A comparative overview on Blockchain-based applications for Software Engineering

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***Abstract*—In less than a decade, blockchain technology has seen a rise in popularity due to its innate security properties and overall disruptive potential. Surpassing its initial use in fintech and cryptocurrencies, blockchain and similar distributed ledger technologies have been used in healthcare, supply chain management, and within the public sector. However, recent studies show that blockchain-based technologies have found uses in software engineering (SE) as well. Namely, blockchain technologies can be used in all phases of the Software Development Life Cycle - software requirements, the engineering/development process, software testing and quality assurance, as well as software maintenance.**

In this paper, by utilizing existing literature regarding blokchain technologies and SE, we provide insight on which type of blockchain technology could be beneficial for each of the use-cases in SE, highlighting the advantages and potential disadvantages. We discuss various consensus mechanism support, smart contracts technology, as well as storage solutions, tu finally give recommendations for identified use-cases.

***Index Terms*—Blockchain, Smart Contracts, Software Engineering**

I. Introduction

Since the publication of the Bitcoin whitepaper [1] in 2008, blockchain technologies (BCTs) are gaining popularity not just in finance and cryptocurrencies. The rise of various healthcare, supply chain, government and public sector solutions powered by BCTs show us that the underlying technology firstly presented in Bitcoin is disruptive [2, 3]. This rise in popularity has brought Blockchain to the attention of researchers to its application in software engineering (SE). Indeed, the properties of blockchain paved way for blockchain-oriented software engineering (BOSE) [4, 5], in which specific SE practices should consider blockchain or similar technologies as a viable option within the Software Development Life Cycle (SDLC).

The uses of blockchain for different SE applications have been studied in previous literature [6, 7], however, this research is limited only to literature overview papers. We are motivated to provide technology suggestions for the identified uses of blockchain in SE, due to the fact that many blockchain technologies and platforms can be distinguished, each one having its own advantages and disadvantages.

Our main research questions arise from the emerging blockchain-based solutions in SE. Indeed, the number of papers found in literature regarding potential uses of blockchain-based solutions in SE is increasing [7]. Therefore, we pose the following research questions on order to fill the gap of using concrete technologies for specific SE use-cases.

RQ1: What is the trend of utilizing blockchain in SE?
RQ2: What blockchain technologies and platforms are used when developing SE applications?
RQ3: What are the most common use-cases for blockchain technologies in SE?
RQ4: What insight can we gain by comparing different blockchain technologies for different applications in SE?

In this paper, we firstly provide a brief overview of blockchain technologies and blockchain-based use-cases in SE. Afterwards, we identify distinct existing blockchain-based platforms and solutions to these use-cases, relying on the requirements of each case. We provide insights on the factors such as implementation complexity, a need consensus mechanism(s) and smart contracts, as well as overall advantages and disadvantages of utilizing blockchain at all.

II. Brief Blockchain overview

The rise of BCTs lead to an entirely different approach in which data is being accessed, processed, and stored. In addition, due to the linked hash- and asymmetric cryptography-based security properties paired with distributed consensus, various solutions in the Information and Communication Technology (ICT) sector based on blockchain can improve current data security, especially when compared with similar centralized ICT solutions. The blockchain itself can therefore be viewed as a distributed ledger, in which all events, termed transactions, are stored in cryptographically linked blocks [8] which cannot be modified without extreme difficulty [9]. The data within the transaction, e.g. changes to a electronic health record (EHR), learner certificate, current version of a public document [10–12], is grouped with an unique cryptographic signature. This grouping of data, digital signature and hash values ensures that the blockchain is append-only. Differently from traditional, centralized ICT solutions, where all the data is being kept in a single, often known location, the blockchain is configured in a manner to be simultaneously distributed among all active members of the peer-to-peer (P2P) network. These members are called nodes.

The blocks in the blockchain can hold either a single or multiple transactions (defepngin on the technology itself), and are often viewed as a data structure. In addition to the transaction data and the block header with and ID

and time stamp, a block contains a hash pointer to the previous block as well. These blocks hence form a chain, tracing back all the way to the first block, which is called the genesis block. The process of adding a new block to the blockchain with validated transactions is managed by all (or a selected set) of nodes. This process is called a distributed consensus mechanism. This is different from a centralized system, in which an separate entity exist which controls the data flow. The consensus mechanism is determined by the technology itself. In Bitcoin's Proof-of-Work mechanism, nodes compete for correct transaction validation by solving a processor-heavy puzzle. In Ethereum's Proof-of-Stake, the node which validates transaction can be chosen pseudo-randomly, depending on the node's stake in the network.

A blockchain therefore relies on P2P networks, asymmetric cryptography, and a consensus mechanism. These three pillars secure blockchain transactions and blocks, making them valid. When a validated block is added to the blockchain, an real-time update on the network occurs.

III. Blockchain and Software Engineering

Whereas there exists a plethora of literature regarding BCT-based solutions in fintech, healthcare, supply chain management, and the public sector, articles regarding blockchain and SE is still lacking [13]. However, studies such as [4], covering over 1000 repositories on the popular site GitHub identifies an increase in projects regarding the two most popular blockchain plaforms, namely Bitcoin and Ethereum. This was the basis for our comparative research regarding BCT-based application in SE.

It is important to note that blockchain is not a single technology - the term refers to different forms of distributed databases with variations in their technical and governance arrangements and complexity [14]. For instance, the Hyperledger blockchain is often termed Distributive Ledger Technology (DLT). This was the basis for the first part of our search string. The second part referred to SE or SDLC. Using the boolean operators for the search, our final search string is as follows:

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(~blockchain OR distributive ledger
OR ~DLT) AND (software engineering OR
~SDLC)
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where the ~ sign refers to synonyms. We performed the search process using IEEExplore, ACM Digital Library, Springer Link and Google Scholar libraries from 2015 to 2022.

Table I
Initial search results.

Library	Results
ACM Digital Library	2,729
Springer Link	5,985
IEEExplore	12,607
Google Scholar	20,200

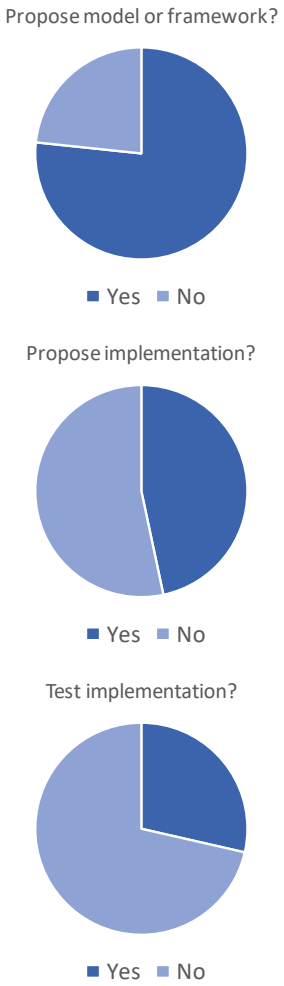

Figure 1. Considered papers and implementation percentage.

After discarding papers unrelated to the Computer Science and Software Engineering fields, different versions of the same paper, a total of 34 papers have been considered, including four existing literature overview papers, grouped into seven research topics, similar to [6]:

- Software Requirements
- SE Process
- Software Testing
- Software Quality
- Software Maintenance
- Configuration and deployment management
- Professional practices and guidelines

Excluding the four literature overview papers, the 30 papers considered have been further analyzed if they propose a theoretical model and/or implementation for the given topic, as shown in Fig. 1. A total of 23 papers (77%) propose a model or framework for a blockchain-based solution in SE. However, only 14 papers (47%) propose an implementation and out of those only 4 papers (29%, or 13% overall) have some kind of test implementation in the paper itself.

Table II
BLOCKCHAIN SE USE-CASES.

Use-case	Description	Type of blockchain	Alternative
Software Requirements	Blockchain enables an auditable history of requirements that is visible and verifiable by authorized users, such as partners and customers.	Permissioned, Hyperledger	Permissioned Ethereum fork
SE Process	Blockchain which communicates with services such as GitHub, agile-board tools etc. Developers can be miners, testers can be validators.	Ethereum	Any blockchain that supports smart contracts.
Software testing	Blockchain to handle issues in software testing such as the lack of transparency and the difficulty in establishing mutual trust between testers and software buyers/sellers.	Permissioned, hybrid. Hyperledger-like	Ethereum fork
Software quality	Blockchain to determine skill level of developers/testers. Platform to empower software teams to dynamically propose sustainability and quality metrics which are then used to validate sustainable code.	Permissionless, Bitcoin-like.	Ethereum
Software maintenance	Blockchain for continual software maintenance, even beyond regular maintenance. Open-source community.	Permissionless, Ethereum-like.	Hyperledger
Configuration and deployment management	Blockchain-based software license validation.	Bitcoin-like	Ethereum
Professional practices and guidelines	Platform for collaboration on open-source code commits and administration. Verification process with miners.	Permissionless, Ethereum-like	Bitcoin-like

IV. BLOCKCHAIN IN SE USE-CASE DISCUSSION

Out of the seven identified research topics and propositions in the literature overview, we present viable use-cases for Blockchain-based solution in SE [6]. For each use-case we propose a type of blockchain, with an alternative. The results are shown in Table 2.

In the software requirement process, every requirement change could be considered a transaction, and therefore kept in the blockchain. All records can therefore be accessed by authorized users, both from the development teams, as well as authorized clients, customers, partners and stakeholders [15]. For the SE process itself, a blockchain could be setup which can communicate with tools such as repositories (e.g. GitHub), or project management tools like agile boards or similar [16–18]. In addition, when testing a functionality, developers act as miners, while testers can be transaction validators. Regarding software testing, blockchain can overall improve transparency issues and lack of trust between tester teams. This type BCT-based solution would be a permissioned ledger, best implemented in Hyperledger.

Software quality issues can be handled by a BCT by applying a solution to determine the skill level of developers and/or testers. Applying an Ethereum-like permissionless blockchain, issues in software maintenance can be addressed [19]. For software configuration and deployment, a Bitcoin-like custom blockchain can be used for software license validation.

Finally, regarding professional practices and guidelines in SE, a blockchain-based platform can be used for open-source code commits and administration, with an incentive mechanism with miners for the verification process [20, 21]. This type of blockchain can be either Ethereum- or Bitcoin-like.

V. CONCLUSION

In this paper, we have firstly conducted a literature overview of topics regarding blockchain and software engineering. Since the novelty of the technologies and limited application in SE, a total of 34 papers including four review papers have been selected as a basis for furhter use-case analysis. Although only 13% of the selected papers present a some sort of implementation of blockchain in SE, seven possible topics for blockchain and SE have been identified, which corresponds to previous literature overview [6].

In future work, we intend to start implementing blockchain-based solutions for Belgrade Metropolitan University and it's study program for Software Engineering. Namely, we intend to develop a blockchain-base code repository which can be used in the examination process. Furthermore, we intend to develop a solution for small-scale voting within the Departments of the University.

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