Development of an Internet of Things Hub for Intelligent Machines and Systems

Masterarbeit

zur Erlangung des akademischen Grades „Master of Science (M.Sc.)“ im Studiengang Wirtschaftsingenieur der Fakultät für Elektrotechnik und Informatik, Fakultät für Maschinenbau und der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover

vorgelegt von

Daniel Olivotti

[redacted]

Prüfer: Prof. Dr. Michael H. Breitner

Hannover, den 30. September 2016

Abstract

This thesis deals with the development of an Internet of Things (IoT) Hub for intelligent machines and systems. Nowadays companies need to offer services apart from selling only products to be competitive. Thereby more and more services can result from new Internet of Things (IoT) approaches. These services are typically enabled by a central IoT platform. The development of an IoT Hub for intelligent machines and systems is done by an design science approach according to Hevner et al. (2004) and Hevner (2007). In a first step a literature review is performed and relevant literature and architectures presented. Afterwards the requirements of engineering companies are recorded and use cases described. On the basis of this requirements and the literature analysis a reference architecture for an IoT Hub is developed and discussed. Finally recommendations for practitioners and further research are stated out.

Keywords:

Internet of Things, IoT, Gateway, Hub, Reference Architecture

Contents

1 Introduction

„. . . purchasing 10-20 different services from 10-20 different vendors using 10-20 different apps with 10-20 different user interfaces. If that's the way IoT goes, it will be a long tough slog to Nirvana.“

Bob Harden, Principal, The Harden Group

Nowadays companies need to offer services apart from selling only products to be competitive. Thereby more and more services can result from new Internet of Things (IoT) approaches. These services are typically enabled by a central IoT platform. An IoT platform is the connection between devices, also called things, IT-hardware and software as well as business processes (Gartner Inc., 2016a). On the customer site topics like machine analysis, predictive maintencance or monitoring become essential. Especially a higher productivity, lower costs or leaner processes are the goal. Various types of platforms and a widespread range from local platforms for a single company to wide-range platforms for multiple partners in a value network exist. According to the researchers of Gartner, IoT architectures are nearly at the peak of inflated expectations (see Figure 1) whereas IoT platforms are in the innovation trigger phase. This states out the relevance of both topics. However, a time between 5 to 10 years for a possible mainstream adoption is estimated.

Central core of such a platform is an so called IoT Hub. The Iot Hub is the part that enables communications with devices and cloud services. It is important to state out, that IoT Hub is not a fixed term yet and some companies use it in different ways in their product description. Although the the term seems to be the more suitable for the developed artifact in this thesis and an explanation will be given in the following chapters. The development of a reference architecture for an IoT Hub, based on requirements of an engineering company (component suppliers), is the focus of this thesis. As already mentioned it is obvious that such an IoT Hub cannot be developed without an even rough architecture of the environment or setting.

Nowadays various reference architectures exist, but the focus often lies on mobile devices, such as smart phones and tablets whereas the developed reference architecture aims to establish an IoT Hub for the producing goods industry and their machines. It is essential to ensure productivity of this machines at all time and down times are accompanied

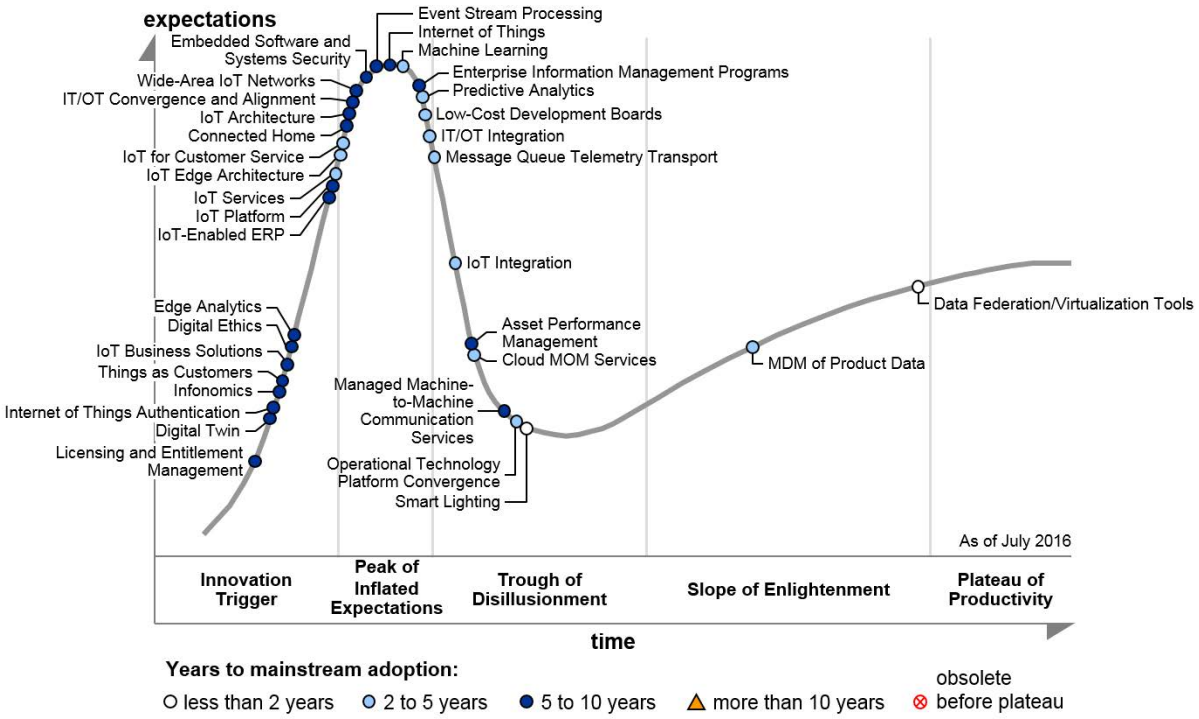

Figure 1: Gartner Hype Cycle for the Internet of Things, 2016 (Gartner Inc., 2016a)

with high cost. On the other site many reference architectures are focused on the private consumer market which has different aims from the producing industry sector and is not fitting the requirements of it. The value network and analysis across different machine operators, plant and machinery builder, and component suppliers should also be considered. Along with the integration of different companies, security concerns comes along which can cause legal debates (e.g. the owner of data). But also for a single company security is important when accessing on data in a cloud or platform from across the world. The treatment of company information and no unintended access to others must be ensured at all time. "The result is that no single architecture will suit all these areas and the requirements each area brings. However, a modular scalable architecture that supports adding or subtractingcapabilities, as well as supporting many requirements across a wide variety of these use cases is inherently useful and valuable" (Fremantle, 2015).

For a structured analysis and development the following research questions should be answered within this thesis:

RQ1: What are the requirements for an IoT platform and an IoT Hub for an engineering company?

RQ2: How does a reference architecture for an IoT Hub for intelligent machines and systems look like?

The first research question aims to pick up the requirements engineering companies faces in order to offer or integrate in an existing IoT platform.This requirements are necessary in order to develop such an platform and especially an IoT Hub. In order to match these requirements an extended requirement analysis is performed within an engineering company in Germany. The second research question aspires to combine different existing reference architectures for the relevant context to meet the prior identified requirements. Therefore based on an literature review reference architectures are identified, analyzed and combined.

The thesis is structured as follows (see Figure 2 on the next page): The introduction is followed by the theoretical background in chapter 2. Herein an overview about IoT and Industrie 4.0, Machine-to-Machine communication and Cloud- as well as Fog-Computing is given. Afterwards chapter 3 presents the research design. In order to answer the research questions an Design Science approach is used and combined with other methods, which are described in the following chapters. The current state of research is presented in Chapter 4 and is achieved by a literature review according to Webster and Watson (2002). In this chapter also relevant architectures for the model development are presented. The main part of this thesis is the requirements analysis in chapter 5 and the model development in chapter 6 which is based on the prior identified architectures and requirements. The discussion of the results follows in chapter 7. To ensure a benefit for practitioners, implications and recommendations are added in chapter 8. Subsequently, limitations of this thesis are be presented in chapter 9 and finally a conclusion and an outlook is drawn in chapter 10.

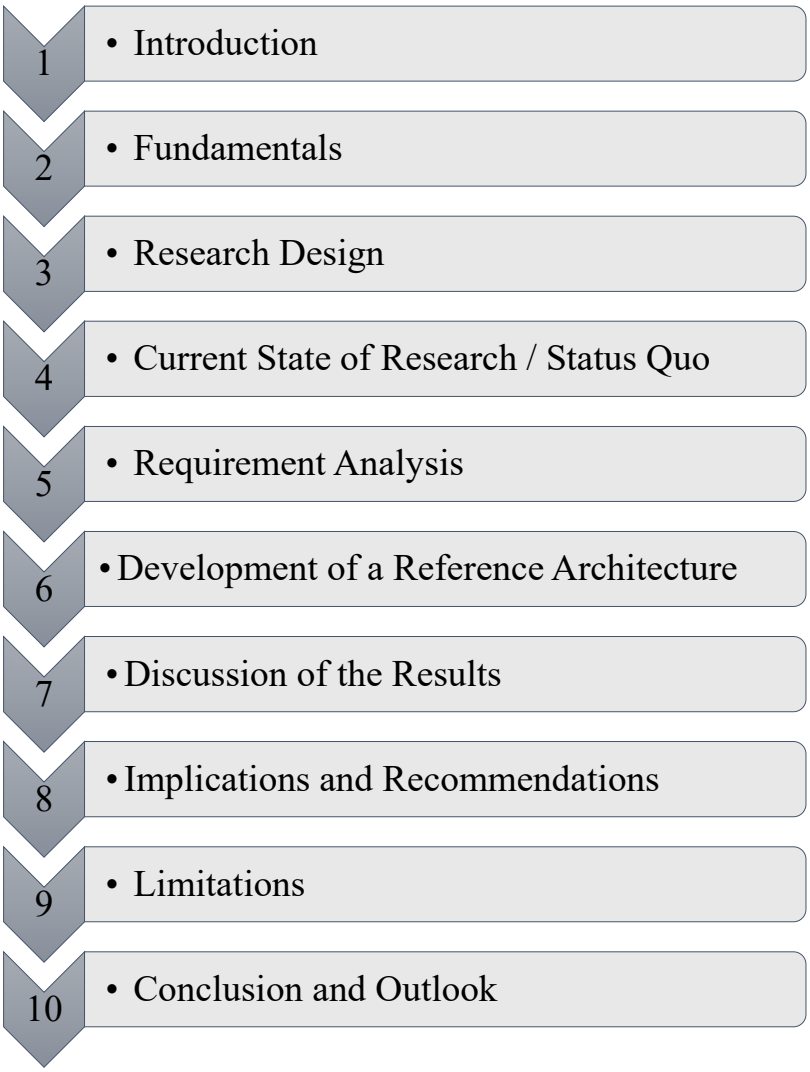

Figure 2: Structure of this Thesis

10 Conclusion and Outlook

> *„The IoT is removing mundane repetitive tasks or creating things that just weren't possible before, enabling more people to do more rewarding tasks and leaving the machines to do the repetitive jobs“*
>
> Grant Notman, Head of Sales and Marketing, Wood & Douglas

This thesis deals with the development of an IoT Hub for intelligent machines and systems. Therefore a reference architecture is developed based on a comprehensive requirement analysis within an engineering company (component suppliers). Additionally a second engineering company is addressed due to a focus group discussion. The development of the presented reference architecture is done by a design science approach according to Hevner et al. (2004) and Hevner (2007). Within this design science approach a literature review by Webster and Watson (2002) is conducted. Not only high academic papers but also whitepapers and industrial which means commercial solutions are considered. Thereby two generic architectures or architectures designed only for the consumer sector stated out the necessity to develop a reference architecture for the industrial sector. Further qualitative and quantitative studies are conducted in an engineering company in order to take the requirements in consideration and to further specify the reference architecture. Furthermore, a focus group discussion within a workshop with two engineering companies generates two use cases. One of this use cases is also considered in this thesis when working out the requirements. The construction of the reference architecture is done orienting on construction guidelines and techniques by vom Brocke (2007) and vom Brocke and Buddendick (2006). The model is based on the IoT-A Architecture (IoT-A, 2016) and improved by various other architectures and the in the interviews worked out requirements.

As in some parts of Chapter 9 stated out further research is necessary and recommended. An evaluation is not part of this thesis. As a preparation for evaluation the use cases are developed within two engineering companies. On basis of the use cases the architecture is developed and an evaluation can be performed. Therefore interviews shall be done in the near future to evaluate, optimize and extend the reference architecture further.

The developed architecture is designed based on the requirements of an engineering company (component supplier) with round about 3500 employees. A differentiation between

small, medium and large companies and different value stream networks should be done in future works. Therefore more experts and decision makers from various companies should be interviewed.

Some companies of the sector are interested in rapidly offering such a cloud-based service to their customers. With the help of a prototype this could be realized and promoted. Therefore techniques for software development are recommended. As explained, agile software developing should be preferred in contrast to the classical water fall, spiral or V-model for software developing. The prototype should be implemented in a real industrial production if possible. This would deliver data from sensors and actuators which can be analyzed afterwards. Also the amount and frequency of data streams can be specified and back-end systems can be selected and customized. Therefore a data model should be developed in further research. Here Big Data topics are highly relevant and should be included for further research.

A process model for the implementation of an IoT Hub and an IoT solution is also helpful. As this thesis is developed in the context of a company within a research project an implementation is planned. With the help of a process model the implementation could be coordinated and evaluated. The developed IoT Hub strongly depends on the surrounding environment. An embedding in a comprehensive IoT architecture is done partially, this should also be extended in future research.

Besides, the technical aspects of the business cases are important success and acceptance factors. Some ideas of business models are presented in this thesis, especially in the qualitative study and the use case. A further depth analysis of requirements for new business models and their development are recommended to be carried out.