

Analysis of Cryptocurrency Technologies for Electric Mobility

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

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Hannover, den 28. März 2018

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1 Introduction

This chapter gives an introduction into the topic by explaining its relevance, as well as pinpointing motivation and approach of this thesis.

1.1 Relevance

In the past years, blockchain projects emerged across all sectors. Many companies and governments experimented with various use cases such as logistics and supply chain processes¹, energy trading² or public health and identity management systems³. According to a global benchmark study, the growth of blockchain start-ups steadily increased in the last years, resulting in a total number of more than 115 blockchain start-ups in 2017 (HILEMAN et al., 2017). Additionally, many large companies set up special business units and research labs dedicated to blockchain technology. Especially the energy industry discovered a lot of potential use cases. Players like Siemens, Vattenfall or Innogy are already experimenting with international and local energy trading as well as payment systems for electric mobility charging (PwC et al., 2017).

Contradictory to that, there are only very few use cases that were implemented and demonstrated in a fully functional way. Many projects still have the status as *proof-of-concepts* and are restricted to a limited number of participants in isolated networks (HILEMAN et al., 2017). Compared to traditional centralized systems, blockchain has advantages and disadvantages. On the one hand, blockchain enables innovative benefits. Third trusted parties can be eliminated from multi-party processes, which can reduce costs and make processes both more transparent and faster. On the other hand, blockchain is also confronted with criticism and depreciated as temporary hype. The redundancy that secures open blockchain systems leads to large amounts of required energy as well as scalability problems. Private blockchain systems can solve these issues, but they rely on trusted parties and therefore deconstruct the key feature that makes blockchain technology unique. Even though blockchain entails a high degree of disruptive potential, there are still many unanswered questions and complex challenges ahead.

1.2 Motivation

This thesis focuses on the potential application of blockchain for electric mobility. In Germany, the charging infrastructure consists of a heterogenous landscape of different payment and registration systems. Blockchain could facilitate an efficient, open and homogenous payment system for the charging of electric vehicles. This use case has already been partly analyzed in scientific literature. For example, KIM et al. propose a technical concept for a billing system for mobile chargers using blockchain (KIM et al., 2017). Other

¹See <https://www.nytimes.com/2017/03/04/business/dealbook/blockchain-ibm-bitcoin.html>, visited on March 6, 2018.

²See <https://www.computerworld.com/article/3191256/sustainable-it/blockchain-used-to-power-brooklyn-microgrid-for-solar-energy-re-sale.html>, visited on March 6, 2018.

³See <https://e-estonia.com/solutions/>, visited on March 6, 2018.

papers developed detailed technological concepts covering different aspects from P2P trading to automatic routing (KANG et al., 2017; HUANG et al., 2018). Additionally, some scientific contributions analyzed the scalability of blockchains in private test environments with a limited set of nodes (PONGNUMKUL et al., 2017; ANIELLO et al., 2017). Anyhow, there are two important aspects that are not covered by current research. In order to assess the suitability of blockchain for the application for electric mobility, this thesis analyzes these two aspects, being described in the following.

The first aspect, that is not fully assessed, is the general suitability of blockchain application regarding the technology's key characteristics. While blockchain can facilitate high security and transparency, it also comes with complex challenges. Hence, for some use cases blockchain may be the right choice, for others a conventional database may be better suited. Even many organizations do not know how to evaluate the applicability of blockchain for their use case. Unfortunately, a structured and universal decision framework to evaluate the applicability of blockchain, does not exist. Hence, this thesis develops a framework to evaluate use cases regarding their blockchain suitability. Additionally, it can guide practitioners through the most relevant blockchain design choices. With the help of this test, this thesis analyzes the blockchain suitability for electric mobility.

Secondly, current research does not deal with the analysis of public blockchain systems, such as cryptocurrency technologies. While there are already performance benchmarks of private blockchains with a limited set of nodes, there are no comprehensive empirical studies regarding the scalability of open blockchain systems (ANH et al., 2018; PONGNUMKUL et al., 2017). For comparison, an existing payment system like VISA can handle more than 24,000 transactions per second⁴. Hence, it is unclear whether a blockchain can scale to the required performance level of an electric mobility payment system. Furthermore, the exact requirements of such a system are unknown, too. Concluding, both will be quantitatively analyzed and compared in this work.

1.3 Approach

This thesis is divided into seven chapters in order to follow a structured approach as shown in table 1. The first chapter gives an overview of the topic and explains the motivation and general approach. The second chapter lays the knowledge foundation for the understanding of this thesis. Therefore, all basics concepts of blockchain technology are explained and the state of the energy industry and electric mobility is presented. Also, some practical examples regarding the application of blockchain in the energy industry are shown. The third chapter provides information regarding the current state of research. It shows relevant scientific literature, identifies the research gaps and deducts the research questions.

As first part of the main analysis, the **Blockchain Suitability Test** is developed in chapter 4. Therefore, the main characteristics of the technology are examined and aggregated into a visual framework based on decision paths. The test is then applied for the electric mobility use case in order to assess its general suitability for the application of blockchain. Lastly, the test is validated with the help of qualitative expert interviews and

⁴See <https://usa.visa.com/run-your-business/small-business-tools/retail.html>, visited on March 5, 2018

Table 1: Structured Approach of this Thesis (own representation)

Chapter	Content/ Objectives
1 Introduction	Explain relevance and motivation, give overview of general approach
2 Fundamentals	Lay the knowledge foundation regarding blockchain technology, electric mobility, the energy system and the application of blockchain in the energy sector
3 State of Research	Present existing scientific approaches and research gaps, deduct research question and explain research design
4 Blockchain Suitability Test (BST)	Analyze blockchain's key characteristics, develop general suitability test and demonstrate it for electric mobility, validate test with qualitative expert interviews and discuss results
5 Cryptocurrency Performance Matrix (CPM)	Define scalability requirements for the electric mobility use case, quantitatively analyze performance of current cryptocurrency technologies, present and discuss results regarding scalability requirements
6 Limitations and Outlook	Point out limitations and shortcomings of the analysis and present open questions for further research
7 Conclusion	Summarize the results

the results are being discussed.

The second part of the analysis is carried out in chapter 5. Therefore, empirical data from public cryptocurrencies is gathered. Their performance is evaluated in a quantitative analysis and presented in the **Cryptocurrency Performance Matrix**. The results are then being discussed and compared to the requirements of an electric mobility payment system.

In chapter 6 the limitations of the previous analysis are explained and an outlook is given, pointing out possible ways for further research on blockchain technology. Finally, the content of this thesis is summarized in chapter 7. The transcription rules, the interview guide, the transcripts of the interviews as well as a draft of the second version of the BST can be found in the appendix.

7 Conclusion

This thesis analyzed the suitability of blockchain and cryptocurrency technologies for the application for electric mobility. In particular, the usage of blockchain for a nationwide homogenous payment system for the charging of electric vehicles was assessed. Therefore, the analysis focused on the two aspects *general suitability* and *scalability* of blockchain technologies.

To examine the first aspect, a universal framework was developed that facilitates the evaluation of use cases regarding their suitability for blockchain as well as the key design choices of a potential blockchain architecture. This framework, called the **Blockchain Suitability Test**, was then demonstrated for the electric mobility use case and afterwards evaluated with the help of six qualitative interviews of blockchain experts from different backgrounds. The demonstration showed that blockchain is indeed suitable for the application for electric mobility. The decisive criterion is the existence of a variety of untrusted parties that interact within the electric mobility environment. An open blockchain back-end could aggregate different tasks, such as the authentication of EV drivers at charge points, the authorization of charging processes at private and public charging infrastructure with the help of smart contracts, as well as the automatic execution of payment and billing processes for EV drivers and charge point operators. Hence, blockchain has the potential to make the technical electric mobility landscape more homogenous and transparent. Furthermore, eRoaming platforms could become obsolete in the future. Anyhow, there are still major challenges ahead. The implementation would require major collaboration efforts between all involved organizations, such as automotive and charge points manufacturers. Also, it remains to be evaluated which type of blockchain would be most suitable. For example, a public solution would require strong privacy protection that could be enabled through cryptographic technologies such as zk-SNARKs. The use of a permissioned blockchain would be easier to control and more scalable, but could limit the adoption to a predefined set of companies. In contrast, a permissionless blockchain could profit from a faster and limitless adoption. Lastly, the user-friendly management of the customer's private keys is an important issue that must be solved before blockchain can be implemented on a big scale.

To examine the second aspect, the performance of nine popular cryptocurrency technologies was analyzed and the results were presented in the **Cryptocurrency Performance Matrix**. Additionally, a prognosis regarding the required performance of a payment system for EV charging in Germany was made, provided the assumption of roughly 2.7 million EV drivers in the year 2025. Therefore, three different charging scenarios were defined, that showed scalability requirements from 6.9 to 35.4 Tx/sec. The first key result was that only the Ethereum blockchain is currently operating at a performance level that could meet the demands of two of the electric mobility charging scenarios. With a calculated median rate of 13.7 Tx/sec, the Ethereum blockchain tops the required rates of charging scenario two (8.8 Tx/sec) and three (6.9 Tx/sec). Hence, the scalability of Ethereum is sufficient to implement a blockchain based payment system, including all charge stations of automotive manufacturers and public infrastructure. In contrast, none of the analyzed technologies operates at a performance that the first charging scenario

(also including private infrastructure) requires. Anyhow, the theoretical calculations show that for example Bitcoin Cash could handle a maximum of 32 Tx/sec, and hence, is very close to the requirements of the first charging scenario (35.4 Tx/sec).

Furthermore, the analysis showed that, apart from Bitcoin and Ethereum, none of the cryptocurrencies are operating at full capacity. Therefore, the performance of public cryptocurrencies could not be fully analyzed due to the lack of empirical data. Because of their early development state, some technologies only provided blockchain explorers with very limited functionalities, which could not be used for the extraction of large data sets. This especially applies for new, alternative technologies, such as IOTA or Nano, that promise very high scalability rates of several thousand transactions per second. Anyhow, the information that their explorers presented, indicated that they currently also run at a very low performance level. In conclusion, as long as these technologies are not utilized on high performance levels, an empirical analysis of their scalability remains to be carried out.

Blockchain is still a very young technology. Especially regarding trust problems and non-transparent multi-party processes, it entails significant benefits over traditional database systems. But it also comes with technical challenges that are still unsolved. Therefore, the application of blockchain has to be carefully assessed for each potential use case. For electric mobility, blockchain could unfold its potential by aggregating a variety of existent systems. The scalability of today's most popular cryptocurrency technologies is sufficient to handle the required performance of a payment system for electric vehicle charging. Therefore, the success of blockchain will rather be depended on the solving of other technical challenges such as data privacy and key management, as well as the willingness of organizations to collaborate in the development of decentralized systems.