

Use of Blockchain Smart Contracts in Software Engineering: A Systematic Mapping

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Abstract. A smart contract is one of the safest mechanisms in the form of computerized and authorized legitimate commitment between two parties. This form of securing commitments has been gaining popularity on the last years in a variety of fields. However, and maybe because of its relative novelty, there is not a clear understanding of its possibilities. This study is aimed to cover the usage, benefits and challenges on the use of Blockchain Smart Contracts in Software Engineering in the form of a Systematic mapping. The most common use of the smart contracts is to work as a digital code that plays the role of a mediator, which removes human intervention. The availability of professionals in this area is a reported challenge along with the client's trust on usability with respect to security. Besides, this paper identifies various difficulties that have not been yet addressed by existing methodologies. As a consequence of our findings, more practical use of this system can open doors for further research.

Keywords: Smart contracts · Software engineering · Block chain

1 Introduction

Blockchain technology is becoming the key solution to provide reliability and security without any need for central supervisory authority to validate a panoply of transactions. Blockchain is a decentralized transaction and data management technology based solution developed initially for Bitcoin cryptocurrency [1]. Literature reported a wide set of blockchain applications ranging from cryptocurrency, financial services, risk management, Internet of Things to public and social services [2], naming just a few of the most important and reported fields of application. Nevertheless, and in spite of its popularity there are reported challenges of this technology such as scalability and security problems still not tackled [3].

Blockchain is a technology that provides an environment to create distributed decentralized applications, which are meant to complete transactions between two parties without any involvement of any third party. It's a peer-to-peer network where the transaction or a mutual goal can be achieved without relying on a third party [4]. This term "blockchain" is the system on which Bitcoin transactions are being completed. Rooted in the technological needs of Bitcoin, nowadays it is the most commonly used application of Blockchain technology [1].

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This technology works on distributed ledger technologies (DLT), where, multiple entities hold a copy of ledger and all participants are naturally permitted to contribute. These transactions are stored in a distributed ledger in a series of blocks [5] and participants are called nodes. All the nodes in the network have a copy of all the transactions occurred in the network. In DLT all the nodes agree on a common truth, as the correctness of ledger, any change in the ledger made by any node have to be accepted by all other participants in the network [6].

Smart contracts are small pieces of codes, which are executed when a certain specified condition comes true. These smart contracts are written in Turing-complete languages that run on the blockchain platform [6]. We can say that, it's a self-executable digital contract that releases digital payments once the conditions fulfill the requirements. There are many blockchain platforms available to write the smart contracts but the most used are Ethereum based [7]. There are many fields in which smart contracts are being used but in our systematic mapping we will only focus on the use of smart contracts in software engineering.

In recent years we have seen a huge increase in the number of software development companies, numbering more than 100k software and I.T companies including small and medium-sized [8]. One can say that software companies arena is dominated by small and medium size organizations [9]. Now every company wants to have more clients but the domains are getting more complex and in a wider range, and small companies cannot have enough employees to cover all the fields or business aspects. To meet these requirements, outsourcing to third-party contractors is a regular practice is software arena [10]. However, in global software development several concerns appear including real competence to perform the work to be done and trust appear apart from traditional issues like requirements stability. This later problem is even more tangible in global settings [11]. In this scenario, smart contracts can play a crucial role in outsourcing governance so none of the parts can breach or make changes to the contract [8].

This interaction between smart contracts and software engineering seem to be a promising field to researchers and practitioners alike. However, in spite of the attractiveness of the field and its potential, to the best of authors' knowledge, there is not a systematic literature review devoted to identify opportunities and potential problems in this interaction. Literature devoted efforts in literature reviews on Blockchain [1] or smart contracts [7] both from a general or business specific perspective [12–17], however, as stated before there are not previous literature reviews on Blockchain based smart contracts and their application in Software Engineering. This paper is aimed to bridge this research gap.

The objective of this systematic mapping is to research the use of smart contracts in software engineering. We aim to study the prospective problems or opportunities facing in software engineering, while using smart contract. The mapping study will help us to find the problems in blockchain based smart contracts in software engineering and its possible solutions.

2 Research Methodology

The systematic mapping method was used to explore the studies related to the use of blockchain based smart contracts in software engineering. Our study follows the guidelines by Petersen et al. [18]. By means of this work, we will be able to find the exact studies to map, the important papers and articles that will help us to answer our research questions. The purpose of this study is to structure and characterize the state of the practice on smart contracts applied to software engineering, analyzing previous works published in the literature to provide an overview of the topic and to help discover potential gaps for future research. Due to the breadth of the topic, a systematic mapping study was selected by authors to identify and categorize all relevant research papers (referred to as primary studies) related to this topic. Authors followed these steps to conduct the systematic mapping.

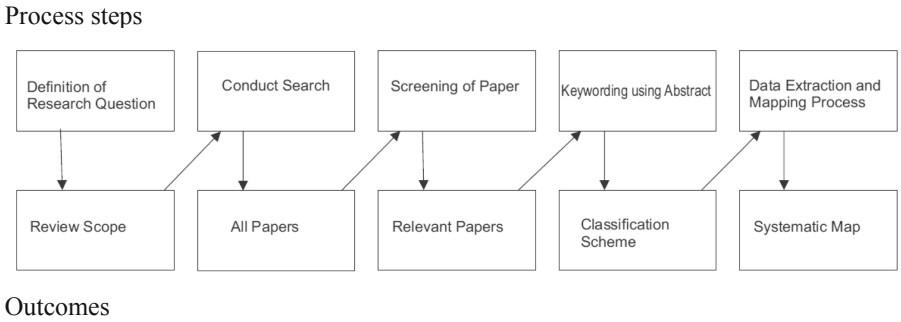

Fig. 1. Systematic mapping process

We followed the steps specified in the Fig. 1 to perform the systematic mapping. The process starts with defining the research questions and searching for relevant papers, followed by screening of papers, reading the abstract and extraction of data for mapping. All the steps produce results accordingly and the final result is in fact, a systematic map of the topic.

2.1 Goals and Research Questions

The goal of our research is to gain an insight into the problems and opportunities of using Blockchain smart contracts in software engineering. So in order to get an overview of this subject in a structured and sound way, authors define three research questions.

RQ-1: What are the challenges or benefits of using Blockchain based smart contracts in software engineering?

RQ-2: What are the most reported uses of blockchain based smart contract in software engineering?

RQ-3: What aspects of software engineering are most affected by initiatives in blockchain based smart contracts?

2.2 Study Protocol

Regarding the keywords for the search, after some exploratory searches using different combination of keywords, the researchers jointly established the final string to be used in the search for papers in the databases. Although small modifications in the syntax were performed, the general string was:

("smart contract") AND ("blockchain") AND ("software engineering")

With regards to databases, the following databases were used to find relevant literature on the topic:

- ACM Digital Library (http://dl.acm.org)
- IEEE Explore (https://explore.ieee.com)
- SpringerLink (https://link.springer.com)
- ScienceDirect (https://www.sciencedirect.com/)
- Wiley Online Library (https://onlinelibrary.wiley.com).

This set of sources was chosen by authors, given that they are among the most relevant sources of articles within the broad field of computing and because they are accessible using institutional accounts. The search was performed at the beginning of 2019 in the aforementioned databases using Zotero as a reference management tool in order to store studies and also to avoid duplications.

Inclusion and exclusion criteria were stablished in order to exclude articles and studies which are not relevant to answer research questions stated before. Table 1 depicts the inclusion and exclusion criteria that authors implemented in this systematic mapping:

Table 1. Inclusion and exclusion criteria fort the mapping

Inclusion criteria	Exclusion criteria
The papers are in software engineering area in which the research scope being the use of blockchain smart contracts in this filed	Studies not written in English
The full text of the paper is available	The full text of the paper is not available
The paper is related to smart contracts problems or challenges in software engineering	The papers are from other fields of Computer Science
The paper is showing the possible solutions of smart contract problems in software engineering	Non-technical papers

We applied the following three filters to identify the specific papers answering our research questions:

- **Filter 1:** The resulting papers of the search string, have been scanned by reading the title, keywords, abstract, results, conclusion, number of citations, and year of publication and by applying inclusion/exclusion criteria from Table 2.
- **Filter 2:** We then read full text of the papers that passed the filter 1.

- **Filter 3:** We studied the papers that we filtered out from filter 2. Then we included those papers, which actually describe the benefits and challenges of use of Smart Contracts in Software Engineering.

For our study, authors followed a systematic mapping, depicted in Fig. 2. In this regard, we used keywords to reduce the time needed to map the classification scheme to make sure that we include all the studies, which are related to our research. This search contains two steps. In the first step we read the abstracts and keywords of the selected papers to check the contribution of that paper, identifying what are the main goals of each paper and what aspects it is exploring. This helps to classify the papers in categories. When abstracts not enough to get the understanding of the selected paper then the reviewer can also go through the introduction and conclusion of the papers. Finally, when the keywords have been chosen, then they can be clustered to form categories for the map.

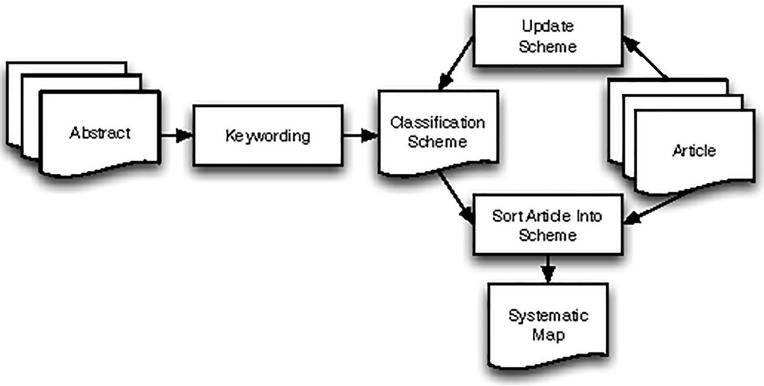

Fig. 2. Classification scheme

In our study, authors classify papers into three different categories, Research Scope, contribution type and research type. Each consisting of a set of categories to which we can map the papers. These categories are presented and defined in the following tables:

Table 2. Research scope

Category	Description
Possible uses	In this category, only the uses of the smart contracts are discussed
Opportunities	This category contains articles with different opportunities
Compatibilities	This category includes compatibility of the smart contracts in current software engineering practices
Aspects	This category includes aspects, which are influenced by mart contracts in software engineering

Table 3. Contribution type

Category	Description
Process	A process describes the activities, action and their work flow
Tool	A software tool is developed to support different aspect of software variability
Model	How things should be done is describe in this model
Technique	It is used to achieve the specific task. It could come accompanied with a support tool

Table 4. Research type

Category	Description
Solution proposal	In which the solution of the problem is proposed
Opinion paper	Someone express the personal opinion
Experience paper	What and how something has been done in practice
Validation research	Technique not yet been implemented in practice and novel
Evaluation research	It is shown that how the techniques are implemented

3 Results

Table 5 presents results of the search performed in the different databases including papers filtered in each of the three steps implemented:

Table 5. Results obtained in the different databases and steps

Source	*Initial*	*Step 1*	*Step 2*	*Step 3*
ScienceDirect	22	13	1	1
IEEE	25	0	0	
ACM Digital Library	142	11	11	7
Wiley (Online Library)	4	0	0	0
Springer	178	4	4	0
TOTAL	*371*	*28*	*16*	*8*

Apart from results themselves, it is also worth to present frequencies in each aspect. That is, the Analysis of the outcomes presenting the frequencies of publications for each category. It results in concluding which categories have been highlighted in past research and then, to find gaps and possibilities for future research work. This is further demonstrated by x-y coordinates scatterplots with bubbles in category intersections. The size of the bubble depends on the number of articles that are pair in each category, corresponding to the bubble coordinates. Figure 3 presents the information in a graphical way:

During the classification process, we sorted the articles to the scheme adopted. In this process, we used Excel where we classified different articles in classes defined

previously in Tables 2, 3 and 4. The analysis shows the frequency of the papers in the past and the research gaps in these. To show this research frequency graphically, we used bubble plot. Bubble plot is a two-dimensional plot where observation data is shown in circles. The size of the bubble shows the number of articles or papers in each category in Fig. 3.

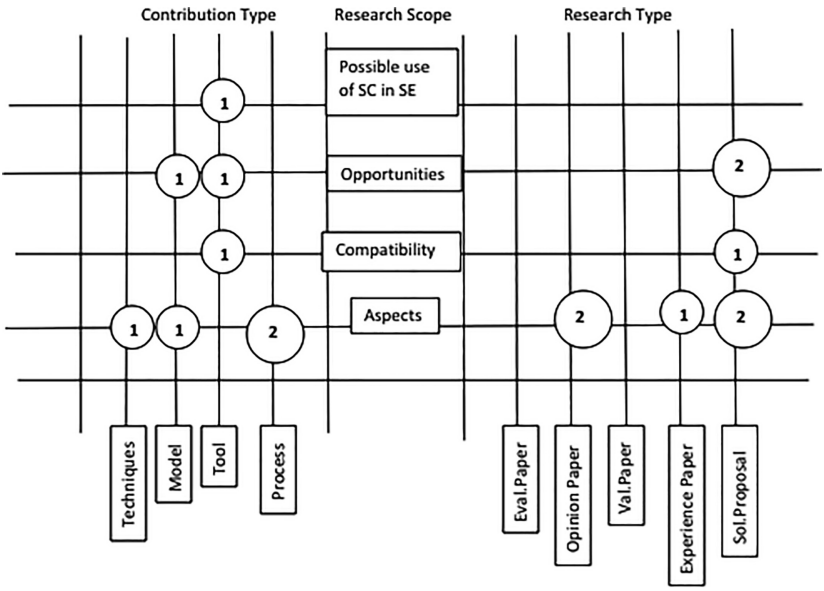

Fig. 3. Bubble plot of the distribution of contributions among the three criteria

The plot clearly shows that the number of Experience papers, Solution proposal and Processes are more in numbers. All of these papers are with different opportunities and aspects. In research type we found more papers in Experience and opinion papers. Whereas in contribution type, we found more papers which are describing the process. There are fewer papers in other aspects and opportunities, therefore a need to do further research in those areas.

4 Analysis and Discussion

In this section, research questions are answered in an isolated way by authors as follows:

RQ-1: What are the challenges or benefits of using Blockchain based smart contracts in Software Engineering?

A set of challenges when applying Blockchain based smart contracts in software engineering was reported by literature. The first challenge is the need to find

recognized professionals with specialized skill in Blockchain and software engineering at the same time [19]. This talent shortage has an impact in industry and affects software process in a negative way [5].

On the other hand, the main purpose of using Smart Contract is to enhance software security. To prove this, some testing is required to check whether the Smart Contract is able comply with legal systems involved. Then Blockchain transactions also have to test that it really does not allow to double spending.

In perspective of challenges, one of the key challenges is how to preserve security while developing smart contracts. Several known attacks exploited the inflexibility of smart contracts in attempts to steal digital currency from users [7]. For this reason, there should be a strategy to prevent such attacks.

Nowadays outsourcing in software development is very common. Hence, the developer and employers need to establish trust between themselves. It's a difficult task to do it manually but, with the help of inclusion of smart contracts this problem can be mitigated [6].

RQ-2: What are the most reported uses of blockchain based smart contract in software engineering?

In existing software development systems, the involvement of human in the loop for verification of different tasks is a must. This leads to lack of automated reward collection system, which is crucial for mutually untrusted parties to collaborate [20]. An automated reward collection system is built using Smart Contract, which automatically runs tests and produces the results. Cyclometric complexity is another application of smart contracts, which helps to identify the code bugs and helps in predicting the complexity of the code. Similar to that, the proposed digitizability complexity helps to understand the complexity of the statement and hence it refrains complex codes before the design/development state starts [5]. Additionally, if the developer is outsourced by the employer, then, to build trust between the parties a smart contract based system is introduced. Through this, both the developer and employer are able to benefit from a secured relationship [8].

RQ-3: What aspects of software engineering are most affected by initiatives in blockchain based smart contracts?

Singi in [21] stated that software development is becoming a distributed process rapidly, with small teams working virtually from their locations. When they work on projects, sometimes they add third party codes in software products without reporting to their team lead. This could lead to a low quality of the final product, which is not good for the company's reputation. To comply with this, a blockchain and smart contract based infrastructure is proposed. This will keep track of the developers who will add third party code or components to the final product. So, if that open source code is non-compatible, it will advise them with regards to best practices and mitigating actions. Before the development process begins, the consultants can check the coding complexity involved in the development process using smart contracts [5]. If a new piece of software is required to be developed or just modified, then the employer just can upload his work with the reward and the developer who will be interested will accept it. Then he will develop the software and deliver to get his reward. So, there will be no need of any mediator company between employer and employee [8].

5 Conclusions, Limitations and Future Work

In this paper we illustrated the use of blockchain based smart contracts in software engineering. The main motivation of this study was to examine how the smart contracts can be beneficial for software engineering and underline possible rooms of improvement of fields of research. Maybe the most important aspect underlined by our study is the need of competence in the field. Although talent wars are not new in software arena e.g. [22], our study underlines the need to develop professionals in the area. This leads to identify avenues of research in the talent management but also in the educational field.

The aim of this study was to structure and characterize the state of the practice on software engineering and smart contracts, analyzing previous works published in the literature to provide an overview of the topic and to help discover potential gaps for future research. For that purpose, the authors decided to use a general search string to not bias the study towards any specific field inside software engineering. However, including in the scope of this research knowledge areas inside software engineering (e.g. Requirements Engineering) would have provided a richer set of primary studies and should be considered for a future work.

Finally, another aspect that could threat this study is researcher bias. This could have affected the selection of primary studies, their classification and the accuracy in data extraction. To reduce this threat of validity, both researchers devoted their time in the selection and classification of primary studies designing and implementing a protocol for the inclusion and exclusion criteria along as resolving disagreements by discussion.

References

1. Yli-Huumo, J., Ko, D., Choi, S., Park, S., Smolander, K.: Where is current research on blockchain technology?—A systematic review. PLoS ONE **11**, e0163477 (2016). https://doi.org/10.1371/journal.pone.0163477
2. Zheng, Z., Xie, S., Dai, H.-N., Chen, X., Wang, H.: Blockchain challenges and opportunities: a survey. Int. J. Web Grid Serv. **14**, 352–375 (2018). https://doi.org/10.1504/IJWGS.2018.095647
3. Zheng, Z., Xie, S., Dai, H., Chen, X., Wang, H.: An overview of blockchain technology: architecture, consensus, and future trends. In: 2017 IEEE International Congress on Big Data (BigData Congress), pp. 557–564 (2017). https://doi.org/10.1109/BigDataCongress.2017.85
4. Hegedus, P.: Towards analyzing the complexity landscape of solidity based Ethereum smart contracts. In: 2018 IEEE/ACM 1st International Workshop on Emerging Trends in Software Engineering for Blockchain (WETSEB), pp. 35–39 (2018)
5. Pradeepkumar, D.S., Singi, K., Kaulgud, V., Podder, S.: Evaluating complexity and digitizability of regulations and contracts for a blockchain application design. In: Proceedings of the 1st International Workshop on Emerging Trends in Software Engineering for Blockchain, pp. 25–29. ACM, New York (2018). https://doi.org/10.1145/3194113.3194117

6. Wang, P., Liu, X., Chen, J., Zhan, Y., Jin, Z.: QoS-aware service composition using blockchain-based smart contracts. In: Proceedings of the 40th International Conference on Software Engineering: Companion Proceedings, pp. 296–297. ACM, New York (2018). https://doi.org/10.1145/3183440.3194978
7. Macrinici, D., Cartofeanu, C., Gao, S.: Smart contract applications within blockchain technology: a systematic mapping study. Telemat. Inform. **35**, 2337–2354 (2018). https://doi.org/10.1016/j.tele.2018.10.004
8. Król, M., Reñé, S., Ascigil, O., Psaras, I.: ChainSoft: collaborative software development using smart contracts. In: Proceedings of the 1st Workshop on Cryptocurrencies and Blockchains for Distributed Systems, pp. 1–6. ACM, New York (2018). https://doi.org/10.1145/3211933.3211934
9. Sanchez-Gordon, M.-L., O'Connor, R.V., Colomo-Palacios, R.: Evaluating VSEs viewpoint and sentiment towards the ISO/IEC 29110 standard: a two country grounded theory study. In: Rout, T., O'Connor, R.V., Dorling, A. (eds.) SPICE 2015. CCIS, vol. 526, pp. 114–127. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-19860-6_10
10. Casado-Lumbreras, C., Colomo-Palacios, R., Ogwueleka, F.N., Misra, S.: Software development outsourcing: challenges and opportunities in Nigeria. J. Glob. Inf. Technol. Manag. **17**, 267–282 (2014). https://doi.org/10.1080/1097198X.2014.978626
11. Colomo-Palacios, R., Casado-Lumbreras, C., Soto-Acosta, P., Misra, S., García-Peñalvo, F.J.: Analyzing human resource management practices within the GSD context. J. Glob. Inf. Technol. Manag. **15**, 30–54 (2012)
12. Wang, Y., Han, J.H., Beynon-Davies, P.: Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. Supply Chain Manag. Int. J. **24**, 62–84 (2018). https://doi.org/10.1108/SCM-03-2018-0148
13. Queiroz, M.M., Telles, R., Bonilla, S.H.: Blockchain and supply chain management integration: a systematic review of the literature. Supply Chain Manag. Int. J. (2019). https://doi.org/10.1108/SCM-03-2018-0143
14. Taylor, P.J., Dargahi, T., Dehghantanha, A., Parizi, R.M., Choo, K.-K.R.: A systematic literature review of blockchain cyber security. Digit. Commun. Netw. (2019). https://doi.org/10.1016/j.dcan.2019.01.005
15. Li, J., Greenwood, D., Kassem, M.: Blockchain in the built environment and construction industry: a systematic review, conceptual models and practical use cases. Autom. Constr. **102**, 288–307 (2019). https://doi.org/10.1016/j.autcon.2019.02.005
16. Drosatos, G., Kaldoudi, E.: Blockchain applications in the biomedical domain: a scoping review. Comput. Struct. Biotechnol. J. **17**, 229–240 (2019). https://doi.org/10.1016/j.csbj.2019.01.010
17. da Silveira, F., Neto, I.R., Machado, F.M., da Silva, M.P., Amaral, F.G.: Analysis of Industry 4.0 technologies applied to the health sector: systematic literature review. In: Arezes, P.M., et al. (eds.) Occupational and Environmental Safety and Health. SSDC, vol. 202, pp. 701–709. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-14730-3_73
18. Petersen, K., Vakkalanka, S., Kuzniarz, L.: Guidelines for conducting systematic mapping studies in software engineering: an update. Inf. Softw. Technol. **64**, 1–18 (2015). https://doi.org/10.1016/j.infsof.2015.03.007
19. Porru, S., Pinna, A., Marchesi, M., Tonelli, R.: Blockchain-oriented software engineering: challenges and new directions. In: 2017 IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C), pp. 169–171 (2017). https://doi.org/10.1109/ICSE-C.2017.142

20. Rocha, H., Ducasse, S.: Preliminary steps towards modeling blockchain oriented software. In: Proceedings of the 1st International Workshop on Emerging Trends in Software Engineering for Blockchain, pp. 52–57. ACM, New York (2018). https://doi.org/10.1145/3194113.3194123
21. Singi, K., Pradeepkumar, D.S., Kaulgud, V., Podder, S.: Compliance adherence in distributed software delivery: a blockchain approach. In: 2018 IEEE/ACM 13th International Conference on Global Software Engineering (ICGSE), pp. 126–127 (2018)
22. Radant, O., Colomo-Palacios, R., Stantchev, V.: Analysis of reasons, implications and consequences of demographic change for IT departments in times of scarcity of talent: a systematic review. Int. J. Knowl. Manag. **10**, 1–15 (2014). https://doi.org/10.4018/ijkm.2014100101