The Use of Blockchain in Financial Area:
A Systematic Mapping Study

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ABSTRACT

Blockchain is a technology for decentralized transactions that has been widely used with cryptocurrencies such as Bitcoin. Many studies have been conducted in the last decades, approaching cryptocurrencies, and blockchain technology, more strongly in the context of financial transactions. However, little has been done to provide a panoramic view of the current literature; as a consequence, a careful understanding of the state-of-the-art papers remains limited and inconclusive. This study, therefore, aims to classify and provide a thematic analysis of studies on the use of blockchain in the context of financial area, thus allowing to create a clear systematic map of the current literature, and identify challenges and research opportunities. To achieve these objectives a systematic mapping study (SMS) approach was performed to answer 6 research questions. In total, 1884 studies were reviewed from 6 data sources, being 23 studies selected after a careful filtering process. The main findings were: (1) Over 65% of the selected studies concentrated on adopting two blockchain platforms named Hyperledger Fabric and Ethereum; (2) Over 60% used blockchain technology to increase security; (3) Most studies did not reveal the consensus algorithm used; (4) Fintech (or Bank) and loan were the most explored application areas; (5) Over 60% focused on producing prototype rather than frameworks; and (6) most studies were published in conferences. This study can benefit research community by generating a map of the literature, serving as a starting point for future researches. Moreover, this study reports some challenges worth investigating.

CCS CONCEPTS

• **Computer systems organization** → **Real-time system architecture**; • **Software and its engineering** → *Designing software*; • **Security and privacy** → **Distributed systems security**.

KEYWORDS

Blockchain, Bank, Financial, Fintech, inter-bank, Application security, Financial technology

1 INTRODUCTION

Transactions between parties in current systems of the financial area are usually conducted in a centralised way, requiring the involvement of a trusted third party (e.g., a bank) [4]. Blockchain technology emerges as an alternative to enabling decentralized transactions, avoiding the involvement of a central regulatory party. Although it can be used for various purposes, it is in the financial area that it has been most used. In 2008, Nakamoto [30] showed the feasibility of using blockchain technology in real-world settings, proposing a peer-to-peer platform enabling the payments between people without a third party to control the system. This article is emblematic in showing the starting point for the emergence of Bitcoin cryptocurrency.

In practical terms, *blockchain technology* could be briefly defined as a list of data blocks that are linked using cryptography. This chain of blocks is maintained in distributed databases, where each data block points to the next block, and so on, from the first to the last data block. Many studies have been proposed in the last decades using this technology, mainly to support financial transactions.

Blockchain has received a lot of attention in recent years, given that to the innovation offered to keep the data safe. Basically, the blockchain is a distributed database, each transaction is verified and, after stored, it is not possible to modify the transaction anymore. Because of this nature, many of other sectors non-financial and specially financial have interest to learn and apply the blockchain in their systems. The power offered by blockchain matched with the financial requirements, many companies are investing in research, testing or applying the technology. Big companies are creating and evolving the blockchain like Linux Foundation, IBM, Intel and also other financial institutions like central banks of China, Singapore, the UK, the US, as well as banks like J.P. Morgan, Barclays Bank, Bank of England [14] among others. According to Tapscott [38] blockchain can improve the services, increase the transparency of formation and save money. The companies believe that the blockchain reduce the complexity of bank processing and replace expensive database and middleware processing applications. Blockchain technology also supports fast multi-entity transaction settlement and clearing, and enhances fraud prevention and anti-money laundering protection [41].

However, little has been done to provide a panoramic view of the current literature; as a consequence, a careful understanding of the state of the art papers remains limited and inconclusive. This study, therefore, aims to classify and provide a thematic analysis of studies on the use of blockchain in the context of financial area, thus allowing to create a clear systematic map of the current literature, and identify challenges and research opportunities. To achieve these objectives a systematic mapping study (SMS) approach was run to answer 6 research questions. In total, 1884 studies were reviewed from 6 data sources, being 23 studies selected after a careful filtering process. Our study is based on well-established review guidelines [25] [32] and already validated methodologies, such as those in [8] [17].

The rest of the paper is structured as follows: The Related Work (Section 3) presents the related papers with this systematic mapping study; The Methodology (Section 4) shows the methodology applied in this research describing the research questions and search strategy; The Study Filtering (Section 5) describes the process applied to

filter and select the primary studies; The Results (Section 6) presents the results obtained from the previous steps; Discussions and Challenges for Future Research (Section 7) discusses the results and challenges for the future and; The limitations (Section 8) presents the limitations of this research; Conclusions and Future Works (Section 9) presents the conclusions comparing the result and future works in the next steps. Acknowledgment (Section 10) presents the acknowledgment of the authors by the support received.

2 BACKGROUND

This section presents the required background to understand this study. To achieve this objective, the blockchain Technology (Section 2.1) and Systematic Mapping Study (Section 2.2) are presented as follows.

2.1 Blockchain Technology

The blockchain technology was applied in large scale when Bitcoin was introduced by Nakamoto [30] in 2008. This technology enabled the creation of a decentralized digital currency called Bitcoin and it enabled the creating of decentralized payment system without a third party to manage the transactions. It is a distributed ledger that provides append-only data that can be verified and it is tamper-proof. The transactions are verified and approved by distributed nodes, after this, the transactions are recorded in a block of transactions, each block is identified by a cryptographic hash and stored in chronological order, creating a chain of block.

2.2 Systematic Mapping Study

Systematic Mapping Study (SMS) is used to structure a research area [32]. The SMS is used to create an overview of research area, classifying and counting the studies related to the categories. The SMS identifies the gaps that are not covered by the current researches and offers the insights for new researches.

3 RELATED WORK

This section has the purpose to show and compare other studies that used systematic mapping study and blockchain. By a comparing the studies it is possible to identify the differences and similarities. These process also can be used to identify the opportunities to expand the research in order to cover the identified gaps. To research the related work it was applied the search string *"Blockchain AND Systematic Mapping Study"* in the same databases used to search the primary studies. The related work were selected according to similarity with this research.

In total, 6 studies were selected. To compare the studies the following compare criteria (CC) was developed and the results are in Table 1.

- **Financial Area (CC01):** Studies related with financial area;
- **Specific area of interest (CC02):** Studies about a specific area;
- **Consensus algorithm applied (CC03):** Studies that report the consensus algorithms applied;
- **Reason to apply blockchain (CC04):** Studies that report the motivation to apply blockchain for their requirements;

Overview of selected studies:

Table 1: Comparative analysis of the related works selected

Related Work	Comparison Criteria			
	CC1	CC2	CC3	CC4
The study proposed	●	●	●	●
Abrishami and Elghaish [2]	○	●	●	◐
Agbo et al. [3]	○	●	●	●
Alharby et al. [4]	○	○	○	◐
Macrinici et al. [26]	○	○	●	○
Tribis et al. [40]	○	○	○	●
Yli-Huumo et al. [46]	○	○	◐	◐

● Completely Match ◐ Partially Match ○ Do not Match

- **Abrishami and Elghaish [2]** applied a literature review in a construction industry. The authors present a development framework to build a blockchain solution using Hyperledger Fabric.
- **Agbo et al. [3]** applied a systematic review to identify the state of the art in the development of blockchain applications for healthcare.
- **Alharby et al. [4]** applied a systematic mapping study focused on identifying how the academic researchers have taken up smart contract technologies and what were the outputs.
- **Macrinici et al. [26]** applied a systematic mapping study analysing 64 papers of variety areas. The study mapped the state of research applying blockchain identifying the trends, also categorized the problems and solutions applied to using smart contracts and blockchain.
- **Tribis et al. [40]** applied a systematic mapping study analysing 40 papers to explore and identify the gaps of use of blockchain for supply chain management. The conclusion shows that 45.71% of studies concentrated in propose a solution to supply chain management designing new blockchain based frameworks but many of those studies has a lack of real performance evaluation on the industrial context.
- **Yli-Huumo et al. [46]** applied a systematic mapping study analysing 41 papers of varied areas. The study identified the gaps of the studies, for example, a lack of concrete evaluation of the solutions topics that were not studied like throughput and latency. The studied provided some recommendations for future researches focusing in the technical challenges.

In this research, it was focused on finance area and on discovering how the blockchain is applied, what consensus is the most common and why it was selected. Indeed, it aims to discovery what methods of research have been applied and where the studies have been published.

4 METHODOLOGY

In order to apply the systematic mapping to review the literature and find the gaps [32], this research adopted the follow steps to search and select the primary studies.

4.1 Research Questions

The research questions were used to guide the research. To achieve this objective six research questions (RQ) were defined to explore

different aspects. The Table 2 enumerates all research questions used in this study, it also describes their purposes and related variables.

4.2 Search Strategy

It defines the search terms that match with the objective of the research. These terms were used to identify and reference the studies in the digital libraries. To select the studies it was applied an automatic search process against all the data bases using the search terms previously selected. After identifying the studies, it was applied the criteria to include or exclude the studies as reference. The following steps were applied: (1) selection of databases related with this research, (2) definition of the search string using the main terms and synonyms and (3) definition of the inclusion and exclusion criteria.

4.2.1 Data Sources. In this step, it was defined the electronic databases where studies were published to apply the defined filter. It was selected six databases, displayed in Table 3, the selected databases are related, or they allow to apply filter in computer science or correlated areas, it was also was based on the coverage of their search engine, to find the most relevant journals, conferences, papers, etc.

4.2.2 Search String. The search string used to find the studies on the databases was the combination of the main terms and their synonyms. This combination was applied on each search engine of the each database. The results were used to create a list of studies that could potentially contribute to this systematic review. The search string and synonymous are presented in Table 4.

A combination of main terms and synonyms using the logical operators "AND" and "OR" was created, it resulted in the following sentence:

("Architecture" OR "Design") AND ("Blockchain" OR "Ledger") AND ("BANK" OR "Fintech" OR "Financial" OR "Inter-Bank")

4.2.3 Inclusion and Exclusion Criteria. The studies found by the search string on the data sources form a collection of research of related studies. It was defined the Inclusion Criteria (IC) and the Exclusion Criteria (EC) for this collection. The IC criteria were used to perform a filter in order to find the most relevant studies to be used in the systematic mapping. The EC criteria were created to identify which studies should be removed from the collection.

The IC applied to the studies:

- **IC1:** Related to the search string and research question goal;
- **IC2:** Written in English;
- **IC3:** Published until 2019;
- **IC4:** Available as full papers in digital databases;

Then, the EC applied to the studies:

- **EC1:** Match the keyword in search string but the context is different from research purposes;
- **EC2:** Not written in English;
- **EC3:** The title did not have any specified term in the search string, or even the meaning of the title is completely contrary to the purpose of the issues addressed in the research questions;
- **EC4:** The abstract did not address any aspect of the research questions;

- **EC5:** Appeared in duplicate;
- **EC6:** Do not meet the motivation of the research questions;

5 STUDY FILTERING

To select the most representative studies, it was developed a process to filter the studies. The process consists of performing 8 steps to filter the studies, these steps are explained below.

- **Step 1: Initial Search**. Search and collect the results of the studies from the query applied against the search engines using the search string defined in 4.2.2. In this step it was found 1884 studies from the data sources defined in 4.2.1.
- **Step 2: Impurity Removal (EC1 and EC2)**. Applied the EC1 and EC2 to exclude the studies that do not meet the context of this systematic review.
- **Step 3: Filter by Title and Abstract (EC3 and EC4)**. Applied the EC3 and EC4 to remove the studies that returned as a result from the search string. In this step, the studies that did not match with the criteria EC1 and EC2 and were not related with the research questions were removed.
- **Step 4: Studies Combination**. The filtered studies were joined in the same combination, to proceed to the next step.
- **Step 5: Duplicate Removal (EC5)**. Considering that a study can be found in more than one database, in this step it was applied the EC5 to remove all duplicate studies.
- **Step 6: Addition by Heuristics**. To increase the number of relevant studies, the authors decided to add some studies applying the backward snowballing [32]. These studies were included according to the inclusion and exclusion criteria.
- **Step 7: Filter by Full Text**. All the studies were read completely to apply EC6, excluding the studies that were not related to the research question or to software engineering.
- **Step 8: Study Selection**. Select all the filtered studies as primary studies to answer the RQ's.

The Figure 1 shows the result of each step of the filter process. A total 1884 studies were selected in the initial search, in the second step, after applying the impurity removal criteria, 521 studies were filtered, which led to an amount of 1363 studies removed. Following the filtering process all the studies titles and abstract were revised to check if they match this research, remaining 43 studies. In third and fourth step, the studies were combined to remove duplicates, because the same study returned from different databases guaranteeing that only one study was used. After removing duplicates, more 5 studies were added by heuristics, these studies were not returned from databases in the first search, but they were found when each database was manually reviewed using keywords or applying backward snowballing. In the full text filter, all the studied content was reviewed, 34 studies were filtered in this step. In the last step, it was selected the most representative studies that matched this research, as the result, 23 primary studies were found.

6 RESULTS

This section presents the collected results regarding the formulated research questions.

Table 2: Research Questions and their description and related variables

Research Question	Description	Variable
RQ1: What platforms were studied?	Create a list of platforms that were used by the applications	Tools
RQ2: What was the motivation to apply blockchain?	Clarify what motivated the companies to consider the adoption of blockchain	Purposes
RQ3: What algorithm of consensus was applied?	Identify the most widely used consensus algorithm	Algorithms
RQ4: What were the contributions of studies?	Finds out the area of each contribution of studies	Areas
RQ5: What were the methods of research?	Investigate and understand what methodologies the researchers applied	Research Methodologies
RQ6: Where the articles were published?	Identify venues where studies have been published	Publication Venues
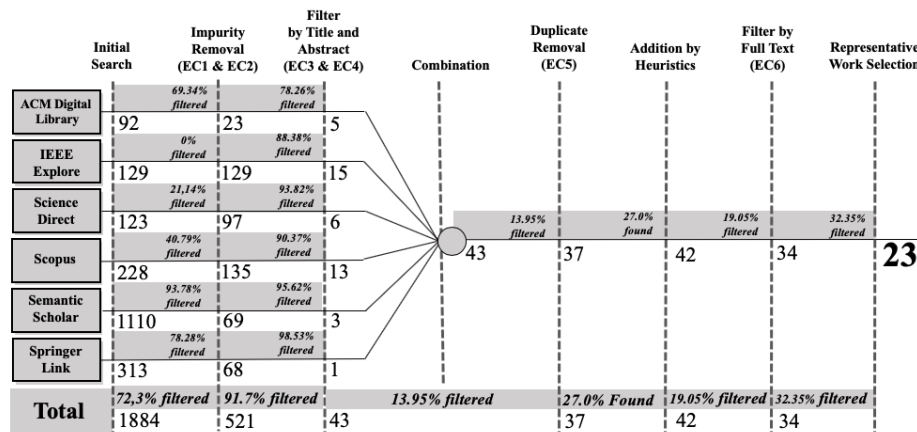
Figure 1: Studies filtered

Table 3: Databases and its digital addresses

Databse	Address
ACM Digital Library	http://dl.acm.org
IEEE Xplore	http://ieeexplore.ieee.org
Science Direct	https://www.sciencedirect.com
Scopus	https://www.scopus.com
Semantic Scholar	https://www.semanticscholar.org
Springer Link	http://www.springerlink.com/

Table 4: Search string main terms and their synonyms

Main Term	Synonym
Architecture	Design
Blockchain	Ledger
Bank	Financial, Fintech, Inter-Bank

Table 5: RQ1: What platforms were studied?

Tool or Framework	Studies	Percentage	Primary Studies
Ethereum	10	43.48%	[22] [15] [9] [33] [28] [29] [31] [18] [12] [7]
Hyperledger Fabric	6	26.09%	[36] [13] [43] [42] [47] [23]
Not Informed	3	13.04%	[24] [27] [45]
BeihangChain	1	4.35%	[41]
Hydrachain	1	4.35%	[41]
Proprietary	1	4.35%	[37]
QTUM	1	4.35%	[6]
Tendermint	1	4.35%	[1]

6.1 RQ1: What platforms were studied?

Table 5 shows the results. The purpose of this RQ was to discover what are the most used platforms in larger scale nowadays. Considering that there is a great number of technologies and some of them are in am early adoption stage or have already been tested by the community and do not point to this way, discarding the use of such technology.

The most used blockchain platform was Ethereum [16]. The Ethereum is an open source blockchain platform created by Vitaly Dmitriyevich, based on the Bitcoin created by Satoshi Nakamoto [30], but with modifications. When using a public network, Ethereum can run millions of transactions per day, supporting executions of smart contract scripts.

The second most used blockchain platform is Hyperledger Fabric [21], this is an open source blockchain platform, it is described according with the web site as: *"an enterprise-grade permissioned distributed ledger framework for developing solutions and applications. Its modular and versatile design satisfies a broad range of industry use cases"*. Created by Linux Foundation in 2016 with the combination of 2 code bases, one of these code bases was created by IBM and the other created by Intel. At the moment, the Hyperledger Fabric is one of many projects under the Hyperledger umbrella.

Finally, the other blockchain platforms mentioned by other studies do not have all the fame of the first contenders. The QTUM [35] is an open source blockchain platform, based on Ethereum blockchain the QTUM promises a significant performance compared to other platforms, the QTUM is also a criptocurrency. The Hydrachain [19] is another blockchain based on Ethereum and

BeihangChain, it uses Byzantine voting and the data collection is carried out concurrently to increase the speed of the process, and thus it has a unique block for the creation process [41]. The Tendermint [39] is another open source blockchain platform, unlike others platforms, Tendermint it is not based on Ethereum and it has its own blockchain platform implementations, it is also a consensus algorithm. One of the studies reported that used a proprietary blockchain implementation.

6.2 RQ2: What was the motivation to apply blockchain?

Table 6 shows the results. The purpose of this RQ was to identify the motivation behind the decisions to test and apply blockchain. The features provided by the blockchain platforms attend the requirements of financial applications in general. In this RQ it was possible to identify the motivations of the studies to apply blockchain features to increase the security of the stored information. The concern with the security (14, 60.87%) makes sense given that the regulatory law like General Data Protection Regulation (GDPR) enforces the financial institutions to keep the data safe avoiding the leak of information.

Table 6: RQ2: What was the motivation to apply blockchain?

Reasons	Studies	Percentage	Primary Studies
Increase security	14	60.87%	[36] [22] [33] [1] [29] [43] [6] [47] [18] [12] [7] [27] [45] [23]
Increase transparency	8	34.78%	[22] [13] [42] [9] [31] [47] [45] [23]
Decentralized solution	5	21.74%	[33] [37] [47] [45] [23]
Integrity of information	5	21.74%	[33] [29] [37] [9] [24]
Avoid fraud	4	17.39%	[22] [41] [6] [24]
Secure sharing of information	4	17.39%	[13] [43] [42] [7]
Guarantee of immutability	2	8.70%	[13] [1]
Privacy of information	2	8.70%	[42] [31]
Avoid duplicate transactions	1	4.35%	[1]

6.3 RQ3: What algorithm of consensus was applied?

Table 7 shows the results. The purpose of this RQ was to know what algorithm of consensus was applied. Given that the consensus is one of the most important aspects of blockchain, this RQ shows that the studies are extremely fragile in this aspect. Most studies do not show the consensus applied, it is not possible to claim if that they had the intension of not reporting or due to lack of knowledge, using the default implementation of the chosen platform.

The Kafka consensus is used in Hyperledger Fabric, it is a permissioned voting-based that provides a crash fault tolerance it is good for the performance but, on the other hand, it is not a Byzantine fault tolerant, which prevents the system from reaching agreement in the case of malicious or faulty nodes [20]. The implementation of Kafka consensus uses the Apache Kafka [5], a distributed streaming platform.

Practical Byzantine Fault Tolerance (PBFT) is a generic algorithm consensus, that allows the distributed systems continue working even if a node in the blockchain network has faulty or acts as a malicious node. These problems are common in a distributed systems, with this implementation the honest nodes arrive in a consensus and the network is not affected by a malicious or faulty node.

Table 7: RQ3: What algorithm of consensus was applied?

Algorithm	Studies	Percentage	Primary Studies
Not Informed	15	65.22%	[22] [41] [15] [9] [33] [28] [29] [42] [31] [24] [18] [12] [7] [27] [45]
Kafka	2	8.70%	[43] [47]
PBFT	2	8.70%	[37] [23]
Solo	2	8.70%	[36] [13]
Proof of Stake	1	4.35%	[6]
Tendermint	1	4.35%	[1]

Proof of Stake represents a class of consensus algorithms in which validators vote on the next block, and the weight of the vote depends on the size of its stake. It is considered an improvement over Proof of Work (PoW) because of less consumption of electricity, reduced centralization risks, security against different types of 51% attacks, and more [16]. It can be applied on Ethereum blockchain platforms.

Solo is a simple consensus algorithm for the Hyperledger Fabric, it is called solo because it runs a single instance of orderer service. It is useful for development, but is not recommended for the production environment, given that it will be the unique instance of the ordering service on the network, the instance will be a single point of failure.

Tendermint [39] is a Byzantine-fault tolerant (BFT) state machine replication. It is claimed that the Tenedermint tolerates up to 1/3 of machines failing arbitrarily, and it can replicate deterministic state machines written in any programming language. The consensus provided by Tendermint can be applied to work on Ethereum, Hyperledger Fabric and other blockchain platforms.

6.4 RQ4: What were the contributions of studies?

Table 8 shows the results. The purpose of this RQ was to find out what areas were used to apply the blockchain. In the financial area there is a great number of sectors and opportunities, it was possible to identify that the majority of the researches were applied on banking or fintech's.

Table 8: RQ4: What were the contributions of studies?

Area	Studies	Percentage	Primary Studies
Bank or Fintech	12	52.17%	[41] [15] [13] [1] [28] [43] [37] [24] [12] [7] [45] [23]
Loan	4	17.39%	[29] [42] [31] [47]
Investment	3	13.04%	[9] [33]
Payment System	2	8.70%	[6]
Insurance	1	4.35%	[36]
Tax Payment	1	4.35%	[22]

Even though the majority of studies were applied in on banks or fintechs (12, 52.17%), the result presents a diversity of blockchain

studies in subareas of financial area. This diversity shows the potential of blockchain, in conjunction with the smart contracts, automated actions can be executed accelerating the execution of process and increasing the transparency of contracts executed.

A smart contract is an executable code that runs on the blockchain to facilitate, execute and enforce the terms of an agreement between untrusted parties. It can be thought of as a system that releases digital assets to all or some of the involved parties once the predefined rules have met [10].

6.5 RQ5: What were the methods of research?

Table 9 shows the results. The purpose of this RQ was to find out what the methods of research were applied for each study. It was possible to identify that the majority of the studies were a prototype.

Table 9: RQ5: What were the methods of research?

Research Type	Studies	Percentage	Primary Studies
Prototype	15	65.22%	[36] [22] [15] [9] [13] [33] [29] [43] [42] [37] [31] [47] [18] [12] [45]
Framework	4	17.39%	[1] [7] [27] [23]
Case Study	3	13.04%	[41] [6] [24]
Design	1	4.35%	[28]

The prototypes were developed in a controlled context to solve or to prove the applicability of blockchain platforms and the solution designed. The frameworks present help the others to apply a blockchain, the frameworks also have an enormous importance, while the prototype provides the working of blockchain platforms, the framework is more generic and it can be reused in other situations. The case studied presents the current state of blockchain, the use cases reported the results of use of blockchain in real life.

6.6 RQ6: Where the articles were published?

Table 10 shows the results. The purpose of this RQ was to find out where the studies were published. It was possible to identify that the majority of the studies were published in the conferences.

Table 10: RQ6: Where the articles were published?

Publisher	Studies	Percentage	Primary Studies
Conference	16	69.57%	[36] [6] [15] [9] [13] [33] [1] [29] [43] [37] [31] [24] [12] [7] [27] [45]
Journal	7	30.43%	[22] [41] [28] [42] [47] [18] [23]

7 DISCUSSIONS AND CHALLENGES FOR FUTURE RESEARCH

This section presents a discussions and further challenges that were identified in in the selected primary studies.

(1) The consensus algorithm. The consensus algorithm is very important to improve the security in a blockchain network. All the information is validated to be appended on the blockchain, and the consensus ensures that the nodes agree on a unique order in which entries are appended [11], but not only the security, the consistency

of information as well. There is a great number of consensus implementation available, each implementation has advantages and disadvantages, speed, security, purpose, etc.

In the financial applications, it is required that the stored data be consistency and that systems involved need to respond fast to the final users. The nature of interaction between user interface and customers is synchronous, the user interface (UI) should confirm the transaction of the user in a short time. On the other hand, the nature of blockchain platforms is asynchronous, so it is necessary to choose the best consensus style to avoid the change of nature of financial application or try to avoid the interfere in a good user experience.

Future research should focused to answer these challenging questions: (1) How to choose the ideal consensus implementation for each application? (2) What is the ideal consensus for financial applications?

(2) Blockchain Platforms. In the recent years with the interest of academy and companies in blockchain concepts, it is possible to observe an expressive number of new blockchain platforms. However, it is possible to notice that some platforms became a standard choice, in other words, the community created around the platforms helps the blockchain to solve the challenges in order to be used in large scale and as well as to spread the blockchain concepts. Besides that, the features provided by each platform, solve the challenges in each application or business context with different approaches or techniques. It is necessary to highlight that this competition is important to incentive the community to research new techniques or new features but, in some cases, the features of one platform overlap the features of other platforms with minimal changes.

This research shows through the RQs that some studies are using the same blockchain platform. In some cases, they created their own platform. Each platform has its own application programming interface (API) or software-development kit (SDK) to integrate with them. It is not easy to change the blockchain platform provider.

The future research should answer the following challenge questions: (1) Is it necessary to define a specification for a blockchain platform? (2) What should the standard features of a blockchain platform be? (3) What features are mandatory for the financial applications ? (4) How to choose one platform over the other?

(3) Methods of Research. The method of research applied in the major of the studies was prototype. In this case the studies aim to develop a design and implementation to solve the problem in their contexts. However, each research pointed to a solution for the specific case. In this situation the environment was controlled and the problem is a part of something bigger.

There is a lack of diversity of studies with different research methods, it was identified only 2 cases studied and 2 frameworks. This number is insignificant for the financial area, contrasting with many prototypes. It is necessary to observe to the current applications used in a financial context, like core banking application, the money-laundering prevention or the payments systems used in credit card ecosystem and others and analyse how these systems will interact with the blockchain, a new paradigm comparing with the current state.

For future research, it should answer the following challenge questions: (1) What is the ideal research method to show the power

of blockchain? (2) What the design style should be applied to enable the transition to blockchain platforms?

(4) Architecture. It was possible to identify the necessity of more studies that cover a more generic problem and address the design solution in a more fashioned style. To apply the blockchain in large scale it is necessary to establish a suitable software development style, in a blockchain solution as well as in applications that intend to interact with blockchain. To expand the blockchain adoption it is important to define the design between blockchain and external world. Blockchain-oriented Software Engineering (BOSE) [34] lists some practices that need to be addressed like smart contract testing, blockchain transaction testing, the criteria to select the proper blockchain implementation.

By nature, the financial applications are critical, and in general they work 24 hours 7 days per week, involving a complex system. In financial systems there is a great number of legacy systems, regulatory requirements, integration between systems, security requirements, among others. This scenario can lead blockchain applications to a numerous corner cases or edge cases. To avoid unexpected situations and avoid a big effort to implement and test new solutions using blockchain, it is important to develop a set of development styles to addresses these challenges.

The design of software architecture for a typical financial application handle concurrency, high availability and fault toleration, it is not a coincidence that the blockchain also handles these requirements. But now, the architecture style changed with the introduction of blockchain. Some steps to build a hybrid decentralized software architectures are presented in [44].

The future research should answer the following challenge questions: (1) How to choose the architecture style to use blockchain in a financial application? (2) What are the architecture design the financial applications need to communicate with the blockchain components? (3) What are the requirements that influence int the architecture style to apply blockchain in financial application?

8 LIMITATIONS

This research is limited only to studies related with financial area and published in a number of scientific research database linked to computer engineering or co-related areas. The commercial studies or other articles published in a non scientific website were not considered in this research.

9 CONCLUSIONS AND FUTURE WORKS

From the systematic mapping study presented in this review of the literature, it was possible to identify that the most used framework was Ethereum, and in common, the majority of the studies applied a prototype as a research method. In a high level it was possible to identify where the researchers are spending the efforts.

This paper describes the classification and an analysis of the studies published in the financial area. The results present what platforms were used, the motivation, where the studies were applied, and more technically what the consensus algorithm was applied. In a high level, this research shows how the researchers are studying to evolve blockchain and introduce this promises technology in a large scale. There is a great direct interest between financial

requirements and blockchain, like, security, transparency, tamper proof and reliability to enforce all the regulatory law.

It is clear that there is a long road to spread the blockchain concepts and many opportunities to explore. According to this systematic mapping there are opportunities to expand the research in case studies or frameworks to turn the adoption of blockchain easier to develop and to integrate with other legacy applications, as well as design a good architecture. On the other hand, the lack of technical details emerged as it is possible to observe in table 7 answering about the consensus mechanism applied by the studies.

Many questions and challenges should be addressed to enable the blockchain in real world. The software architecture style needs to be adapted to using all the benefits provided by the blockchain providers, applying the boundary context design between the applications or domain objects.

For the future works, it is being planned to develop an architecture style or a set of architecture styles to apply blockchain in conjunction with other financial applications creating a small architecture guide framework to apply and enable blockchain platform for financial applications. The architecture style fashioned should be more generic and flexible, for this it is mandatory that this architecture should address the previously discussed challenges.

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