symbIoTe ecosystem, and platform owners offered pre-release evaluation of the symbIoTe software.

For Smart Stadium (Section 4.3), validations of the location-based information and promotional services were carried out in situ during an off-season sports event with selected stadium visitors, employees, and the manager. The involved participants responded generally positively, and usability feedback has already been integrated in the app.

The EduCampus use case validation (Section 4.4) investigated both integration efforts on the software implementation side, and the practical accuracy of enabler-based indoor positioning. It found symbIoTe integration to be a manageable task even for students with no prior background on semantic technologies and ontologies. Furthermore, positioning accuracy was better than 3.2 meters across floors and mobile operating systems.

The Smart Yachting use case validation (Section 4.5) involved workers and operators at port authorities and simulated the automatic acquisition of information from a yacht's sensors that are attached to the mooring workflow. The possibility to have detailed information about the vessel's route directly on the screen instead of a generic description, like those currently inserted in paper forms, plus exact data about the yacht state has been strongly appreciated.

Section 5 then provided an additional evaluation of platform owners' perspectives. Here, validation and market hypotheses were generated and evaluated, providing supplementary views on symbIoTe functionality and values by providers, programmers, and businesses.

In terms of academic outreach, the partners are happy to announce two publications (one submitted, one accepted) with direct relationship to the work performed in Task 5.3. The EduCampus use case served as the basis for an evaluation of cross-platform IoT use

cases, using symbIoTe to connect two indoor navigation platforms [2]. First results from the Smart Residence use case, particularly involving the Smart Mirror SMILA, are reported on in [1].

7 References

[1] K. Kreiner (AIT), C. Löw, S. Schröder (UNIVIE), M. Falgenhauer, K. Reiter, K. Edegger (AIT). SMILA: An interactive smart mirror for monitoring health. Accepted for Medical Informatics Europe 2018, April 24-26, 2018, Gothenburg, Sweden

[2] M. Schneider, M. Jacoby, B. Hippchen, R. Herzog, S. Abeck. Enabling IoT Platform Interoperability Using a Systematic Development Approach By Example. Accepted for 3rd Workshop on Interoperability and Open-Source Solutions for the Internet of Things (InterOSS-IoT) 2018, June 06, 2018, Bilbao, Spain

[3] symbIoTe project Deliverable D1.3 -- Final Specification of Use Cases and Initial Report on Business Models. Jan 2017

[4] symbIoTe project Deliverable D1.2 -- Initial Report on System Requirements and Architecture. Sep 2016

[5] symbIoTe project Deliverable D1.4 -- Final Report on System Requirements and Architecture. Jul 2017

[6] P. Ballon and J. Pierson. 2007. Designing for Networked Communications: Strategies and Development. S. a. J. Heilesen. pp. 137-166, ISI Global. Quoted after: D. Schuurman, D. Mahr, L. De Marez and P. Ballon, "A fourfold typology of living labs: An empirical investigation amongst the ENoLL community," 2013 International Conference on Engineering, Technology and Innovation (ICE) & IEEE International Technology Management Conference, The Hague, 2013, pp. 1-11. doi: 10.1109/ITMC.2013.7352697.

[7] symbIoTe project Deliverable D3.1 -- Basic Resource Trading Mechanisms and Access Scopes. Dec 2016

[8] symbIoTe project Deliverable D5.2 -- Report on System Integration and Application Implementation. Aug 2017

[9] symbIoTe project Deliverable D5.5 -- Documentation of Trial Preparation Procedures. Mar 2018

[10] symbIoTe project Deliverable D7.4 -- Initial Exploitation Plans (CONFIDENTIAL). Jul 2017.

[11] Schabauer, Johannes, Gerald Schimak, Gerhard Dünnebeil, and Martin Litzenberger. "openUwedat-a ToolBox Solution for Integrated Air Quality and Traffic Monitoring." In EnviroInfo, pp. 695-706. 2012.

[12] S. M. R. Islam, D. Kwak, M. H. Kabir, M. Hossain and K. S. Kwak, "The Internet of Things for Health Care: A Comprehensive Survey," in IEEE Access, vol. 3, pp. 678-708, 2015. doi: 10.1109/ACCESS.2015.2437951

[13] Sathish J Kumar and Dhiren R Patel. Article: A Survey on Internet of Things: Security and Privacy Issues. International Journal of Computer Applications 90(11):20-26, March 2014.

[14] Nicola Bui and Michele Zorzi. 2011. Health care applications: a solution based on the internet of things. In Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL '11). ACM, New York, NY, USA, Article 131, 5 pages. DOI: https://doi.org/10.1145/2093698.2093829

[15] symbIoTe project Deliverable D2.6 – Domain-Specific Enablers and Tools, Nov 2017.

[16] symbIoTe project Deliverable D5.4 - Integrated Prototype and Developed Applications, Aug 2018

[17] 3GPP TR 22.872 - 3rd Generation Partnership Project: Technical Specification Group Services and System Aspects, Study on positioning use cases; June 2018; Available at http://www.3gpp.org/DynaReport/22872.htm

8   Acronyms

AAL	Ambient Assisted Living
AIT	Austrian Institute of Technology GmbH
ASC	Automated Supply Chain
ATHC	Atlètic Terrassa Hockey Club
BDD	Behavior-Driven Development
BIM	Best Practice Information Model
BLE	Bluetooth Low Energy
C&M	Research Group Cooperation & Management
CO	Carbon Monoxide
DDD	Domain-Driven Design
DoW	Description of Work
EU	European Union
FER	Faculty of Electrical Engineering and Computer Science, University of Zagreb
GA	Grant Agreement
GPS	Global Positioning System
H2020	"Horizon 2020" EU Research and Innovation Programme
HCI	Human-Computer-Interaction
ICT	Information and Communications Technology
IoE	Internet of Everything
IoT	Internet of Things
KIT	Karlsruhe Institute of Technology
KPI	Key Performance Indicator

L1	Level 1
MVP	Minimum Viable Product
NOx	Nitrogen Oxide
OC1	Open Call 1
OC2	Open Call 2
PoI	Point of Interest
POPD	Protection of Personal Data
QoE	Quality of Experience
S3M	Smart Space Middleware
SDEV	Roaming Smart Devices
SMER	Smart and Ecological Routing
SMILA	Smart Mirror Integrated Living Assistant
SSP	Smart Space Port
UNIVIE	University of Vienna
VNA	Value-Network-Analysis
WP	Work Package
WTP	Willingness-To-Pay

9 Appendix

The Appendix collects materials that support the main chapters on use cases and provide additional case-specific details, without being required for the overall comprehension of the results.

9.1 Smart Residency Use Case

This subsection describes additional details for the Smart Residency lab tests performed at UNIVIE's laboratory by AIT and UNIVIE in November 2017 and March 2018. The material (questionnaires, instructions) below is translated to English from the original German version used in the test.

9.1.1 Test Planning and Initial Pre-Validation Runs

Before the test campaign with actual (young adult and elderly) participants, we ran an initial test with two student helpers from our department who had not helped setting up the experiment nor read the test plan beforehand. The test run used the same room setup, questionnaires, test instructions, and interactions with the Smart Mirror as the actual campaigns. We timed the parts of the test in these pre-validation runs:

- Pre-test questionnaire: 7:00 minutes
- Reading test instructions: 2:30
- Interactive test with device: 1:00
- Post-test questionnaire: 10-20 minutes

9.1.2 Pre-Interaction Questionnaire

This is the questionnaire supplied to Smart Residency lab test users before their interaction with the Smart Mirror.

1. Anonymized participant ID (so we can correlate the pre- and post-test questionnaires)
2. Gender --- male / female / choose not to state
3. Age --- below 18 / 18 to 25 / 26 to 35 / 36 to 45 / 46 to 55 / 56 to 65 / 66 to 75 / over 75
4. Current occupation --- (free text)
5. Field(s) of occupation --- (free text)
6. Do you own smartphones or tablets? If so, which one(s)? --- Tick all that apply: none, Android, iOS, Windows, Other (specify)
7. How many hours per day do you use your smartphone/table? --- less than 1 / 1 to 3 / 3 to 6 / 6 to 9 / more than 9.
8. Have you heard about the "Internet of Things" before? --- Yes / No
9. Do you have smart devices at home? --- Yes / No / I don't know
10. If so, which devices? --- (free text)
11. How conscious are you about your health? --- Very (1) ... Not at all (7)
12. Which fitness goal have you tried to reach? --- Tick all that apply: None, lose/gain weight, eat healthier, more exercise/fitness, quit smoking, build up muscles, other (specify)
13. Did you reach your goal(s)? If so, to what extent? --- (free text)

14.   If not, why did you stop? --- Tick all that apply: too little time, too little incentives, too little perceived progress, too difficult to keep going, other (specify)
15.   Do you have experience with fitness trackers? If so, with which ones? --- Tick all that apply: none, Jawbone, Fitbit, Apple Watch, MyFitnessPal, Google Fit, Runtastic, other (specify)
16.   Do you currently use a fitness tracker? --- Yes (I have been using one for a while already), yes (but only recently), no (nor am I planning to change that), no (not anymore), no (but I would like to), other (specify)
17.   What aspects speak for a fitness tracker? --- (free text)
18.   What aspects speak against a fitness tracker? --- (free text)
19.   How often do you check your weight? --- Never / every few months / every few weeks / weekly / multiple times a week / daily
20.   Which of these values would be useful for you to reach a goal? --- Tick all that apply: weight, body fat, blood parameters, calorie intake, step count, heart rate, sleep quality, other (specify)
21.   Anything else that you want to remark? --- (free text)

9.1.3 Test Instructions

After filling out the pre-interaction questionnaire, participants received the following instructions in writing:

- Put on the wristband.
- Go to the room next door where the mirror is located, and step in front of the mirror. To the left of the mirror, there is a scale.
- Follow the instructions of the mirror, until the mirror tells you that the assignment has ended.
- Return the wristband to the lab supervisors, and fill in the second questionnaire.

9.1.4 Post-Interaction Questionnaire

This is the questionnaire supplied to Smart Residency lab test users after their interaction with the Smart Mirror.

1.   Anonymized participant ID (so we can correlate the pre- and post-test questionnaires)
2.   Indicate to which degree you agree with each statement --- I agree completely / I agree / maybe / I disagree / I disagree completely.
   - I could imagine using the system on a regular basis.
   - I think the system is unnecessarily complex.
   - I think the system is easy to use.
   - I think I would need technical support to use the system.
   - I think that the different functions of the system are nicely integrated.
   - I think that the system is too inconsistent.
   - I think that most people could quickly learn to use the system.
   - I think that using the system is very cumbersome.
   - I felt very confident I was using the system correctly.
   - I had to learn many things before being able to use the system.

3. Indicate to which degree you agree with each statement --- I agree completely / I agree / maybe / I disagree / I disagree completely.
   ● I got along nicely with voice command.
   ● The font size was far too large for me.
   ● Identification via the bracelet (BLE beacon) was much too slow.
   ● I found the voice output very pleasant.
   ● The amount of information that the mirror offers to me is absolutely insufficient.
   ● The font size was far too small for me.

4. Would you prefer different ways of wearing the BLE beacon, other than as a bracelet? --- Tick all that apply: No, necklace, pendant, sewn into a piece of clothing, barrette, brooch, other (specify)

5. Would you prefer different ways identifying, other than the BLE bracelet? --- Tick all that apply: No, face recognition, fingerprint, password / PIN, unlock pattern (Android), voice recognition, other (specify)

6. If so, why would you want to identify in a different way? --- (free text)

7. Did you encounter any problems while interacting with the mirror?

8. Did you ever get stuck and had to ask the test supervisors for help? --- Yes / no / I don't know

9. Could you envision using the Smart Mirror in your own home? --- Yes / no / maybe

10. Could you envision the Smart Mirror helping to pursue fitness goals? --- I disagree completely / I disagree / maybe / I agree / I agree completely

11. Which other features could be helpful so that the Smart Mirror can support you in pursuing fitness goals? --- (free text)

12. Would you recommend the intelligent mirror to your friends/relatives? --- Yes / no / maybe

13. For the next three questions, please put yourself into the position of an elder friend/relative. Indicate what you think they would answer (I agree completely / I agree / maybe / I disagree / I disagree completely).

   ● They would get along nicely with voice command.
   ● The font size would be far too large for them.
   ● Identification via the bracelet (BLE beacon) would be much too slow for them.
   ● They would find the voice output very pleasant.
   ● The amount of information that the mirror offers to them would be absolutely insufficient.
   ● The font size would be far too small for them.

14. Still answering from that person's perspective, indicate what you think they would answer (I agree completely / I agree / maybe / I disagree / I disagree completely).

   ● I could imagine that they would use the system on a regular basis.
   ● I think the system would be unnecessarily complex for them.
   ● I think the system would be easy to use for them.
   ● I think they would need technical support to use the system.
   ● I think that they would quickly learn to use the system.
   ● Using the system would be very cumbersome for them.
   ● They would very feel confident they were using the system correctly.
   ● They would need to learn many things before being able to use the system.

15. Would the Smart Mirror make their everyday lives easier? --- I disagree completely / I disagree / maybe / I agree / I agree completely
16. If so, why and how? --- (free text)
17. Whom were you thinking of while answering the last three questions (age, gender)? --- (free text)
18. Would you provide the data collected by the mirror to others? --- No, never / only in an anonymized form / yes, without any restrictions / other (specify)
19. If so, who would that be? --- Tick all that apply: My family, my friends, institutions (nursing services etc.), doctors, companies, research institutes, other (specify)
20. Anything else that you want to remark regarding the data collected? --- (free text)
21. Which other usage scenarios can you envision for a smart mirror like this? --- (free text)
22. What did you like particularly about this mirror? --- (free text)
23. What did you like not quite as much? --- (free text)
24. If you could change something about the mirror, what would that be? --- (free text)
25. Anything else you would like to remark regarding this study overall? --- (free text)

9.2 Smart Mobility and Ecological Routing Use Case

This subsection describes additional details for the SMER validation performed in Zagreb during campaign of collecting air quality measurements and user routing using the developed symbIoTe applications. The material (questionnaires, instructions) are going to be presented to all participants in English language, and if some of participants do not understand it, they will be provided by translation during the questionnaire.

9.2.1 Questionnaire Planning and Initial Results

The questionnaire will be disseminated to all participants at the end of their measurement campaign to obtain their individual opinion regarding the offered services and functionalities both from symbIoTe and end-user application perspectives. The planned time for solving questionnaire is 20 minutes, and instructions will be provided before the participants start. The results will be described in the Deliverable regarding the deployments of use case D5.6 symbIoTe Trials, Deployments & Assessment

9.2.2 Questionnaire

General information

1.   Name
2.   E-mail
3.   Age group
4.   Sex
5.   Mobile phone data: manufacturer, model, Android version

Questions regarding user routine and application usage

How often do you ride a bike?

| ○ I don't own a bike |
| ○ Almost never |
| ○ Less than once a month |
| ○ Less than once a week |
| ○ Few times a week |
| ○ Daily |

How often do you take walks (longer than 20 minutes)?
○ Never
○ Less than once a month
○ Less than once a week
○ Few times a week
○ Daily

Did you use CUPUS (sensing) app?
○ Yes
○ No

Did you use symbIoTe SMEUR (routing) app?
○ Yes
○ No

Questions regarding wearable sensor and CUPUS (sensing) app

How often did you use the CUPUS (sensing) mobile app?
○ Never
○ Less than once a week
○ Several times a week
○ Most days of the week
○ Daily
○ Several times a day

I think that I would like to use this app frequently

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the app unnecessarily complex

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I think the app was easy to use

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I think that I would need the support of a technical person to be able to use this app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the various functions in this app were well integrated

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I think there were too many inconsistencies in this app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I would imagine that most people would learn to use this app very quickly

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the app very cumbersome to use

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I felt very confident when using the app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I had to learn a lot of things before I could get going with this app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am satisfied with the ease of process of connecting a wearable sensor to the mobile application and starting the data acquisition process

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I would share data that I have collected with other users

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

If I would share my data, it would be important for me that data is anonymized

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am interested in contributing and publishing the air pollutant measurements during my day-routine

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am interested in buying an air quality sensor to be able to contribute the air pollutant measurements

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am interested in using this app outside of this trial

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

Questions regarding route request, PoI search and usability of symbIoTe SMEUR (routing) app

How often did you use the symbIoTe (routing) mobile app?
- ○ Never
- ○ Less than once a week
- ○ Several times a week
- ○ Most days of the week
- ○ Daily
- ○ Several times a day

I thought that I would like to use this app frequently

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the app unnecessarily complex

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I thought the app was easy to use

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I thought that I would need the support of a technical person to be able to use this app

	1	2	3	4	5	6	7	8	9	10	

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the various functions in this app were well integrated

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I thought there was too much inconsistency in this app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I would imagine that most people would learn to use this app very quickly

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I found the app very cumbersome to use

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I felt very confident when using the app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I had to learn a lot of things before I could get going with this app

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am satisfied with the ease of process of requesting the route between my current location and the chosen target destination

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am satisfied with the ease of process of requesting the route between my current location and a PoI (Point of Interest)

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am satisfied with suggested Points of Interest

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am satisfied with the duration of the data acquisition and route calculation (latency)

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I do not care from which data source the data for my routing comes from

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I would like to be able to filter by data source

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I would like to have only one application which collects data and provides routes

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

I am interested in using the app outside of this trial

	1	2	3	4	5	6	7	8	9	10	
I do not agree	○	○	○	○	○	○	○	○	○	○	I completely agree

Concluding questionnaire

Did you always use the two apps together, or did you favor one app over the other?

What were reasons not to use the CUPUS (sensing) app?
What were reasons not to use the symbIoTe SMEUR (routing) app?
Did you encounter any critical problems that prevented you from using the apps?
Do you see a value in the routes provided based on air quality?
What did you especially like about the system?
What did you especially dislike?
Would you recommend the system to friends / family?
1   2   3   4   5 Very   unlikely   o   o   o   o   o   Very likely
Could you imagine other applications for the air quality measurements?
Other comments and suggestions

9.3 Platform Owner Perspectives

This subsection describes additional details for the evaluation and validation of Platform Owner Perspectives discussed in Section 4.

Below is a set of tables and diagrams, resulting from Round B meso level validation of business hypotheses.
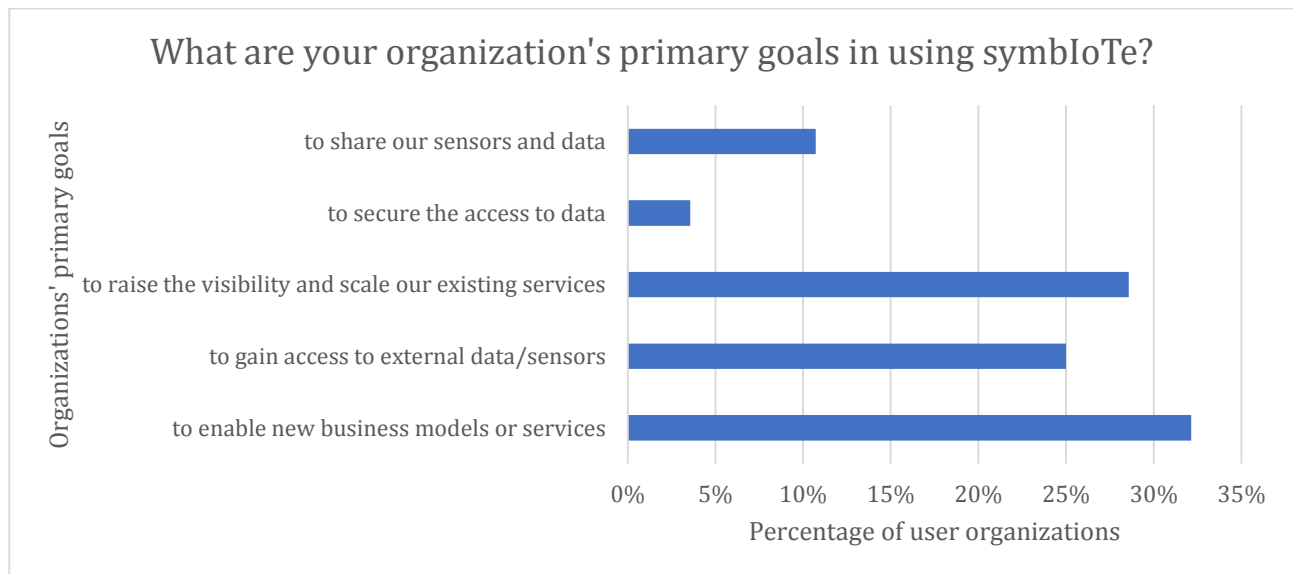
Figure 18: User organizations' primary goals
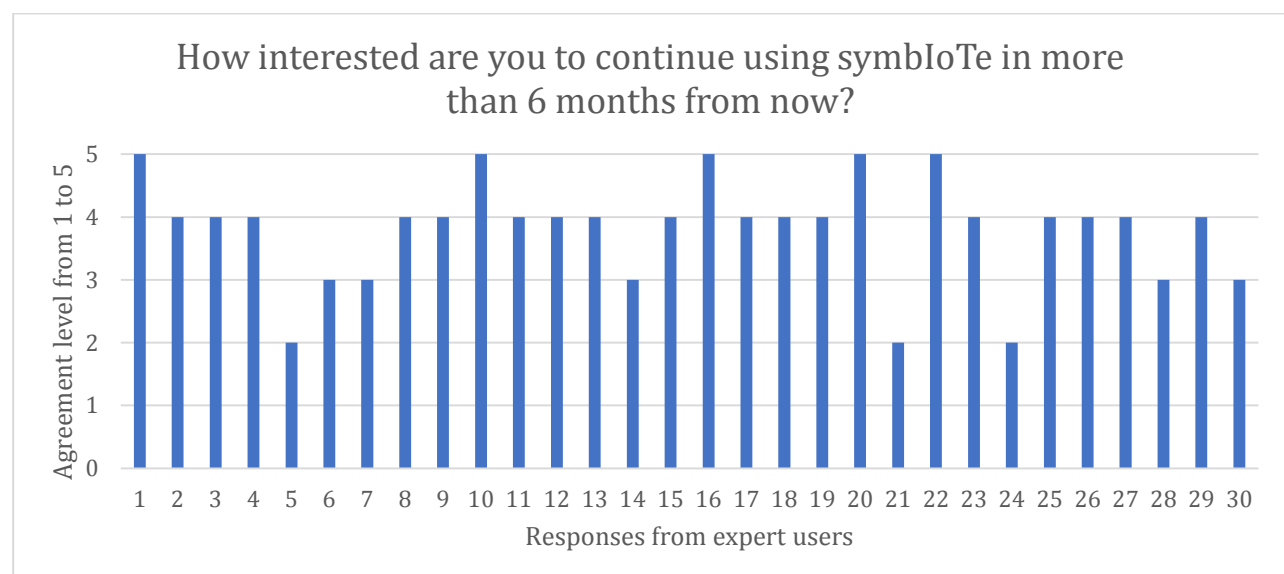
Figure 19: Organizations' interest in using SymbIoTe after end of the project.

3 respondents were not interested to continue using SymbIoTe after the project ends. When approached for dig deeper interviews, their main concerns were:

a) They lack a long-term vision for SymbIoTe middleware upgrades and maintenance,

b) They are unwilling to experiment with their existing solutions,

c) They are open to change their minds when other companies approve it first,

d) They think SymbIoTe software should be more stable and faster,

e) They think it's difficult to figure out where SymbIoTe fits in their IoT platforms and business scenarios.
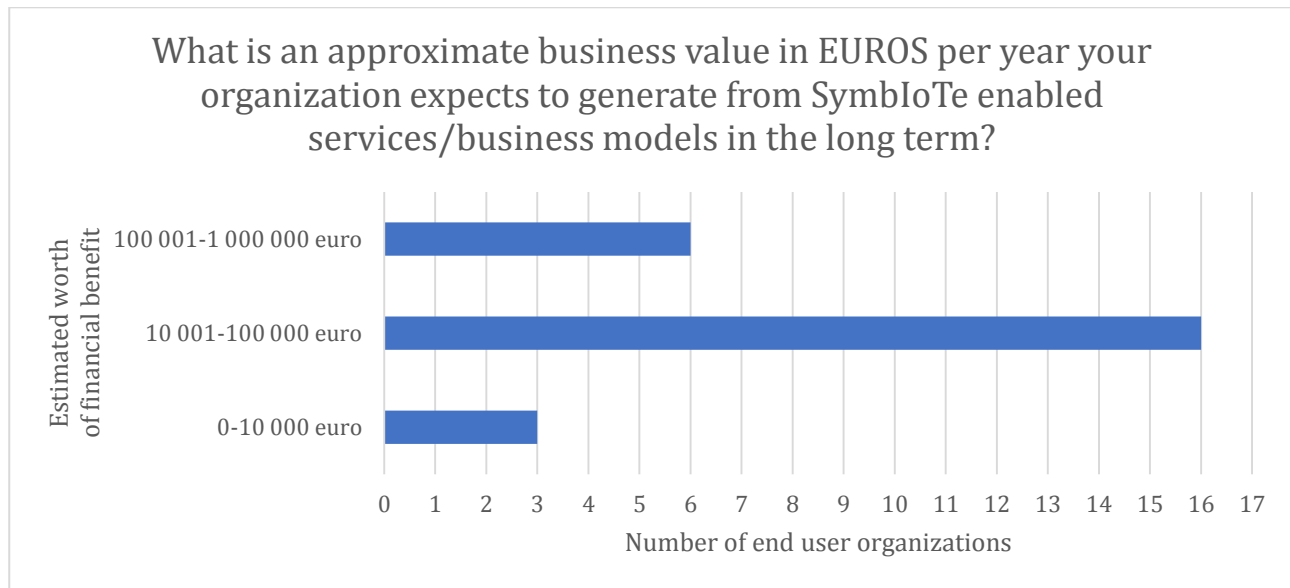
Figure 20: Estimated worth of financial growth for organizations

Six respondents expect high ROI. In their post-survey opinions the biggest value from SymbIoTe is:

- the ability to access multiple platforms and devices, not just federate with those you already know,
- the ability to use it for building AR applications,
- considerable improvement in the speed of operations from Release 1 to 3,
- standardized way of reading IoT data for Augmented Reality purposes,
- the way sensors are contacted via enablers,
- neatly tested security layer.

Table 8: Positioning SymbIoTe as innovation enabler

Questions	Replies – average from 1 to 5 where 5 strongest
Do you think symbIoTe is suitable for commercial purposes?	3.3
Do you think symbIoTe is suitable for experimental purposes?	4.5
Do you think symbIoTe will help increase the competitiveness of your solution?	3.6
Do you think symbIoTe could help you develop new services or business models?	3.8

Following are results of technical survey addressed to 276 participants (IT companies and individual developers) of End user panel. The goal was to achieve 10% of responses, at least half of them external. Finally, 30 responses (11%) were gathered, including 18 external and 12 representing consortium members.

Table 9: Validation of component specific user journeys

Questions	Replies
How did you proceed when integrating with symbIoTe middleware?	75% strictly followed the documentation 11% intuitively installed components by their names 14% other
Did you know SymbIoTe supports different semantic information models?	80% Yes 20% No
Are you planning to create your own smart space agent?	22% Yes 43% No 35% Maybe
If yes, which hardware platform are you using for creating your own smart space agent?	3 x Raspberry Pi 1 x Philips Hue 1 x Waspmote
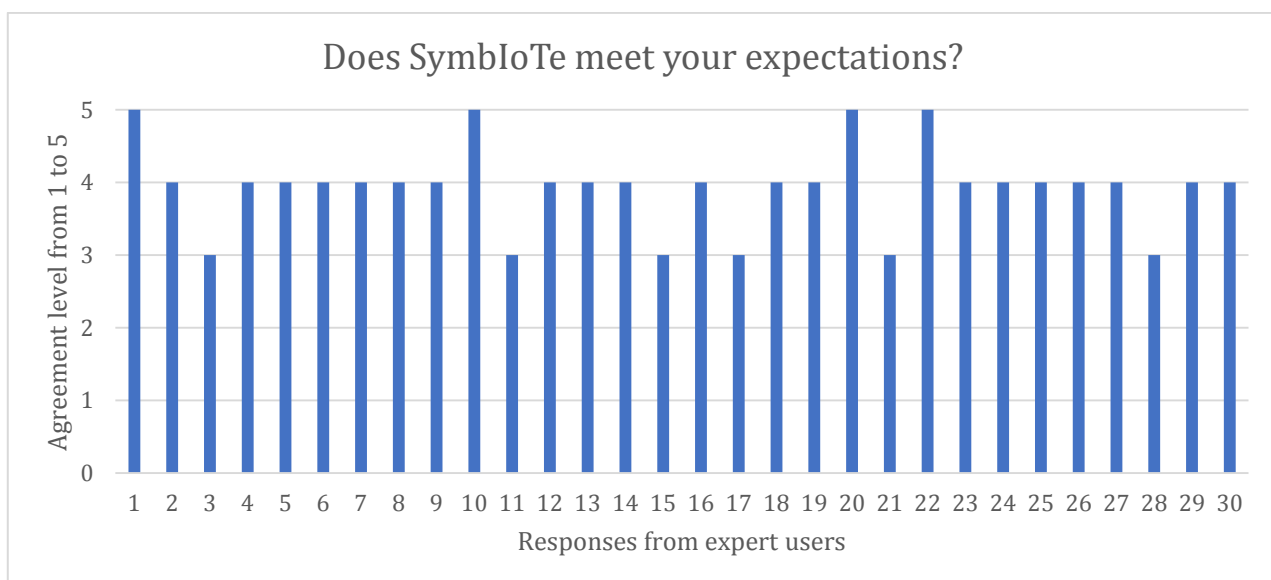
Figure 21: SymbIoTe expert users' satisfaction - overall

Based on your experience, how easy in general is it to find the technical information you need from symbIoTe?
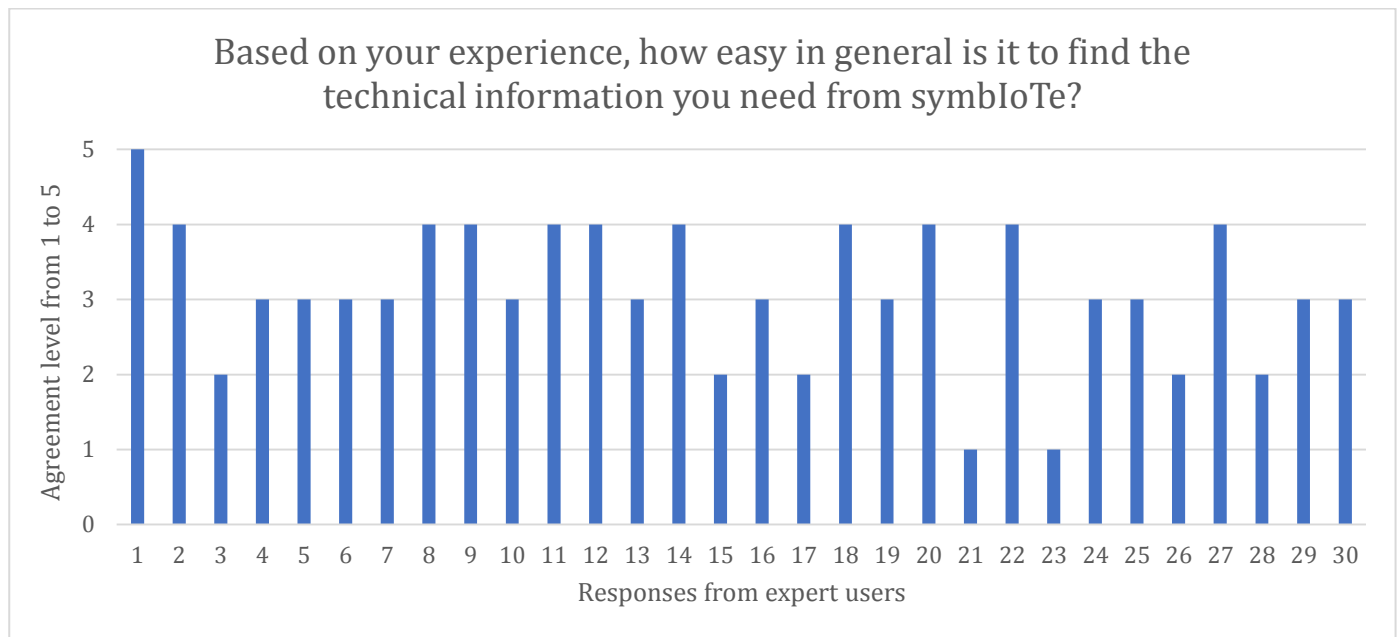
Figure 22: Expert users' opinion on the availability of technical information

Seven respondents disagreed. 3 of them used all ways offered by SymbIoTe, i.e.: website, Github, support team. 2 didn't know about the possibility to contact SymbIoTe support team. 1 of them didn't know about symbIoTe website and used only Github.

Is the documentation of symbIoTe components on Github informative and user-friendly?
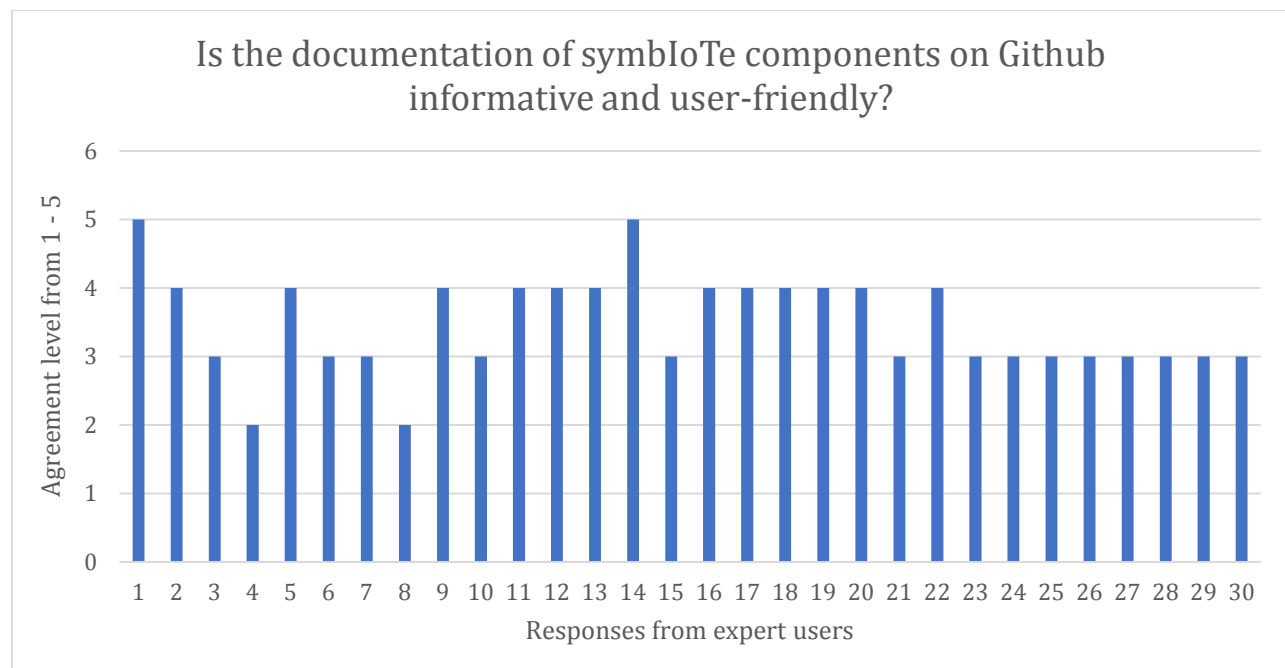
Figure 23: Expert users' evaluation of SymbIoTe components' documentation

Two least satisfied respondents were approached to dig deeper:

- documentation missing the concepts and details,
- examples are only good for a first start, but inefficient for continuous usage,

- obscure error messages that hide more than they reveal (e.g. Error 500, something went wrong),

- it is a new environment, so it's necessary to go through documentation to find a suitable component. Maybe part of documentation with simple use cases of each component would help.

- why not put all information together in one place?
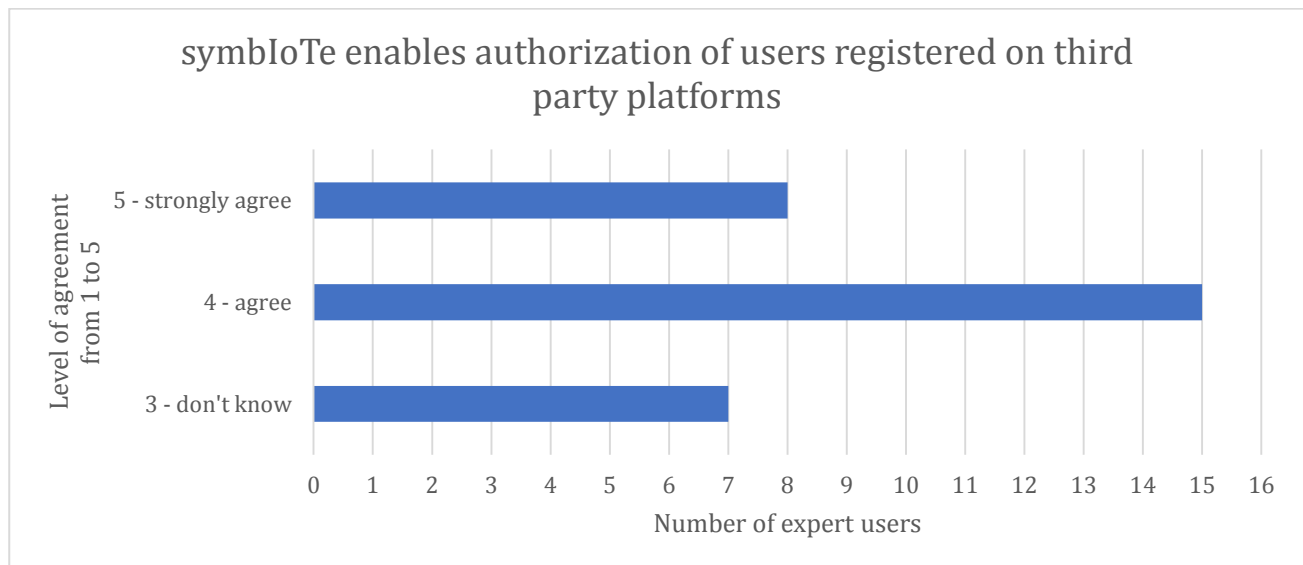
Figure 24: Expert user validation of key functionalities - third party authorization
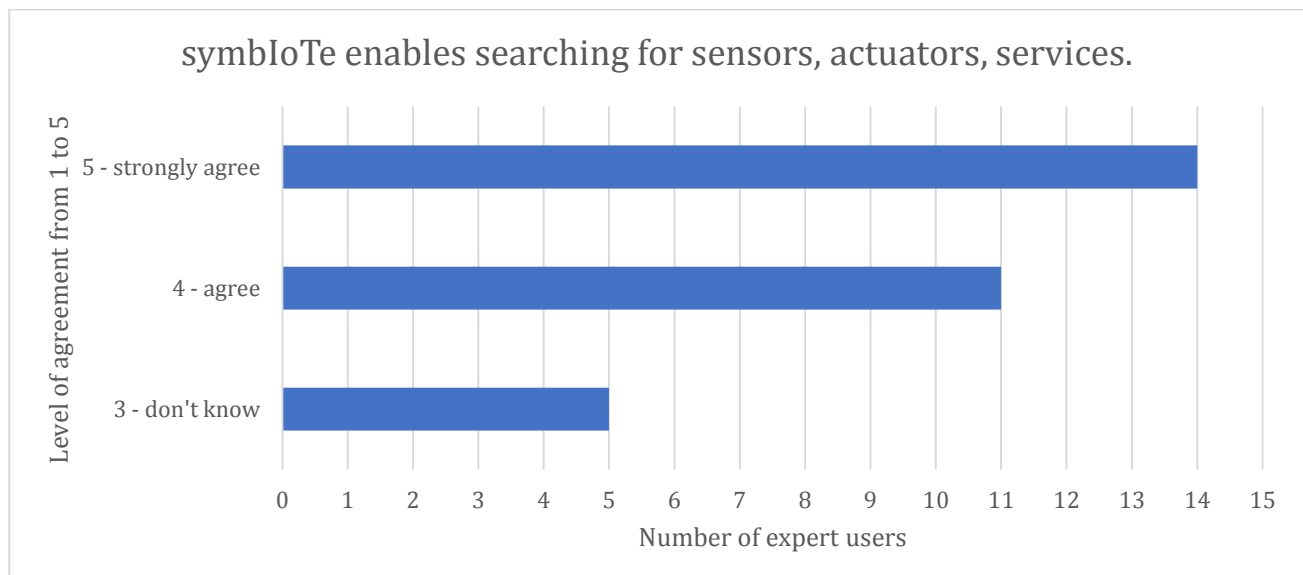
Figure 25: Expert user validation of key functionalities - searching for resources
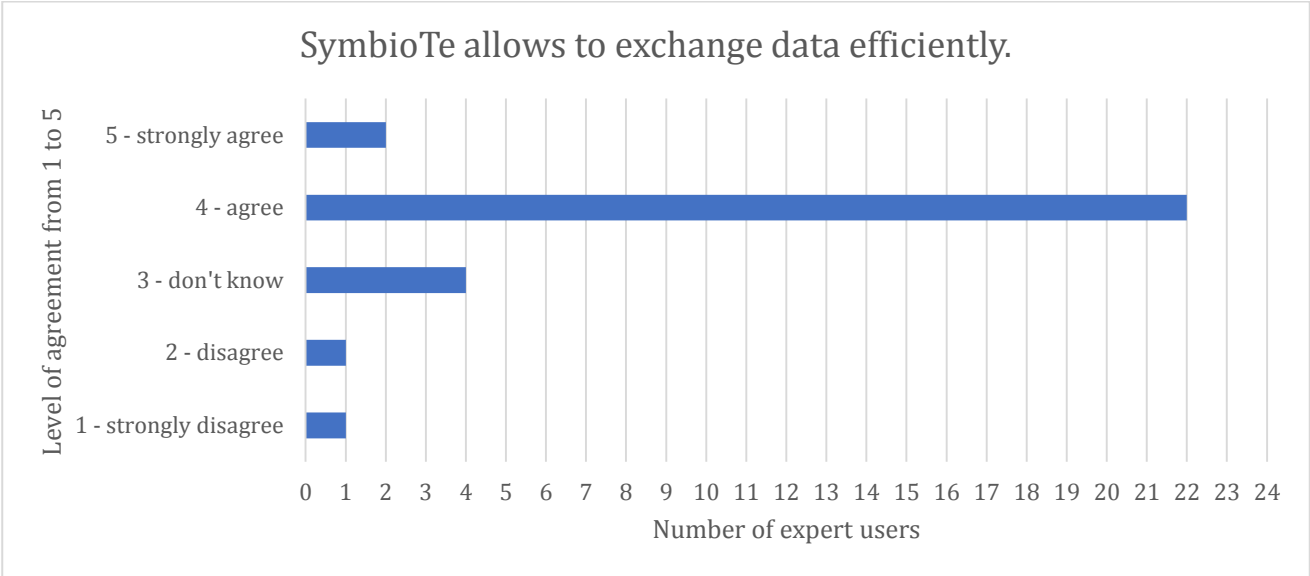
Figure 26: Expert user validation of key functionalities - exchanging data
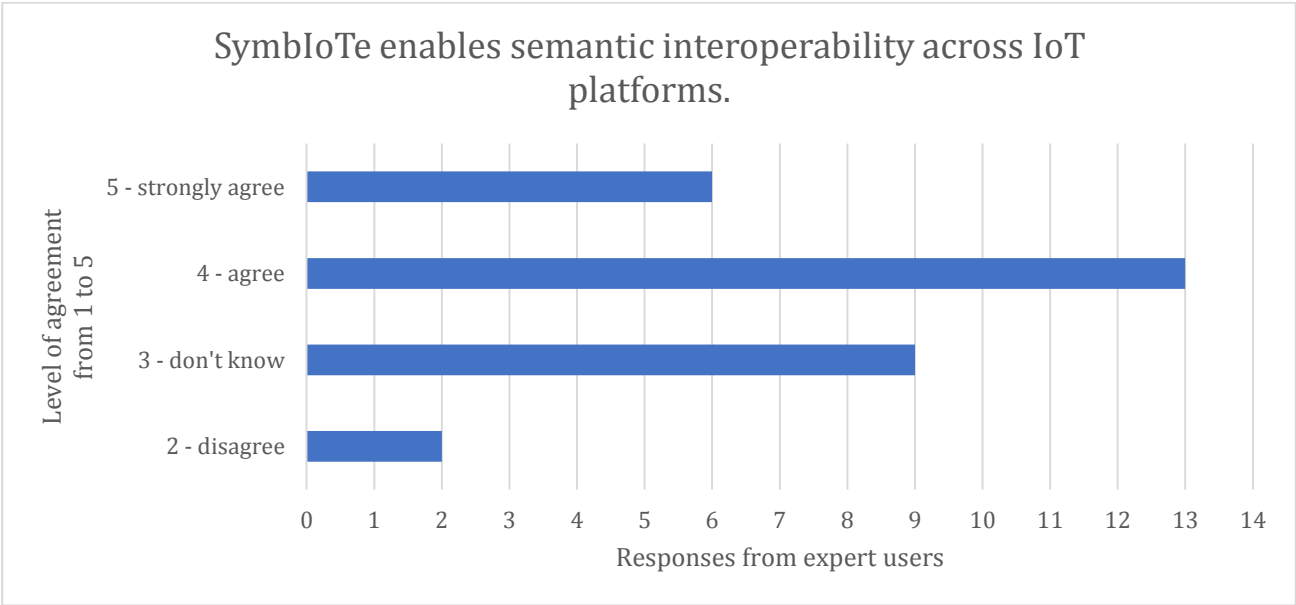
Figure 27: Expert user validation of key functionalities - semantic interoperability
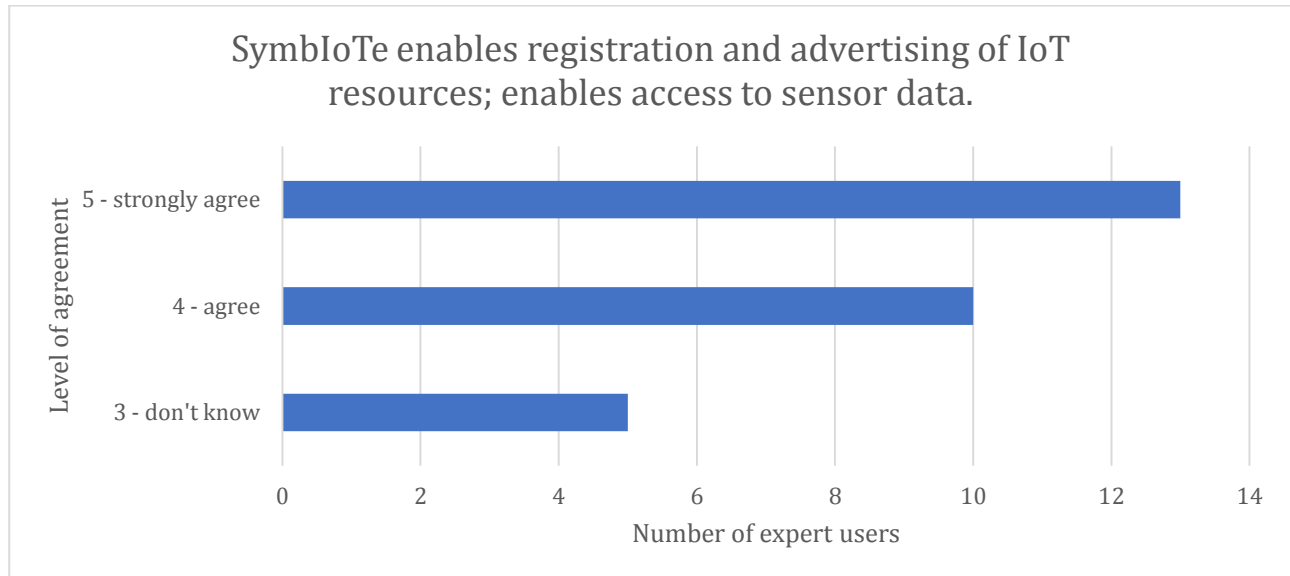
Figure 28: Expert user validation of key functionalities - registration and access to data
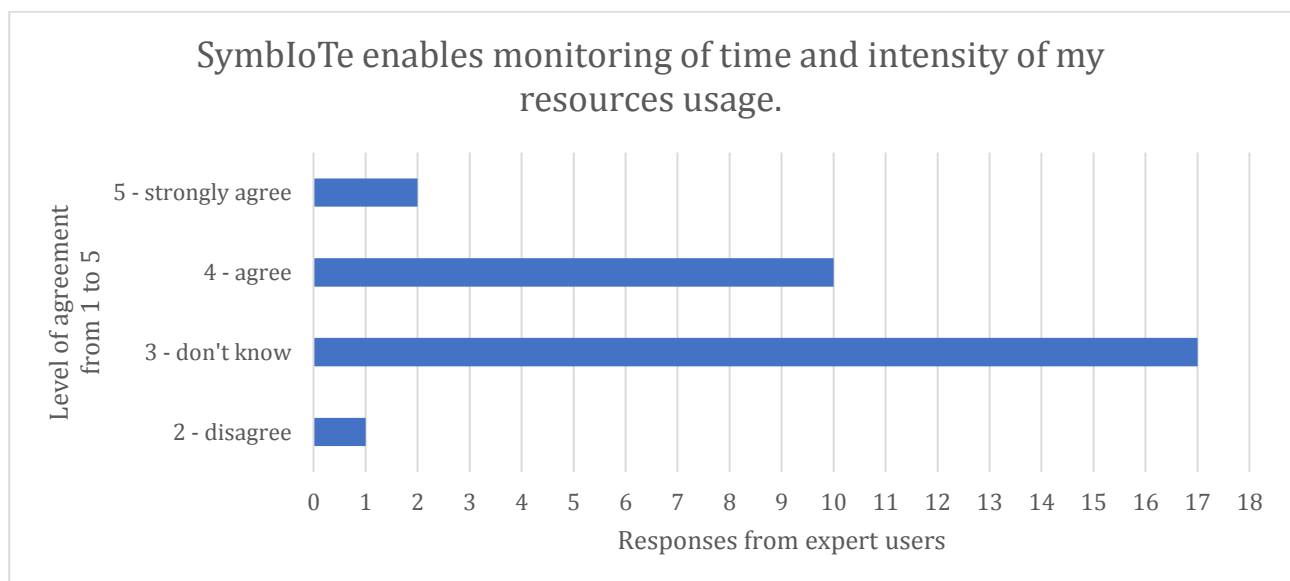
Figure 29: Expert user validation of key functionalities - brokering and trading data
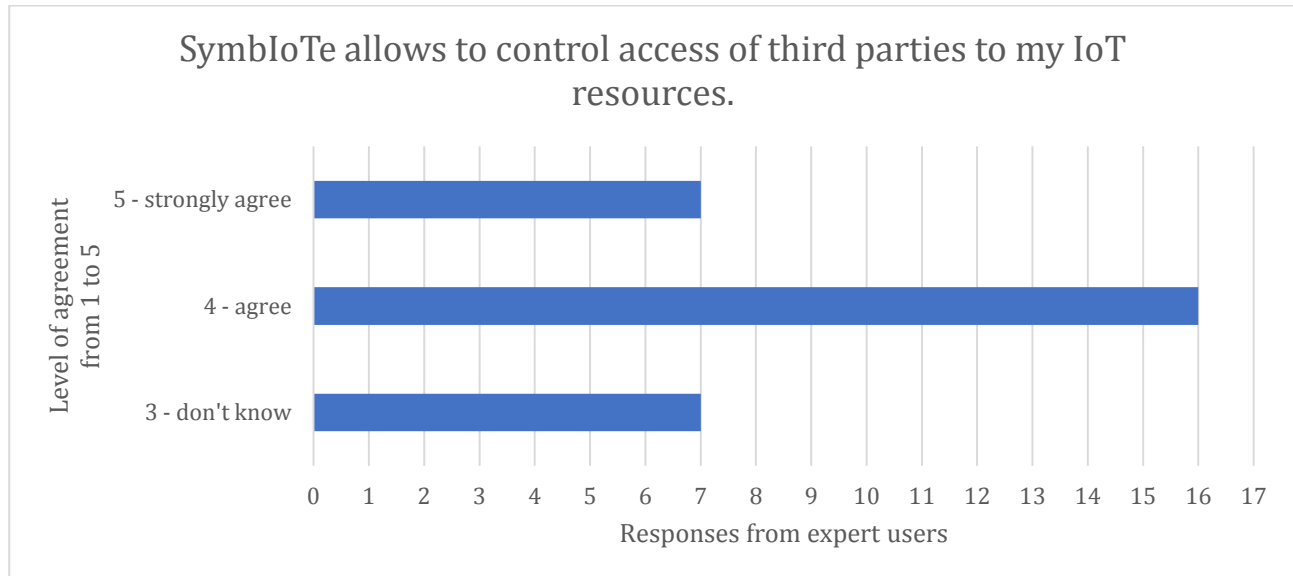
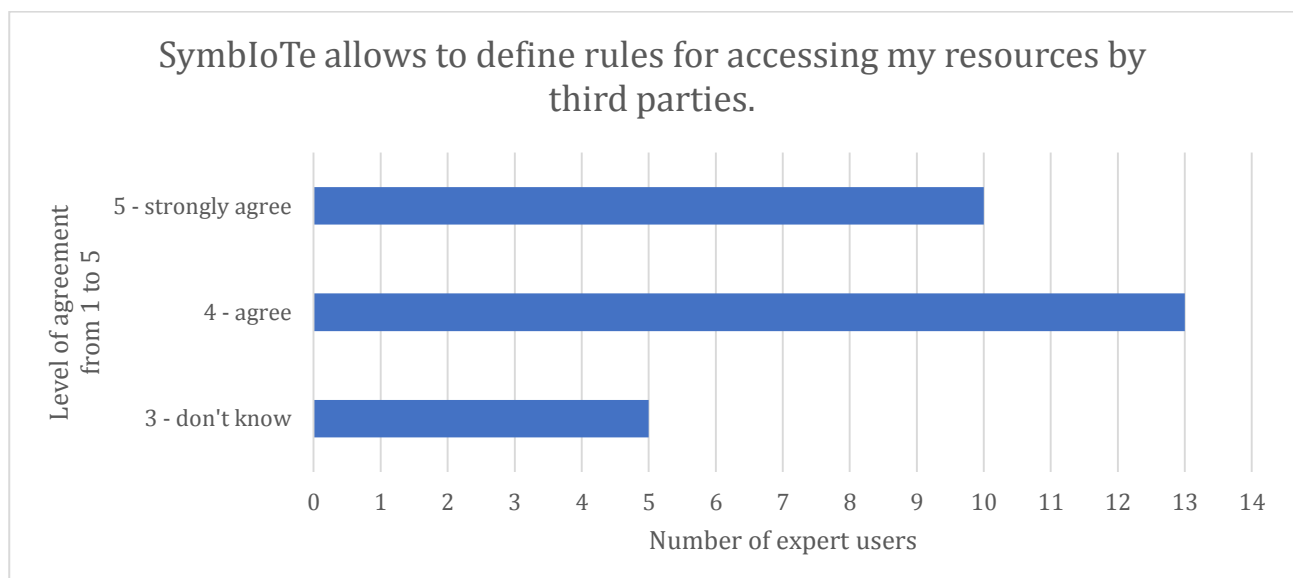Figure 30: Expert user validation of key functionalities - external access control

Figure 31: Expert user validation of key functionalities - definition of rules

In your opinion, do SymbIoTe components operate properly?
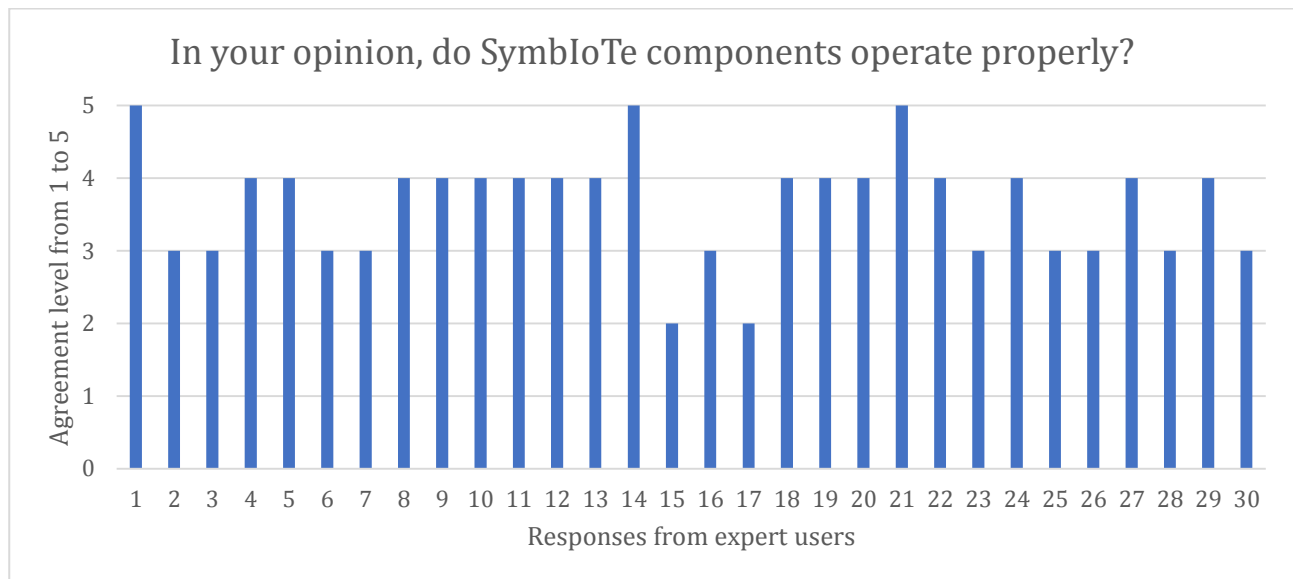
Figure 32: Expert user satisfaction - operation of components

In your opinion, is it true that the procedure of searching sensors/data via symbIoTe is efficient?
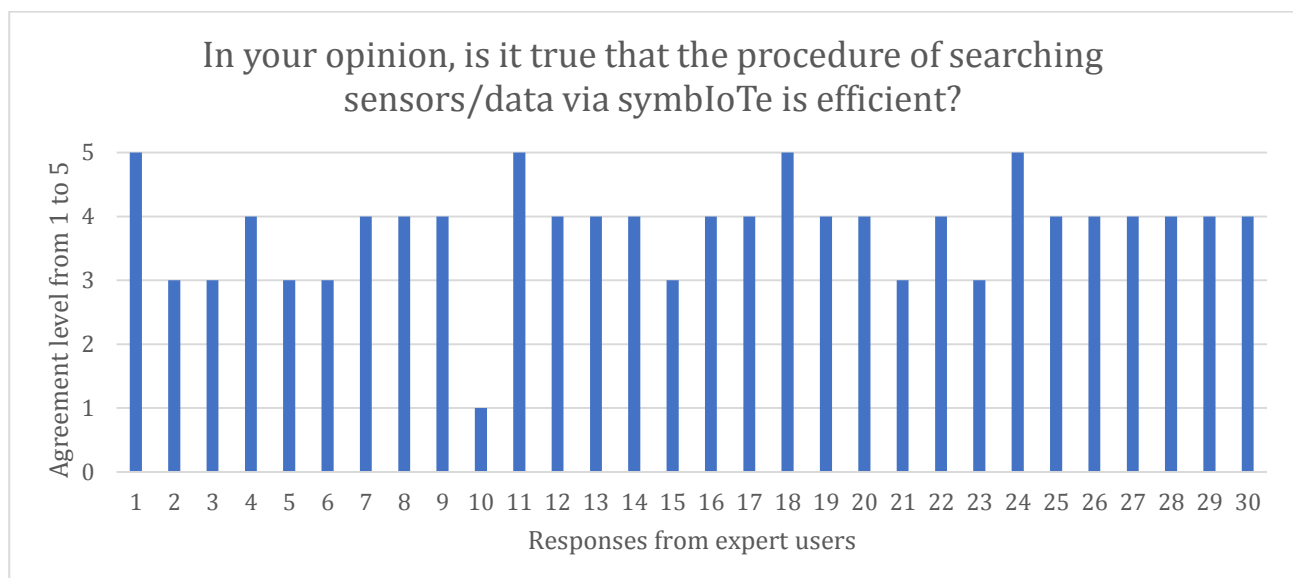
Figure 33: Expert user satisfaction - data search efficiency

The single dissatisfied respondent's major concern is the overall speed of the software. They can see an improvement from Release 1 to the current stage, but would expect even better results.
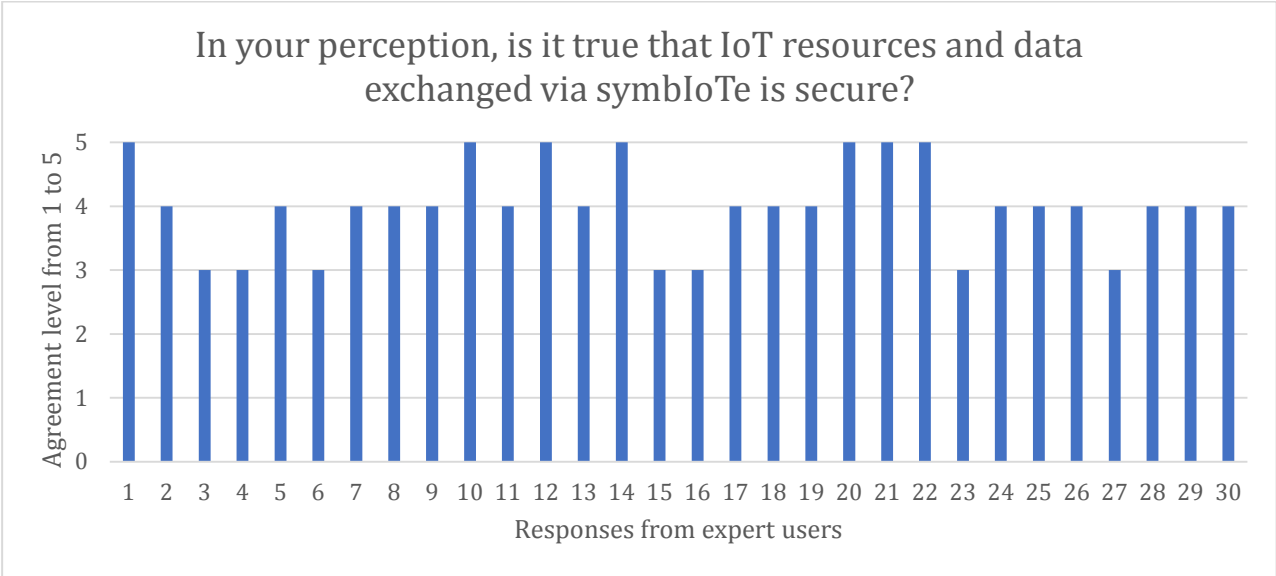
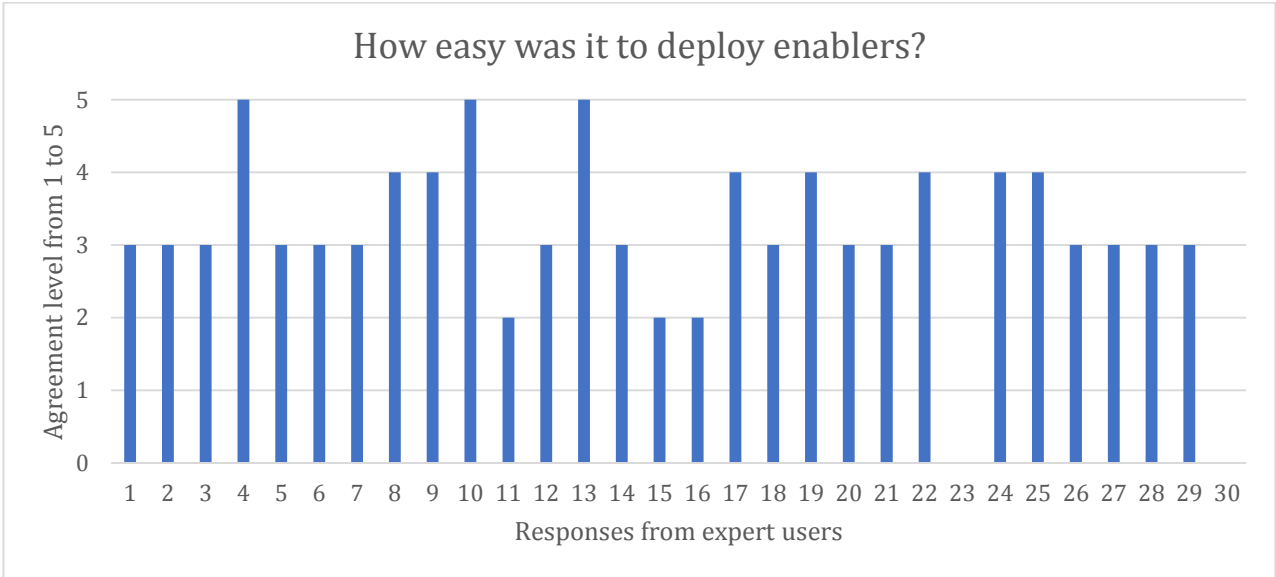Figure 34: Expert user satisfaction - data security

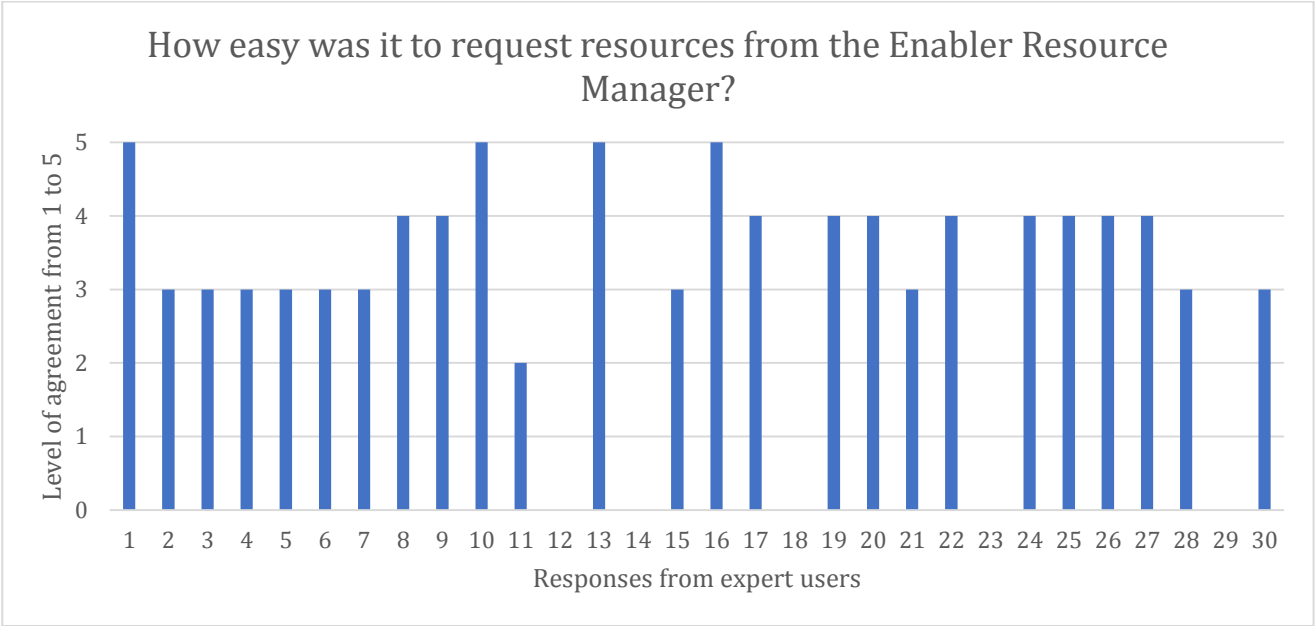Figure 35: Expert user satisfaction - deployment of enablers

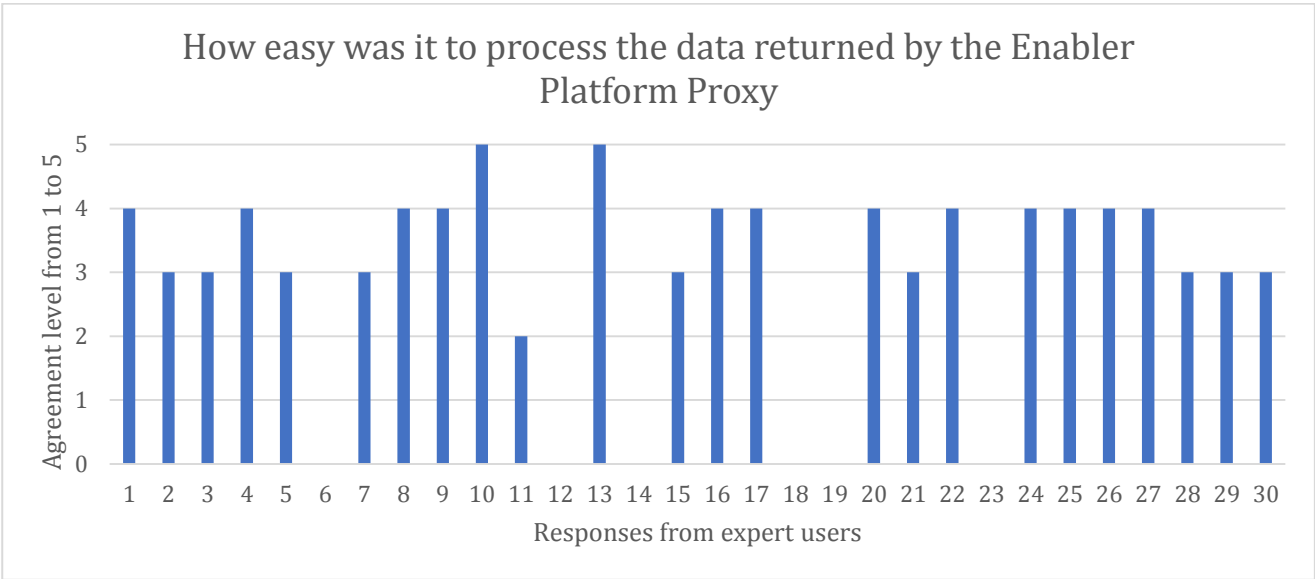Figure 36: Expert user satisfaction - requesting resources from ERM

Figure 37: Expert user satisfaction - processing data from EPP

Table 10: SymbIoTe MVP evaluation form – for round A interviews.

Offering	Functionalities	Description	Level of interest for your business, score 1-5 where 5 is highest
IoT Resources Search Engine	Semantic IoT search engine Unified access to IoT resources Registration and controlled publication of IoT resources	Symbiote middleware acts as "search engine" allowing you to discover IoT resources (sensors, actuators, composite services), including (but not limited to) semantic search mechanisms to applications/enablers. 2. It also provides a unified (OData-like) and secure API to access IoT resources provided by other parties. Symbiote search results return metadata of the appropriate resource so that applications can access resources by directly interacting with respective IoT platforms. 3. It additionally offers a mechanism to register and advertise your IoT resources.	
Semantic Interoperability	Semantic Interoperability	SymbIoTe offers three levels of semantic interoperability by enabling description of IoT resources metadata: i) out-of-the-box basic interoperability by using a high-level ontology (called Core Information Model, CIM), ii) advanced interoperability by using a domain-specific ontology (called Best Practice Information Model, BIM) for platforms operating in the domains Smart Mobility, Smart Yachting, Smart Stadium and Smart Residence, iii) symbIoTe can ensure interoperability between specific platforms by providing custom ontologies (called Platform-Specific Information Model, PIM), which can be used as extensions to the CIM.	
Secure Access Control	Controlled access to IoT resources Security of resources and flows	SymbIoTe allows you to control access to your IoT resources. As IoT platform owner you can give various access rights to the offered resources. Moreover, these processes are performed in an inherently secure way by using appropriate Attribute-Based Access Control (ABAC) policies. By providing a flexible and lightweight ABAC-based access control, symbIoTe can also be used to secure existing IoT platforms.	
Services on top of IoT resources	Domain Enablers	???	