Blockchain Use Cases: A Systematic Study

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***Abstract*—The emergent blockchain technology has become even more widely used in various areas, apart from financing, where bitcoin is already a great success. Fully secure, highly available and with many consensus algorithms on the network, the use of this technology, as well as any emergent one, offers challenges and opportunities that need to be explored. This paper proposes a systematic mapping of challenges, opportunities and common problems in many areas.**

Keywords-blockchain; Systematic Mapping; Challenges; Smart Contracts

I. INTRODUCTION

From a survey developed by Mettler [1], it was identified that until 2025, about 10% the Gross National Product will be provided from the use of blockchain technology. That was an important data to encourage big companies to invest more than half billion dollars in 2015, in search for new approaches and challenges to using this technology. The great interest in blockchain is due to the fact that it withstands a safe and distributed network with inviolable lodgers, as well as the fact that there is no authorized dealer [2] that interferes in the result and data control.

Blockchain technology has been drawing attention in the market because of its good acceptance with cryptocurrency, such as bitcoin. It is an electronic payment system peer-to-peer in which the algorithm proof-to-work is used to ensure an irreversible transaction history [2]. Several areas, such as healthcare [34][39], IoT [5][10], chain of supplies [16][17], energy [6] and public sector [18][41] are developing cases of use with blockchain technology to create new business opportunity, decrease of costs, audit data, integrate with stakeholders basis, improve generation process and increase security of transmitted data.

However, with the adoption of new technologies in projects, challenges, problems, characteristics and opportunities appear in the analysis of the pre-project or during the development through blockchain technology in projects.

According to Nakamoto [2], blockchain is a public distributed timestamp server that registers every transaction that happens and allows data storage, verification and audit of those. Blockchain consists in an array of blocks composed of many transactions and every block is linked to another, as a chained list. The authenticity to each transaction is verified by a digital signature based in Elliptic Curve Cryptography (ECC).

Another concept to be considered is the use of smart contract. They are customized scripts that perform the necessary logic to provide a complex service, like management of state and controlling verification of credentials [26]. It contains the business logics that may interact with other contracts, make decisions, store data and send cryptocurrency to another recipient [7].

This paper aims to answer these questionings in the context of adopting this technology in projects.

This study is divided in 4 sections. In the first one, it will be explained how the blockchain technology works. In Section 2, it will be explained how the research protocol will be developed. In Section 3 a thorough examination will be carried out from primary studies. Finally, the conclusion will be in the fourth section.

II. PROTOCOL APPLICATION

Based on Kitchenham's work [4], a well-defined outlining protocol stage is necessary to reduce the researcher bias. The following protocol was divided in stages. In the first one, it was made a main survey question with secondary ones, aiming a broader research. The second stage is the criteria protocol definition for insertion or exclusion of papers. The third stage is the application of primary studies selection protocol. The fourth stage will be checklist generation in order to verify research quality. The fifth and last stage will be the analysis whether the present research is relevant.

A. Survey Questions

- How to analyze the viability of blockchain in projects?

From the main survey, secondary questions were formulated with the aim of helping understand the problem.

- *Which challenges and opportunities are there with blockchain solutions?*
- *Which characteristics are more present in blockchain solutions?*
- *Which are the most common problems found in blockchain projects?*

B. Insertion and Exclusion Criteria

In order to reduce researcher bias, it was created a criterion through a well-defined protocol. For this research,

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only studies which aim to present characteristics and challenges in the adoption of blockchain technology in projects will be considered. This systematic mapping will be limited to verify studies which were published from 2016 on.

The following exclusion criteria were used.

- Studies not published in English.
- Studies which are unavailable online.
- Studies not based on this present research or unpublished.
- Preface, brochure, interviews and reports.

C. Search Strategy

The following virtual libraries were used:

- IEEE Xplore;
- Sciencedirect;
- ACM DL

Combinations of strings were created to guarantee that relevant information would not be excluded when querying different search engines and databases. As a result, three search strings were created

- ((blockchain AND challenges) OR (blockchain AND opportunity));
- ((blockchain) AND (solution OR characteristics OR application));
- ((blockchain) AND issues);

With the creation of search strings in each virtual library, the option advanced search was used on September 30th, 2018 and some papers published from January 2016 until 2018 were included. The result of each respective digital library, which were later removed to avoid duplicate of papers by Mendeley tool, was grouped according to their respective virtual library as shown in Table 1.

TABLE I. THE AMOUNT OF STUDIES FOUND IN EACH VIRTUAL LIBRARY

Library	Number of articles
IEEE Xplore	1001
Science Direct	104
ACM DL	183

The combination of strings showed a result of 183 research articles from Science Directory Library. In IEEE Xplorer there, were a total of 1001 research articles. Finally, the ACM DL Library generated 104 papers as shown in Table 1.

D. Choice of Studies Process

In this section, the process of choice of primary research articles will be outlined by using a protocol of insertion and exclusion.

In the first stage, 1288 research articles were found from virtual libraries. After the removal of duplicates, there were 906 distinct files left. For this process, Mendeley software was used along with Zotero.

Within the developed protocol, in the second stage, each research article was verified whether they were in the context of the research or not, with the analysis of artefacts titles.

However, certain studies, after a thorough analysis of titles, could not be conclusive regarding their relevance to this study. Due to that, a third stage was added: abstract verification.

In the fourth stage, the introduction and conclusion of the work were analyzed to verify relevance of the state of art approached in this paper.

Lastly, a qualitative analysis will be made from the reading of all articles left, excluding, this way, artefacts that are not relevant to this research.

After the execution of the stages of the protocol, 1249 studies were removed, and a total of 39 artefacts were analyzed.

E. Quality Control

In order to evaluate this research quality, it is necessary the primary studies to be analyzed critically. All in all, a protocol was developed and executed to minimize the amount of initial studies. Based on that, a following stage was deemed necessary, in which, it was made the reading of the research articles. Six secondary questions were then created with the purpose of evaluating the credibility and relevance of each artefact.

The three initial questions were used to investigate how blockchain technology is generally being used in projects, as criteria for excluding unrelated artefacts. The other questions were used to evaluate if the paper approaches themes that add value to the use of blockchain in projects, as well as if the paper found does not approach only blockchain.

The questions that will help assess the quality of the research are:

1. Were the challenges and opportunities of blockchain technology use clear in the article?
2. Were the characteristics of blockchain technology well-approached in the research?
3. Were the common problems with the blockchain approached?
4. Was a survey developed with the user about the implementation of blockchain project?
5. Was the article not restricted to just discussing blockchain?
6. Does the paper make an analogy of the use of blockchain adding value in the final product?

After the analysis and extraction of articles chosen, based on the protocol, there were a total of 39 files left, which were approved in the quality control. The process of quality control will be explained in the next section. It will focus in remaining 39 artefacts.

III. RESULTS

Based on the execution of the developed protocol, 39 primary studies were selected [2] and [4] – [41]. It was

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identified the use of blockchain in different areas, as described below.

According to the selected primary studies, it was observed a higher demand in the use of blockchain technology in the IoT, healthcare, cryptocurrency, government, energy and voting, respectively.

In the next section, a quantitative and qualitative analysis of the primary studies was held.

A. Quantitative Analysis

The research showed a total of 39 primary researches by 126 different authors and they were published from 2016 to 2018. It was identified a total of 229 keywords related to blockchain.

In regards to frequency of publishing, it had a growth of interest for blockchain's. In 2016, it had 2 publishing. followed by 17 in 2017 and 20 in 2018. The large amount of publishing across the years show up a huge interessing for blockchain.

From the primary studies, the interest in blockchain was identified in the areas of IoT, healthcare, supply chains, government, big data, design, cloud computing and digital property.

Among 39 primary articles found, 229 keywords were found. The most found keywords were: internet of things (7), bitcoin (5), iot (4), government (4), smart contracts (6), cryptocurrency (3), iot security (3), cloud computing (3), trust (3), decentralized iot (2), consensus protocols (2), blockchain challenges (2), voting (2), food safety (2), data integration (2), egovernment (2), finance (2), distributed ledger (2), business (2), voter (1), big data (1), food chain (1), and smart agriculture (1).

It has been observed with keywords in the research that the use of blockchain can be applied in diverse areas that go beyond Nakamoto [1] in cryptocurrency. That is a fact of relevance to this research.

B. Qualitative Analysis

The result of the qualitative analysis will be displayed in this section from 39 primary studies, taking into consideration six criteria, to evaluate the credibility and quality of the studies. The classification of artefacts will be either positive (1) or negative (0) and there will be a reference to the article.

TABLE II. QUALITATIVE ANALYSIS OF PRIMARY STUDIES

Study	Q1	Q2	Q3	Q4	Q5	Q6	Total
[5]	1	1	1	1	1	1	6
[6]	1	1	1	1	1	1	6
[7]	1	1	1	1	1	1	6
[8]	1	1	1	1	1	1	6
[9]	1	1	1	1	1	1	6
[10]	1	1	1	0	1	1	5
[11]	1	1	1	0	1	1	5
[1]	1	1	0	1	1	1	5
[12]	1	1	1	0	1	1	5
[13]	1	1	1	0	1	1	5
[14]	1	1	0	1	1	1	5
[15]	1	1	0	1	1	1	5
[16]	1	1	1	0	1	1	5
[17]	1	1	1	0	1	1	5
[18]	1	1	1	0	1	1	5
[19]	1	1	1	0	1	1	5
[20]	1	1	1	0	1	1	5
[21]	0	1	1	1	1	1	5
[22]	1	1	1	0	1	1	5
[23]	0	1	1	0	1	1	4
[24]	1	0	1	0	1	1	4
[25]	1	0	1	0	1	1	4
[26]	1	1	0	0	1	1	4
[27]	0	1	1	0	1	1	4
[28]	1	1	0	0	1	1	4
[29]	1	1	1	0	1	0	4
[3]	1	1	1	0	1	0	4
[30]	1	0	1	0	1	1	4
[31]	0	1	1	0	1	1	4
[32]	1	0	1	0	1	1	4
[33]	0	0	1	0	1	1	3
[34]	0	0	1	0	1	1	3
[35]	1	0	0	0	1	1	3
[36]	1	0	1	0	1	0	3
[37]	0	0	1	0	1	1	3
[38]	0	0	1	0	1	1	3
[39]	1	1	0	0	1	1	3
[40]	1	1	0	0	1	0	3
[41]	1	0	0	0	1	1	3
Total	31	28	30	9	39	35	171

Based on the results as shown in Table 2 it was observed from the first question, there is, indeed, a great tendency for blockchain use to generate opportunities and challenges in many areas. Among the 39 selected articles, 28 described that the characteristics of the use of blockchain can help in projects. Analyzing the third question, related to common problems, the primary articles showed high rate of problems in the adoption of blockchain in projects. Analyzing the result of the fourth question, it was observed that the use of surveys was not relevant as a tool to support decision and generate new opportunities. The fifth question is focused on quality assessment, since it analyzes whether the articles are restricted to describing blockchain only. Thus, the sixth question is related to verifying whether blockchain adds value to the final product. In conclusion, from 39 selected articles, 35 use blockchain as an addition to the final product.

IV. DISCUSSION

The following subjects will be approached in the primary studies according to the questions used in the quality control assessment. It will be taken into account the studies

involving IoT, government and healthcare, once these are the most recurrent subjects.

1. Which challenges and opportunities are there with blockchain solution?

In IoT, according to [5], it was identified that the blockchain network can help in Iot area to keep data safely and immutable. This way, generating opportunity to track data that was once generated by different devices. One of the greatest challenges in integrating data generated by devices and network is due to the fact that these devices have already delivered corrupt data. Therefore, it is necessary that the devices to be tested before is put in the network, besides of being allotted, in order to avoid physical alteration.

Reyna et al. [5] comments about the value that blockchain brings, providing a network where information is traceable, immutable and highly safe. In cases which the data is provided by devices, blockchain will play an important role integrating the parts.

Elsden et al. says in his article [21] that the outcome of the survey resulted in the use of blockchain in IoT, as a way of keeping the devices interoperable and safe for sharing and exchanging messages.

To the author Smith, the safety in IoT with integration in blockchain networks is challenging due to the limitations in processing, being necessary a smaller precision in the algorithm proof-of-state, used on the network. This approach can generate attacks in blocks with bigger reputation, generating new blocks with invalid data.

As opportunity, Kahn and Salah [10] defend that blockchain technology, based on smart contracts, can be used to manage, control and, the most important, keep IoT devices safe. Another point raised is the possibility of using a public key of 160-bit form blockchain generated by Elliptic Curve Digital Signature algorithm (EDCSA) instead of 128 bits from IPV6. blockchain can generate and allocate addresses offline for around $1.46 * 1048$ IoT devices., removing needs of an entity internet Assigned Numbers Authority (IANA) central authorizer of devices.

In article [26] it reports that the possible use of blockchain in the network can track millions of connected devices, process transactions and coordinate devices, allowing connection peer-to-peer to send messages and allowing blockchain to control the devices connected through smart contracts.

Regarding healthcare, Jiang et al. [39] verified that great part of the products developed that used blockchain recorded only data generated in EMR (electronic medical records), ignoring data from PHD (personal healthcare data). In the article [13] the author debates the necessity of not manipulating data generated from EHRS (electronic health records). It can entail manipulation of data, and consequently, problems to patients.

The use of blockchain, along with smart contracts, will help keep the integrity, safety and immutability of network data. This way, a greater collaboration among hospitals and clinics will help save 93 billion dollars in 5 years' time in the USA from the safe mass data sent from blockchain [13].

According to Mettler [1] the possibility to create a shared infrastructure among researchers and doctors comes from data generated by patients using blockchain. This will allow further analysis of wasted resources, operational problems and improvement of user service. The author comments about the challenges in patient's data privacy, and about the possibility to create a new platform, where users would be in control of their data.

At last, there is an opportunity for the user to be compensated for allowing access to their data in the blockchain. Alhadhrami [36] exposes that the data privacy in the blockchain network is a challenge due to public data. Therefore, it is necessary to take some precautions in the moment of sending data to the network. In article [26] it comment about the opportunity of using public blockchain as a way of centralizing data from patients with the challenge of patronizing the data inserted.

In government, Antipova [32] describes the opportunity of using blockchain to help audit data, removing the need for a centralizing entity and avoid fraud, since these transactions in the network are inviolable.

There are challenges in the area of public blockchain. The need for attention in anonymous transaction in the network, deems necessary the supervision of a third-party with the intention to avoid possible alterations in the result and audit. Batubara [41] comments that there are challenges in the adoption of blockchain in e-governments. She mentions the creation of new governmental models, as well as acceptance, since the creation of a platform needs the cooperation of multiple institution and stakeholders.

As seen in [12] it portrays the opportunity to use blockchain as an integration tool among different governmental database. In article [18] it is mentioned that the use of blockchain in governmental solutions will help reduce costs, frauds payment error and the transparency of shared data between government and citizens.

2. Which characteristics are more present in blockchain solutions?

In the IoT area, Karafiloski and Mishev [26] describe the use of blockchain smart contracts along with smart lockers connected to the network, to create a renting system without the need of a third party. The network consensus is the tax agent. Khain and Salah [10] argue that the data transmitted from the devices to blockchain will always be encrypted and signed by the sender. That guarantees authentication and integrity of the data sent.

Another feature is the possibility of audit transmitted data form devices in the network and smart contracts, as a decentralized authenticator with simple logic rules and multi-party. That would have minor complexity to the devices, if we compare the traditional authorization protocol in which Role Based Access Management, OAuth 2.0, OpenId, IMA DM and OMA Lightweight M2M are used.

According to Alketbi et al. [18] the change from a centralized architecture to a distributed P2P will remove flaws, throughput and raise in scalability of the system. Blockchain will favor in setup management of devices, storage of sensitive data and to enable micro payment.

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Regarding healthcare, Alketbi et al. [18] sees the use of blockchain as a facilitator for sharing files among users and doctors, insurance agencies and others, with privacy in focus, and smart contracts, so that the user is in control of the data. Shae and Tsai [13] argue about the need of not manipulating the data in clinical trials in order to avoid health problems in the patients. In this article, blockchain is described as a solution to this problem, since the data in the network are safe, transparent, available in real time and inviolable. Consequently, contributing to a greater precision in the report.

The research articles [26] and [34] describe the need of choice in which the used data must be sent to the blockchain network. It is proposed the insertion of user metadata, such as visitor ID, provider ID and payer ID with a linkage to an external database.

In government area, Antipova [32] exposes the need for government standardization of database in the blockchain, to maximize compatibility, interoperability, repeatability and quality.

The possibility to audit the data inside the blockchain network in real time is a very important characteristic that will help the government to identify fraud swiftly.

According to [12] using blockchain in government area will help unify different public service base to allow user improve their data understanding through authorized smart contracts. Olnes e Jansen [9] analyzed that digital ID management, safe records maintenance of digital files are more adequate cases for government inside the blockchain.

From T. D. Smith's survey result [11], it was found the use of Ethereum as a widely used platform.

3. Which characteristics are more present in blockchain solutions?

In IoT, Karafiloski and A. Mishev describe [26] that the limitation in processing devices and mining timing transactions will limit the number of devices to do that in the network. Billions of devices in the network can lead to a crash. In their research article, Khan and Salah [10] report that even if blockchain provides a robust safety to IoT, there is still a mechanism problem of consensus, upon mining hashing power which can be compromised, allowing the invader to be the network owner. Equally, private key generated in the network are dynamically limited, allowing the attacker to compromise some account in the network.

In healthcare, the articles [34][11] relate the issue of keeping all the healthcare database in the network due to its high operational costs and the possible security breach in public blockchain encrypting. Shae and Tsai [13] mention that data coming from clinical trials sent to blockchain can entail problems in final reports, since they are shown and updated in real time.

In government, Hou [12] comment that the use of blockchain in governmental solutions involve the integration with various systems, different organizations and problems with time and expenses that hinder solution. The use of blockchain as a way of keeping long term unused data, since it guarantees data reliability. The author defends that data should be recorded in blockchain as well as in third-party. In the article [18] summons that blockchain can be attacked by Dos(Denial of Service) causing and impact in processing legitimate pending transactions to miners leading to slowness in the network.

Olnes and Jansen [9] created a survey with the main people in the public sector in 2018, observing emerging technologies: Robotics, Blockchains, Artificial Intelligence and Virtual Reality. As a result, the majority answered that blockchain is immature and not ready to be used in the public.

4. How to analyze the viability of blockchain use in projects?

From this present research, it has been observed that there are challenges and problems in adopting an emergent technology such as blockchain. Once the viability of using blockchain in projects, some characteristics must be observed according to some points below.

Safety:

- In projects which there is the need of keeping sensitive data in the network, some precautions should be taken to avoid data to be read by others [36]. It is necessary the adoption of a routine of cryptography before the data is involved in the network.
- A. Reyna et al. [5] mentions that recorded data in the network are inalterable, which gives more security in projects that require reliability. The case described is in IoT.
- For solutions which require the need for integration among many parts involved, A. Reyna et al. [5] mentions that the network will help keep data integrity, if there is the necessity for every transaction to be signed by the sender.

Data Integration:

- A. Reyna et al. [5] observes that blockchain will help with the integration of data provided by different devices safely, once all data is signed by the sender. This will help with more critical projects which need data integration, transparently and safely.

Auditing:

- For projects in which there is the need for assessment in real time. Antipova [32] describes that blockchain network will help avoid fraud and increase transparency of data, due to the fact that every transaction is public and inalterable.

Data availability:

- In projects which require high availability of data, Nakamoto [2] describes that blockchain will help keep high availability of data connected via peer-to-peer with respective duplicate in blockchain network

Removal of Centralizing Entity:

- Kshetri and Voas [3] write that the removal of a centralizing entity will help create in not manipulating of results, as well as in controlling data. This will help projects to remove a

centralizing entity in controlling data, as well as not manipulating data.

Smart Contract:

- Khan and Salah [10] defend that blockchain based in smart contracts can be used to manage, control, and the most important, to keep IoT devices safe. This matter, raised by the author, can help projects to create smart contracts as self-manageable micro services with business rules in the blockchain network.

Data Uniformity:

- Karafiloski and Mishev [26] mention the opportunity of using blockchain network as a centralizer of public data from patient, creating a standardization of data inserted and this project usually involves stakeholders. It is necessary that the parts involved create a protocol of data before sending the transaction to the blockchain network.

Limitations:

- For Smith [11] in IoT, the integration with blockchain network is challenging due to the fact that devices have limited processing, being necessary a smaller precision in the consensus proof-of-state used by network. That can result in a massive attack on account of the consensus being reduced. This limitation is taken into consideration in projects which there is the need for mining of micro processed transactions or devices with limited processing.

V. Conclusion and Future Work

This paper aimed to identify opportunities, problems and challenges in the use of the emergent blockchain technology in many areas. It has been found 906 initial studies, with a total of 39 primary artefacts left.

To assure quality of the evaluated primary research articles, a protocol was developed composed by four stages, resulting in a great interest for using blockchain in areas such as healthcare, IoT and government. In each area, there is the interest of assuring safety of data, integration of data and scalability of services through blockchain.

Regarding viability of blockchain use in many areas that do not involve finance, there are still problems and challenges in diverse areas that have been presented. It is necessary a deeper research per area in order to mitigate risks in the adoption of and emergent technology in small and big projects.

This works presents a important summarization of blockchains aspects such as problems, challenges and opportunities of technology adoption in projects and it adds important set of information for the area, as for now, the amount of works presenting consolidated ideas related to blockchain are not common and are important in a theme that can be explored in a variety of ways.

As a future work, guidelines are to be created to provid projects and engineers with means to better choose the adoption of blockchain technology in several areas.

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