Information Architecture, 10th Semester

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Semantic Unified Data Model as Information Architecture Development Basis for the Heterogeneous IoT Data on the User-oriented Web-based Platform

MASTER'S THESIS

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ABSTRACT

Internet of Things requires infrastructures capable of supporting multiple, scalable services, where semantics and ontology play important role in the interoperability of IoT devices with other data sources. In this study, I investigate a complex web-based ecosystem, that integrates heterogeneous data coming from the internet-enabled devices and other services to support the interactions of different user groups. I also present a conceptual framework of the Unified Data Model (UDM) that serves as a basis for such integrations and user activities. The UDM itself may imply entirely technical subject for data management, but it is inaccurate because when UDM performed to its full potential, it can support technology and business practices, as well as facilitate information creation process for non-expert end-users. Despite the fact that the unified data models are not a new concept and there are existing proposals for IoT solutions, this study reveals the Unified Data Model that is suitable for web-based platforms were its users create, manage and share information based on the Unified Data Model within the context of the IoT. The purpose of the research is to outline how good data structure can solve some of the Information Architecture challenges, such as findability of data, content organization, labelling and navigation. This is relevant in the IoT context since more and more people nowadays are developing new solutions at home, others consider the possibility of monetising data, or just demand a comfortable living. Therefore, it is important to support their needs and tasks to help them create or find relevant information.

The research is based on the case study, where semantic IoT Unified Data Model has found many different application opportunities, helped development of business strategy, and continuously creates new IoT scenarios with people involvement. While working within the humanistic area, the study was created based on the personas and scenarios that served as a guideline throughout the analysis process to describe the Unified Data Model application possibilities. In order to develop reliable personas and scenarios, I have also made the research on each of the user group, their needs, and how IoT is adopted in people lives.

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2 INTRODUCTION

This introductory chapter presents the research background and challenges in the research area. The purpose here is to explain reader the aim of the study, introduce the scope of the project, and possible delimitations.

2.1 RESEARCH BACKGROUND AND CHALLENGES

The Internet of Things has gained significant importance in innovative technology and economic development. It has a variety of definitions due to distinctive use within various application domains, yet a concept of it is to connect physical objects (things) to the internet in order to enable an intelligent exchange of data with other physical or abstract things (Dictionary.com, 2018) at any time and place. In the past decade, most known and advertised internet enabled things were part of 'smart home' and 'personal healthcare' sectors, some of which were thermostats, weather stations, smart sensors, lighting, activity trackers and other wearables. In recent years, it has created a lot of interest among companies threatened by the competition, consumers focused on energy saving and increasing their level of comfort and researchers analysing data, patterns and user behaviour. Research shows that IoT leads to multiple advantages, such as efficiency, automation of daily tasks, time and money saving, improvement of the quality of life, new information and knowledge creation (Shetty & Manjaiah, 2017). This emerging technology is considered to have a bright future, yet it also faces many challenges, such as privacy and security, which is caused by lack of expertise working with a massive amount of data; interoperability and standardization - due to a large number of different manufacturers, communication between devices is very complicated, or in some cases impossible; Complexity brought by the diversity of technologies including hardware and software solutions makes integration very complex with a high risk of failure (Rose, Eldridge, & Chapin, 2015; Shetty & Manjaiah, 2017). As a matter of fact, close to three-fourths of IoT projects do not achieve the desired outcome due to technological complexity, lack of expertise in the area, lack of funding and ignorance of human factor (Cisco, 2017). The prediction was made that the growth of new users will generate device traffic that will reach over twenty-six billion by 2020, which is three times more compared to 2015, and machine-to-machine device amount will increase by half in the smart home sector within five years (Cisco, 2016). Real-life IoT projects have difficulties testing innovative solutions with the real user involvement and finding their information needs.

A vast amount of data that is transmitted from IoT data sources needs to be presented to people in different ways depending on the context. It is still unclear what challenges will arise creating user interfaces when the enormous amount of data will be used by users on a daily basis. The traffic generated by devices and connected services may bring a lot of innovation and complexity to the development process and design of user-centred solutions. As of now, the information-rich environments that integrate multiple IoT Platforms and web services will face the opportunity to handle the enormous amount of data. From information architecture perspective challenges such as ubiquitous information access, content representation and findability/re-findability may create difficulties creating usable and understandable interfaces.

2.2 THE DOMAIN

This project is carried out in collaboration with the small-sized company Seluxit, which is specializing in embedded electronics, cloud solutions and software development in the field of IoT for twelve years and has gained significant knowledge and experience within this area. Seluxit core business is a cloud service solution, called *Seluxit IoT Platform*, that consists of many components ensuring internet-enabled device connectivity, fast and secure data exchange between other physical things, abstract networks, and third-party services. Based on the experience and their customer needs, Seluxit has started its own-sponsored project at the beginning of 2016 called *Wappsto* - a web application store and data marketplace that facilitates different service integration and data exchange. Wappsto is a web-based platform that combines services integrated using Application Programming Interfaces (API) and other data that can be accessed through different user-oriented web applications, called wapps. (Seluxit, 2018) Figure 1 represents how data coming from different sources is connected through APIs and mapped in to the Seluxit Unified Data Model (see Chapter: THE UNIFIED DATA MODEL ANALYSIS), which allows creating complex integrations, configurations in wapps, as well as create the possibility of information sharing and exchange between its users.

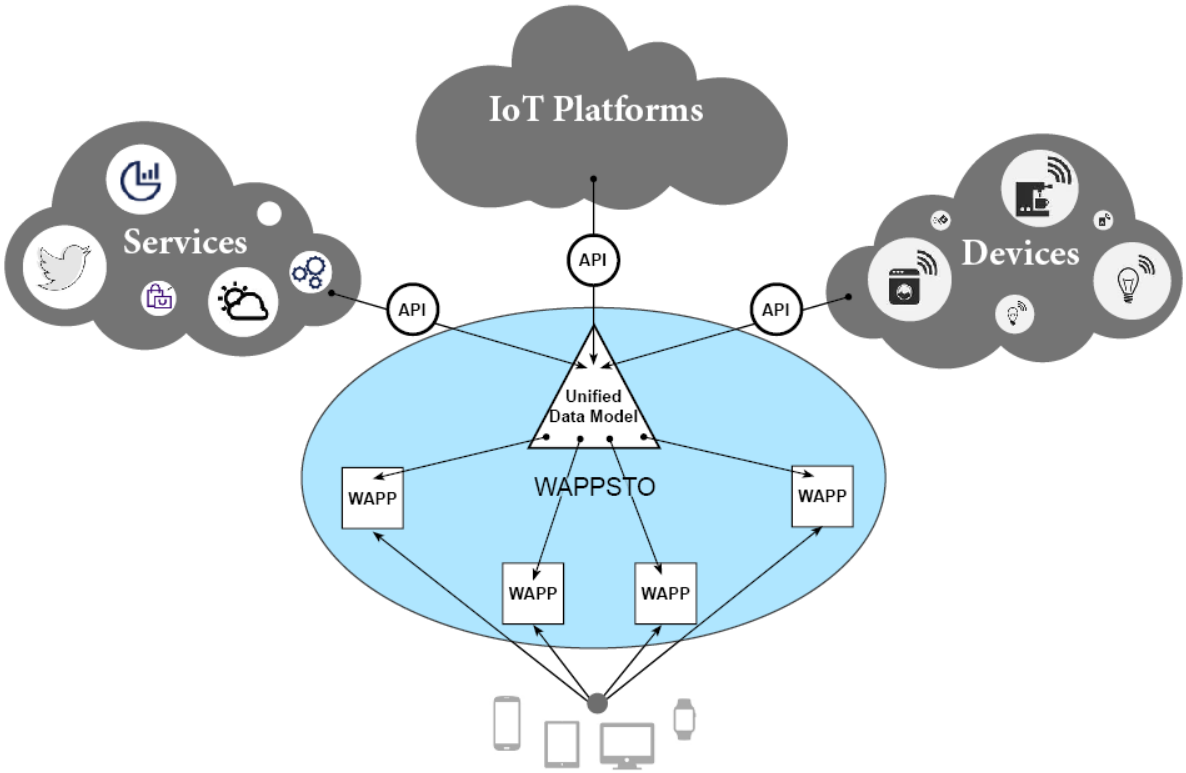


Figure 1: Wappsto Platform Overview: Interoperability of IoT data and services using APIs into the Seluxit Unified Data Model.

Wapps can be launched in a browser through Wappsto or run using Wappsto cloud services to ensure constant functionality. The purpose of Wapps is to separate complexity of the whole system, by dividing functionality into smaller parts that can be adjusted accordingly to a specific context and adapted to the end-user needs. Such Wapps can create new data by integrating services through API's, combine data to produce new information or create configurations, manage automation processes, etc. An example of a

Wapp functionality could be garden sprinkler automation based on the weather forecast or all light control within a building despite their manufacturer or communication protocol. Another reason for creating support of wapp is to allow Wappsto users to create their own integrations and Wapp designs, that would allow them to share or sell their solutions to other people.

The figure below (Figure 2) shows the relation between Seluxit IoT Platform (Seluxit logo placed in the shape of a cloud), Wappsto, third-party services, and devices. Icon on the left represents hardware (all physical devices: sensors, light bulbs, gateways, actuators, etc.) that connect to the Seluxit IoT Platform cloud using API, while smartphone icon on the right and below the cloud stands for applications. This representation shows a connection to a single IoT platform, yet it can be extended to support a diversity of platform, which creates a vast amount of possibilities to make data interoperable.

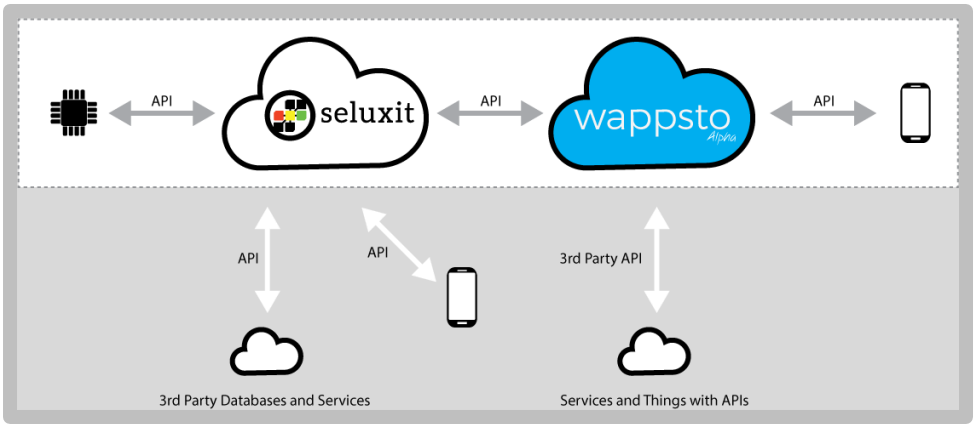


Figure 2: Integration of Seluxit IoT Platform and other services into Wappsto. (Seluxit, 2018)

Currently, Seluxit is introducing a data market features that would increase integration possibilities and facilitate new information and knowledge creation. The long-term goal regarding Wappsto is to establish characteristics of an infrastructure (Star & Ruhleder, 1996) making platform invisible and ubiquitous to the users.

2.3 RESEARCH PROBLEM

The vast amount of data that comes with IoT makes it harder for the users to find relevant information and things. Web-based platforms like Wappsto are the first movers to offer interaction for the diversity of users, where people can develop and design for other people within the IoT context. Nevertheless, there are challenges that are inevitable in such cases. First of all, there is a technological complexity that such platforms need to hide to make interaction possible and interfaces usable. That involves making coherent information architecture among multiple web applications, recognizable content structures and accessible information. Second, there are many IoT assets that need to be linked together and be maintainable. Lastly, there is a challenge on the conceptual level, which requires proper explanation and a way to deliver relevant content to the right users within the appropriate context. It appears, that the IoT-derived Unified Data Model at Seluxit is a central touchpoint between the technology, the business model and the users, which also connects IoT device data together with other cloud-based services creating new IoT use cases with people involvement. That makes it interesting to investigate from information architecture perspective. Therefore, following research question was made:

How can IoT-derived Seluxit Unified Data Model help to solve Information Architecture challenges on the web-based ecosystems that integrate the vast amount of heterogeneous data?

2.4 Purpose of the Study and Contribution

The aim of this study is to explore and describe information creation and provision on the web-based platform Wappsto where its users create, manage and share data based on the Unified Data Model within the context of the IoT. In this study, I will present the role, value and possible disadvantages of using the Seluxit Unified Data Model from Information Architecture perspective based on the diversity of examples.

The contributions of this study is a presentation and visualisation of the Seluxit Unified Data Model that can serve as an example of structuring IoT data on the application layer, and how it can be utilised to solve data interoperability and Information Architecture challenges such as content structure and information findability and navigation, on the web-based, user-driven platforms.

2.5 Delimitations

This section is intended to serve as an outline of things which the reader will not find in this report.

The data model presented here can be used for different projects and applied on different platforms, yet the angle of this study is web-based platforms, where people design for people and face an enormous amount of heterogeneous data. The data described below is intended to serve as an example of mapping data coming from diverse internet-enabled devices, and web services that can communicate using RESTful APIs, therefore I will not provide technical reports or detailed documentation on how to integrate the model into a web-based platform. I also do not make an exhaustive comparison of the IoT unified data models in the way that others do, rather I am taking it from a humanistic perspective.

Even though there are many areas that can be investigated, the examples of application in Information architecture area will be scoped down to content organisation and findability for the above-mentioned user groups.

Since the main purpose of this study is to explore the IoT Unified Data Model from Information Architecture angle, this report does **not** include or describe following aspects:

- Data access control and security;
- User data privacy;
- The Internet of Things device communication protocols;
- The Internet of Things Platform architecture.

Figure 1 displays integration of devices that are connected using APIs, IoT Platforms and data services. In this study, I will not exemplify the integration of IoT Platforms due to higher complexity which does not fit the time scope of this research.

The possibility of applying this model to the Industrial IoT will not be discussed since I am exploring only consumer-oriented web platform.

3 LITERATURE OVERVIEW

The literature review is formed based on the uppermost layers of different fields since the aim of this study is to give an overview rather than doing it exhaustive. As I have mentioned in the Delimitations section, this study is not involving industrial IoT, therefore, most of the literature involving this subject was bypassed. Despite the fact that the Internet of Things, unified data models and complex web-based ecosystems where people design for people are not novel and have been investigated by many researchers, the combination of all is not an easy subject to explore. The innovation involved in the Wappsto development and business strategy had an impact on the way this research was performed and the literature review.

3.1 THE INTERNET OF THINGS AND PEOPLE AND DATA INTEROPERABILITY

The IoT has no clear boundaries for its definition and application area since it has a diversity of possible relationships such as thing-to-person, person-to-thing and thing-to-thing that offers new ways of solving problems and operating on a daily basis (Mačiulienė, 2014). Technology requires developing suitable mechanisms to properly adapt to people context and work (Javier, et al., 2015). *"Internet of People (IoP) refers to the digital connectivity of people through the Internet infrastructure forming a network of collective intelligence and stimulating interactive communication among people"* (Maozhen, 2017).

Data semantisation is the key to IoT data interoperability which becomes an essential part of daily life and creates possibilities for knowledge interaction and sharing (Feifei, Qingjuan, Tao, & Huansheng, 2018). The data processing and integration can be done in different ways but due to the lack of standards and the heterogeneity, the key role is played by the middleware that allows communication between different applications. In platforms like Wappsto, a lot of freedom is given to non-professionals, to design and develop solutions that fit their needs. The tasks are performed by the different user groups and therefore a lot of the complexities have to be hidden by the middleware to enable users to integrate things and services, ensure findability of the data and present content in an organised way. While there are papers presenting or researching middleware frameworks for IoT (Park & Song, 2015; Huacarpuma, et al., 2017; Chelloug, 2017; Mačiulienė, 2014), there are few that research web-based middleware solutions from usability perspective (Mei & Huang, 2004) or Information architecture perspective, especially for the IoT web-based middleware.

3.2 DATA, INFORMATION, KNOWLEDGE

In this study, I explore how *data* is supplemented by meaningful user input to create *information*, and transform into *knowledge* with the help of the unified data model and semantics. The three lower layers displayed in the figure (Figure 3) are used to adapt the meaning to the context of semantic IoT.

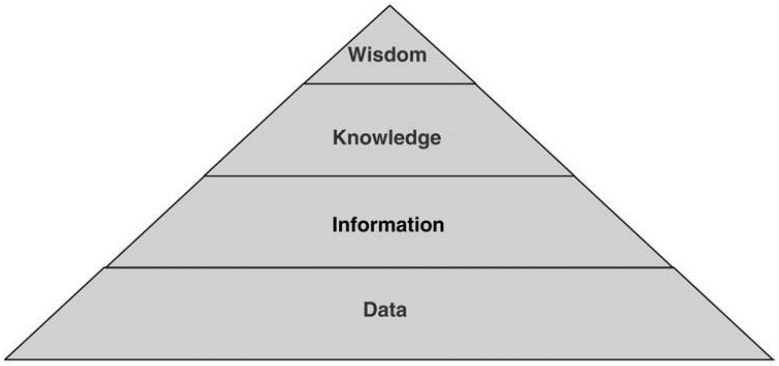


Figure 3: The DIKW hierarchy. (Rowley, 2006)

The above terms – *data*, *information and knowledge* (Figure 3) have many definitions, yet Rowley (2006) provides a summary of these definitions where data is described largely in terms of what it lacks - the meaning or value, it is unorganized and unprocessed and it serves as a foundation for defining information. In this study, data stands for all data produced by IoT devices or services. *"Information is defined in terms of data and is seen to be organized or structured data. This processing lends the data relevance for a specific purpose or context and thereby makes it meaningful, valuable, useful and relevant. [...] Knowledge is know-how, and is what makes possible the transformation of information into instructions. Knowledge can be obtained either by transmission from another who has it, by instruction, or by extracting it from experience."* (Rowley, 2006) The Unified Data Model provides the structure to the raw data and means of processing, storing and retrieving the data. In order to give meaning to the data it is given to the platform users in a different context to include existing and generate new information. Knowledge is all the experiences and user backgrounds that are used to create new information and knowledge.

3.3 INFORMATION ARCHITECTURE

There are many practices for designing information structures on the web, yet it can be a challenging task when facing complex web-based platforms. Challenges of IA outlined by other information architects, such as content representation, findability/re-findability (Ding & Lin, 2010, pp. 133-140) may also create difficulties creating user-friendly and understandable interfaces, especially due to the heterogeneity of data. In this study, multiple theories are applied to support the analysis within the Information Architecture framework. Ding and Lin define information architecture in the following way: *"Information architecture is about organizing and simplifying information, designing, integrating and aggregating information spaces/systems; creating ways for people to find, understand, exchange and manage information; and, therefore, stay on top of information and make right decisions"* (2010, p. 2). Morville, Rosenfeld and Arango (2015) present broader meaning of IA which revolves around:

- the structural design of shared information environments;
- the synthesis of the organization, labelling, search, and navigation systems within digital, physical, and cross-channel ecosystems;
- the art and science of shaping information products and experiences to support usability, findability, and understanding;

- an emerging discipline and community of practice focused on bringing principles of design and architecture to the digital landscape.

Moreover, Morville, Rosenfeld and Arango have presented information architecture ecology (2015, pp. 31-38), that can be vital almost in every study or project since it brings three important areas that need to be taken into perspective for wither developing strategy for information use or in this case, to present ways how it can be applied.

Figure 4 illustrates how Information Architectures is approached in this project. The model is based on information architecture ecology (Rosenfeld, Morville, & Arango, 2015, p. 32), which brings Content (Wappsto components, user-interface, etc.), Context (business strategy, goals) and User (target audience and their needs). That allows getting three different perspectives which are equally vital in information architecture strategy development. The Data Structure is placed in the middle because it serves as a basis for all three areas, which will be presented based on examples in the following chapter.

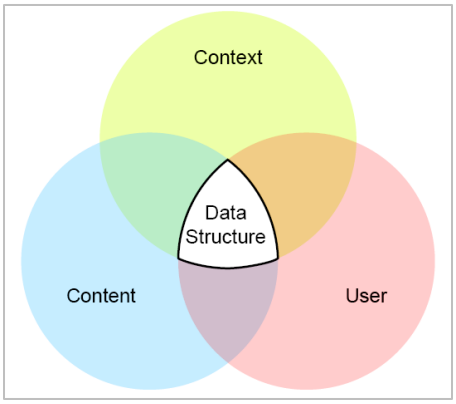


Figure 4: Data Structure as basis of Information Architecture ecology.

In this project, I will focus only on the intersection where all three areas of IA ecology intersect, taking data structure (Seluxit UDM) as connecting part.

Context: Seluxit have developed two main products – IoT Platform and Wappsto which have similar technologies and both are based on the Seluxit Unified Data model, yet they have different business strategies and offer a different value proposition for their target groups, which I explain in the following chapter.

Content: On one hand, the existing structure of Wappsto, its components and tools are constructing a large part of the content. On the other hand, the content is created by the different user groups who interact with the Seluxit Unified data model either directly or behind the scenes while integrating things, creating metadata or new information. The analysis part will describe both occurrences that are based on the **User** interactions**,** tasks they perform and their information needs.

While some literature suggests ways of handling information architecture for Big Data and the IoT (Stackowiak, Licht, Mantha, & L., 2015) to support expert decisions and technical considerations, in case of Wappsto, it is consumer oriented and the major part of the content is created and used by the end-users. Therefore, in this study, the four information architecture components (navigation, organisation, labelling and search systems) are used for the analysis of the application of the Unified Data Model since they are directly related to the above-mentioned IA challenges and are central in IA framework.

The analysis is also supported by other theories like navigation that is defined as a process of goal-directed seeking and locating hyperlinked information which includes links labels and other elements that help people orient themselves (Kalbach, 2008), therefore classification (Bowker & Star, 1999), metadata (Wilson, 2012), taxonomies and facets (Tunkelang, 2009) will be applied in the examples.

4 METHODOLOGY

This chapter describes methodological considerations and aspects of analysing data during this study. it presents the research approach, design and methods for data collection and techniques used for the analysis.

4.1 RESEARCH APPROACH AND DESIGN

The study is carried out within pragmatist research paradigm, therefore solving the real-life problem and providing practical application is the centre of the research (Mackenzie & Knipe, 2006). The design of this research was chosen to be a case study which can be defined as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence" (Robson, 1993, p. 146). This case study details are important since it develops a view of reality and human behaviour and allows developing needed skills for the researchers (Flyvbjerg, 2006). The type of this case study is mainly descriptive when presenting the Seluxit UDM and exploratory when it comes to investigation of possible user interactions and data model application possibilities.

While working within the humanistic field, in this study, I use an inductive approach (Bryman, 2016) to investigate different theories and find the answer to the problem statement, and to provide the best possible understanding of the subject.

4.2 EMPIRICAL DATA AND RESEARCH METHODS

In the study, multiple empirical data collection methods were used. The data collection method has primarily been qualitative, however, some of the basis for the analysis were quantitative, such as statistics and analytics for Persona and Scenario creation which will be described in more details in further sections of this chapter. The table below represents the overview of the data collection methods, why they were used in this study, and their sources. The table includes primary, secondary data and previously published studies.

Data usage	Empirical data types	Data sources
Investigation of present IoT Unified Data Models and importance of semantics and ontology in the field of IoT.	Collection of papers and Semantic Standardisation workshop materials	(McCool, 2017); (IAB, 2016) (Bajaj, Agarwal, Singh, Georgantas, & Issarny, 2017); (Ganzhaa, Paprzyckia, Pawlowski, Szmeja, & Wasielewska, 2016) (Bermudez-Edo, Elsaleh, Barnaghi, & Taylor, 2016)
	Semi-structured interview	Appendix 4: Interview "The Unified Data Model from a Business Perspective" transcript. (Lux, 2018);
The Seluxit Unified data model description and exploration of its usage in the Seluxit IoT Platform and Wappsto.	Reports, Documentations, Presentations	(Seluxit Platform Open API Documentation, 2016); (Lux D., Seluxit REST-ful open API for Lemonbeat devices, 2016); (Lemonbeat GmbH, 2017); (Seluxit, Wappsto Documentation, 2018)

Analysis of the Seluxit UDM from a business perspective	Semi-structured interview Presentations Report	Appendix 4: Interview "The Unified Data Model from a Business Perspective" transcript. (Lux, 2018); Appendix 3: Wappsto Value Proposition (Boyles & Tonnesen, 2018) Marketing analysis (Varjonen & Hasan, 2018)
	Personal observations and notes based on the discussions with Seluxit.	
Persona description of different user groups, identification of user needs and scenarios	Reports/ Whitepapers Articles and presentations	(Stack Overflow, 2017); (Slashdata, 2016); (Schön, Ebner, & Kumar, 2014); (Gemalto, 2017); (IDC, 2015); (i-scoop, 2017); (Altimeter, 2017) (VisionMobile, 2017)
	Infographics, charts	(Verizon, 2016) (Altimeter, 2017)
	Community blogs	(OpenHAB, 2018)
	Personal observations and notes from the field and based on the discussions with Seluxit.	

Table 1: An overview of empirical data used in this study.

4.2.1 Understanding context through a semi-structured interview

A semi-structured interview was conducted with the member of Thing-to-Thing Research Group (T2TRG)[1], Seluxit CEO and co-founder - Daniel Lux (Seluxit, 2015). The purpose of the interview was to elucidate understanding from a business perspective, explore the Unified Data Model history and application over years, as well as discover its benefits and disadvantages. The interview was semi-structured in order to remain flexible and allow adapting my questions to get a deeper understanding of the topic. The interview was performed at the office, where interviewee could feel comfortable and remain open during the conversation in a quiet surrounding for his reflections. (Kvale, 2007) The interview was recorded for the easiness of transcription process and not to miss out on any important information. The interview consisted of ten main questions and multiple sub-questions, which are presented in a table below. In the right column of the table, the reasoning for such questions is described.

Questions	**Reasoning**
Question 1: As a member of the Thing2Thing research group, could you elaborate on the current state of the IoT data model standardisation? What is your opinion about its future?	To find out a personal opinion of the IoT research group member to get another perspective that the available information on the internet.
Question 2: What is your opinion about standardisation and generalisation of data? What are the positive and negative aspects of that?	To find out a personal opinion of the standardisation from both positive and negative sides.
Question 3: There are other unified data models that are used by large communities. Why not using the structure that is approved by many other larger companies?	To understand why the Seluxit data model is preferred to other data models developed by large communities and get insight on how it is perceived in the company.

[1] https://irtf.org/t2trg

Question 4: If you had to compare Seluxit unified data model to other IoT data models, what would be the main benefits or disadvantages of having your own data model? (E.g. IPSO)	To learn about advantages and disadvantages of the Seluxit data model compared to other data models from company's perspective.
Question 5: Over twelve years you had many customers with different requirement. What was your experience? What are the benefits/disadvantages of the UDM when integrating new devices into the IoT platform?	To learn about advantages and disadvantages of the Seluxit Unified Data Model when integrating new things based on the experiences with customers.
Question 6: It was many years ago when the first iteration of the data model was created at Seluxit. What was the initial reason for creating it and has it changed? How is it used now?	To investigate reasoning for the initial implementation of the Seluxit UDM, understand the needs from business and technology perspective, as well as find out if it has changed over the years considering that the business model has changed.
Question 7: How does it influence Seluxit business strategy and development of services that are offered to your customers? Is it Seluxit business model shaping the unified data model or the other way around?	To understand the influence of the Seluxit data model on the business strategy and development of services. Find out what is in the initial starting point for Seluxit current business model.
Question 8: How the data model is used in Wappsto and why?	To find the role of the data model in Wappsto.
Question 9: What does it mean to base everything on the Data Model? Do you see any disadvantages of doing that?	To investigate risks that may appear.
Question 10: What business opportunities does it open? 1. … for Seluxit? 2. … for targeted user groups: a. Manufacturers b. developers	To find out about business perspectives that Seluxit is facing as well as investigate business opportunities for Wappsto target groups.

Table 2: Interview "THE UNIFIED DATA MODEL FROM A BUSINESS PERSPECTIVE" questions and reasoning.

Due to the fact that some of the interviewee's answers may include subjective opinion, to avoid bias, in the analysis, I am trying to engage also different opinions from the literature and make the case study valid (Yin, 2014) and reliable. Moreover, with this interview I am not looking to prove or disprove a specific statement, rather explore and try to understand.

4.2.2 Secondary research study and meta-study

Online documents, reports, published studies and statistics were collected and analysed to identify the current state of IoT data standardisation and existing unified data models, which led me to the topic of the importance of semantisation and ontologies.

4.2.2.1 Getting to know users – Personas

In order to get to know the users of Wappsto and understand what role they play, Persona method was applied based on the most recent data analytics, statistics and surveys, which is exemplified in the Data Treatment section. Personas are representations of fictional users of the certain products and designs. They describe real people with their life backgrounds, values, and goals, which I used for picturing user interactions and interface behaviours in Wappsto. In this project, personas were created based on Nielsen's (2013) guidelines to display three primary target groups of Wappsto – developers, manufacturers, and homeowners. A detailed description of all the groups is presented in the analysis part. In this study, Personas as a tool to focus on the real-world user expectations and uncover their

needs, backgrounds, habits and interests while investigating the application of the Seluxit Unified Data Model (Snitker & Co., 2007; Nielsen, 2013; Harley, 2015).

The user groups are quite distinct from each other, therefore, for every group, two to three personas were created in order to distinguish specific user needs and characteristics with regards to interaction points in Wappsto. Developers were separated based on their level of advancement in programming, and professional expertise. They consist of the very advanced developer, middle range developer, and a developer who has limited knowledge in programming and specialising mainly in frontend development and user interactions. Manufacturer category consists of two personas. One of them is a corporate persona, which represents manufacturers who want to integrate IoT into their product and compared to other personas, it describes company's weaknesses, advantages and motivation. Another persona that falls into manufacturer group is a maker type since these are the people who can perform similar actions in order to develop devices, prototypes, etc. Homeowner group consists of two Personas who have different motivations for using such web platforms like Wappsto and therefore create a different kind of interactions.

4.2.2.2 Scenarios

Scenarios were created to capture and summarise interactions in of all three user groups. Scenarios help visualize the environment and experience, as well as generate new ideas (Rosenfeld, Morville, & Arango, 2015). They are based on the Personas described in the analysis part to show how people needs are involved in this study. *"[…] needs are not only closely interlinked with the persona but also with the situation that the persona experiences. The goal emerges from both the situations and needs of the persona."* (Nielsen, 2013, p. 82) In the scenarios, Personas perform different search activities within three higher-level informational needs such as *Lookup*, *Learn* and *Investigate* (Marchionini, 2006). *Casual* lookup presented by Russel-Rose & Tate (2013, p. 224) is omitted in this study since there was no possibility to retrieve the required type of data due to the immaturity of Wappsto. Moreover, the purpose of scenarios is not to cover all the possible use cases, but to create an overall image and help the reader.

4.2.3 Observations

Some direct observations in the field (Seluxit office, community forums (openHAB, 2018)) were also used to understand the context of user group activities and get insights of their tasks and goals (Rogers, Sharp, & Preece, 2011) which helped creating realistic scenarios. These observations were noted, revised and redrafted to put into ideas and summarise scenarios. Some photos, drawings, and stickers were used for that purpose. An example of that can be found in the appendix (Appendix 8).

4.2.4 Data treatment

Due to the fact that personas are fictitious characters, they are often criticised for not meeting real people needs. To avoid this limitation of the method, I have based Personas on most recent statistics from different sources (see chapter Personas). The table below describes some of the examples of what information was taken into consideration and how this quantitative data was used in personas and scenarios.

Data	Data source	Data usage

Over 80% of developers are male. Over 60% have a higher degree Over 75% of developers are interested in new job opportunities. A bit over 13.1% of developers are actively looking for a job.	Developer survey results (Stack Overflow, 2017)	All these facts are respectively integrated into developer persona demographics. For example, two out of three are male and employed. All of them have a higher education degree and one of the personas is unemployed.
The horizons of Home IoT Adoption	"State of Internet of Things in the Home" (Appendix 1: Three horizons of Home IoT Adoption Anticipated) (Altimeter, 2017)	Homeowner personas are described based on two most adopted horizons since it represents the current state of IoT in Smart Home sector.
29% of people are interested in monetizing their data in return for offers	Survey "What do consumers want from their connected future?" (Gemalto, 2017)	In the scenario, persona (Kent) wants to exchange or sell his data in order to get profit.

Table 3: Examples of data treatment in persona and scenario creation process.

4.2.5 Data Limitations

Besides having made qualitative research and collecting quantitative empirical data, it would still be relevant to perform data collection based on the real people input who have used the Seluxit Unified Data Model in their work and spare time routines in order to get more insights. Unfortunately, there are not many users, in general, using the technology at this point in time. Moreover, the data in Wappsto is anonymised for ethical and security reasons. Due to the fact that Wappsto is still a new technology, there is no data analytics that is integrated to learn about the usage of the system.

5 THE UNIFIED DATA MODEL ANALYSIS

In the IoT, a vast amount of "unstructured data" needs to be transmitted, adapted to context and stored. Therefore, NoSQL type of databases is more accepted due to their scalability and performance compared to traditional relational databases (Techopedia, 2018) where the unified content metadata models are used for finding relevant content and relations (Coleman, 2015; Mallikaarachchi, 2010). Some of the major reasons behind unifying IoT data are to reuse application functionality and configurations, combine data into meaningful data sets, and to develop machine learning. Unification of service is also required in order to combine heterogeneous data sources and develop sophisticated applications that allow combination or such services to IoT devices. The advantage of having interoperable platforms with unified data structure is a possibility to create complete automation, and information exchange and sharing between different user groups.

The following sections will describe the importance of the semantics and ontology in the data structures and present the Seluxit Unified Data Model structure and components together with the examples of data mapped into the model. Afterwards, the data model business perspective will be described and analysed which will be followed by the application examples that are based on the human interactions on the web-based platform Wappsto.

5.1 IoT Data Semantisation

Recent research (Jara, et al., 2014; Dongmyoung, Yunchul, & Yonggeun, 2016; Murdock, et al., 2016) outlines importance of semantics and ontology in IoT systems as the key to interoperability of heterogeneous devices and services to create infrastructures that bring value to the end-users, therefore data structure based on ontology and semantics is needed. Raw data that comes from any source is meaningless without the metadata. The example below (Figure 5) depicts the increase on meaningfulness with the increase of descriptions added to the data. Metadata is required on both levels - data level and device level.

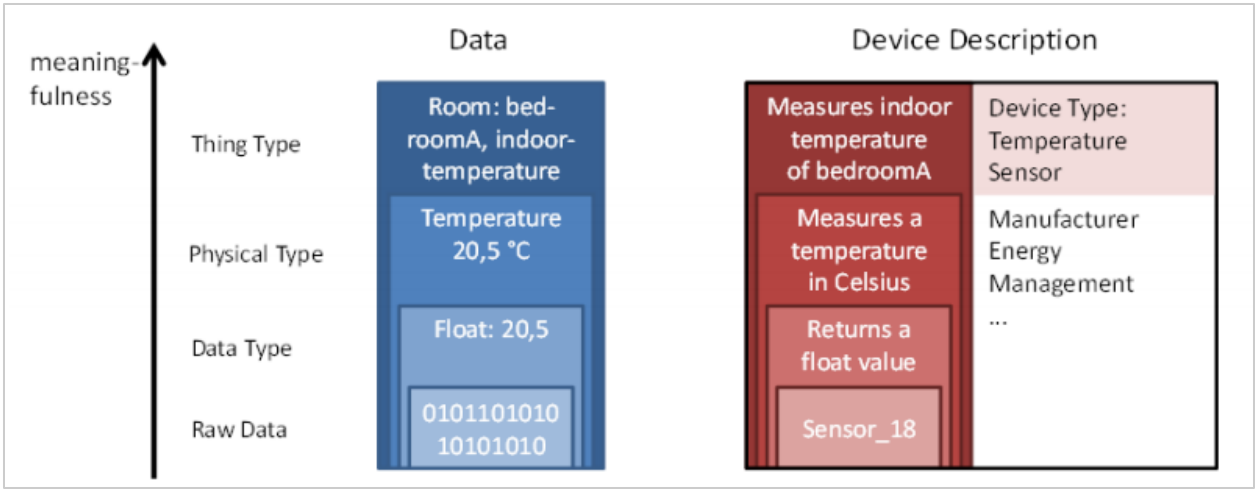


Figure 5: "Meaningfulness of the data, increased with metadata" (Murdock, et al., 2016).

Semantic structure and data ontology are the basis for creating the unified data model. They describe the nature of data and its relationships, as well as create distinct, meaningful elements that can combine

certain data sets. These important factors enable accurate interpretation of data, easy exchange across platforms and promote platform continuous development and new integrations.

During the interview, Daniel Lux (2018) has shared his opinion regarding the IoT data models and their standardisation process. Technology is advancing due to use of microservices, and application of ontology and semantics to facilitate interoperability. Despite the contribution brought by the research group, during the conversation an observation was made regarding standardisation of the IoT data model by the Internet Engineering Task Force (IETF) research group. The critique was concerning the research moving slow and being slightly distant from the real world and lack of research application in real use cases that can reveal some important aspects. That can be explained that semantic ontologies which are used in practice are often proprietary and are closed within individual organisations, which limits researchers and engineers to access application specific ontologies to be applied in practice, modify and extend (Ganzhaa, Paprzyckia, Pawlowski, Szmeja, & Wasielewska, 2016). Over the past two years, different data models have emerged, yet most of them did not succeed due to the high complexity of the things and because the specification of the model and operations related to the model are not aligned. Major disadvantages of other IoT data models are lack of semantics or their misuse, that can cause confusion for different people, lack of ontology, and unclear naming due to the possible misconception of technologies used in the field of IoT. (Lux, 2018)

5.2 The Seluxit Unified Data Model

In this section, I will explain the idea behind the Seluxit Unified Data model. The examples of how heterogeneous and complex data from different sources can be adopted in the platform will be presented in a form of figures and tables.

5.2.1 Structure and Semantic Components

The basic structure of the model has derived from the IoT context and consists of data sets such as Network, Device, Value and State which are marked as light blue on the image below (Figure 6: Components of the Unified Data Model.). In order to support different 3rd party APIs that do not describe IoT devices (e.g. log or streaming data, calendars, message feeds, etc.) it can be expanded to include Sets and Objects, which are marked as light green on the figure below (Figure 6).

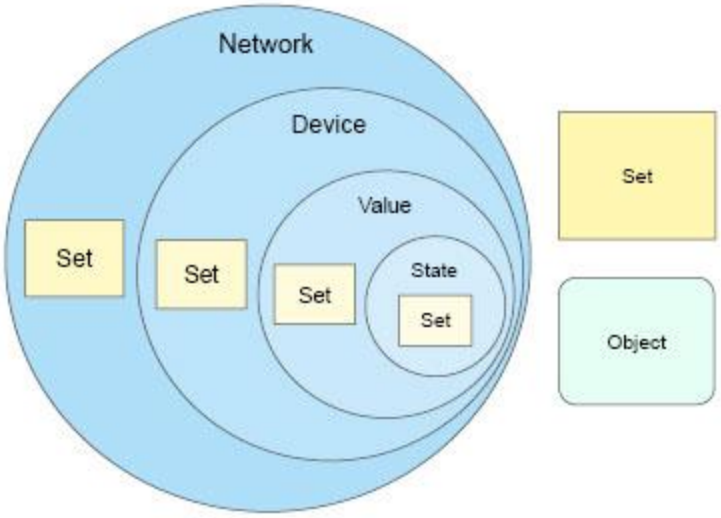


Figure 6: Components of the Unified Data Model.

5.2.1.1 Network

A network is a collection of information that can contain heterogeneous data that comes from a cloud service, IoT device (gateway/bridge or another Internet-enabled thing), or even other the IoT platform. Network groups underlying components such as devices and sets. The table below (Table 4) presents attributes of the Network component, the explanation of these attributes and the examples.

Attribute	Meaning	Example
id	Universally unique identifier.	<unique_id>
name	Meaningful user-friendly name of a value.	Philips Hue Bridge
device	An array of a device connected to the network.	See section **Error! Reference s ource not found.**
created_by	The creator of the network. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>
set	An array of universally unique identifiers that group certain objects or the data model components.	See section Set.

Table 4: The Seluxit UDM Network component attributes.

5.2.1.2 Device

A device is a group of values that describes them by providing valuable information to users and machines. Metadata that describes a device contains information about where device values came from, how they were created, communication, protocol, description, etc. The table below (Table 5) presents attributes of the Device component, the explanation of these attributes and the examples.

Attribute	Meaning	Example
id	Universally unique identifier.	<unique_id>
name	Meaningful user-friendly name of a value.	Ceiling lamp
version	A version of the device	1.3
description	Meaningful user-friendly description of the device and its purpose.	A smart sensor device that measures humidity and temperature every 15 minutes.

manufacturer	Manufacturer of the device	Philips
serial	Serial number	00984-62317-625
protocol	Device communication protocol	TCP/IP
communication	Device communication type	Always online
values	An array of values.	See section **Error! Reference s ource not found.**.
created_by	The creator of the device. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>
set	An array of universally unique identifies that group certain objects or the data model components.	See section Set.

Table 5: The Seluxit UDM Device component attributes.

5.2.1.3 Value

Value describes the actual data that is produced by the device or a data source. The purpose of a Value is to inform what is the data, how it should be displayed and treated. The table below contains an attribute that describes data. The table below (Table 6) presents attributes of the Value component, the explanation of these attributes and the examples.

Attribute	Meaning	Example
id	Universally unique identifier.	<unique_id>
name	Meaningful user-friendly name of a value.	Outdoors temperature
type	Generic value type.	temperature, humidity, camera, etc.
permission	Defines if a value is readable only or you can write data to it.	Read, write, read and write
state	An array of value states depending on the permission.	See section State.
status	Status of the value.	pending, update, etc.
number string blob xml	Data type, which contains multiple attributes defining the data type. The number may have minimum and maximum allowed number, step size and a unit of the measurement; String and blob – string encoding and maximum length of the string; XML – xml schema definition and xml namespace.	number: {min: 0, max: 100, step: 1, unit: "%"} string: {max: 50, encoding: "utf32"}
log	Historical data.	Log: {type: hour, timestamp: }
created_by	The creator of this value. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>
set	An array of universally unique identifiers that group certain objects or the data model components.	See section Set.

Table 6: The Seluxit UDM Value component attributes.

A value can have one or two states (See the following section) depending on its permission (read, write or both). Values that have only a 'Report' state (e.g. Humidity sensor reports room relative humidity 15 minutes). If a value has a 'Control' state, it can be controlled (e.g. Light bulb can be switched 'on' or 'off'). In other cases, the values will have both the control and the report states (e.g. Light bulb was switched on and the report message was sent from a device confirming that the action was successful.)

5.2.1.4 State

A state is a child of a Value. Value is an actual description of a valuable data that comes from a certain source, such as how it should be treated, displayed, what permission does it have and what is its purpose. The table below (Table 7) presents attributes of the State component, the explanation of these attributes and the examples.

Attribute	Meaning	Example
id	Universally unique identifier.	<unique_id>
type	The type of the data (is it send to the source or received from). Can be either "Report" or "Control".	Report
data	The actual data, which is either string, number, xml or a blob.	39
timestamp	The time it was created (Unix timestamp or ISO format date)	2018-03-27T08:42:46.960Z
status	Status of the data (was the data sent to the source or it failed)	Pending
created_by	The creator of the state. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>
price	The price of the data.	0
set	An array of universally unique identifiers that group certain objects or the data model components.	See section Set.

Table 7: The Seluxit UDM State component attributes.

5.2.1.5 Set

Set is an array of universally unique identifiers that can be classified as a group of related objects or the data model components that are different from the above-mentioned meta attributes. The table below (Table 8) presents attributes of the Set component, the explanation of these attributes and the examples.

Attribute	Meaning	Example
id	Universally unique identifier.	<unique_id>
name	Meaningful user-friendly name of the group.	Favourites
group	An array of objects that define their type and universally unique identifier.	[{"type": "network", "id": [<unique_id>, …, <unique_id>}, {"type": "device", "id": [<unique_id>, …, <unique_id>}]
description	Meaningful user-friendly description of the group and its purpose.	A group of favourite devices and networks.
created_by	The creator of the state. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>

Table 8: The Seluxit UDM Set component attributes.

Sets allow grouping data that is either domain or user specific, which allows creating new categories, relations and creating new, processed information.

5.2.1.6 Object

The Object is a combination of Values that require different description than the example of the value above. Some special type of data that need to have particular treatment can be mapped into the Object attributes displayed in the table below (Table 9) together with the explanation of these attributes and the examples.

Attribute	Meaning	Example

id	Universally unique identifier.	<unique_id>
name	Meaningful user-friendly name of the object.	Spatial coordinates
value	An array of objects that have specific data description.	[<custom_data_object>, …, <custom_data_object>]
description	Meaningful user-friendly description of the group and its purpose.	A list of spatial coordinates that describe a point in the universe.
created_by	The creator of the state. Since data may come from different sources and can be generated by web applications, such parameter can be vital.	<unique_id>
set	An array of universally unique identifiers that group certain objects or the data model components.	See section Set.

Table 9: The Seluxit UDM Object component attributes.

5.3 BUSINESS PERSPECTIVE

The statistics show, that the Internet of Things will give rise to new business models and bases of competition, both for the companies that use IoT systems and for those that supply IoT technology (McKinsey & Company, 2015). This section describes the Seluxit Unified Data Model from Seluxit business perspective, giving insights on how it was put into IoT practice and what opportunities it has open for the company.

Seluxit was involved in IoT projects for over twelve years and over these years the Unified Data Model has been iterated and evolving into a mature data structure that is now applicable in different solutions. The unified data management promotes technical efficiencies and also supports strategic, data-oriented business goals. (Russom, 2010) The model serves as a basis for the Seluxit IoT Platform which was company's main product, and recently it has given the opportunity to develop an innovative web-based platform Wappsto. Both technologies are using web service-based communication method that allows data to be transmitted between two applications or electronic devices over the World Wide Web (TechTarget, 2016). The web services are developed using RESTful APIs approach which uses internet mechanisms based on the HTTP protocol. This gives an advantage for developers to understand, use and make easier and faster implementations (RestCase, 2017). While both products share similar technologies (Appendix 6) and pricing model (Seluxit, 2018; Seluxit, 2018), their business strategy has differences. Wappsto can be defined as platform ecosystem which is driven by the Internet of Things (Tiwana, 2013) The web-based platform software is extended through the diversity of APIs to extend its functionality and allow access of different interfaces based on the context. "*The three groups of participants in a platform ecosystem—platform owners, app developers, and end-users—have unique needs and motivations for participating in it*" (Tiwana, 2013, p. 61). The table below describes value proposition for three Wappsto user groups (Boyles & Tonnesen, 2018; Seluxit, 2018) that represent the above app developers and end-user. The following groups are involved in the creation of the two-sided marketplace (Varjonen & Hasan, 2018).

User Group	Consumers	Developers and makers	Manufacturers and service provider
Value proposition	Possibility to • connect their things together to build, personalised smart life	Get tools that allow collaborating and make things smart and services work together. Have access to other data that can enrich their solutions.	A way to connect their products to the internet and connect them to other products and services.

	• use free or buy ready solutions, • buy, sell, share and exchange data.	A way to profit from smart things and services. Do not need to worry about receiving and managing micropayments, hosting solutions.	Have access to 3rd party services and data that can enrich their devices. Have access to generic user interfaces that can remotely control their devices out of the box.

Table 10: Wappsto value proposition for the three user groups.

The research shows, that interoperability is critical for maximizing the value of the IoT and on average, 40-percent of the total value that can be unlocked requires different IoT systems to work together (McKinsey & Company, 2015, p. 23). The benefits of having the Unified Data Model are to have integrated solutions work out of the box with third-party services and devices, data privacy and security (Lux, 2018) by reusing the domain knowledge and user interfaces that are based on the Seluxit UDM. Whether it is a protocol, service or a thing integration can speed up some time in the first steps. A data model is also a valuable tool to ensure that the needs of the business are met (CA Technologies, 2013). Historical data can enable identification of trends and patterns which in the future can promote business intelligence and business user information needs or help to make informed decisions (CA Technologies, 2008). Nevertheless, there is always a risk of failure since such platforms require engagement and synergy between all three defined user groups. Platform ecosystem is user dependent and without one of the user groups, Wappsto can become less interesting to other user groups which can cause demotivation and usage termination.

5.4 Examples of Data Mapping into the Model

This section presents examples of how heterogeneous data can be mapped into the data model.

As it was mentioned earlier (Figure 1), Wappsto integrates three types of sources using APIs – IoT platforms, IoT devices and services. Below two examples of these integrations are mapped into the Seluxit Unified Data Model. Some of the attributes and value objects are omitted in this example to simplify it and present general idea. The complete example can be found in JSON schema format in the Appendix (10 and 11).

5.4.1 Mapping of the IoT device.

An example below (Table 11) shows the mapping of one of the most popular smart products on the market - Philips Hue bridge[2] which has one device included – lightstrip and only limited amount of values for the simplicity of the example.

[2] **Bridge** – This is used to enable your smart bulbs to communicate with each other and the Portal via the internet. The main set of APIs are those offered by the bridge. These allow you to control all settings of the lights in your system. These APIs require direct access to your bridge so you'll only be able to access them when your app and bridge are on the same local network. (Philips, 2016)

Network

Name: Philips Hue Bridge

Device

Name: Hue lightstrip
Manufacturer: Philips
Description: Philips Hue White and Colour Ambiance Lightstrip. Dimmable LED Smart Light

Value	**Value**

Name: on,
Type: Extended colour light,
Permission: r,
Status: ok,
Number: {
min: 0,
max: 1,
step: 1
}
	Name: brightness,
	Type: Extended colour light,
	Permission: r,
	Status: ok,
	Number: {
	min: 0,
	max: 255,
	step: 1
	}

State Type: Report, Data: 1, Price: 0, Timestamp: 2018-03-08T10:36:04.998Z	**State** Type: Report, Data: 100, Price: 0, Timestamp: 2018-03-08T10:36:05.424

Table 11: Mapping of the Philips Hue set of the device into the Seluxit Unified Data Model.

5.4.2 Mapping of the Service

The following example shows the mapping of the OpenWeatherMap data service[3] - current weather (Table 12).

Network

Name: OpenWeatherMap

[3] OpenWeatherMap – API that provides free access to current weather data for any location. The data is returned in JSON, XML, or HTML formats (https://openweathermap.org/api).

Device

Name: Current Weather
Manufacturer: OpenWeatherMap
Description: Provides current weather values based on specified location.

Value

Name: city,
Type: location,
Permission: rw,
Status: ok,
String: {
max: 99
}

State

Type: Report,
Data: Aalborg,
Price: 0,
Timestamp: 2018-03-12T23:08:12.370Z

State

Type: Control,
Data: Aalborg,
Price: 0,
Timestamp: 2018-03-12T23:08:12.370Z

Value

Name: temperature,
Type: temperature,
Permission: r,
Status: ok,
Number: {
min: -999,
max: 999,
step: 1,
unit: K
}

State

Type: Report,
Data: 274.077,
Price: 0,
Timestamp: 2018-03-12T23:08:12.370Z

Table 12: Mapping of the OpenWeatherMap weather service into the Seluxit Unified Data Model.

5.4.3 URI Hierarchy Example

The example below (Table 13) shows the Uniform Resource Identifier (URI) meaningful structure path that provides access to the description data description.

```
https://<DOMAIN>/network/<NETWORK_UUID>/device/<DEVICE_UUID>/value/<VALUE_UUID>/state/<STATE_UUID>
```

Table 13: Complete URI hierarchy example.

5.5 Application Examples Based on User Interactions

This chapter presents user groups that are playing an important role in Wappsto and in the field of IoT in general. First I will present the user groups and their possible activities in Wappsto. Afterwards, there will be a description of Personas that represent people from each of the groups. As it was mentioned in the methodology chapter, these personas are factious, but to make this study more reliable, they are based on the research and statistics. This approach allowed me to create realistic scenarios that display user interactions based on their needs. At a later stage of this chapter, I will analyse the Seluxit UDM role in Information Architecture and I will provide examples of how semantically structured data can help the end-users interact with the diverse IoT data.

5.5.1 User Groups and Their Needs

The main target groups in this study are developers and manufacturers since those are people who can potentially generate valuable content and information that eventually becomes interesting for the consumer market. Developers in this context are people or companies with different levels of programming skills, who specialise in World Wide Web software application development or create and maintain websites (Dictionary.com, 2018). Manufacturer group consists of companies that produce

devices that can potentially be connected to the internet. This group contains companies that do not have resources and/or time to build their own solutions and require expertise in the field of IoT. Homeowners are the consumers of products and solution developed by the developers and manufacturers. Another important category of targeted people is makers. Maker Movement has an ideology to create and develop new and challenging things using new tools. Makers could be hardware or software developers, or enthusiast, who like innovation (Schön, Ebner, & Kumar, 2014). This group is also important since these people are enthusiastic and have the need to experiment, create something innovative and useful even though sometimes just for fun. The statistical data shows that they are likely to begin start-ups. *"Even if not everything and every action amongst makers is digitally driven, making deeply builds on the development of the "Internet of Things" (IoT). Small computers or digital devices and tools, which are connected via the Internet, are built and used to create or produce new products."* (Schön, Ebner, & Kumar, 2014).

The table below (Table 14: User groups and their activities which are possible because of the Seluxit Unified Data Model.) outlines the user group general activities in Wappsto that are possible because of the unified data structure that creates new IoT use case scenarios.

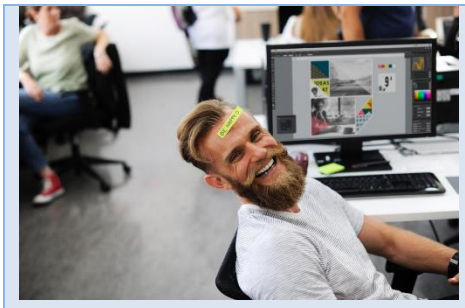
User group	User groups general activities
Developers	• Create functionality, configurations and automation for personal or commercial use. • Translate service data into the data model to make them available for other people. • Connect things and services. • Create new information based on processed data • Map IoT devices into the unified data model • Create interactive and usable user interfaces
Manufacturers and Makers	• Create and connect new things based on the unified data model • Deliver new services based on user data
Homeowners	• Buy, sell, share and exchange data • Create new information • Search for new tools, information. • Integrate solutions • Create configurations and automation using applications developed by other people.

Table 14: User groups and their activities which are possible because of the Seluxit Unified Data Model.

5.5.2 Personas

According to the surveys and data analysis made by Stack Overflow (2017) and Vision Mobile (2016) the majority of developers are male, and therefore two out of three developer personas are male, which are coming from different regions, such as Europe, Asia and North America, based on statistics. A major part of developers who are working has side projects since representatives of this group are enthusiastic about learning new things and motivated to improve their skills. These facts and statistic data (see Methodology chapter) are adopted in the following personas.

Developer Persona



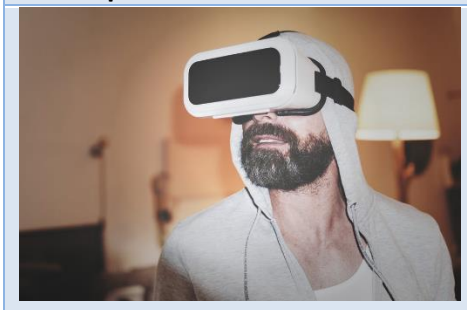
Derek Belmont

Age: 31
Gender: Male
Civil status: Unmarried
Education: Master's degree in Software Development
Occupation: Consultant Software Developer
Social Media Channels: Facebook, Stack Overflow, GitHub, LinkedIn

Derek works as a consultant in a bank, wherein his daily routine, he develops web-based user interfaces to increase customer engagement. He is looking for other job opportunities for professional development. Once in a while, Derek takes freelance jobs for fun and new experiences, since he is inspired to learn new things.
Derek appreciates good documentation and gets very frustrated when the tools he is using are failing his expectation.
In his spare time, he enjoys cooking and socialising with friends.

Table 15: Developer persona "Derek". (Photo source: Pexels.com)

Developer Persona



James Reyes

Age: 42
Gender: Male
Civil status: Married
Education: Master's degree in Computer Science, self-education
Occupation: Certified Ethical Hacker
Social Media Channels: Stack Overflow, GitHub, Meetup, LinkedIn

James currently is hired by a security company where he is working part-time discovering potential malfunction or faults in the software.
James likes sharing his knowledge with peers, therefore he contributes some ideas and solutions on different media channels and participates in discussions, as well as meetups organised by the developer community in his area.
In his spare time of work and responsibilities at home, he frequently explores new technologies available on the internet and finds tasks to challenge his brain or develop something useful. He is interested in virtual reality gaming and everything that goes beyond the daily routines.

Table 16: Developer persona "James". (Photo source: Pexels.com)

Developer Persona

Mia Sato

Age: 23
Gender: Female
Civil status: Unmarried
Education: Bachelor's degree in Multimedia Design
Occupation: Interaction Designer and Web Developer, freelancer
Social Media Channels: Stack Overflow, Behance, Pinterest, Facebook, Instagram, Snapchat

She is in her last year of studying Web Development. She is a fast learner, but the diversity of libraries and frameworks used for developing web solutions is overwhelming her.
She sometimes works as a freelance designer where she produces mock-ups and designs in Photoshop/Illustrator for different projects. Nevertheless, her real strength is interaction design. She does some client side coding (HTML/CSS/JS) in order to develop beautiful, yet usable interactive elements.
All her free time she spends on travelling and photography.

Table 17: Developer persona "Mia". (Photo source: Pexels.com)

Below table (Table 18) describes a representative of a maker movement.

Maker Persona	
 **Frank Kroemer** ***Age:*** 28 ***Gender:*** Male ***Civil status:*** Unmarried ***Education:*** Master's degree in Software engineering ***Occupation***: Software engineer **Social Media Channels:** Stack Overflow, GitHub, Hackster.io, makerspace, LinkedIn	Franks is working in a small company as a software engineer, where he is constantly engaged with the software design, development and testing. When he is off the work, he likes developing his own projects or be social and play board games or role-playing with his friends. Together with friends he often comes up with some crazy ideas for some events or occasions. Frank is passionate about learning new things and developing his creative ideas. He is a naturally curious person, yet he hates repeating some actions, again and again, therefore, he would rather develop a tool that would work instead of him. This is his main motivation to build home automation. He wants to achieve convenient living, as well as to impress his friends, but he is having challenges doing everything on his own due to lack of free time and lack of expertise in some areas. He tried open source IoT platforms yet none of them offers a complete range of services and freedom to satisfy his needs.

Table 18: Maker persona "Frank". (Photo source: Pexels.com)

The following persona is company type of persona which is based on statistics, reports and predictions made in recent years (see Methodology chapter).

Manufacturer Persona

BrightTech ***Founded in:*** 1999 ***Employees:*** 150 ***Industry:*** Lightning and bulb manufacturing ***Strengths:*** quality products, great customer engagement. ***Weaknesses***: large competition, no knowledge about IoT solutions and application development.	BrightTech is categorised as a small to a medium-sized company which is self-owned. Their products range from indoor light bulbs and lamp designs to outdoor lighting. Company's current project is to manufacture internet-enabled products that would attract new customers and lower the risk of losing their current users. Since all their products are consumer-oriented, they want to deliver better customers service and support by increasing user experience and introducing innovative ways to utilise their products. They also want to gain insights into user patterns to offer better services and improve their products. In order to create competitive advantage, they want to reduce time to market and create feasible prices for their customers. The challenge for the company is to achieve their goals since IoT solutions require time, money and experience, which they do not have in abundance.

Table 19: Manufacturer persona "BrightTech". (Photo source: Pexels.com)

The homeowner type of personas are based on the surveys that outline people needs and expectations in smart home sector and statistics on IoT adoption (see Methodology chapter).

Homeowner Persona	
 **Kent Dias** ***Age:*** 35 ***Gender:*** Male ***Civil status:*** Unmarried ***Occupation***: CEO **Social Media Channels:** LinkedIn, Facebook, Twitter	Kent has a chain of boutiques selling leather good and designer clothes. It is his family business he inherited from his father. Kent is soon getting married, therefore he recently has built a house outside the town, where he is planning to live with his family. He spent a lot of money to equip it with a large number of smart things, such as smart meters, surveillance system, smart locks, high precision sensors measuring weather conditions in the area and home appliances. He is considered to be a first mover since he always stays updated with newest technologies and trends, therefore he is using Wappsto to connect all his things together. Kent has heard about people monetising the IoT data. Kent is considering that the data he obtains from his smart devices and his usage patterns can be interesting for the municipality, which is trying to make a sustainable life in the region, while weather data can be useful for his neighbours, who are farmers and can benefit from precise measurements of the weather condition. He would be willing to exchange his data for something in return if it does not create too much hassle for him.

Table 20: Homeowner persona "Kent". (Photo source: Pexels.com)

Homeowner Persona	
 **Andy Moor** ***Age: 53*** ***Gender:*** Male ***Civil status:*** Married ***Education***: Bachelor of Architecture ***Occupation***: Architect **Social Media Channels:** LinkedIn, Facebook	Andy is a family person who lives in suburbs with his wife and four kids. The house he lives in with his family has a big garden that they enjoy to spend time in. The problem with the garden is that it is hard to maintain, especially in a hot season. Andy has purchased smart irrigation system that waters it when the soil sensors report that the soil is getting too dry. The application made by the irrigation system manufacturer is not usable and is not complete. It also does not allow connecting smart devices of different manufacturers. He wants to connect his intelligent robotic lawnmower, so that it can cut the grass before the watering and connect the weather forecast data, in order to save some money on watering and ensure proper plant care. Andy is fine to pay any reasonable amount of money to make the setup he wants to avoid the hassle and spend more time with the family instead.

Table 21: Homeowner persona "Andy". (Photo source: Pexels.com)

5.5.3 Analysis Based on User Scenarios

This section describes user scenarios that are based on the Personas presented in the previous section. The scenarios are made to demonstrate interactions of different users depending on their needs in different situations and contexts. Considering that the scope of this project was focusing on interactions with all three user groups, following scenarios are part of one bigger story that presents the interactions of all three user groups and uncover usage potential of the Seluxit Unified Data Model. The figure below (Figure 7) displays a general overview of all the groups and data flow from one user to another. The figure also displays how the Seluxit UDM allows connecting different data sources and bring people together.

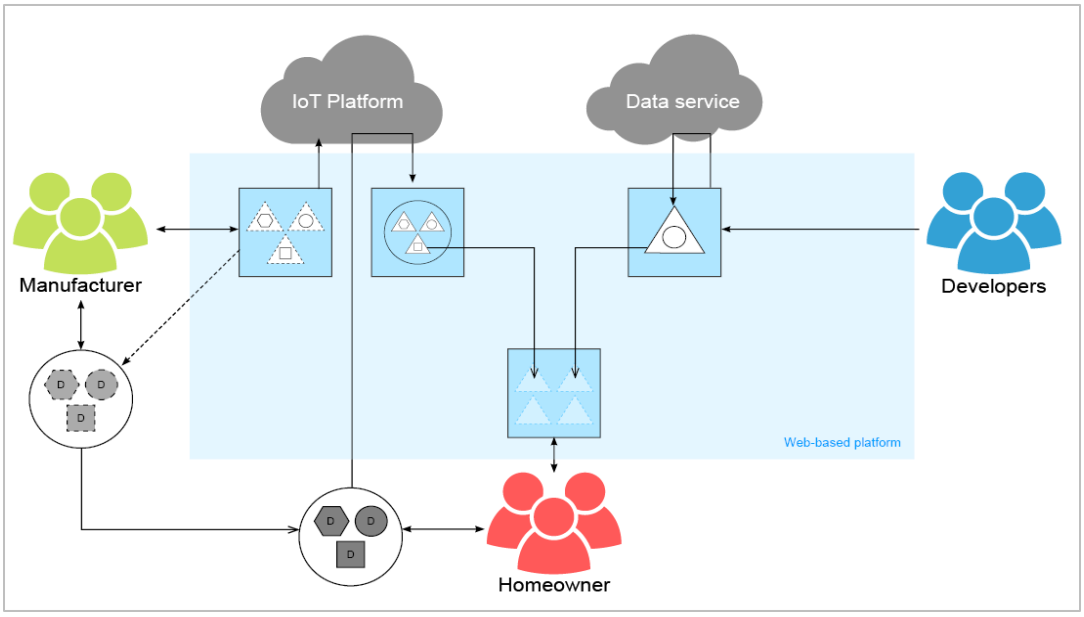


Figure 7: Three different user group (Manufacturer, Developer and Homeowner) interactions which are possible by as the result of the data structure. Large blue squares represent different web-based applications that are part of the larger ecosystem. Triangular shapes represent data based on/converted into the unified data model.

The following scenarios will expose more detailed view and description of the above picture. Each of the scenarios is supplemented with the additional user steps that are based on the Personas and collected empirical data. In these scenarios, the "IoT Platform" is already integrated IoT Platform technologies (Appendix 6:) developed by Seluxit, yet hypothetically can be any IoT platform that allows the secure data storage and transfer. When reading the following scenarios, it is important to take in consideration, that some explanations and conclusions may appear at a later stage of this chapter because some of the scenarios are linked to represent the diversity of use cases.

Manufacturing operations in IoT take more than a half of the money spent in the IoT in total (i-scoop, 2017). The results show that almost three-fourths of organisations feel that IoT is critical to their competitive advantage (Verizon, 2016; i-scoop, 2017). Demand from the customer side is the main driver for the manufacturers to invest in the Internet of Things (IDC, 2015), yet due to their lack of expertise, they seek for IoT solutions/platforms to make their products connected. The first scenario describes corporate persona – "BrightTech", which goal is to create a competition on the market by creating a smart solution in a short time and at low cost. The scenario consists of multiple steps that are visually presented in Figure 8.

Scenario A – BrightTech decides to connect their products to the internet to create the smart lighting system.

BrightTech knows that their lack of expertise in this area is a large disadvantage. They want to announce about their new IoT products range already in a few months, yet they are afraid that without a concrete solution they may fail and lose customers. They are looking for inexpensive possibilities to develop first hardware and software prototypes to have a proof of concept. BrightTech's project manager assigns a task to his team to find multiple solutions and investigate

them from different perspectives such as time, money, complexity, security, requirements from the technology side and flexibility. The team does research and finds different IoT prototyping solutions. The BrightTech team tries Wappsto as one of the solutions.

(1) BrightTech employee searches for "IoT rapid prototyping" on the internet.

(2) He finds a tool called "IoT Rapid Prototyping" that allows creating a device prototype fast and free of charge.

(3) The link takes him to Wappsto ecosystem, where he is required to register and install a prototyping tool to create personalised data.

(4) An installed Wapp allows the user to create abstract data structures (Appendix 5: "IoT Rapid Prototyping" Screenshots), which user uses to create a prototype.

(5) Using provided user interface, he fills out the forms (Figure 9) with the technical specifications and other information required to describe BrightTech's future device (e.g. what is his device, its name, what is its purpose, etc.)

(6) He is pleasantly surprised that he does not need to think of how to structure this type of information and the tool automatically creates a structured data model and generates required certificates to ensure a secure connection. (a) The tool also registers the data on the Seluxit IoT Platform (b) and generates the example code that can be uploaded to a Raspberry Pi[4] or another piece of hardware. The example code helps him develop desired functionality faster than creating everything from scratch.

(7) The user uploads the required files on the physical device.

(8) A device communicates with the IoT Platform that stores that data and allows remote control.

Table 22: Scenario A.

[4] Raspberry Pi - a tiny and affordable computer that you can use to learn programming through fun, practical projects (https://www.raspberrypi.org).

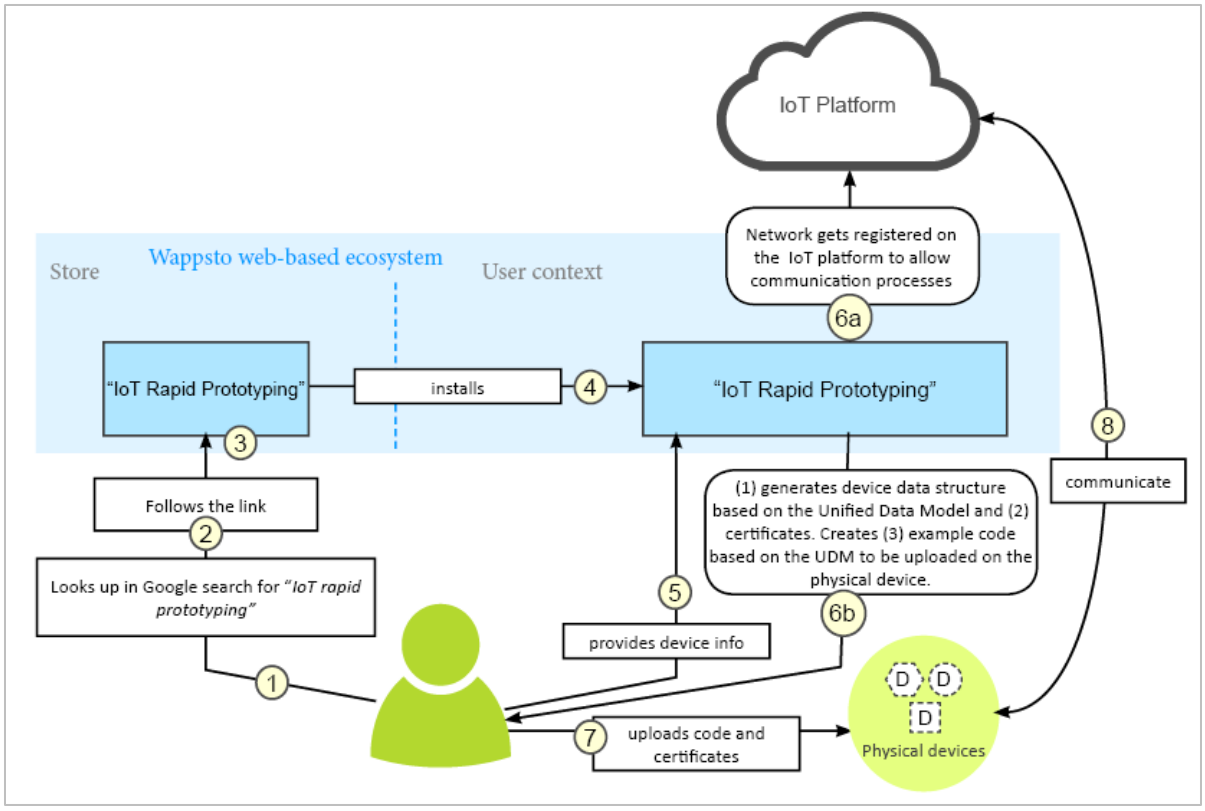


Figure 8: Scenario A visualisation.

People with little programming knowledge or no knowledge at all have the possibility to develop IoT solutions. The example below (Figure 9) allows creating and generating parts of the device code by filling the device information into automated forms that prevent possible errors and can guide the user through the process to increase understanding. Programming by the example is a basis for creating new programs where modification of a working example speeds up development as it provides stronger setting than writing code from start (Hartmann, Wu, Collins, & Klemmer, 2007). Having a developed data structure simplifies the creation process since it does not require thinking of a number of possible ways to describe data.

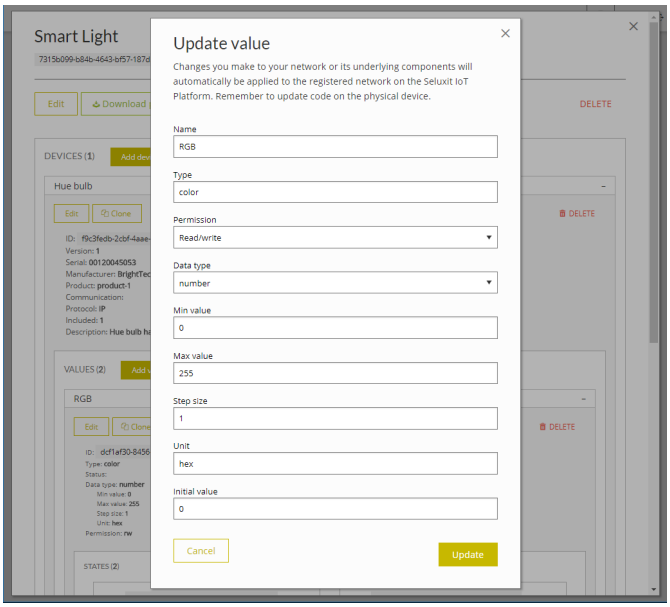


Figure 9: "IoT Rapid Prototyping" screenshot. Value editing panel of a Smart Light network. (Scenario A)

In this specific scenario, it is not required to create a complex IoT platform to enable secure data communication and storage. Another benefit is the choice of web solution that does not require the development of mobile applications to support different mobile platforms like Android and iOS. Web-based applications are cost-effective to develop, accessible for a range of devices and are easily customisable. This has an influence on time to market and allows focusing on the essential product of the company (Cohen, Eliasberg, & Ho, 1996) and decreasing the cost of the final product which is the key components that can accelerate IoT adoption (McKinsey & Company, 2015).

While companies are forced to adopt new technologies, as it was mentioned in the previous chapter, it does not always turn out to be a success. Solutions that allow a vast amount of integrations and simplify prototype creation allow manufacturers to test their product ideas using agile culture and practices (Beyer, 2010) without taking high risk and investing large amounts of money into IoT projects. That means that smaller companies like BrightTech can benefit from multiple things, such as easy integration of their thing to the web-based platforms where they can be immediately controlled through the user interface and tested. Moreover, manufacturer type of companies building specific data models to support their own business strategy and products, lose the potential of integrating other solutions (Lux, 2018), which complicates use cases and limits their customers to develop their automation setups with devices of other manufacturers. For manufacturers, Wappsto opens new possibilities:

- to make their solutions more versatile,
- to get access to new services and data,
- to decrease new internet-enabled product time to get on the market,
- and to give freedom for their customers to fulfil their needs. (Lux, 2018)

All the following scenarios will give more details on these possibilities and involve other user groups.

Scenario B: BrightTech hires a developer to create a web application that enables bulb remote control.

BrightTech wants to offer their customers a smart solution that can enable automatic light bulb dimming based on the daylight time and weather conditions. So that when outside is getting dark, the light would adjust brightness and when it is cloudy outside, the light would change the colour temperature to a warmer colour. To implement the solution, they hire a web developer for the first iteration of a web application.

Derek is hired by a recruiter on LinkedIn from BrightTech as an external consultant-developer to develop a user-friendly web app. His task is to investigate technology and create first application prototype based on the initial requirements. BrightTech still does not have physical device prototypes to share with Derek, therefore they share with him the device data structure which they made using IoT Rapid Prototyping tool in Wappsto.

Derek needs to learn how Wappsto works so he reads available documentation about Wapp creation and the unified data model. Derek creates an account in Wappsto and installs development tools "Wapp Creator" (Appendix 7). He starts the development process by using device structure received from BrightTech which he is familiar with since it resembles the UDM he saw in the documentation. He notices that "Wapp Creator" offers usable and intuitive functions which ease his job of developing an application. To retrieve a network from a database he needs to use "getNetwork()" function with the specific parameters, which works a similar way for retrieving devices, values and states. Having the data to work with, he implements initial means of controlling bulbs for testing purposes. In order to create a configuration of the bulbs based on the weather forecast, he connects 3rd-party service using API and maps it into same data model (as it is shown in the section *Mapping of the Service*). That would allow the users, who install the application, automatic connectivity and setup of their preferred location (e.g. the town where his house is located, precise geographic coordinates).

Table 23: Scenario B.

The possibility for manufacturers to create an early prototype based on generic and tested data structure has also other benefits than above-mentioned. In the Scenario B, the abstract data structure is given to a developer, which gives him a clear idea about the future device structure, possibilities and limitations. First of all, it can increase understanding of the requirements on the early stage. Second, the integrated development environment that is based on the Unified Data Model can utilise such data to enhance development and create testing possibilities without having an actual physical device. Third, sharing of the abstract data structure, like smart light device metadata and its relations, can shorten development time, which is crucial for manufacturing company marketing and business strategies (Cohen, Eliasberg, & Ho, 1996).

Creating devices based on the data model also allows integration and synchronisation of an other abstract thing, for example, weather data, that allow to enrich the data, create intelligent configurations and enhance automation (Scenario B). The following scenario describes the advancement of BrightTech ideas based on the possibilities that arise with new data and shows the need for developers which is followed by the interactions of a developer persona "Derek".

In the scenarios A and B, the Unified Data Model is adopted to support reuse of domain knowledge and advance end-user development tools like IoT Rapid Prototyping (Figure 9; Appendix 5: "IoT Rapid Prototyping" Screenshots and Wapp Creator (Appendix 7:) by allowing automated user interfaces to generate the device code and increase the speed of application development. Without the UDM, this would not be possible. Well-defined semantics in the data model ensures that platforms share the same meaning for the data they exchange and verify consistency. Metadata simplifies application development and enables interoperability (Intel, 2017) especially when integrating multiple data sources. The meaningfulness of the code is vital for developer understanding and development process. Moreover, it can provide efficiency in the data retrieval and increase data integrity. The table below (Table 24: Example of the Unified Data Model adoption into IDE JavaScript functions to support developers.) presents the examples of the Seluxit Unified Data Model adoption in the IDE – Wapp Creator, that increases developer understanding when retrieving or integrating data.

Functions based on the Seluxit UDM	**Explanation**

`getNetwork(attributes, options)`
`getDevice(attributes, options)`
`getValue(attributes, options)`
`getState(attributes, options)`
`addNetwork(network, options)`
	Functions based on each of the Seluxit UDM component that allows retrieving components based on the parameters.

Examples of functions with parameters	**Example of function usage**

`getDevice({`
`  "manufacturer": " BrightTech "`
`})`
	This example allows to retrieve all user Devices that are manufactured by "BrightTech".

`getValue({`
`  "type": "light",`
`  "_parent": {`
`  "manufacturer": "BrightTech"`
`  }`
`})`
	This function allows getting all user Values that has type "light" and are part of the device that is manufactured by "BrightTech".

`getValue({`
`  "type": "light"`
`})`
	This function allows retrieving all the user Values that has type "light" no matter who manufactured it and what other parameters it has.

Table 24: Example of the Unified Data Model adoption into IDE JavaScript functions to support developers.

The example of the function shows the discovery of the data based on its properties, like *manufacturer* or *type*, and relationships - *parent*/*children*. Such structures and relationships allow data indexing which can decrease information retrieval time and respectively create better user experiences. It also gives flexibility for the developers to limit or expand their application functionality by specifying the data parameters (see Table 24). Requesting data by the specific UDM parameter allows developers to create

configurations with unlimited possibilities. Examples of that could be creating rules for any light taking in consideration only their technical capabilities, creating a brand-specific application that manages setups between different types of devices, or even mixtures of both. Without generalised data structure, it would not be possible or would require doing functionality for supporting each of the things repeatedly (IFTTT, 2018) or have predefined flows for creating functionality (Stringify, 2018). The major benefit that can be outlined here is the reuse of some functionalities and given to people freedom, which is represented in the following scenario.

Scenario C: Integration of open-source data for the common good. James, during the last developer meetup on IoT topic, was challenged to integrate an API in Wappsto to evaluate the technology. He chose to integrate an open source weather forecast API. (1a) To make it available in the other user context he had to create a wapp using developer tools (Appendix 7) and retrieve service data using API. (1b) James translates service data into the Unified Data Model (in a similar manner as it is presented in Table 11) using standard web programming language. Once creating a structure, he adds newly created *Network* to his user context using functions provided in the documentation (Table 24). (2) He publishes the application to the store so that other people can use it for free. (3) A user finds and installs the application. (4) The tasks in the application background constantly retrieve the data from the service and update the view on the user's device. (5) The user interacts with the data and is able (6) to integrate it into other configurations.

Table 25: Scenario C.

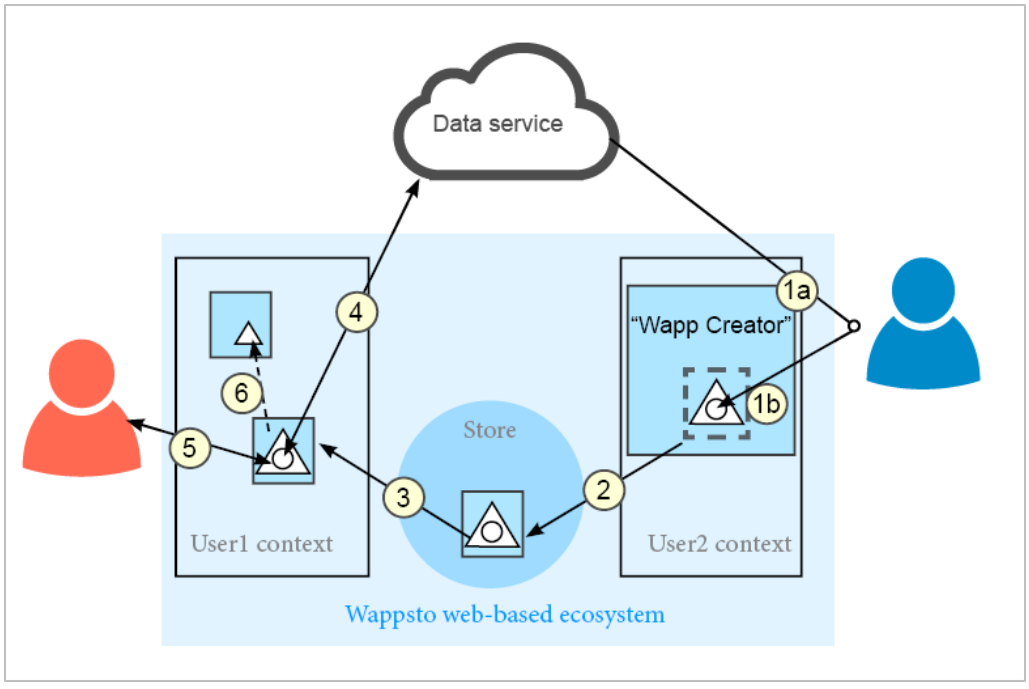


Figure 10: Scenario C illustration.

The Scenario C shows how the data created in one application in the user context, can be used by another application to combine functionality (Scenario C (6)) since programming resources (Table 24) built on top of the same data structure allow such data findability.

The following scenario presents consumer side integrations and possibilities for the developers that arise having accessible data for the development of new solutions. The scenario is supplemented by a figure that visualises the user actions and information integration.

Scenario D: Diverse application possibilities by re-using the same data.

(1), (2) Mia's parents have bought BrightTech starter kit in a store and have followed the instructions to make their devices connect to the internet (3). In the instructions, they also get guided through the steps to install an app in Wappsto store to use BrightTech system remotely (5) and benefit from the integrations with the weather data (5a). Both Mia and her parents like the smart light solution and automation options that BrightTech is offering, but the bulb control, and interaction was unintuitive to them. Therefore, Mia decides to develop her own solution that is focused on the application design.

Mia tries developer tools (Appendix 7) in Wappsto and learns that she can develop Wapps for herself using same bulbs that are installed in her user profile. All she needs to do is from her wapp prototype to request the device using getNetwork("name": "Smart Lights") (Table 24). Mia then quickly creates a nice user interface using web standards with animations and interactive elements to intuitively control the lamps.

Mia was pleasantly surprised that she could easily share her application with the family members without the need to publish it. Everybody in the family liked Mia's solution and after using the application for some time, they encouraged her to publish it to the Wapp store, so that other people can benefit from it too. When publishing the app, Mia decides to earn a bit of money, so she sets a price for her beautiful user interface. Now every time someone purchases the app for his own home setup, Mia gets some money on her account.

Table 26: Scenario D.

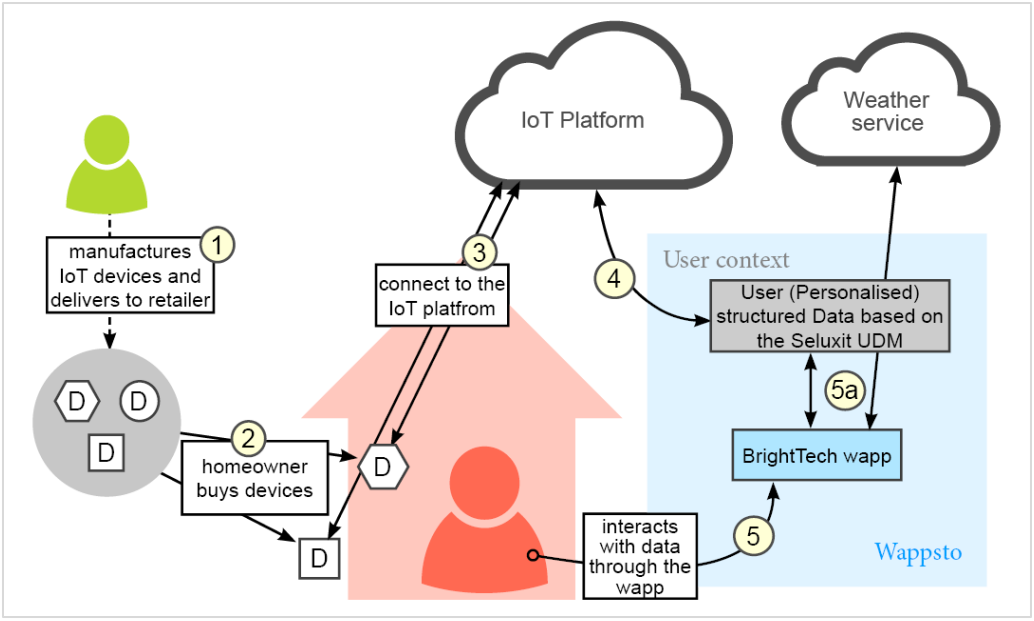


Figure 11: Consumer integrates BrightTech devices.

The scenario D shows how the freedom is given to the customers to fulfil their needs. Moreover, the common data structure allows the reuse of data and to build complex platform ecosystems that for the developers save the hassle of complicated technology setup to host applications, create data and solution sharing with other people for testing purposes, and even creating profit.

Scenario D: Making new things and creating automation. Derek has been using Philips Hue bulbs from over the year now and now he has purchased cheaper alternative from BrightTech to install lights in the remaining parts of his apartment. He notices that BrightTech application for light control is developed using Wappsto IDE. He checks Wappsto store out of curiosity and finds another application that can control lights from different manufacturers which fit his setup at home. He purchases the app and gets inspired by the idea of connecting things together. He wants to make the lights in the corridor to switch on automatically when he is coming home. He investigates how does BrightTech's devices and application work and learns about the set of tools in Wappsto. He purchases some hardware components and sensors that detect movement to make his own smart home solution. He searches for prototyping tools in Wappsto and does all the required steps to connect his sensor to the platform using the UDM (see steps 3-8 in the Scenario A).

Table 27: Scenario D.

For makers, as it is described in the scenario D, the environments for making such actions like creation, testing and development allows generating ideas and quickly adapt them in real life. Without the Unified Data Model such action would be impossible or limited. Rapid prototyping plays an important role in the development, testing and evaluation of embedded technologies and creating interactions. Research shows that prototyping toolkits allow effectively explore the design space, employ prototyping tools to create early prototypes of hardware and software components and accelerate presentation and evaluation for developers' application ideas (Kranz, Holleis, & Schmidt, 2009).

The following scenarios present the end-user side which in this case are homeowners.

Scenario E: Monetising Data. Kent is Wappsto user where he has all his automated devices configured. He saw a new feature that allows monetising the IoT data. Kent decides to share the data from his smart meters with the municipality, which is trying to make a sustainable life in the region and exchange and his usage patterns with the power utility to get energy price reduction in the certain hours of the day. Kent also found out that his neighbour is interested in the weather station readings, which he sells to the neighbour Andy for a monthly micropayment while using his data.

Table 28: Scenario E.

Scenario F: Andy sets up the smart garden Kent wants to pursue his smart garden idea of connecting all devices such as lawn mower, soil sensors and irrigation system from different manufacturers together and connecting it to weather forecast data to save money on the

watering garden and improving his comfort of life. Andy finds Wappsto on the internet and tries to integrate his devices to the internet. He searches for applications in Wappsto store that would support his idea. In order to integrate his all his devices, he installs two apps that convert the data into the UDM. To make automated configuration he finds a paid application that can combine any service or device data and make some simple rules. He purchases the application and buys data from his neighbour for a reasonable price. After installing everything he has all the data in his user context which allows him to make some rules such as: "if it is going to rain, or if the soil is wet, then do not water grass", "if the irrigation system is on, do not cut the grass".

Table 29: Scenario F.

For homeowners, combined solutions with a diversity of devices and data give complete freedom for solution automation (Scenario F), but besides that users can also benefit from sharing data (Scenario E), which is normally a win-win situation. Taking data sharing perspective, the lowest Seluxit UDM components such as Value or State that are shared can lose some of its meaning for the recipient since the top-level metadata is not included. On one hand, this can cause confusion if the description is not provided and data afterwards is treated wrongly. On the other hand, this gives freedom to the user to share raw data without giving some of the private or unwanted details. This can be beneficial for the security reasons that allows collection of anonymised statistical data (like in the example with power utility in the scenario E), or for the data market when it is vital to choose how much data should be available for a certain price tag.

All the above scenarios gave an insight into advantages and disadvantages of the unified data model integration on the web-based platform. The scenarios, also showed user tasks where one of them is information search. "Modeling needs and behaviours forces us to ask useful questions about what kind of information users want, how much information is enough, and how they actually interact with the architecture." (Rosenfeld, Morville, & Arango, 2015, p. 40) The chapter *IA Components* will continue the analysis of information search activities based on the theories in the area of Information Architecture.

5.5.4 The Seluxit Unified Data Model Critique

In order to support the above scenarios, the translation of diverse metadata into a common format is required and that can create certain issues. Not all the data would be possible to fit well into the model. In some case, it may require compression (Lux, 2018) or generalisation which can influence the quality and uniqueness of it. A disadvantage that may arise is missing semantics or possible inconsistencies in semantic annotation when describing the data (e.g. *Temperature* versus *temp*, *outdoorTemperature* versus *temperatureOutdoors*) since it is the responsibility of the user to fill out the data. Such solution requires the development of terminology and strict guidelines and suggestions to help the users creating meaningful information set a strong base for the knowledge creation. Another issue from a technology perspective is the software maintenance since the logic and handling is made at the application level. Drastic changes in the data model structure can also have an influence on all the existing data handling.

The current version of the UDM does not support important variable such as geographical location of that data which can be an important factor for the data market. There are many devices equipped with the Global Positioning System (GPS) and report their location for tracking purposes. Such data is already supported and can be mapped into the Seluxit UDM *value* component, yet for the data market purposes, geographical location metadata is missing. It could allow creating geographical schemes that could ease data search and findability based on user and data proximity. As it was mentioned above, the

model has been evolving and shaping based on the business strategy, customer needs and technology requirements, therefore, it may need to be expanded already in the near future to facilitate data findability and enrich built-in tools.

5.5.5 IA components

The challenges organising information increase correspondingly to the content growth. Even though it is not a new challenge, it still remains a problem for Information Architects that is caused by ambiguity, heterogeneity and differences in perspectives of individuals (Rosenfeld, Morville, & Arango, 2015).

This section describes the application of the Seluxit Unified Data Model in IA components (Rosenfeld, Morville, & Arango, 2015) to solve findability and content structure challenges.

5.5.5.1 Content Organisation

The Seluxit UDM provides organisation structure that introduces a logical grouping of the data sets based on their characteristics. This plays important role in information findability and understanding. It is rare that people know exactly what they are looking for and what questions to ask when searching for information. The process of finding information is often not too-simple and involves multiple iterations (Rosenfeld, Morville, & Arango, 2015, pp. 39-51). Therefore, to support people information needs it is important to design systems to be understandable and organised creating awareness of place in information environments.

The Seluxit UDM can be classified as a metaphor-driven scheme for data item grouping since some of its components may be physical things, while other – abstract and may not exist in real life, yet they both share similar characteristics, which can help users to understand and relate to. Example of that can be previously mentioned Open Weather Map service, where current weather forecast was named a device, and current weather data such as temperature, humidity, etc. were mapped as values.

Organised, semantic structures besides influencing findability of information can also help users understand new information and unfamiliar contents. Such structures reflect physical environments that play placemaking role. (Rosenfeld, Morville, & Arango, 2015) The order and hierarchy of the data model components creates a sense of place and adds meaning to the information. The figure below (Figure 12) is a conceptual representation of the Seluxit UDM based on Philips Hue Bridge example, while Figure 13 represents real life device setup. The organisational structure in Figure 12 reflects the logical representation of *Network* as a data source (bridge), *Device* – a physical device or machine which contain some information that is grouped into subsets called *Values*, which have two states *Report State* and *Control State*. Figure 13 shows physical device representation. *Philips Hue Bridge* serves as a gateway, that connects two devices to the internet – *Light bulb* and *Hue lightstrip*. Below the devices are displayed their possible states. The light bulb in the current example has a current state that is set on the device – *"on"* and a state *"off"* which is upcoming state of the device being set by the user, while the lightstrip states may represent different colour hues (in the example it is orange and blue).

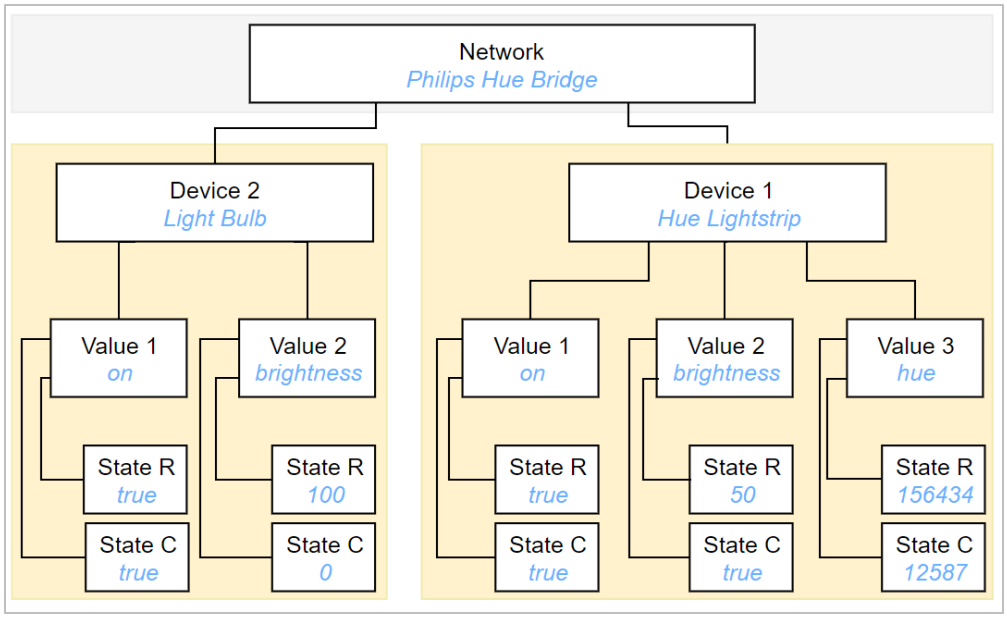


Figure 12: Example of the Philips Hue Bridge organisational data structure mapped into the Seluxit UDM.

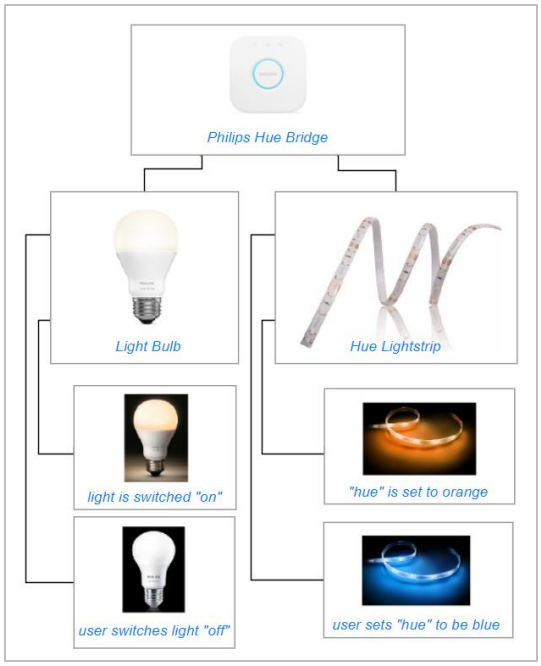


Figure 13: Physical device representation: Philips Hue Bridge with two devices that represent multiple states.

5.5.5.2 Navigation and labelling

Every link in hypertext creates a category. That is, it reflects some judgment about two or more objects: they are the same, or alike, or functionally linked, or linked as part of an unfolding series. (Bowker & Star, 1999)

In information findability and creating navigation, the labelling systems are vital since they describe categories, options, and links in language that is meaningful to users (Rosenfeld, Morville, & Arango, 2015). The Seluxit UDM main components together with the metadata it contains, allow creating labels

and categories that are understandable and meaningful for the user which can have an impact on the data findability. The table below (Table 30) exemplifies such combinations.

Examples	Description
Temperature in Celsius	**Values** which are described as the **temperature** and produce data in Celsius **unit.**
Philips device	**Devices** of a specific **manufacturer.**
The temperature in your area	**Values** which are described as the **temperature** within the radius of the user **location.**
Devices that contain temperature	**Devices** where one of its **value types** is **temperature.**
My temperature sensors	All **sensor devices** that include **temperature** measurements within a specific **user** context.

Table 30: Examples of categories and labels that are created based on the Seluxit Unified Data Model.

The above combinations and the UDM components itself can be used as hyperlinks, headings, navigations and for indexing purposes. Moreover, on Wappsto with added user context, it allows creating advanced navigation approaches (Rosenfeld, Morville, & Arango, 2015, p. 203), like personalised recommendation list for the data market. Personalised recommendations can be based on the user existing device data that can benefit from additional information (e.g.: energy consumption or prices, suggestions on optimal usage of things, etc.)

5.5.5.3 Search systems

Search systems allow users to search the content and the Seluxit Unified Data Model can support search systems in different ways. The user context details and known data structures can add value to the search queries which can expand or limit search results in a shorter time frame . Parent-children relationships allow searching and retrieving information based on the parameters of the family members.

Metadata can serve multiple purposes, and carry different functions (Wilson, 2012). It can be used to control search queries, give suggestions based on user input and provide other informational support. The example of that could be supporting Andy persona in his information needs. Andy goes to data market and wants to find an accurate temperature data in the local area to complete his setup. Hierarchical categories and common data types (e.g.: temperature, motion sensor, etc.) give a way of classifying information to create facets (Tunkelang, 2009) and allow the user to refine his search and find relevant information faster. Based on the user input, the suggestion lists can be integrated into search systems that are generated based on the known data model structure and indexes. Additional data (e.g. geographical coordinates) gives different means of representing information (Figure 14) which can reduce cognitive load and decrease time for finding relevant information, or data attributes like minimum and maximum data value combined with data type – temperature can also engage other visual assets (diverse colours of the indicators in Figure 14).

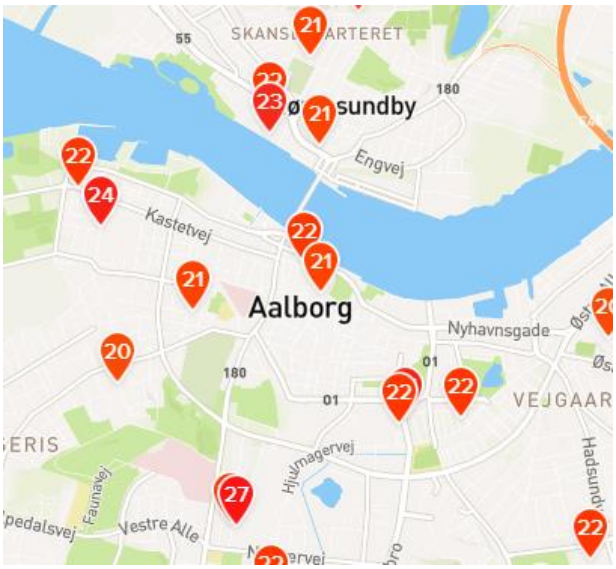


Figure 14: Screenshot of the map view with data indicators (source: WeatherMap[5]).

[5] https://weathermap.netatmo.com/

6 CONCLUSION

The broad aim of this study was to investigate the significance and role of the Unified Data Model used in IoT context from different perspectives. The major purpose was to discover how it influences Information Architecture when a vast amount of information is given to the users. I have explored and visualised in this thesis IoT data provision and structuration on the web-based platform Wappsto, where the unified data model was used as a starting point for synthesis of numerous data sources. The analysis of the Seluxit Unified Data Model has shown to have a big potential for enabling information creation and exchange between users of the platform and creating the ground for the data market.

Besides the fact that each of the above scenarios presents benefits and disadvantages, there are possibilities for development of new IoT scenarios which are only possible because of the user involvement and quality of metadata. To support all the above advantages, it requires "control" of integrated data. Having enough freedom for the users to describe their data cannot be left out of control. People may misuse or ignore the importance of providing good, meaningful description. Such platform ecosystems would benefit from persuasive design concepts to create good development habits and attitude towards the importance of semantic metadata.

6.1 SUMMARY

In order to describe the data model and its application possibilities, first, I exemplified how can physical and abstract things be integrated. Second, I used scenario-based analysis to uncover business opportunities and user information needs based on the research data, as well as present its value to the end-user. Afterwards, I applied different theories to describe the importance of semantically meaningful data structure based on four Information Architecture components.

The unified data model presented in this paper provides four major benefits. First of all, the model already provides a good structure for basic IoT data treatment such as storage, retrieval and processing, but more importantly, it can expand business opportunities by creating connected environment for diverse user activities and building interaction tools to support these activities. It enables IoT data interoperability and cloud-based service data as the result of semantically meaningful hierarchical structure which can easily be expanded and supports custom data. Interoperability on the web-platforms, additionally, solves the problem of creating cross-platform, and cross-domain IoT ecosystems. Second, the model focuses primarily on semantic constructs, which makes it understandable for both – machines and people from different domains. It helps to structure content based on logical categories, meaningful for the user labels based on the data meta descriptions and ontologies (Table 28) which is essential to support user search behaviours and make them succeed in their tasks of finding relevant information. Meaningful labels and predefined categories also allow the creation of indexes and links for building navigation or creating a faceted search that promote information findability. The UDM has a structure resembles real-life things that have a positive effect of people perception and understanding, which can help get familiar with the content in a shorter time or even simplify Information Architect job of visualising IA structures and components.
Third, the well-structured data model has the advantages for different target groups:

- The developers only need to develop interfaces and configurations without thinking of the interoperability and learning new programming languages. By integrating the components of

the data model into programming resources can also give them the flexibility to create the scope of the application and limit/expand the number of supported things (Table 24).

- Manufacturers have the opportunities to create prototypes that allow testing their solutions and interact with the data. Moreover, integration of the UDM into end-user programming tools can also speed up the development process of the devices. Automated tools that can interpret user inputs and generate example code with the built-in data structure and communication capabilities have potential to decrease time to market.
- Users have benefits of sharing or monetizing data, as well as creating home automation solutions.

Finally, all the above data produced by devices and enriched with meaning by different users can evolve into knowledge that supports business intelligence and is useful for business strategy development.

6.2 Research limitations and Future Work

A major limitation of this research is lack of insight from users of Wappsto who have been working with the Seluxit Unified Data Model which could give insights on the usability of the system and would allow collecting a different kind of data. Another limiting factor is innovation. Wappsto is still in the development process and not all the use cases have been uncovered which makes it challenging to exemplify. That did not allow to identify full potential of the model, which could solve interoperability issues caused by existing emerging IoT platforms offering contrasting ways to access things and their data.

Considering above-mentioned this study would benefit from additional data from the real end-users. It would be interesting to find out about such technology appropriation and get insights on how people adapt it to their daily home and work routines. Another interesting aspect to explore would be data personalisation and monetisation, as well as the impact it has from the ethical perspective

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8 REFERENCES

Altimeter. (2017, August 24). *State of Internet of Things in the Home.* Retrieved from Flickr: https://www.flickr.com/photos/altimetergroup/36720458386

Altimeter. (2017, August 23). *The State of IoT in the Home.* Retrieved from Slideshare: The State of IoT in the Hom

Bajaj, G., Agarwal, R., Singh, P., Georgantas, N., & Issarny, V. (2017, July 1). A study of existing Ontologies in the IoT-domain. *CoRR*.

Bermudez-Edo, M., Elsaleh, T., Barnaghi, P., & Taylor, K. (2016). IoT-Lite: A Lightweight Semantic Model for the Internet of Things. *Ubiquitous Intelligence & Computing.* Toulouse: IEEE.

Beyer, H. (2010). *User-CenteredAgileMethods.* Morgan & Claypool.

Bowker, G. C., & Star, S. L. (1999). *Sorting Things out: Classifications and its Consequences.* San Diego: MIT Press.

Boyles, B., & Tonnesen, K. (2018, March). Let's build a smarter life. *IoT Rapid Prototyping*.

Bryman, A. (2016). Social Research Methods. Oxford University Press.

CA Technologies. (2008). *The Benefits of Data Modeling in Data Warehousing.* Retrieved from Sandhill Consultants: http://www.sandhillconsultants.com/documents/data_warehouse_wp_Nov_08.pdf

CA Technologies. (2013). *The Benefits of Data Modeling in Business Intelligence.* http://www.odbms.org/wp-content/uploads/2013/11/Business_Intelligence_Whitepaper.pdf: CA.

Chelloug, S. A.-Z. (2017). Middleware for Internet of Things: Survey and Challenges. *Intelligent Automation & Soft Computing* .

Cisco. (2016, June 7). *Cisco Visual Networking Index Predicts Near-Tripling of IP Traffic by 2020.* Retrieved November 2, 2017, from The Network - Cisco's Technology News Site: https://newsroom.cisco.com/press-release-content?type=press-release&articleId=1771211

Cisco. (2017, May 23). *Cisco Survey Reveals Close to Three-Fourths of IoT Projects Are Failing*. Retrieved February 2, 2018, from The Network - Cisco's Technology News Site: https://newsroom.cisco.com/press-release-content?articleId=1847422

Cohen, M. A., Eliasberg, J., & Ho, T. (1996). New Product Development: The Performance and Time -to-Market Tradeoff. *Management Science* , 173 - 186.

Coleman, M. (2015, February). *Unified Data Models.* Retrieved from https://irasr.aut.ac.nz/__data/assets/pdf_file/0012/32610/Michael-Coleman-UDM-and-Community-Data-Models-MJC-Public.pdf

Dictionary.com. (2018). *Internet of Things*. Retrieved from Dictionary.com: http://www.dictionary.com/browse/internet-of-things?s=ts

Dictionary.com. (2018). *Web Developer*. Retrieved from Dictionary.com: http://www.dictionary.com/browse/web-developer?s=t

Ding, W., & Lin, X. (2010). *The Future of Information Architecture.* Morgan & Claypool.

Dongmyoung, K., Yunchul, C., & Yonggeun, H. (2016). *Research on Unified Data Model and Framework to Support Interoperability between IoT Applications.* Daejeon: The Electronics and Telecommunications Research Institute.

Feifei, S., Qingjuan, L., Tao, Z., & Huansheng, N. (2018). A Survey of Data Semantization in Internet of Things. *Sensors — Open Access Journal*, 1-20.

Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry, 12*, 219-245.

Ganzhaa, M., Paprzyckia, M., Pawlowski, M., Szmeja, P., & Wasielewska, K. (2016). Semantic interoperability in the Internet of Things; anoverview from the INTER-IoT perspective. *Journal of Network and Computer Applications*, 111-124.

Geethanjali, P. (2017). Application of Technologies in Internet of Things. In D. P. Acharjya, & M. Kalaiselvi Geetha, *Internet of Things: Novel Advances and Envisioned Applications* (pp. 245-260). Switzerland: Springer International Publishing.

Gemalto. (2017). *What do consumers want from their connected future?* Retrieved March 2018, from https://www.gemalto.com/mobile/documents/iot-consumer-experience

Harley, A. (2015, February). *Personas Make Users Memorable for Product Team Members*. Retrieved from Nielsen Norman Group: https://www.nngroup.com/articles/persona/

Hartmann, B., Wu, L., Collins, K., & Klemmer, S. R. (2007). *Programming by a Sample: Rapidly Prototyping Web Applications with d.mix.* Newport: ACM.

Huacarpuma, R. C., Sousa, R. T., Holanda, M. T., Albuquerque, R. O., Villaba, L. J., & Kim, T. (2017). Distributed Data Service for Data Management in Internet of Things Middleware. *Sensors* .

IAB. (2016, February). *IoT Semantic Interoperability Workshop 2016.* Retrieved from Internet Architecture Board: https://www.iab.org/activities/workshops/iotsi/

IDC. (2015). *Transforming Manufacturing with the Internet of Things.* Retrieved from https://www.cognizant.com/InsightsWhitepapers/transforming-manufacturing-with-the-Internet-of-Things.pdf

IFTTT. (2018). *If This Than That*. Retrieved from https://ifttt.com/

Intel. (2017, November 14). *The web of Things and Semantic Interoperability.* Retrieved from IETF Datatracker: https://datatracker.ietf.org/meeting/100/materials/slides-100-t2trg-wishi-semantic-interop-of-avs-and-iot-00

i-scoop. (2017). *i-scoop*. Retrieved from The Internet of Things in manufacturing: benefits, use cases and trends: https://www.i-scoop.eu/internet-of-things-guide/internet-of-things-in-manufacturing/

Jara, A. J., Olivieri, A. C., Bocchi, Y., Jung, M., Kastner, W., & Skarmeta, A. F. (2014). Semantic Web of Things: An analysis of the application semantics for the IoT Moving towards the IoT convergence. *International Journal of Web and Grid Services*, 1-16.

Javier, M., Mäkitalo, N., Alonso, J., Mikkonen, T., Canal, C., & Murillo, J. (2015). From the Internet of Things to the Internet of People. *EEE INTERNET COMPUTING*, 40-47. Retrieved from https://ieeexplore-ieee-org.zorac.aub.aau.dk/stamp/stamp.jsp?tp=&arnumber=7061811

Kalbach, J. (2008). *Designing Web Navigation.* O'Reilly Media.

Kranz, M., Holleis, P., & Schmidt, A. (2009). Embedded Interaction: Interacting with the Internet of Things. *IEEE Internet Computing*, 46 - 53.

Kvale, S. (2007). *Doing Interviews.* London: SAGE Publications, Ltd.

Lakoff, G. (1987). *Women, Fire, and Dangerous Things.* London: The University of Chicago Press.

Lemonbeat GmbH. (2017, January 12). *Lemonbeat smart Device Language.* Retrieved from Lemonbeat: https://www.lemonbeat.de/wp-content/uploads/2017/07/LB_LsDL_Specification_v01_12.pdf

Lux, D. (2016). *Seluxit REST-ful open API for Lemonbeat devices.* Retrieved from IETF Datatracker: https://datatracker.ietf.org/meeting/interim-2016-t2trg-04/materials/slides-interim-2016-t2trg-04-sessa-seluxit-rest-ful-open-api-for-lemonbeat-devices/

Lux, D. (2018, April 5). IoT Rapid Prototyping. *IT i Apparater og Maskiner Workshop*. Denmark.

Lux, D. (2018, April 2). The Unified Data Model from a Business Perspective. (E. Mihailova, Interviewer)

Mačiulienė, M. (2014). POWER THROUGH THINGS: FOLLOWING TRACES OF COLLECTIVE INTELLIGENCE IN INTERNET OF THINGS . *SOCIAL TECHNOLOGIES*, 168-178. Retrieved from https://www3.mruni.eu/ojs/social-technologies/article/viewFile/1951/3695

Mackenzie, N., & Knipe, S. (2006). Research dilemmas: Paradigms, methods and methodology. *Issues In Educational Research, 16*, 193-205. Retrieved from http://www.iier.org.au/iier16/mackenzie.html

Mallikaarachchi, V. (2010). *INFORMATION SYSTEMS ANALYSIS - IS 6840, Data Modeling for System Analysis*. Retrieved from UMSL: https://www.umsl.edu/~sauterv/analysis/Fall2010Papers/varuni/

Maozhen, L. (2017). Internet of People. *Concurrency and Computation: Practice and Experience*, 2017.

Marchionini, G. (2006, April). EXPLORATORY SEARCH: FROM FINDING TO UNDERSTANDING. *COMMUNICATIONS OF THE ACM, 49*(4), 41-46.

McCool, M. (2017, November 14). *The Web of Things and Semantic Interoperability.* Retrieved from IETF Datatracker: https://datatracker.ietf.org/meeting/100/materials/slides-100-t2trg-wishi-semantic-interop-of-avs-and-iot-00

McKinsey & Company. (2015). *THE INTERNET OF THINGS: MAPPING THE VALUE BEYONG THE HYPE.* July.

Medina-Santiago, A., Toledo-Nuñez, E. V., Soto-Alvarez, R., Lopez-Estrada, F. R., & Dominguez-Zenteno, J. E. (2016). Open Source Platforms Integration for the Development of an Architecture of Collection and Presentation of Information in "Internet of Things" Projects. *Advanced Networking and Applications*, 2967-2972.

Mei, H., & Huang, G. (2004). PKUAS: an architecture-based reflective component operating platform. *Distributed Computing Systems.* Suzhou: IEEE.

Murdock, P., Basbouss, L., Kraft, A., Bauer, M., Loginov, O., Alaya, M. B., . . . Wang, C. (2016). *Semantic Interoperability for the Web of Things.* ReasearchGate.

Nielsen, L. (2013). *Personas - User Focused Design.* Copenhagen: Springer.

openHAB. (2018). *Community*. Retrieved from openHAB: https://community.openhab.org/t/gardena-smart-system/10961/15

OpenHAB. (2018). *Community*. Retrieved from openHAB Empowering Smart Home: https://community.openhab.org

Park, S., & Song, J. (2015). Self-adaptive middleware framework for Internet of Things. *2015 IEEE 4th Global Conference on Consumer Electronics (GCCE).* Osaka: IEEE.

Philips. (2016). *How hue works*. Retrieved from Hue Developer Program: https://developers.meethue.com/documentation/how-hue-works

RestCase. (2017, November 18). *RESTful APIs Technologies Overview*. Retrieved from RestCase: https://blog.restcase.com/restful-apis-technologies-overview/

Robson, C. (1993). *Real World Research* (2nd ed.). Oxford: Backwell.

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction design, beyond human-computer interaction* (3rd ed.). Chichester: Wiley.

Rose, K., Eldridge, S., & Chapin, L. (2015). *The Internet of Things (IoT): An Overview.* The Internet Society (ISOC). Retrieved February 2018, from https://www.internetsociety.org/resources/doc/2015/iot-overview

Rosenfeld, L., Morville, P., & Arango, J. (2015). *Information Architecture for the Web and Beyond.* Sebastopol: O'Reilly.

Rowley, J. (2006). The wisdom hierarchy: representations of the DIKW hierarchy. *Journal of Information Science*, 163-180.

Russell-Rose, T., & Tate, T. (2013). *Designing the Search Experience: The Information Architecture of Discovery.* Morgan Kaufmann Publishers. Retrieved from http://common.books24x7.com.zorac.aub.aau.dk/toc.aspx?bookid=51039

Russom, P. (2010, May 6). *Introduction to Unified Data Management.* Retrieved from TDWI Research & Resources: https://tdwi.org/articles/2010/05/06/introduction-to-unified-data-management.aspx

Schön, S., Ebner, M., & Kumar, S. (2014, July). eLearning Papers: The Maker Movement. Implications of new digital gadgets, fabrication tools and spaces for creative learning and teaching. Europe.

Seluxit. (2015, August). *Thing-to-Thing joint research group*. Retrieved from Seluxit: http://seluxit.com/blog/2015/08/17/thing-to-thing-joint-research-group/

Seluxit. (2016). *Seluxit Platform Open API Documentation.* Retrieved January 17, 2018, from Seluxit: http://seluxit.com/open-api-documentation

Seluxit. (2018, February). *Products*. Retrieved February 2018, from Seluxit: http://seluxit.com/products/

Seluxit. (2018, March). *Seluxit IoT Platform*. Retrieved from Seluxit IoT Platform: https://iot.seluxit.com/

Seluxit. (2018, February). *Wappsto*, Alpha. Retrieved February 2, 2018, from Wappsto: https://wappsto.com

Seluxit. (2018, November). *Wappsto*. Retrieved from Wappsto: https://wappsto.seluxit.com/

Seluxit. (2018). *Wappsto Documentation.* Retrieved from Rest API: https://restapi.wappsto.com

Shetty, M. M., & Manjaiah, D. H. (2017). Challenges, Issues and Applications. In D. P. Acharjya, & M. Kalaiselvi Geetha, *Internet of Things: Novel Advances and Envisioned Applications* (pp. 231-244). Switzerland: SpringerInternational Publishing.

Slashdata. (2016, May 24). *If there were 100 Developers in the world*. Retrieved from Slashdata: https://www.slashdata.co/blog/2016/05/imagine-world-100-devs

Snitker & Co. (2007). *10 STeps to Personas.* Retrieved from Personas: http://personas.dk/wp-content/LOWRES-Personas-english-version-oktober-200821.pdf

Stack Overflow. (2017). *Developer survey results 2017.* Retrieved from Stack Overflow: https://insights.stackoverflow.com/survey/2017

Stackowiak, R., Licht, A., Mantha, V., & L., N. (2015). *Big Data and The Internet of Things: Enterprise Information Architecture for A New Age.* Apress.

Star, L., & Ruhleder, K. (1996, March). Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces. *Information Systems Research, 7*, 111–134.

Stringify. (2018). *Flows*. Retrieved from Stringify: https://search.stringify.com/flows

Techopedia. (2018). *NoSQL*. Retrieved from Techopedia: https://www.techopedia.com/definition/27689/nosql-database

TechTarget. (2016, November). *REST vs. SOAP: Choosing the best web service*. Retrieved from Search Microservices: https://searchmicroservices.techtarget.com/tip/REST-vs-SOAP-Choosing-the-best-web-service

Tiwana, A. (2013). *Platform ecosystems.* Morgan Kaufmann.

Tunkelang, D. (2009). *Faceted Search.* Morgan & Claypool.

Varjonen, I., & Hasan, R. (2018). *Market Analysis of Wappsto: a perspective of segmentation, demand, and competitivness.* Aalborg.

Verizon. (2016, April). *Reengeneering the world.* Retrieved from Verison Enterprise: http://www.verizonenterprise.com/resources/infographic/ig_som-iot-infographic_en_xg.pdf

VisionMobile. (2017). *State of the developer nantion.* London.

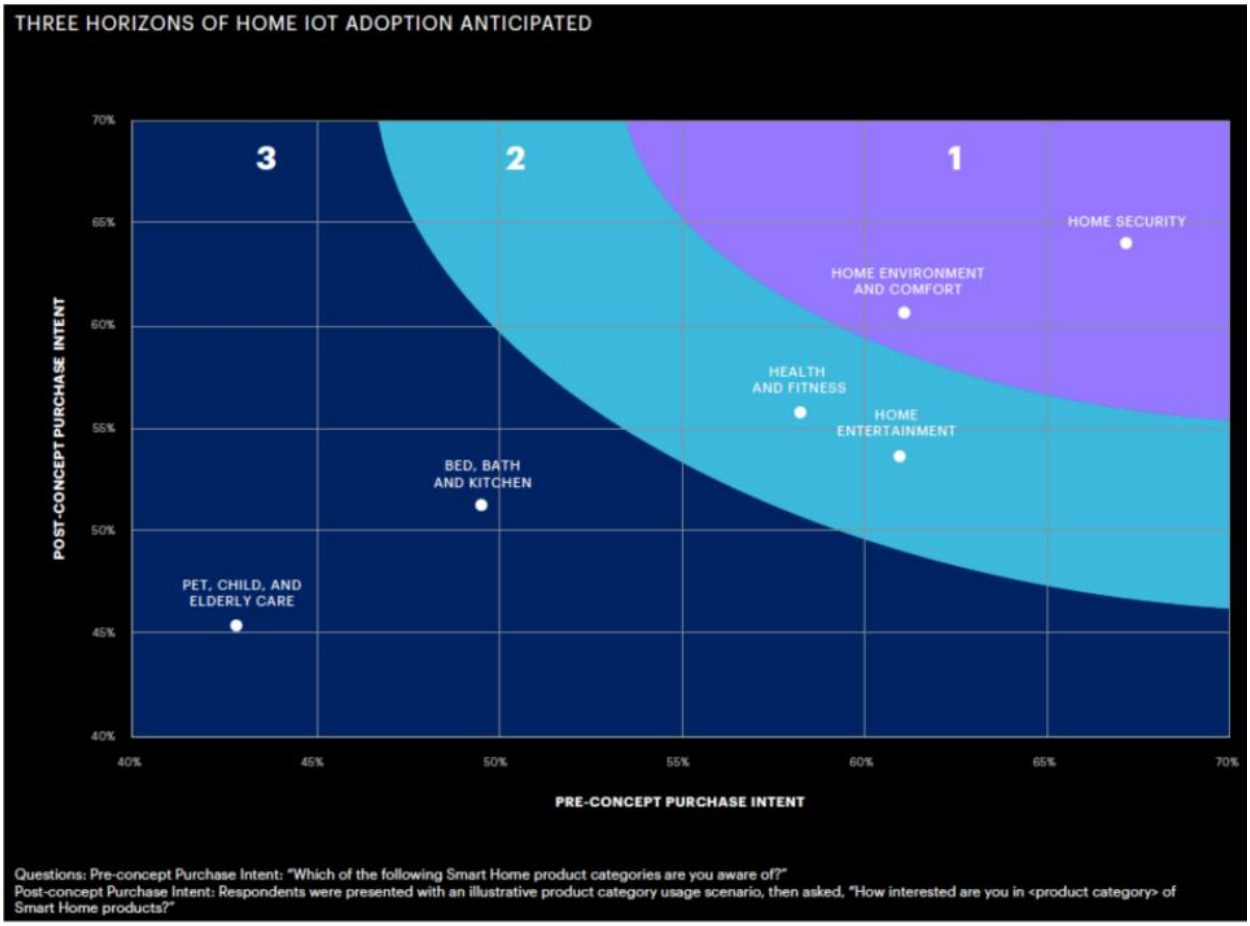
Wilson, M. (2012). *Search User Interface Design.* Morgan & Claypool.

Yin, R. (2014). *Case Study Research.* Sage.

9 APPENDICES

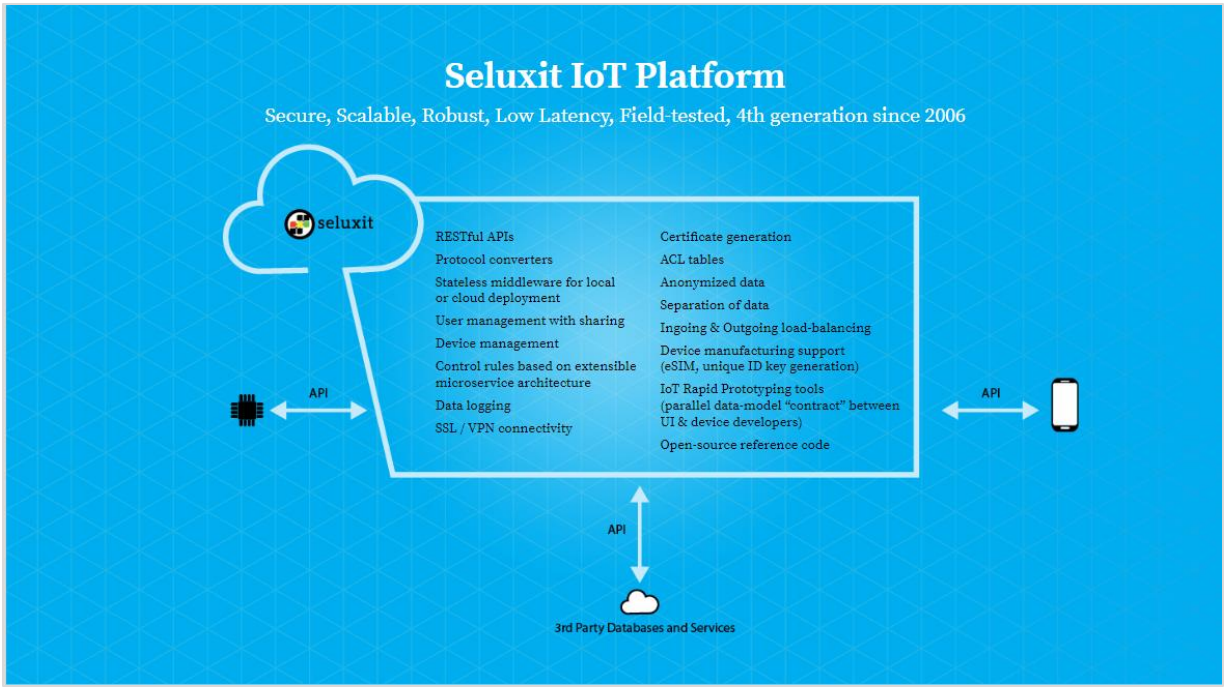
9.1 APPENDIX 1: THREE HORIZONS OF HOME IOT ADOPTION ANTICIPATED

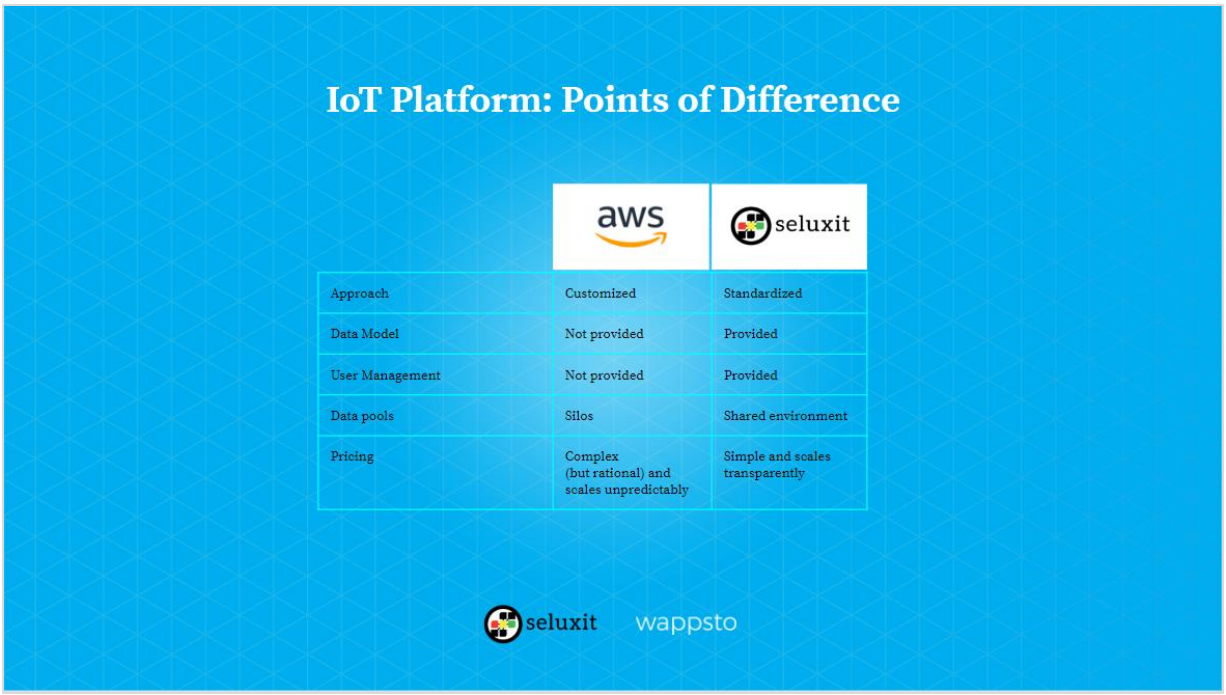
Image source: (Altimeter, 2017)



9.2 APPENDIX 2: SELUXIT IOT PLATFORM

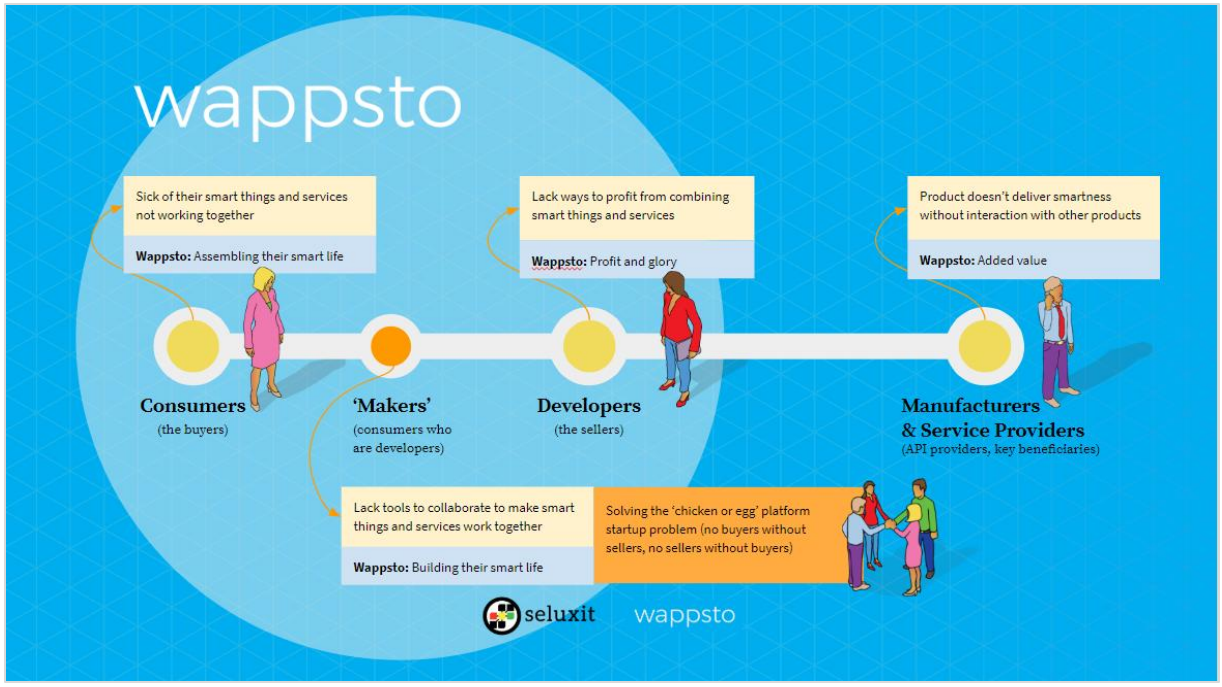
Slides from the presentation. Source: (Lux, IoT Rapid Prototyping, 2018)





9.3 APPENDIX 3: WAPPSTO VALUE PROPOSITION

Slides from the presentation. Source: (Boyles & Tonnesen, 2018)



9.4 APPENDIX 4: INTERVIEW "THE UNIFIED DATA MODEL FROM A BUSINESS PERSPECTIVE" TRANSCRIPT.

E: You being a member of the Thing2Thing research group, could you elaborate on the current state of the IoT data model standardization?
D: The current state...mm... Well, that's difficult. The main thing we can see now is that from where we have been a couple of years ago we saw very many different kinds of data models, it's slowly merging more. More and more data models are merging to fewer solutions, and more and more are dropping away. And from a technical point of view, it's going forwards microservices and semantic interoperability, and ontology is being discussed quite a lot, but from our point of view, it's basically going where we have already been for quite some time.

E: What will happen with that in the future in your opinion?
D: In my opinion, the Thing2Thing research group is doing some good work, however, I think they are a bit too far removed from reality. They will write yet another standard which most likely will not be used. I think standardization will come from successful, large implementation which gains in the market. I think this is not a good subject to be standardized and then implemented. I think it will come from being implemented and used in the market, and then afterwards you standardize it.

E: What is your opinion about standardization in general, about generalization.
D: I think my view the most successful standardization projects are normally where a company actually or very few actors have control, and actually implement something and then it becomes a standard rather than where people sit down and try to specify a standard, and then you try to implement afterwards. And I mean, I have been in ISO standardization group and there we did the other thing where we actually wrote the standard and then started implementing, and it took two decades basically before the standard actually emerge, so it's terribly slow. And this, I think it really depends on the market. If the market is very splintered in many small segments then this can be a way forward, but it's no way a guarantee for success. But if the market is less splintered then you will most likely see one winner emerge, but mm... yeah I mean in some few markets you can see that for example, in the 3GPP standards for mobile phones. You can actually see that there are only very few very strong players. They decide to work together because then the market is existing and big and then standardization can work, but I think if you have more than five companies are parts who are interested, it will most likely not work the standardization, or be very slow.

E: There are other unified data models developed by some communities, by larger companies. Why not using that structure at Seluxit? Why did you have to implement a new one?
D: Because they did not exist when we implemented our stuff, so we are a first mover, so we're ahead of the curve and they still have a lot of holes in their data models. They have some use cases they cannot map and therefore for us as a small player it's an advantage to stay ahead and to implement the functionality. In the end, it's the functionality people want, not the data model. The data model is just the means of the tool for implementing the functionality.

E: Have you investigated other data models? Or have you considered implementing other models into your system?
D: We can implement basically any data model we want in the system because we have generic objects, where you can actually specify them. Data based on an XSD and thereby you can very easily map them. We don't even have to do it ourselves our customers could do it themselves. The thing is that when looking at the other data models, they lack a lot of features which I think are important, they lack sometimes the semantics, they lack ontology, and very often they have the problem that they have bad naming because they come from domain specific solutions, where people call something a service but it's not really a service in the IoT side for example, where people more think of devices and values, and then a lot of confusion will arise because people just don't understand what is meant, what the content is. Even the Restful API you can see that it's quite a simple way of

describing, but still, people don't even understand what you use the different operations for a PUT and a POST and when to use what, what does it mean and it's implemented very often wrong. So I think there is a gap between how you specify the data model and how you specify operations on the data model, so you cannot just specify the data model without the operations. And then I think that the high complexity of the things means that people have difficulties making a standard. Plus, they have no good use cases to actually try this standard.

E: What kind of use cases you can name?
D: I mean in principle, for IoT you can take any IoT device like fitness or a car or an industrial IoT you whether it's a machine or maybe even the whole factory, but the thing is that the IoT cannot stand alone. It needs to be integrated into ERP and CRM systems, and billing systems and maybe into data analysis systems and then all the sudden the models become so complex and so complicated that no one understands them anymore and then you also don't get a very nice solution anymore.
So I think, use cases… In my view we use cases are when you really build a solution with many devices and then you look at the data. What can use it for? Like for example they… A power meter and where you want to have the data, and in order to get the data you need to offer some value. And the value that you could offer is, for example, that you use the electricity meter as a means of the burglary alarm, and then people would be willing to give the data if they get the burglary alarm in return or if they get it for monitoring elderly people out they grandmother. Then they can give the grandmothers power utility as meter data to the company, who wants the data and in return, they get a service that wants them if the grandma is ill or maybe something more drastic has happened.

E: Over 12 years you had many customers with different requirements. Can you elaborate on that experience?
D: Yeah in a way it was surprising how well conceived our first model already was even though through the years we could see requirements… there were some requirements which we could not easily map into our data model and into the operations but we basically always were able to adapt it with small things which didn't break it and still put new functionality in. However, it became very cluttered and that's why in the second iteration, basically, of the data model we moved to microservices where we split the concerns. Where we say okay, we have parts of the data model they describe the data, semantic and maybe also the ontology, and other parts are the data which are the mere pieces of information the measurements and their actions. And by doing it like that and by being able to add new microservices that's a very, very strong paradigm to use. And it means we are more flexible now and we can basically just add anything on top like for example now we have sets we have generic objects and these additional small services that when you design them you want to make them as simple as possible, but not simpler.

E: I guess those are benefits of having a unified data model. But are there any disadvantages?
D: Well, you need to always squeeze things a bit into your data model where it very explicit data model can be written down very explicitly where you say okay, this device is like this but the problem in that is then that you need to… when you implement the code there's no generic code you need to make specific code for every specific thing so your code base bloats very much. But yeah, sometimes the squeezing into the data model takes weird forms.
E: But I guess it compensates on the benefit side right?
D: Yes.

E: Could you tell me more about the integration time for the new product, new solutions?
D: That really depends on the solution, because, if it all… I mean how well do you want to integrate it? Do you completely want to translate it into our data model or not? If you just map it raw then it's easy to put it in but then the reuse value is very little. If you make a more advanced mapping, then you have better reuse, but if the data model is very different from our data model, then more mapping will be needed and in each mapping and then each translation you add complexity and you lose functionality or you might lose information.

E: As you said before, it was many years ago when the first iteration of the data model was created at Seluxit. What was the initial reason for creating it and has it changed over the years?
D: Has the data model changed or…?

E: The reason.
D: The reason? Mm… No, I think the initial reason was that we wanted to create interoperability between different things and we wanted… We called our first standard, we called it a Meta standard from a kind of a… something that can comprise all the other standards and we can always translate all the other ZigBee, Z-Wave and wireless M-Bus, and whatever you have mapped the things in… so, but at that time we were really just focusing on devices, on smart home mainly actually at that time. And from then to now, we still want to do the same thing we want to have the data model fixed and quite narrow but the services around them, they process the information. So, you need to bridge the gap between the data and the semantic, the meaning of the data, and then the relationship between the data things the ontology.

E: Does the data structure have an influence on Seluxit business strategy? If so, how does it influence it?
D: Well, the data structure in a way does have an influence because it makes things possible or doesn't make things possible. If you have a big monolithic data structure and it is hard to share of buy or sell and small bits of data because you take them out of context and you cannot… then you need some programs that can actually chop them up. By having a data model which is filled with microservices with small pieces of information you make that data much more versatile and you now can use it to trade the data in smaller units than you would in a monolithic data model. So you can basically use the divide and conquer strategy on your data and that is directly related to the data model so the opportunities we have now for the data market would not be possible if we didn't have such a data model.

E: What influence does it have on the development of services that you offer to your customers?
D: The data model or …?
E: yes.
D: Well, it means because we have defined much more we have also a lot of services around these this data model that we can… When we make an offer, we can make a better offer than competitors because we save time, we don't have to reinvent the wheel, we don't have to re-implement device management, user management. Everything is already there and therefore we can just reuse that and focus on the essential things which are specific to this customer's solution, how to map it into our model. The more we do this, the better we get and the more easy it will be to map the next one in so further developing their data model will also improve our speed.

E: Now a tricky question. Do you think it's the Seluxit business model that is shaping the data model or the other way around?
D: Well, I think it's both ways in a way, but of course, it's the data model comes from the specific branch where the industry that we work in so now it's called the Internet of Things previously it was Smart Meters, Smart Cities, Smart Home and whatever you can call it. So the specific requirements which came originally from the Smart Home obviously, were decided before and then we made the data model after that, but now the business requirements are changing to also support the other web services like Twitter or Facebook, social media or video or ERP/CRM systems, so they will put new requirements on this, on the system and thereby the data model will need to change again. But the fundamental paradigm how we built it with the microservices should make it possible for us to also implement other types of services and maybe we will need some new microservices, but then we can easily expand.
E: Is that how data model is used in Wappsto?
D: What do you mean?
E: Well. You were talking mainly about IoT interoperability, but…
D: Yeah, in Wappsto where it's broader audience, broader use case which we will meet.

E: What does it mean to base everything on data model? What kind of advantages and disadvantages are based on that?
D: Well, advantages are that if you can map it into the data model then and you can do that more quickly normally. The disadvantage is that sometimes you meet challenges where you cannot easily map it into your data model and then you will need to change your data model and expands and the more code you have which works on the existing data model, the more code you might have to rework in order to support the new feature.

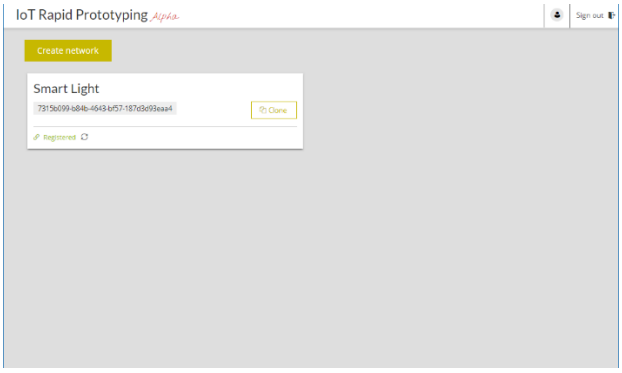
I mean there will always be new requirements which will mean that you will need to change things on your code basis.

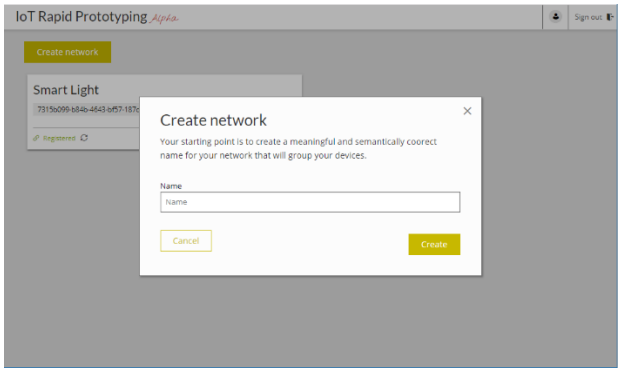
E: Does it open new business opportunities for Seluxit?… the data model?
D: In a way yes, because many of our competitors… or some of our competitors do not define a data model like Amazon does not have a data model and Google IoT solution does not have a data model. That means when two companies build something in Amazon or in Google, then they will most likely choose two different data models and thereby they will not be compatible. Because we always already dictate the data model that means that solutions built on our platform, if we have integrated this platform against third-party services, then this will already work with those as well out of the box. So in that way, it is a benefit for the customer. Furthermore, the customer does not need to think up of a data model, and we have a data model which has proven its worth through 12 years. So we know it's also very robust and it can actually map many things which are needed. So that means the customer actually saves time that he otherwise might lose. And even the data model is kind of related to security even because we anonymize the data by means of you UUIDs of all data points. And this is not something which is commonly seen in many IoT platform. We really take a lot of problems that often are seen and which cause failure in IoT projects we avoid them for the customer by having made them ourselves… yeah… now putting them to their advantage.

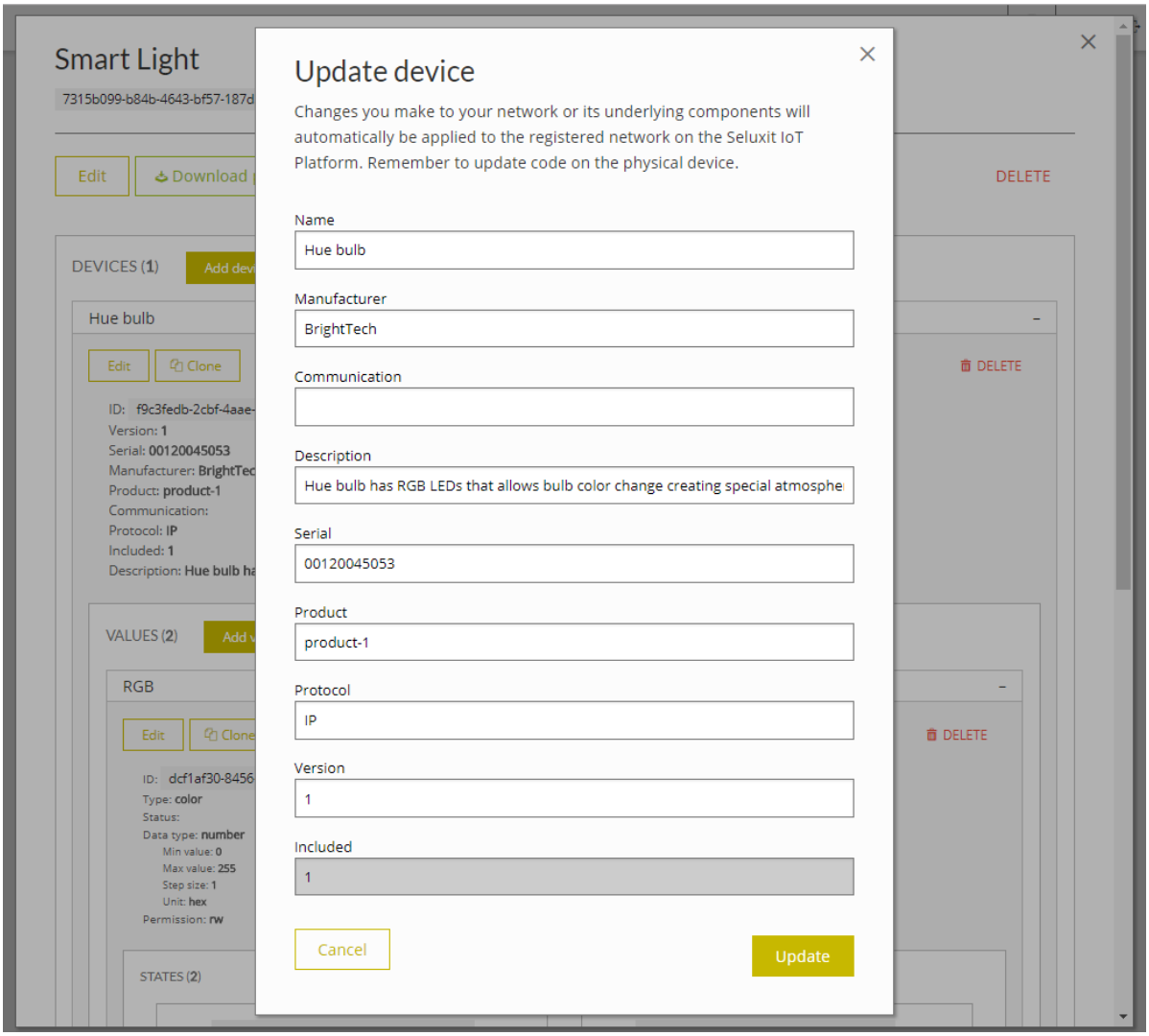
E: In Wappsto you have outlined two major groups which can also have a benefit from the data model. Could you mention some of them? What are those business opportunities for them?
D: Yeah, I guess you mean the developers and the user…?
E: …and manufacturers.
D: The manufacturers? Yeah, for manufacturers, if there are more use cases for their products, so their products can be used in more versatile and different ways that increase the value of the product because there are more customers who can get their desires fulfilled with their product. So for the developers the more products they can actually easily integrate into a solution, the more versatile solutions they can build. And since in Wappsto they can decide themselves if they want to integrate, or what they want to integrate. As long as it's somehow integratable, that gives a lot of freedom, but of course, with freedom, there is also… It has a dark side, more freedom means more risk of failure and more yeah… more choice which can be a problem.

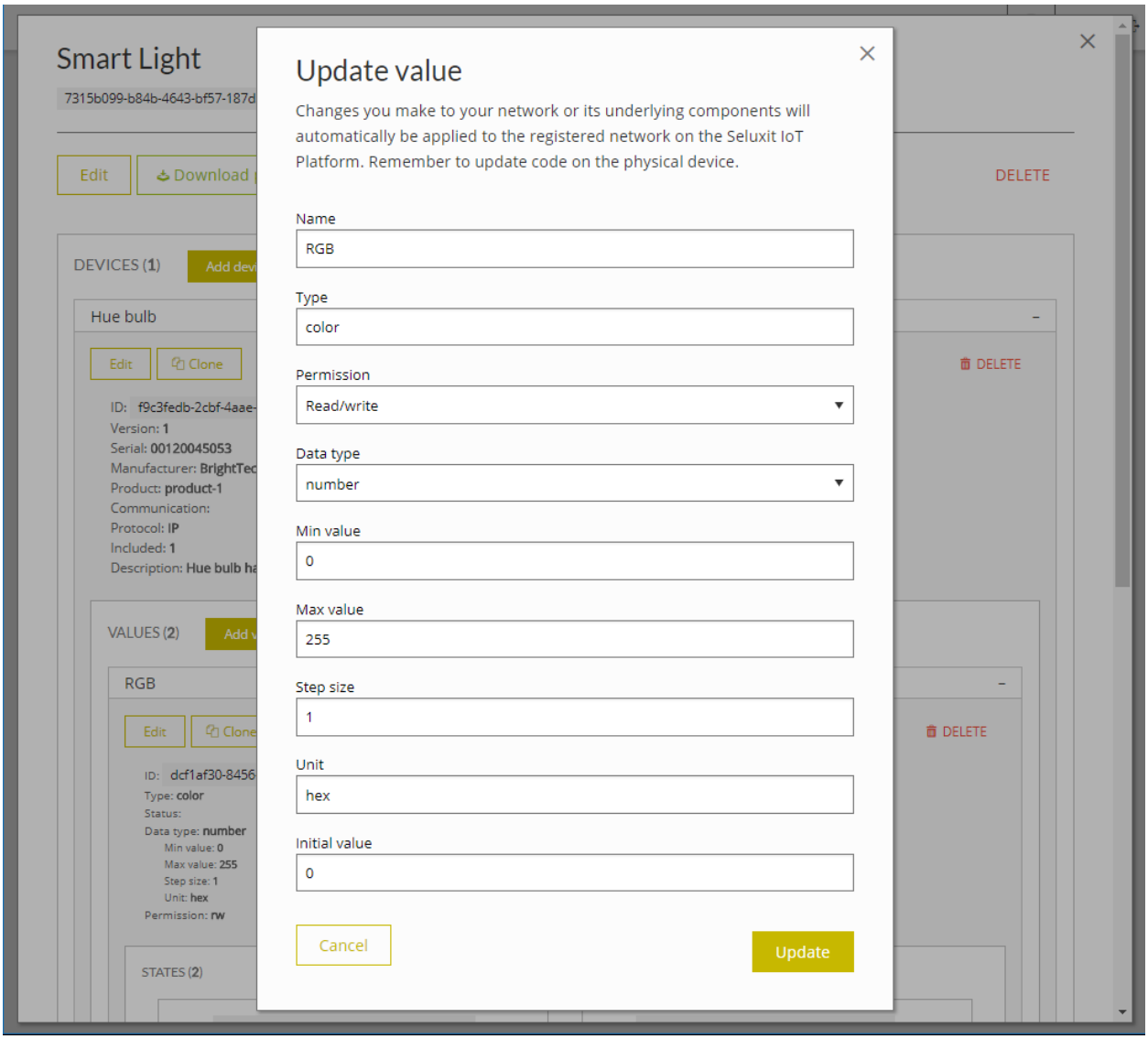
9.5 APPENDIX 5: "IOT RAPID PROTOTYPING" SCREENSHOTS

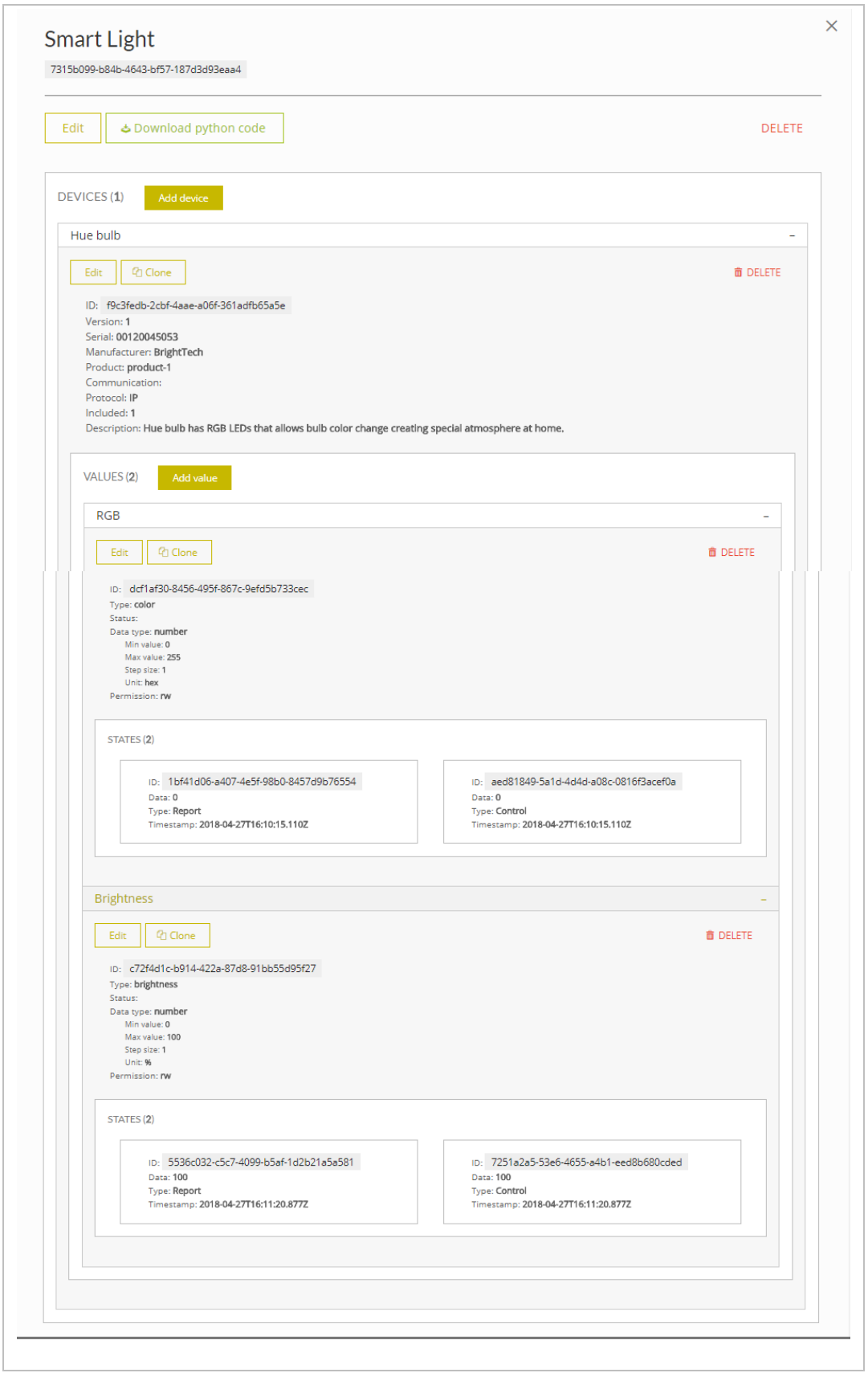
Screenshots of a web-based wapp "IoT Rapid Prototyping" that presents an example of a use case in the *Scenario A*.



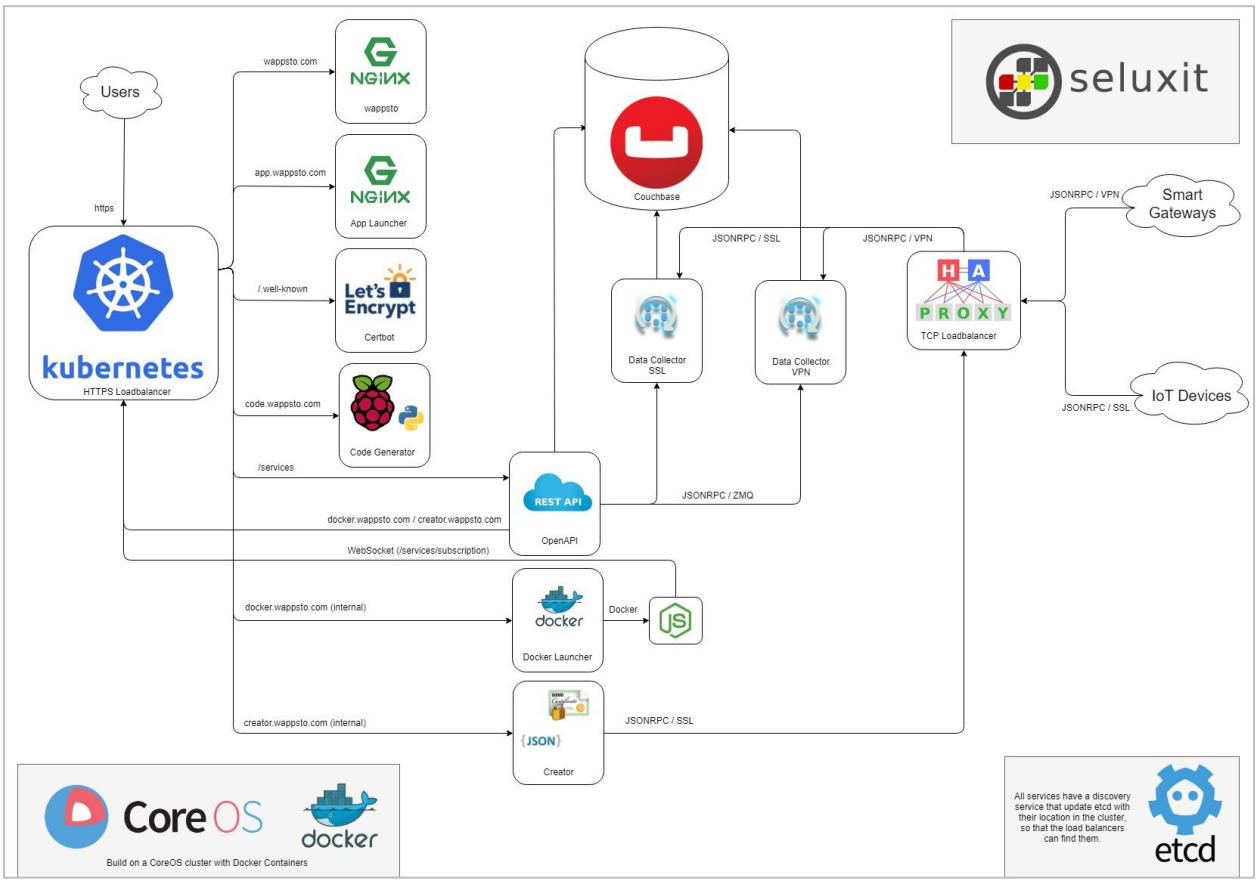




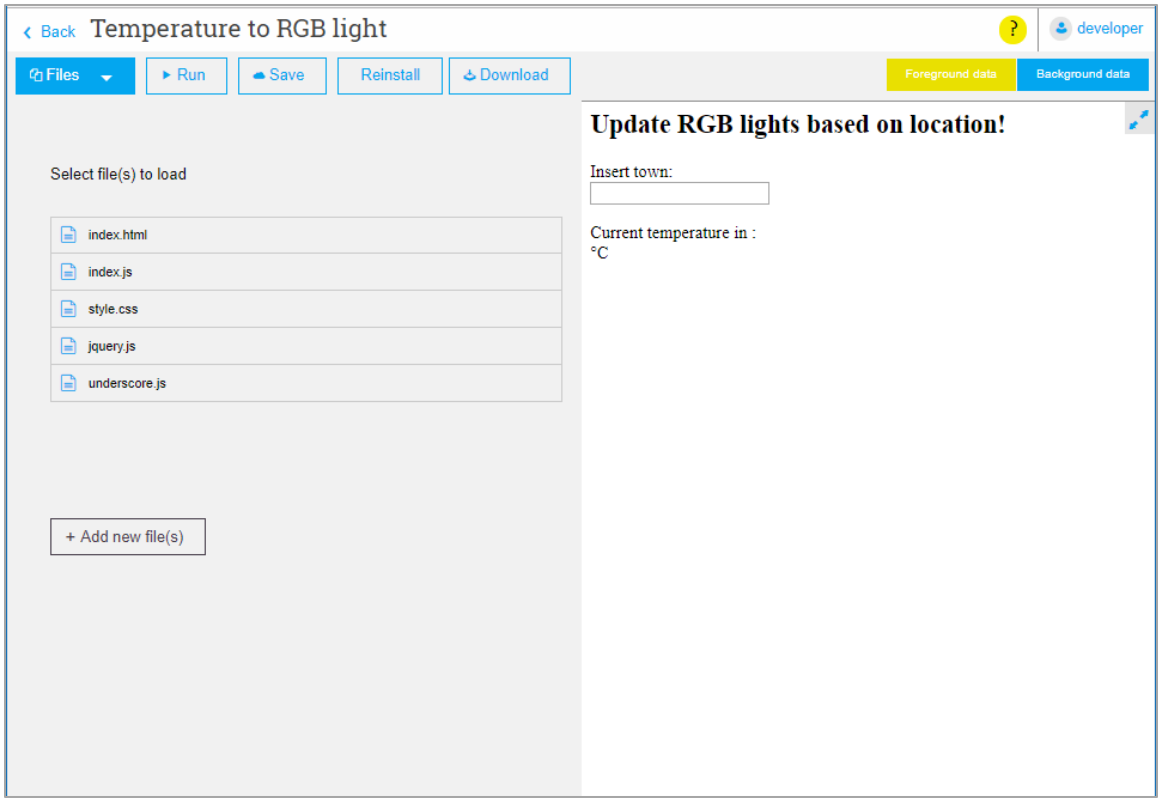

Smart Light
Edit
Download
DELETE
DEVICES (1)
Hue bulb
Edit
Clone
DELETE
VALUES (2)
RGB
Edit
DELETE
STATES (2)
Update value
Changes you make to your network or its underlying components will automatically be applied to the registered network on the Seluxit IoT Platform. Remember to update code on the physical device.
Name
RGB
Type
color
Permission
Read/write
Data type
number
Min value
0
Max value
255
Step size
1
Unit
hex
Initial value
0
Cancel
Update

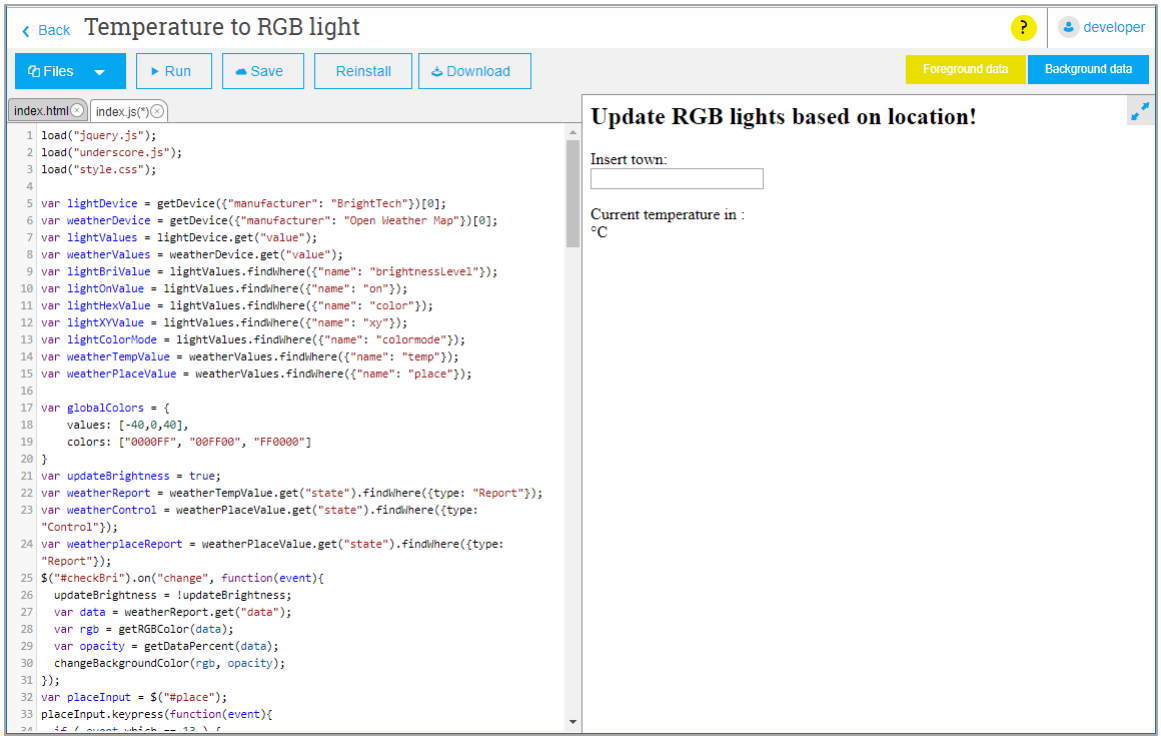

Smart Light
7315b099-b84b-4643-bf57-187d3d93eaa4
Edit
Download python code
DELETE
DEVICES (1)
Add device
Hue bulb
Edit
Clone
DELETE
ID: f9c3fedb-2cbf-4aae-a06f-361adfb65a5e
Version: 1
Serial: 00120045053
Manufacturer: BrightTech
Product: product-1
Communication:
Protocol: IP
Included: 1
Description: Hue bulb has RGB LEDs that allows bulb color change creating special atmosphere at home.
VALUES (2)
Add value
RGB
Edit
Clone
DELETE
ID: dcf1af30-8456-495f-867c-9efd5b733cec
Type: color
Status:
Data type: number
Min value: 0
Max value: 255
Step size: 1
Unit: hex
Permission: rw
STATES (2)
ID: 1bf41d06-a407-4e5f-98b0-8457d9b76554
Data: 0
Type: Report
Timestamp: 2018-04-27T16:10:15.110Z
ID: aed81849-5a1d-4d4d-a08c-0816f3acef0a
Data: 0
Type: Control
Timestamp: 2018-04-27T16:10:15.110Z
Brightness
Edit
Clone
DELETE
ID: c72f4d1c-b914-422a-87d8-91bb55d95f27
Type: brightness
Status:
Data type: number
Min value: 0
Max value: 100
Step size: 1
Unit: %
Permission: rw
STATES (2)
ID: 5536c032-c5c7-4099-b5af-1d2b21a5a581
Data: 100
Type: Report
Timestamp: 2018-04-27T16:11:20.877Z
ID: 7251a2a5-53e6-4655-a4b1-eed8b680cded
Data: 100
Type: Control
Timestamp: 2018-04-27T16:11:20.877Z

9.6 APPENDIX 6: AN OVERVIEW OF THE SELUXIT IOT PLATFORM TECHNOLOGIES

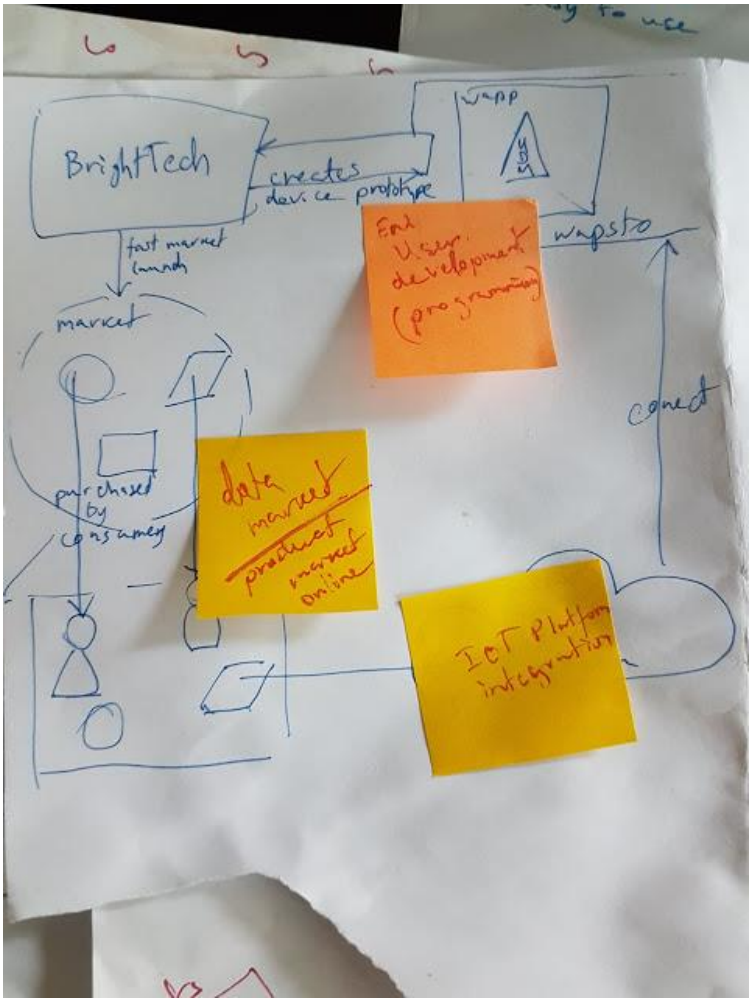


9.7 APPENDIX 7: INTEGRATED DEVELOPMENT ENVIRONMENT BASED ON THE UDM - "WAPP CREATOR" SCREENSHOTS

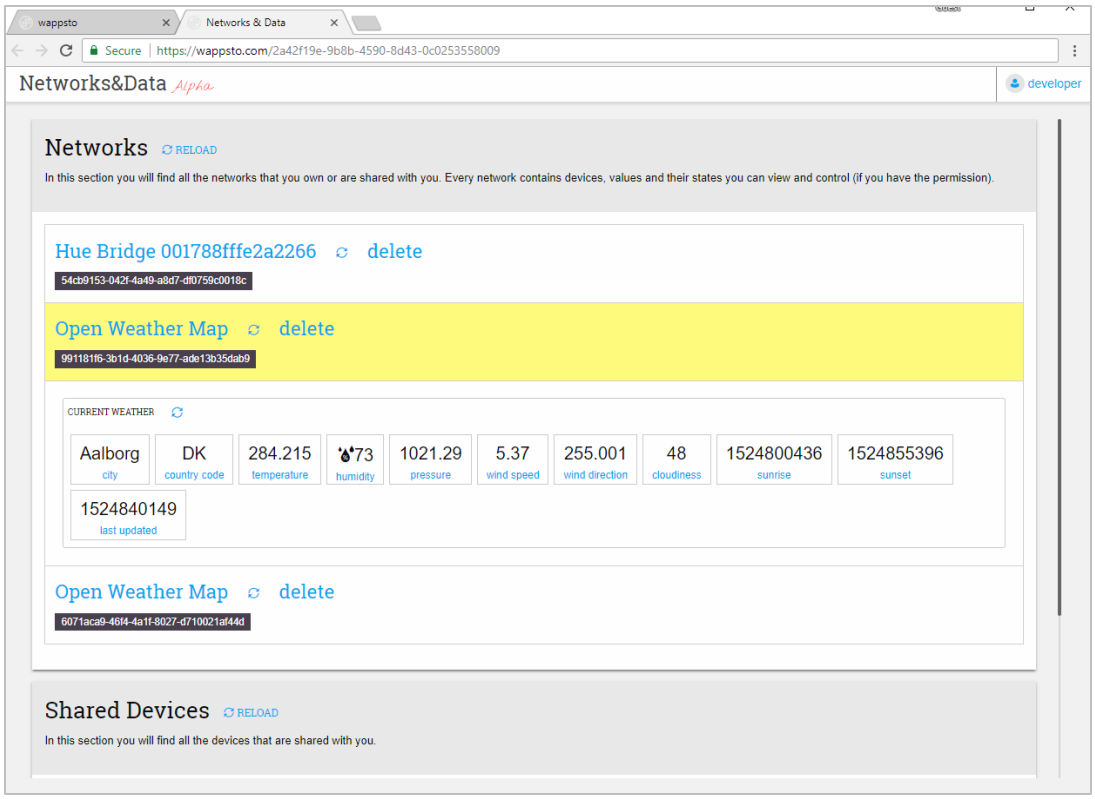


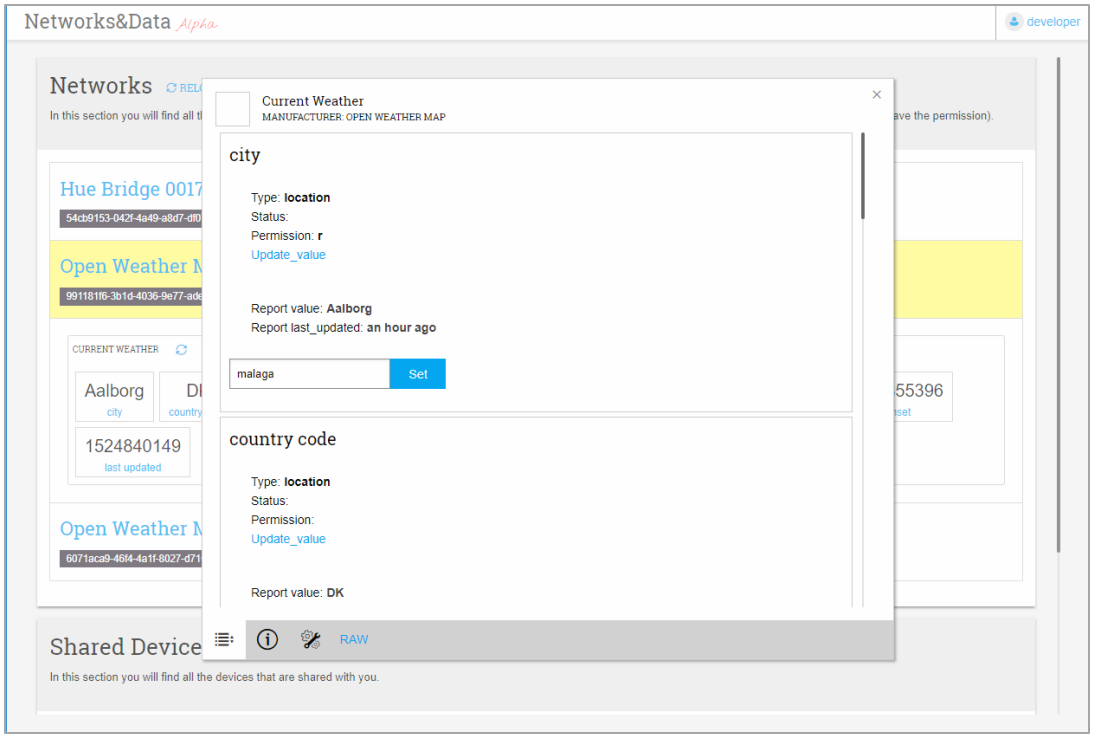


9.8 APPENDIX 8: AN EXAMPLE OF OBSERVATION DATA TREATMENT.



9.9 APPENDIX 9: GENERIC DATA CONTROL IN USER CONTEXT. WAPPSTO SCREENSHOTS





9.10 APPENDIX 10: EXAMPLE OF IOT DEVICE DATA MAPPING IN JSON FORMAT – PHILIPS HUE

The code example was created using Wappsto.


```
{
  ":type":"urn:seluxit:xml:q:network-1.2",
  ":id":"881463a9-00b0-4801-b6e8-78549103d965",
  "name":"Philips Hue Bridge",
  "created_by":{
    "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
    "type":"urn:seluxit:xml:q:installation-1.2"
  },
  "device":[
    {
      ":type":"urn:seluxit:xml:q:device-1.2",
      ":id":"9d86fc0f-24c1-4dc9-a04a-3405e077d1f1",
      "name":"Hue white lamp",
      "manufacturer":"Philips",
      "product":"5",
      "serial":"00:17:88:01:10:29:ff:3c-0b",
      "description":"",
      "protocol":"hue",
      "communication":"always",
      "created_by":{
        "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
        "type":"urn:seluxit:xml:q:installation-1.2"
      },
      "value":[
        {
          ":type":"urn:seluxit:xml:q:value-1.2",
          ":id":"95bf507e-fd0d-4bf7-a1cf-5ce30e9be449",
          "name":"on",
          "type":"Dimmable light",
          "status":"ok",
          "number":{
            "min":0,
            "max":1,
            "step":1,
            "unit":"int"
          },
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          },
          "state":[
            {
              ":type":"urn:seluxit:xml:q:state-1.2",
              ":id":"6a207a2c-f87e-45a7-b5d2-f88586959607",
              "timestamp":"2018-03-07T12:32:05.355Z",
              "data":"1",
              "price":0,
              "status_payment":"free",
              "type":"Control",
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            },
            {
              ":type":"urn:seluxit:xml:q:state-1.2",
              ":id":"211b9e45-e868-42cf-94b7-4ef4bb76464a",
              "timestamp":"2018-03-07T12:32:07.131Z",
              "data":"1",
              "price":0,
              "status_payment":"free",
              "type":"Report",
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            }
          ]
        },
        {
          ":type":"urn:seluxit:xml:q:value-1.2",
          ":id":"d19b6668-e182-4b5e-b6fe-2616a1e57150",
          "name":"bri",
          "type":"Dimmable light",
          "status":"ok",
          "number":{
            "min":0,
            "max":255,
            "step":1,
            "unit":"int"
          },
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          },
```

```
      "state":[
        {
          ":type":"urn:seluxit:xml:q:state-1.2",
          ":id":"ad80f530-d41f-4840-be87-c7504d7c690a",
          "timestamp":"2018-03-07T12:32:05.358Z",
          "data":"254",
          "price":0,
          "status_payment":"free",
          "type":"Control",
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          }
        },
        {
          ":type":"urn:seluxit:xml:q:state-1.2",
          ":id":"649627c2-eccf-4ca1-a7fc-01e5eb639dc5",
          "timestamp":"2018-03-07T12:32:07.167Z",
          "data":"254",
          "price":0,
          "status_payment":"free",
          "type":"Report",
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          }
        }
      ]
    },
    {
      ":type":"urn:seluxit:xml:q:value-1.2",
      ":id":"d32ef324-bcb0-4c1f-b877-c4e13149d22f",
      "name":"alert",
      "type":"Dimmable light",
      "status":"ok",
      "string":{
        "max":99
      },
      "created_by":{
        "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
        "type":"urn:seluxit:xml:q:installation-1.2"
      },
      "state":[
        {
          ":type":"urn:seluxit:xml:q:state-1.2",
          ":id":"78616a82-bef6-496f-97b6-548de3374c0b",
          "timestamp":"2018-03-07T12:32:05.362Z",
          "data":"none",
          "price":0,
          "status_payment":"free",
          "type":"Control",
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          }
        },
        {
          ":type":"urn:seluxit:xml:q:state-1.2",
          ":id":"cf7a4208-23c2-487f-afe2-fd52e0c93f1f",
          "timestamp":"2018-03-07T12:32:07.212Z",
          "data":"none",
          "price":0,
          "status_payment":"free",
          "type":"Report",
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          }
        }
      ]
    },
    {
      ":type":"urn:seluxit:xml:q:value-1.2",
      ":id":"9efed616-edb1-41df-809f-b668b7f6928a",
      "name":"mode",
      "type":"Dimmable light",
      "status":"ok",
      "string":{
        "max":99
      },
      "created_by":{
        "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
        "type":"urn:seluxit:xml:q:installation-1.2"
      },
      "state":[
        {
          ":type":"urn:seluxit:xml:q:state-1.2",
          ":id":"87e0d76d-c9eb-4de3-b63a-d70a9926f290",
          "timestamp":"2018-03-07T12:32:05.364Z",
          "data":"\"homeautomation\"",
          "price":0,
          "status_payment":"free",
          "type":"Control",
```

```
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            },
            {
              ":type":"urn:seluxit:xml:q:state-1.2",
              ":id":"4767291f-9bde-449d-8c92-b69f3cedde11",
              "timestamp":"2018-03-07T12:32:07.084Z",
              "data":"\"homeautomation\"",
              "price":0,
              "status_payment":"free",
              "type":"Report",
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            }
          ]
        },
        {
          ":type":"urn:seluxit:xml:q:value-1.2",
          ":id":"fa4b0a94-7738-4099-80a0-94243d4c89e8",
          "name":"reachable",
          "type":"Dimmable light",
          "status":"ok",
          "number":{
            "min":0,
            "max":1,
            "step":1,
            "unit":"int"
          },
          "created_by":{
            "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
            "type":"urn:seluxit:xml:q:installation-1.2"
          },
          "state":[
            {
              ":type":"urn:seluxit:xml:q:state-1.2",
              ":id":"660616dc-04b8-430b-99e8-3ee72a624361",
              "timestamp":"2018-03-07T12:32:05.366Z",
              "data":"0",
              "price":0,
              "status_payment":"free",
              "type":"Control",
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            },
            {
              ":type":"urn:seluxit:xml:q:state-1.2",
              ":id":"4edbbe14-f7aa-4278-9609-50d9f5d2a11b",
              "timestamp":"2018-03-07T12:32:07.219Z",
              "data":"0",
              "price":0,
              "status_payment":"free",
              "type":"Report",
              "created_by":{
                "id":"975333b4-de85-4a3c-a28a-a7b28a584c40",
                "type":"urn:seluxit:xml:q:installation-1.2"
              }
            }
          ]
        }
      ]
    }
  ]
}
```

9.11 APPENDIX 11: EXAMPLE OF SERVICE DATA MAPPING IN JSON FORMAT – OPENWEATHERMAP

The code example was created using Wappsto.


```
{
  ":type":"urn:seluxit:xml:q:network-1.2",
  ":id":"65c9ec40-d714-4155-9a36-70513333d0ab",
  "name":"Open Weather Map",
  "created_by":{
    "id":"88f06aa1-7627-40c0-b3f3-b4611c3fb53f",
    "type":"urn:seluxit:xml:q:installation-1.2"
  },
  "device":[
    {
      ":type":"urn:seluxit:xml:q:device-1.2",
      ":id":"9b50ef16-6676-4417-bd8a-274d0ed30000",
      "name":"Current Weather",
      "manufacturer":"Open Weather Map",
      "description":"Provides current weather values based on specified location.",
      "communication":"always",
      "created_by":{
        "id":"88f06aa1-7627-40c0-b3f3-b4611c3fb53f",
        "type":"urn:seluxit:xml:q:installation-1.2"
      },
      "value":[
        {
          ":type":"urn:seluxit:xml:q:value-1.2",
          ":id":"f9994e0f-4227-4230-aedf-65479d19e46b",
          "name":"city",
          "type":"location",
          "permission":"rw",
          "string":{
            "max":99
          },
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    }
  ]
}
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